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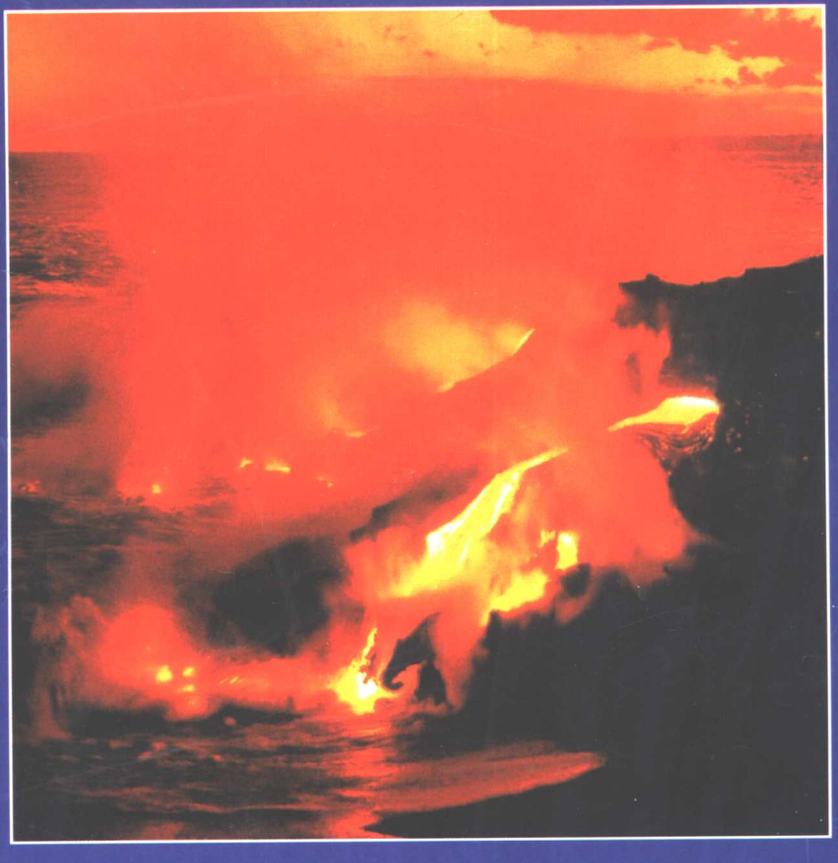
through diagrams

CHEMISTRY

牛津图解中学化学



英汉双语

Michael Lewis

上海教育出版社
牛津大学出版社

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牛津图解中学化学

（英汉双语）

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文杰　麟伟　一毅 译

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Matter and energy

MATTER

Matter makes up all the substances around us.

Matter can be recognized by weighing because it has mass.

Matter exists in three **states**: **solid**, **liquid**, and **gas**.

When the particles of a substance gain or lose energy, the substance may change state.

Melting and boiling points

These are **temperatures at which pure substances change state.**

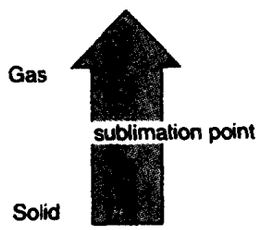
They are used by chemists to:

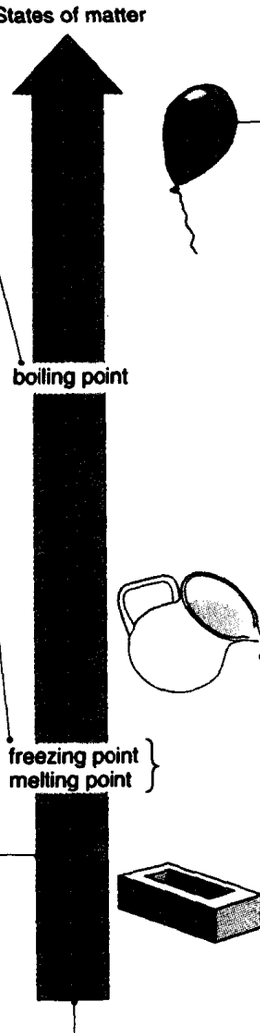
- recognize substances: no two substances have exactly the same melting or boiling points;
- check purity: impurities change melting and boiling points.

Sublimation

This is the process of turning directly from solid to gas (instead of melting to a liquid).

Iodine and carbon dioxide (dry ice) both sublime.





Gas

- has a fixed mass: often very small for such a large volume (balloons float)
- has no fixed volume: can be squashed (used in vehicle tyres to cushion bumps)
- has no fixed shape: can be poured (wind)

Diffusion

The particles of a gas are moving all the time. They move so fast and so randomly that they spread out in all directions until they meet the wall of a container. This is why two gases mix completely with each other. The process is called diffusion.

Liquid

- has a fixed mass
- has a fixed volume: cannot be squashed (used in hydraulic systems)
- has no fixed shape: can be poured (flows along pipes)

Solid

- has a fixed mass
- has a fixed volume
- has a fixed shape: solids are used to build structures

Solids may be either:

- **crystalline**, when they have been cooled slowly:
  the particles have time to form an ordered lattice, or
- **amorphous** (powder), when they have been cooled quickly:
  the particles do not have time to get arranged into a pattern.

ENERGY

Energy is the ability to do work.

Energy of *movement* is called **kinetic energy**, e.g. energy of a moving ball.

Energy of *position* is called **potential energy**, e.g. energy of a raised weight.

Other kinds of energy – heat (thermal), sound, light, chemical, nuclear – are all forms of either kinetic or potential energy. They all depend on the movement or position of particles in matter.

The **heat** in a substance is the sum of the kinetic energy of all the particles in the substance.

The **temperature** of a substance is a measure of the kinetic energy of the particles in the substance. In a hot substance the particles have more kinetic energy than in a cold substance.

THE INTERACTION OF MATTER AND ENERGY

In chemistry we study the effects of applying energy to matter or getting matter to release stored energy.

In chemical plants energy, heat, and pressure are applied to raw materials like crude oil or iron ore, changing them into useful substances that we need.

In power stations fuels react with air. The potential energy stored in the fuel (in the bonds between the atoms) is released as kinetic (heat) energy which is made to do work generating electricity.

物质和能

物质

物质构成我们周围的所有东西。

物质能称重，因为它有质量。

物质以三种**状态**存在：**固态**，**液态**和**气态**。

当一种物质的离子获得或者失去能量时，这种物质会改变状态。

熔点和沸点

熔点和沸点是指**温度**，**在这些温度，纯净物会改变状态。**

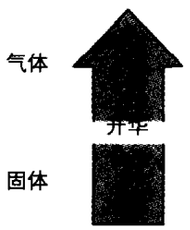
化学家利用它们来：

- 鉴别物质：因为没有两种物质有完全相同的熔点和沸点；
- 测定纯度：含杂质的物质，它的熔、沸点会改变。

升华

固体直接变成气体的过程（而没有先熔化变成液体）。

碘和二氧化碳（干冰）都能升华。



气体

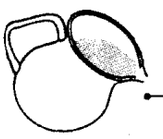
- 有一定的质量：相对很大的体积（如漂浮的气球），质量通常很小。
- 没有固定的体积：气体可以挤压（如用来充填汽车轮胎，以减少颠簸、冲撞）。
- 没有固定的形状：能流动（如风）。

扩散

气体粒子在不断运动，粒子向四面八方运动，既快又没有规则（杂乱无章），直至碰到容器的壁。所以两种气体可以充分混合在一起，这种过程叫扩散。

液体

- 有一定的质量。
- 有一定的体积，不能挤压（应用在水压系统上）。
- 没有固定的形状，能流动（沿着管道流动）。



固体

- 有一定的质量。
- 有一定的体积。
- 有固定的形状，固体可以用来造建筑物。

固体还可以是：

- **结晶的**，当固体慢慢冷却时，固体粒子有时间形成一种有规则的晶格。
- **非结晶的**（粉末），当固体迅速冷却时，固体粒子就没有时间排列成晶格。

能

能是做功的能力。

运动的能叫**动能**，如一个运动的球的能。

由位置决定的能叫**势能**，如一个被举起的重物的能。

其他形式的能——热能、声能、光能、化学能、核能，要么是动能要么是势能的一种形式。它们都由物质粒子的位置或运动来决定。

一种物质的**热能**是这种物质的所有粒子的动能的总称。

物质的**温度**表示该物质粒子的动能大小。物质温度高，该物质粒子的动能比温度低时粒子的动能大。

物质和能的相互作用

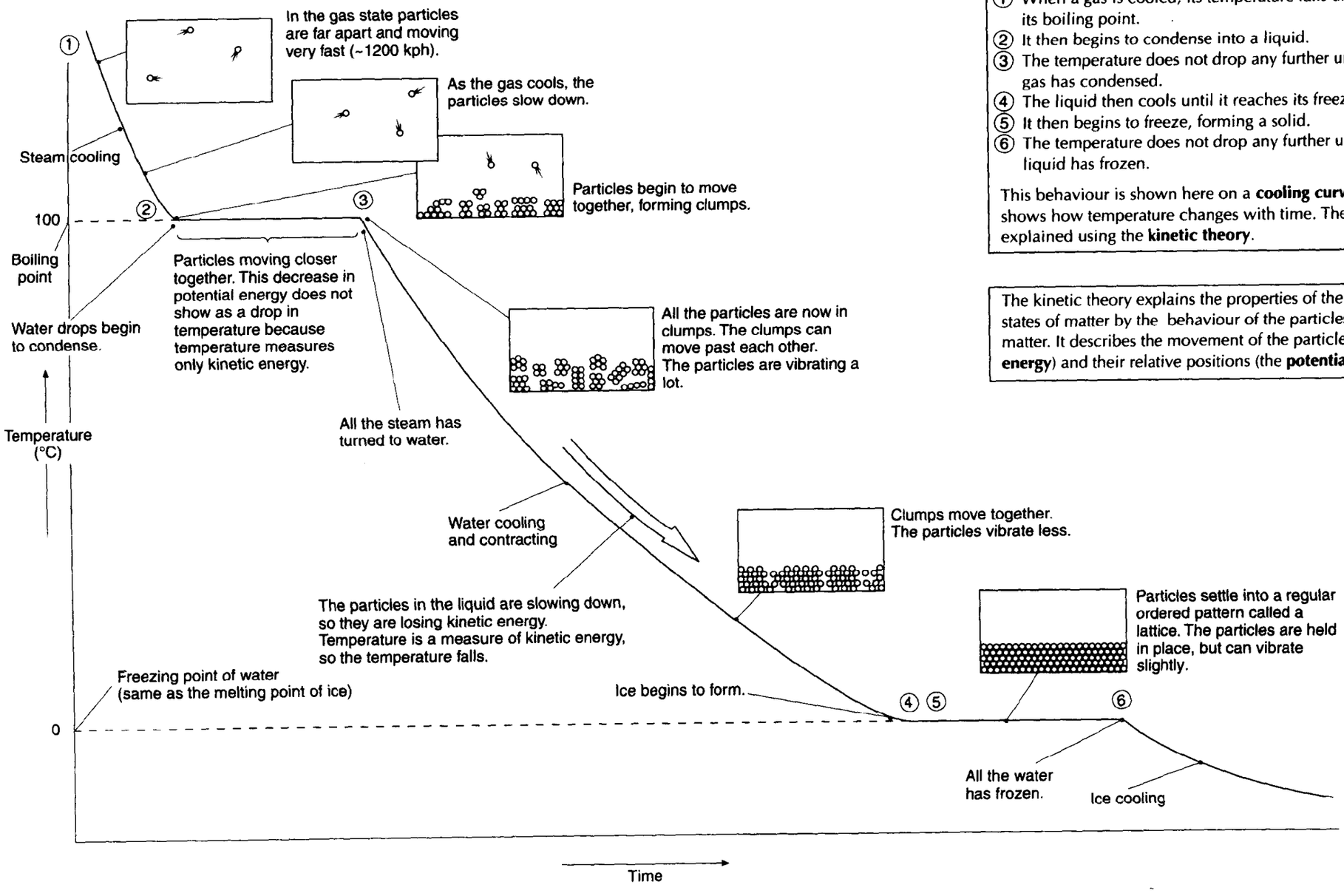
在化学里，我们学习能对物质的作用以及通过释放贮存的能量来获取物质。

在化工厂里，能、热和压力常用来加工原材料，比如原油或铁矿石，把它们变成我们需要的有用的物质。

在发电厂里，燃料跟蒸汽反应，贮藏在燃料里的势能（原子跟原子之间化学键）释放出来变成动（热）能，它们主要用来发电。

Changing state and the kinetic theory

COOLING CURVE FOR WATER



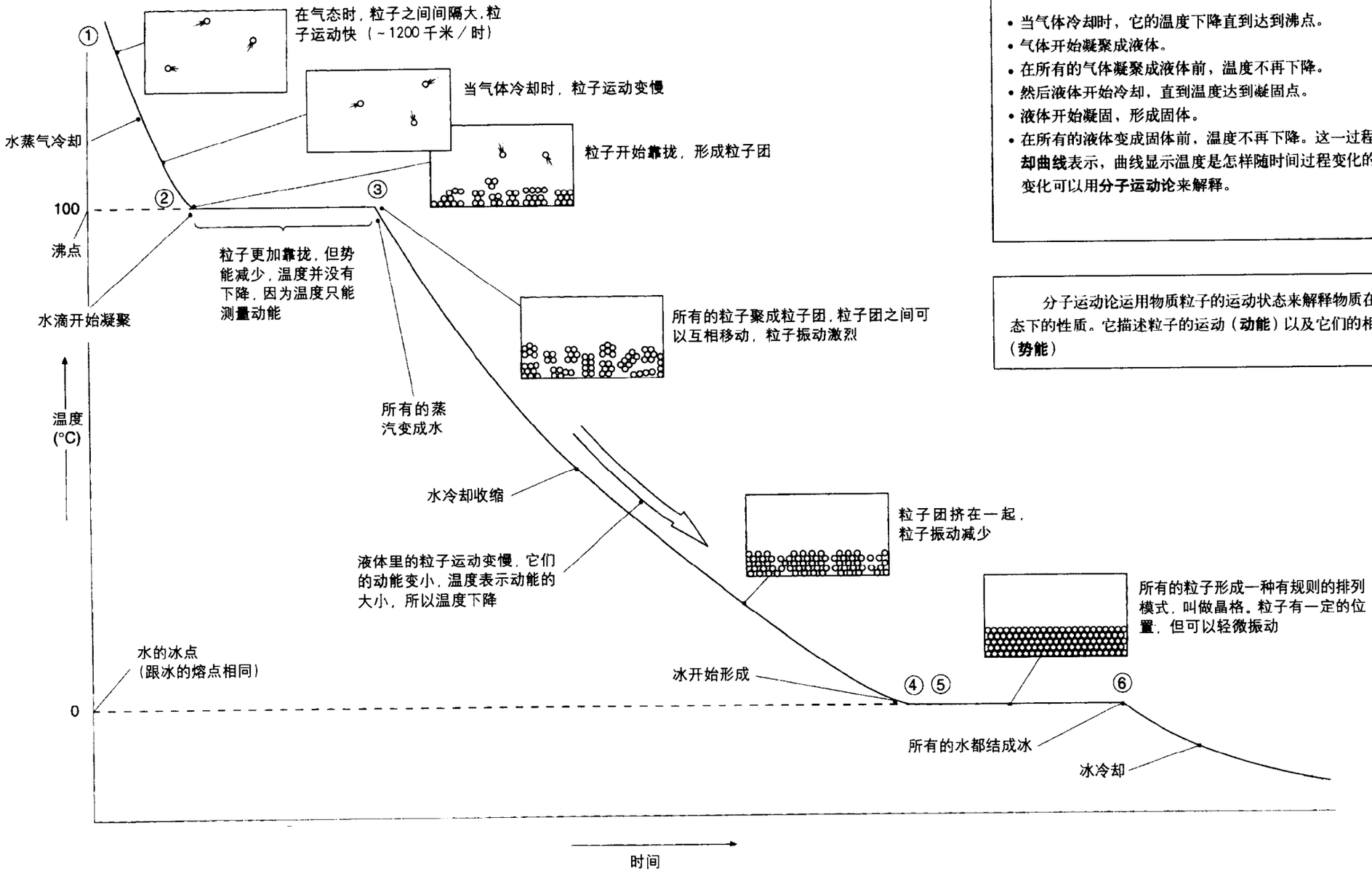
① When a gas is cooled, its temperature falls until it reaches its boiling point.
② It then begins to condense into a liquid.
③ The temperature does not drop any further until all the gas has condensed.
④ The liquid then cools until it reaches its freezing point.
⑤ It then begins to freeze, forming a solid.
⑥ The temperature does not drop any further until all the liquid has frozen.

This behaviour is shown here on a **cooling curve**, which shows how temperature changes with time. The behaviour is explained using the **kinetic theory**.

The kinetic theory explains the properties of the different states of matter by the behaviour of the particles in the matter. It describes the movement of the particles (the **kinetic energy**) and their relative positions (the **potential energy**).

状态变化和分子运动论

水的冷却曲线



- 当气体冷却时，它的温度下降直到达到沸点。
- 气体开始凝聚成液体。
- 在所有的气体凝聚成液体前，温度不再下降。
- 然后液体开始冷却，直到温度达到凝固点。
- 液体开始凝固，形成固体。
- 在所有的液体变成固体前，温度不再下降。这一过程现用**冷却曲线**表示，曲线显示温度是怎样随时间过程变化的。这种变化可以用**分子运动论**来解释。

分子运动论运用物质粒子的运动状态来解释物质在不同状态下的性质。它描述粒子的运动（**动能**）以及它们的相对位置（**势能**）

Elements, mixtures, and compounds

ELEMENTS
- cannot be decomposed
- made of only one kind of atom
- two main kinds: metals and non-metals

Metals
Physical properties
- conduct electricity
- ductile and malleable (can be bent and shaped)

Chemical properties
- form basic oxides, e.g. MgO; CuO
- form cations, e.g. Na^+; Ca^{2+}

Non-metals
Physical properties
- insulators
- brittle (suddenly snap when loaded)

Chemical properties
- form acidic oxides, e.g. CO_2; SO_2; NO_2
- form anions, e.g. O^{2-}; Cl^-; Br^-

IRON FILINGS
grey, magnetic

+

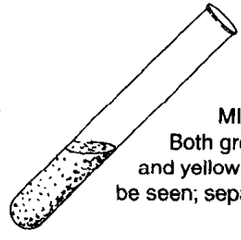
SULPHUR
yellow, low m.p.

Relative amounts in Earth's crust

Element	%	
oxygen	46.6	most abundant non-metal
silicon	27.7	
aluminium	8.1	most abundant metal
iron	5.0	
calcium	3.6	
hydrogen	0.22	
carbon	0.19	forms most compounds

MIXTURES
- made by physical change
- original properties still remain
- have variable composition
- there is no energy change when mixing
- separated by physical changes
- made from elements or compounds

MIX



MIXTURE
Both grey iron filings and yellow sulphur can still be seen; separate with magnet.

Important examples

Air
- mixture of gases
- main components

nitrogen	78%
oxygen	21%
noble gases	0.9%
carbon dioxide	0.04%

- separated by fractional distillation

Petroleum
- mixture of saturated hydrocarbons
- composition changes from one source to another
- separated by fractional distillation

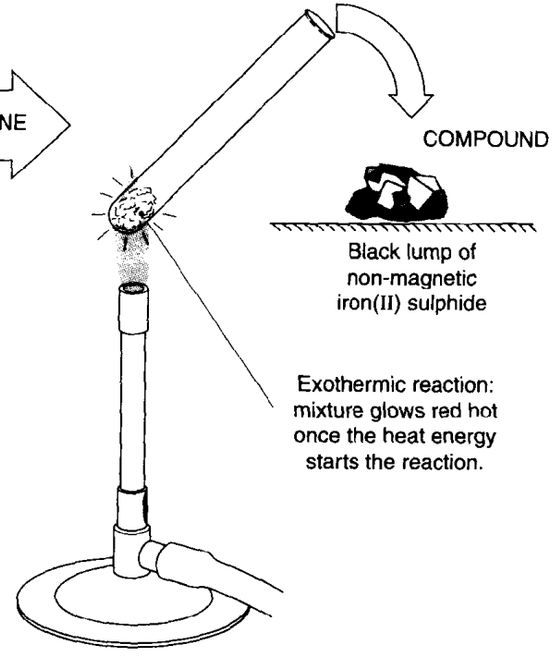
Sea water
- mixture of ionic salts in water

Salt	Mass (g in 100g of sea water)
sodium chloride	2.6
magnesium chloride	0.3
magnesium sulphate	0.2
calcium sulphate	0.1
potassium chloride	0.1

- separated by distillation to collect water, and evaporation to collect salt.

COMPOUNDS
- made by chemical change
- have new properties, different from reactants
- have fixed composition and definite formula
- there is an energy change during combination
- can only be separated by decomposition (a chemical change)

COMBINE



Important examples

water	H_2O
ammonia	NH_3
methane	CH_4
carbon dioxide	CO_2
sodium chloride	NaCl
calcium carbonate	$CaCO_3$
iron oxide	Fe_2O_3

元素、混合物和化合物

元素

- 不能被分解
- 只有一种原子组成
- 分两类：金属和非金属

金属

物理性质

- 导电
- 有延展性（能弯曲和成形）

化学性质

- 生成碱性氧化物，如 Mg、CuO
- 生成阳离子，如 Na^+、Ca^{2+}

非金属

物理性质

- 不导电
- 脆、易碎（当负重时，会断裂）

化学性质

- 生成酸性氧化物，如 CO_2 、SO_2 、NO_2
- 生成阴离子，如 O^{2-}、Cl^- 、Br^-

铁屑
灰色，有磁性

硫
黄色，熔沸点低

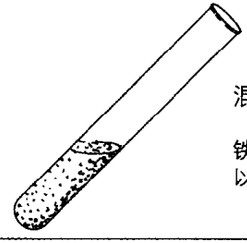
在地壳里的含量

元素	%	
氧	46.6	是含量最高的非金属
硅	27.7	
铝	8.1	是含量最高的金属
铁	5.0	
钙	3.6	
氢	0.22	
碳	0.19	形成大多数化合物

混合物

- 由物理变化而形成
- 保持组成物质的原有性质
- 成分组成可以变化
- 混合时，没有能量变化
- 可用物理变化分离
- 由元素或化合物组成

混合



混合物
仍能看到灰色的铁屑和黄色的硫，可以用磁铁分离。

重要的例子

空气

- 混合气体
- 组成成分

氮	78%
氧	21%
稀有气体	0.9%
二氧化碳	0.04%

- 可以用分馏的方法分离

石油

- 是各种饱和碳氢化物的混合物
- 产地不同，石油的成分也不同
- 可以用分馏的方法分离

海水

- 水中离子化盐的混合物

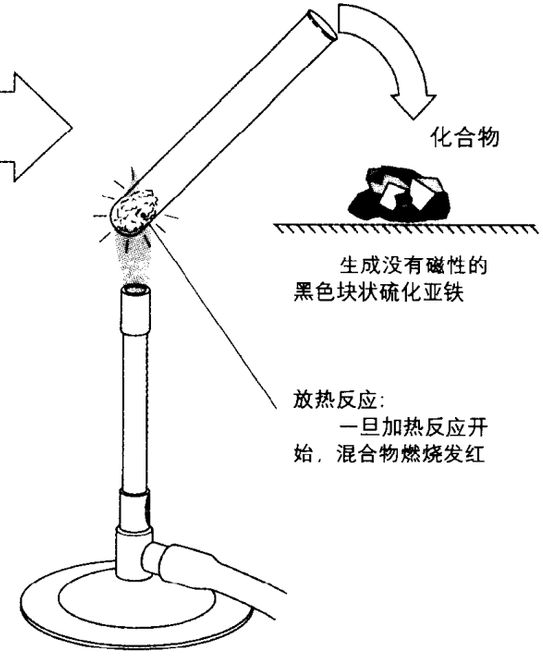
盐	质量（每 100 克水中的克数）
氯化钠	2.6
氯化镁	0.3
硫化镁	0.2
硫化钙	0.1
氯化钾	0.1

- 通过蒸馏收集到的水及蒸发收集到的盐来分离

化合物

- 由化学变化形成
- 跟反应物性质不同，它有新的性质
- 有固定的组成，有一定的化学式
- 在化学反应时有能量变化
- 只能通过分解（一种化学变化）反应来分离

化合



重要的例子

水	H_2O
氨	NH_3
甲烷	CH_4
二氧化碳	CO_2
氯化钠	NaCl
碳酸钙	$CaCO_3$
氧化铁	Fe_2O_3

Mixtures

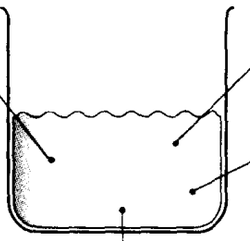
- made of more than one substance
- have variable composition
- properties are those of the original substances added together
- no energy change when mixing happens

SOLUTIONS

Recognized by being transparent – you can see through them.

The **solute** is the smaller part of the solution, often a solid.

The **solvent** is the larger part of a solution, usually a liquid.



Solutions are described as **homogeneous** or **uniform mixtures.**

Both the solute and solvent particles are very small and nearly the same size, so they are all in the same state or phase.

Important examples of solutions

Air
A mixture of gases. Nitrogen (~78%) is the solvent. Oxygen (~21%), the noble gases, and carbon dioxide are some of the solutes. The b.p.s are very close, so air is separated by fractional distillation:

nitrogen boils at -196°C
oxygen boils at -183°C

Nitrogen boils first and comes off the top of the column. Oxygen is left at the bottom.

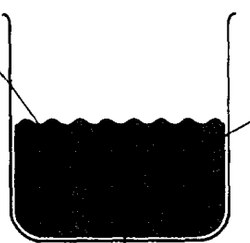
Crude oil
A mixture of saturated hydrocarbons. Composition varies and all the boiling points are very close together. So it is separated into **fractions**, which are groups of hydrocarbons with similar boiling points.

Sea water
Sea water is evaporated to provide common salt (sodium chloride) and the other solutes it contains. In dry parts of the world it is used to provide water for drinking and irrigation. The sea water is distilled, or separated by a process called reverse osmosis.

SUSPENSIONS

Recognized by being opaque – you cannot see through them.

Here the particles which are suspended are much larger than the particles they are suspended in. The suspended particles are actually clumps of pure solid or liquid. They are big enough to reflect light, so the mixture is opaque. Because these big particles are in a different state from the smaller particles, suspensions are called **heterogeneous** or **non-uniform mixtures.**



Often the larger particles sink to the bottom and the suspension separates by itself, but this can take a long time.

Important examples of suspensions

Milk
Particles of fat are suspended in water. They are less dense than water and in time will rise to the top (look at a bottle of full-cream milk).

Emulsion paint
Particles of coloured pigment are suspended in water. They settle to the bottom if the paint has not been stirred for a long time.

Muddy water
Mud particles are suspended when the water is stirred up. But the mud will settle out if the water is left undisturbed.

Salad dressing
Oil particles are suspended in the vinegar when the dressing is shaken. When left to stand the oil and vinegar separate into two layers.

混合物

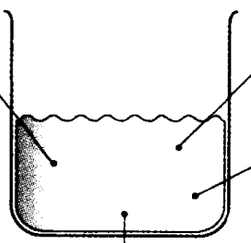
- 由一种以上的物质组成
- 没有固定的组成
- 保持混在一起的原物质的性质
- 当混合时没有能量变化

溶液

透明，可以透过溶液看到对面的东西。

溶质是溶液里量较少的部分，通常是固体。

溶剂是溶液里量较大的部分，通常是液体。



溶液被看作是**均一的混合物**。

溶质和溶剂的粒子都很小。大小几乎相同，所以它们处在同一状态或同一相。

溶液的重要例子

空气

是气体的混合物，其中氮气(~78%)是溶剂。而氧气(~21%)，稀有气体，二氧化碳是溶质。由于它们的沸点非常接近，因此，空气可以通过分馏的方法分离：

氮气沸点是 -196℃
氧气沸点是 -183℃

氮气先蒸发从分馏塔顶部馏出。氧气从分馏塔底部馏出。

原油

是饱和碳氢化合物的混合物，组成不定，且所有的组分沸点非常接近，所以，首先把原油分成几种馏分，每一馏分是一组碳氢化合物，而它们的沸点更接近。

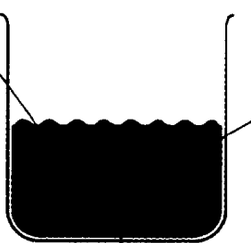
海水

海水蒸发后可以获得食盐（氯化钠）和海水里的其他溶质。在世界上的干旱地区，靠这种方法提供饮用水和灌溉水。人们采用一种逆向渗透的方法将海水蒸馏净化。

悬浮液

悬浮液不透明，无法透过悬浮液看到对面的东西。

悬浮物的粒子要比悬浮液（比如水）的粒子大的多，悬浮粒子实际上是纯固体或液体的粒子团。它们的体积很大，足以反射光，因此，混合物是不透明的，因为这些大的粒子团跟较小的粒子状态不同。所以认为悬浮液是**不均一的，多相的混合物**。



通常较大的粒子沉降到底部，悬浮液自身会分离，不过这一过程需要很长的时间。

悬浮液的重要例子

牛奶

脂肪粒子悬浮在水中，它们不像水那么稠密，脂肪粒子迟早会浮到液体表面（观察一瓶全脂牛奶）。

乳胶漆

颜料粒子悬浮在水中，如果乳胶漆搁置很久没经搅拌的话，颜料粒子会沉到底部。

泥水

搅拌水时，泥浆粒子会浮起，不过当不去搅拌时，泥浆会沉淀下来。

沙拉酱

当摇动沙拉酱时，油的粒子就悬浮在醋里，当静置时，油和醋分离成两层。

Separating mixtures

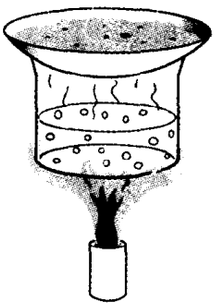
SOLUTIONS

Because all the particles are in the same state, solutions can only be separated by making one part change state.

Evaporation

Evaporation is used to collect the solute. The solvent changes into a gas and leaves the mixture.

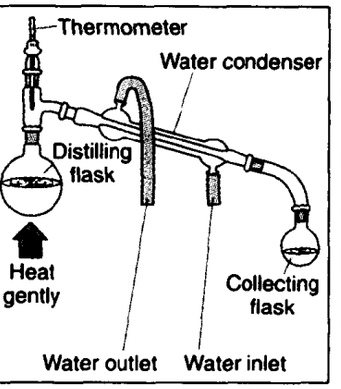
Evaporate in a basin with a large surface area on a water bath to prevent overheating and decomposition of the solute.



Distillation

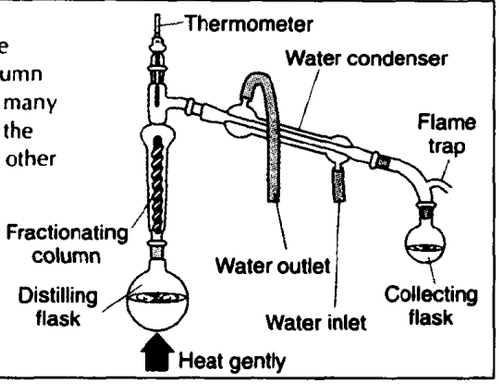
Distillation is used to collect the solvent. The solvent is collected and condensed as it leaves the mixture.

Remember the thermometer. This tells you the boiling point of the solvent, so you can check its identity.



Fractional distillation

This is used when b.p.s are close together. In the fractionating column the vapour condenses and boils many times. Each time the liquid with the lower boiling point gains on the other one and gets to the top first.



Chromatography

This is used when there are many solutes or very small quantities of solute.

Each solute will vary in solubility and in how strongly it bonds to the paper or material in the column. The solute which is most soluble and least well-bonded will travel fastest. So each solute is separated from the others by the process. Solutes can be identified by looking at how far they travel.

SUSPENSIONS

Suspensions are usually easier to separate than solutions because the suspended particles are in a different state. Suspensions can be separated by trapping the larger particles. This is done:

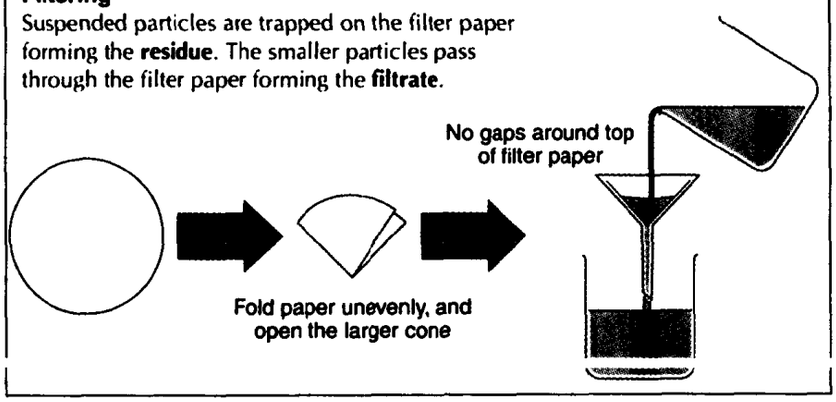
- in filter paper or in a bed of sand
- by careful decanting
- using a tap or separation funnel

Centrifuging

If a suspension is spun very fast, the larger particles move to the outside. So suspensions can be separated by suspending tubes in a centrifuge and spinning them. The residue packs down at the bottom of the tube and the filtrate (liquid) can be poured off.

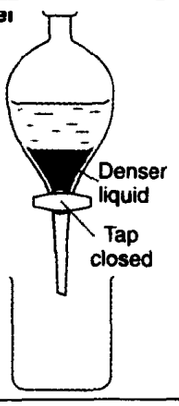
Filtering

Suspended particles are trapped on the filter paper forming the **residue**. The smaller particles pass through the filter paper forming the **filtrate**.



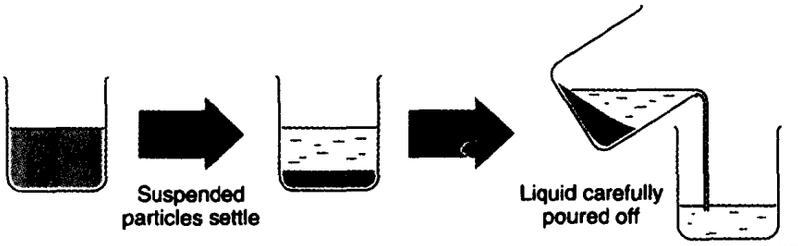
Using a tap funnel

Two insoluble (**immiscible**) liquids can be separated by running off the lower layer.



Decanting

If the suspension has separated out, the top layer can be carefully poured off.



分离混合物

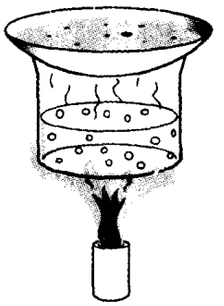
溶液

由于所有的粒子处在相同的状态，所以只能通过改变其中一种（溶剂或溶质）的状态来分离。

蒸发

用蒸发来收集溶质，溶剂变成气体离开混合物。

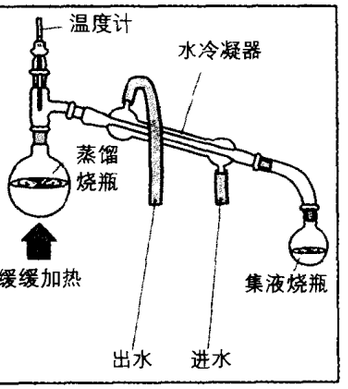
表面积大的蒸发皿搁在水浴上蒸发，可以防止加热过头，溶质分解。



蒸馏

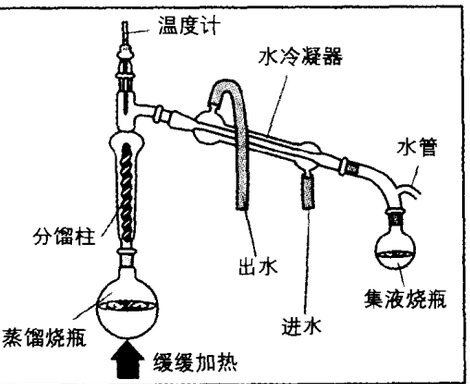
用蒸馏来收集溶剂。当溶剂离开混合物时，它冷凝并被收集起来。

记住要观察温度计，它能告诉你溶剂的沸点，这样，你就能检测溶剂的密度。



分馏

当液体沸点接近时，可以用分馏来分离。在分馏柱里，蒸气多次冷凝，沸腾。而每一次沸点较低的液体比其他液体先蒸发，并到达分馏柱顶部。



色谱法

当有许多溶质，且溶质的量又很小时，可以用色谱法分离。

每一种溶剂的溶解度不一样，而且它对试纸的结合力也不一样。最容易溶解且对试纸的结合力最小的溶剂爬升最快。所以，通过这一过程，一种溶剂就跟其他溶剂分离开来。可以通过观察溶剂在试纸上上升多远来识别它。

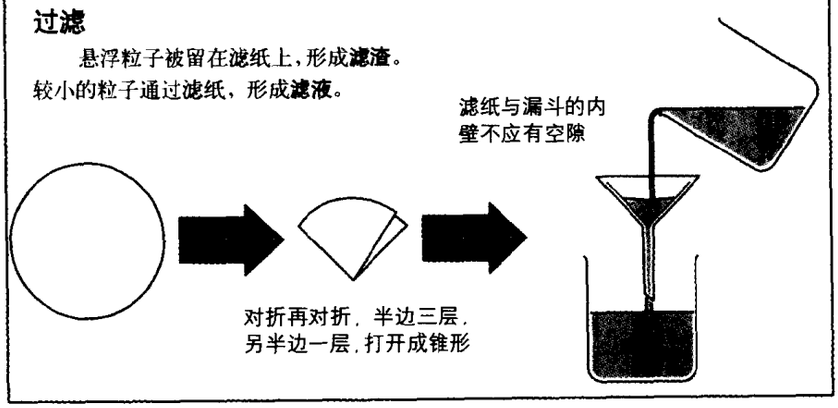
悬浮液

因为悬浮粒子跟溶液里的粒子状态不同，所以悬浮液通常较溶液容易分离，通过分离较大的粒子可以分离悬浮液。步骤如下：

- 用滤纸或沙床
- 小心地倾析
- 用一只活塞或分液漏斗

过滤

悬浮粒子被留在滤纸上，形成**滤渣**。较小的粒子通过滤纸，形成**滤液**。



离心分离

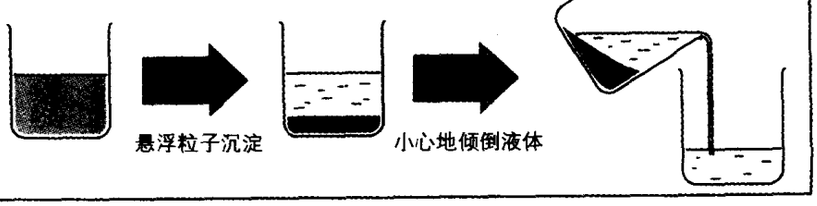
如果高速旋转悬浮液，较大的粒子就会移到外侧。所以把盛有悬浮液的试管悬挂在离心机里并旋转，就可以分离悬浮液。残留物会沉降在试管底部，而滤出液就可以倾倒出来。

用分液漏斗

把下层的液体放掉，可以分离两种互不相溶的液体。

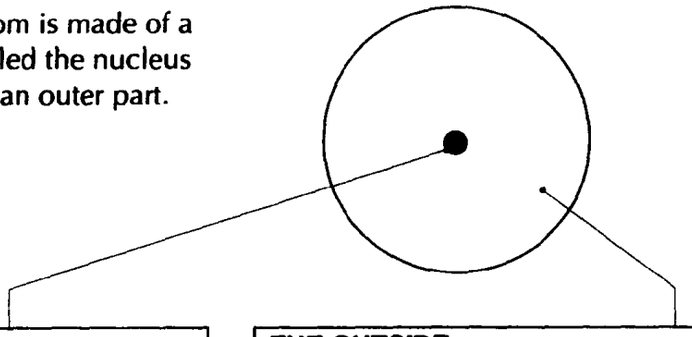
倾析

如果悬浮液已经分层，就可以很小心地把上层液体倾倒出来。



Atomic structure

The nuclear atom is made of a central part called the nucleus surrounded by an outer part.



NUCLEUS

- very *small*: less than 0.1% of the volume
- very *massive*: contains 99.9% of the matter
- so *very, very dense*

Contains particles called:

protons: relative mass 1 unit; relative charge +1 unit

and **neutrons**: relative mass 1 unit; charge 0

Atomic number

The atomic number of an element is the *number of protons in the atoms of that element.*

Mass number

The mass number of an atom is the *sum of the protons and neutrons in the nucleus of an atom.*

All the atoms of an element have the same atomic number.

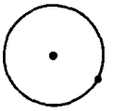
ISOTOPES

The number of neutrons in the atoms of an element can vary.

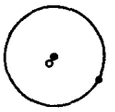
Atoms with the same atomic number but different mass numbers are called **isotopes**.

e.g. there are three isotopes of hydrogen

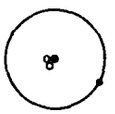
protium
written as $^{1}_{1}H$



deuterium
written as $^{2}_{1}H$



tritium
written as $^{3}_{1}H$



In the nucleus:

- • = proton
- ○ = neutron

So when writing the symbol for an isotope, write the mass number on top and the atomic number underneath.

THE OUTSIDE

- makes up 99.9% of the volume of the atom
- contains *hardly any mass* (about 0.1%), so is mainly empty space
- is *negatively charged*

Contains particles called **electrons**.

Electrons have very little mass – about 1840 times less than a proton or neutron.

Electrons are negatively charged with a relative charge of −1 unit.

The charge on one electron cancels out the charge on one proton.

Shells

Electrons are arranged around the nucleus in groups called shells.

The shells are numbered starting at the centre and working outwards.

The maximum number of electrons in each shell differs:

the *first* shell can hold up to **2**
the *second* shell can hold up to **8**
the *third* shell can hold up to **8**

ELECTRONIC STRUCTURE

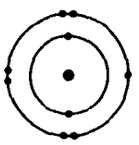
The energy of the electrons in each shell increases with the distance from the nucleus. So electrons in the inner shell have less energy than those in the shells outside. The electrons in each atom go into the shells with the lowest energy, so the inner shells are always filled up first.

The electronic structure (**electronic configuration**) of an atom is the arrangement of the electrons around the nucleus of the atom. It is shown using either a diagram or a list of numbers.

It is worked out like this:

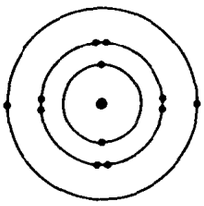
1. Look up the atomic number: this gives you the number of protons. In the neutral atom, the number of electrons is the same as the number of protons.
2. Start filling the shells until the right number of electrons have been placed.

e.g. **fluorine, atomic number 9**
so 2 electrons in the first shell
and 7 electrons in the second shell
written as **2.7**
drawn as



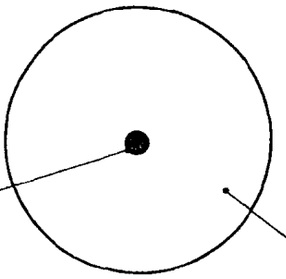
e.g. **magnesium, atomic number 12**
so 2 electrons in the first shell
and 8 electrons in the second shell
and 2 electrons in the third shell
written as **2.8.2**

drawn as



原子结构

核状的原子由处于中心部位的原子核和围绕它的外层部分组成。



原子核

- *很小*：不到总体积的0.1%
- *质量很大*：占原子质量的99.9%
- *非常非常致密*

含有粒子：

质子：相对质量1个单位；相对电荷+1个单位

中子：相对质量1个单位；相对电荷0个单位

原子序数

元素的原子序数就是*该元素原子里的质子数*。

质量数（这里指原子量）

一个原子的质量数就是*该原子原子核里质子数和中子数的总和*。

一种元素的所有原子有相同的原子序数。

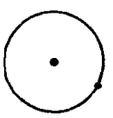
同位素

一种元素的原子里的中子数是可变的。

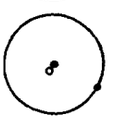
原子序数相同，但质量数不同的原子互称**同位素**。

比如：氢有三种同位素

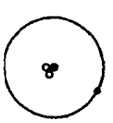
氕
用 $^{1}_{1}H$ 表示



氘
用 $^{2}_{1}H$ 表示



氚
用 $^{3}_{1}H$ 表示



在原子核里
- ● 代表质子
- ○ 代表中子

所以当书写一种同位素时，在右上角写质量数，而在左下角写原子序数。

核外层

- 占整个原子体积的99.9%
- *几乎没有质量（约0.1%）*，整个是空的
- *带负电荷*

所含粒子叫**电子**。

电子质量很小，比一个质子或一个中子质量的1840分之一还小。

电子带一个单位负电荷。

一个电子所带电荷正好跟一个质子所带电荷相抵消。

电子层

电子分层绕核排布，叫电子层。

这种电子层是从内向外排布的。

每一电子层最多容纳的电子数目是不同的：

*第一层*最多能容纳**2**个电子
*第二层*最多能容纳**8**个电子
*第三层*最多能容纳**8**个电子

电子结构

每一层电子的能量随着它跟原子核的距离的增加而增加。

所以内层电子的能量要比外层电子的能量小。

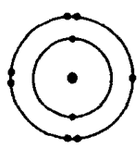
每个原子里的电子都先排布在能量最低的电子层上，因此越里面的电子层总是先充满。

一种原子的电子结构（**电子排布**）就是电子围绕该原子原子核的排布，它既可以用图也可以用表来表示。

步骤如下：

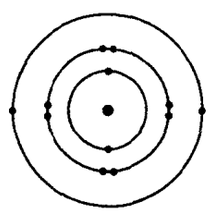
1. 先找出原子序数，它告诉你质子数。在中性原子里，电子数跟质子数是相同的。
2. 填充电子层，直到给出的电子全部填入电子层。

比如：**氟，原子序数是9**
2个电子填入第一层
7个电子填入第二层
用**2、7**表示
用图表示



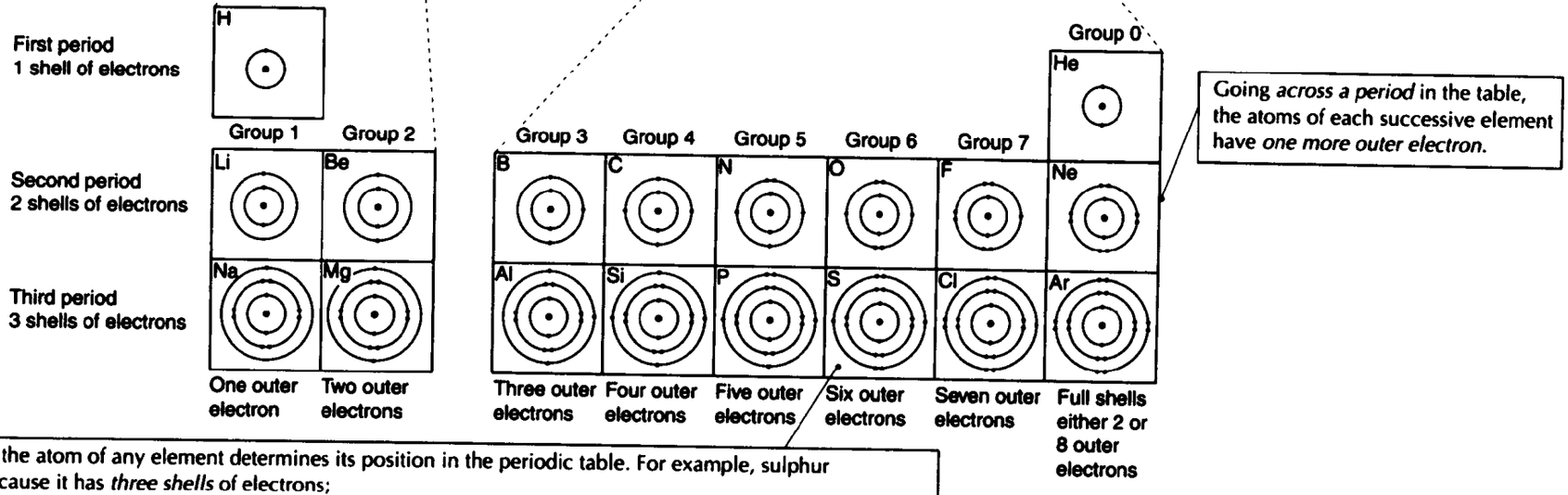
比如：**镁，原子序数12**
2个电子填入第一层
8个电子填入第二层
2个电子填入第三层
用**2、8、2**表示

用图表示



Atomic structure and the periodic table

The arrangement of electrons in an atom – the electronic structure or electronic configuration – is related to the position of the element in the periodic table. The electronic structure for the first three rows of elements is shown below.



Going *across a period* in the table, the atoms of each successive element have *one more outer electron.*

The electronic structure of the atom of any element determines its position in the periodic table. For example, sulphur

- is in the *third period* because it has *three shells* of electrons;
- is in group *six* because it has *six* outer electrons.

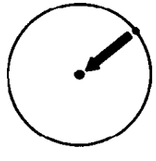
So the electronic structure of sulphur is: 2.8.6. ← Group 6

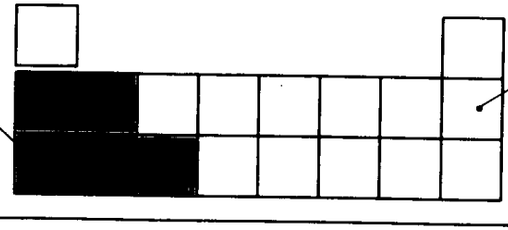
↖ three shells

TWO KINDS OF ATOM

Metal atoms

Atoms of metallic elements are large and attract outer electrons weakly.
e.g. sodium atom



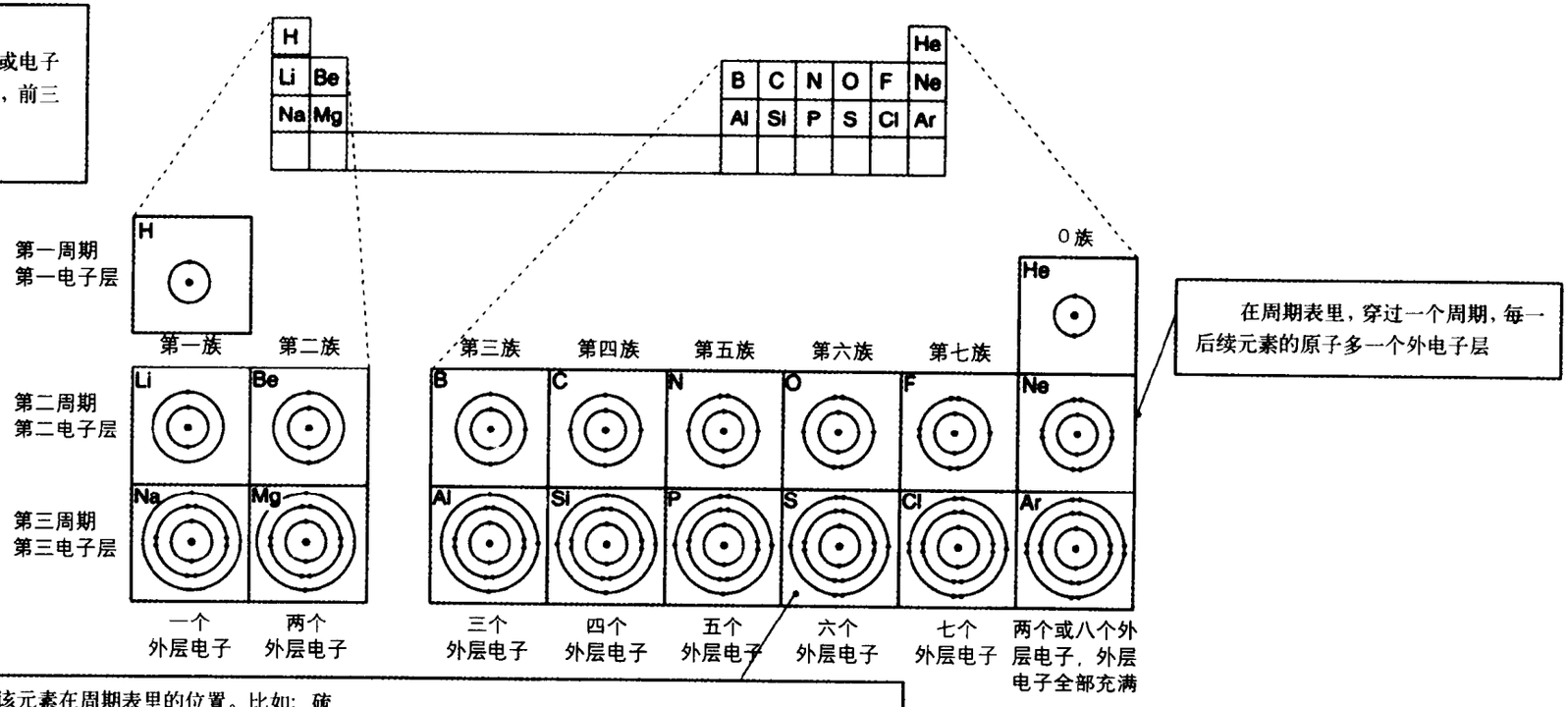


Non-metal atoms

Atoms of non-metallic elements are smaller and attract outer electrons more strongly.
e.g. chlorine atom

原子结构和周期表

原子里电子的分布——电子结构或电子排布——跟元素周期表里的位置有关，前三行元素的电子结构见下图。



在周期表里，穿过一个周期，每一后续元素的原子多一个外电子层

任何元素的原子的电子结构决定了该元素在周期表里的位置。比如：硫

- 在第三周期，因为它有三个电子层
- 在第六族，因为它有六个外层电子

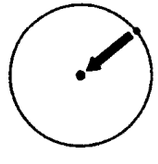
所以硫的电子结构是：2.8.6 ← 第六族
三个电子层

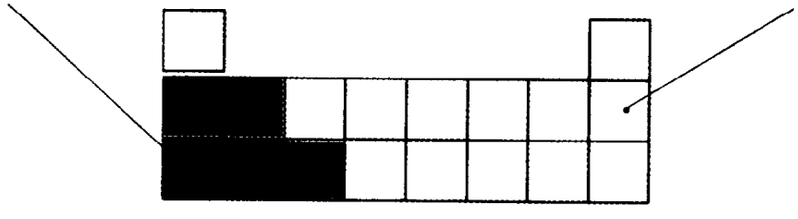
两类原子

金属原子

金属元素的原子较大，对外层电子的吸引力小。

如：钠原子





非金属原子

非金属元素的原子较小，对外层电子的吸引力较强。如：氯原子

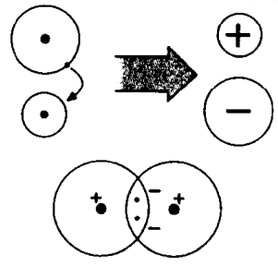
Introduction to bonding and structure

BONDING

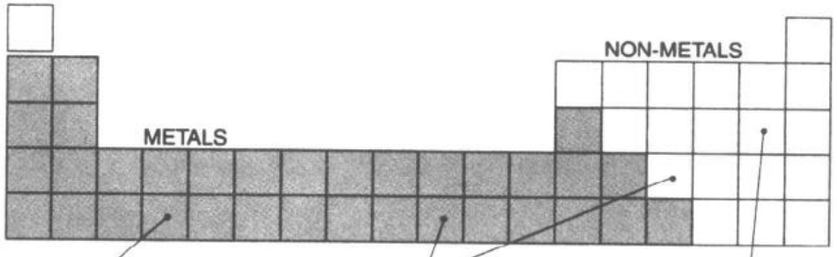
A **bond** is any attractive force between particles.
In every bond, positive particles are attracting negative ones.

If electrons are lost by one atom and gained by another, then the two atoms become oppositely charged and a bond forms.

If electrons are shared between two atoms, then the protons in both atoms attract the shared electrons and another kind of bond forms.



The periodic table helps us decide on the kind of bond



If both atoms are *metallic*, the bond is a *metallic* bond,
e.g. in copper or aluminium.

If one atom is *metallic* and the other is *non-metallic*, the bond is *ionic*,
e.g. in sodium chloride.

If both atoms are *non-metallic*, the bond is *covalent*,
e.g. in carbon dioxide, water, or iodine.

Some compounds like sodium hydroxide have two types of bonding: ionic bonding between the sodium ion and the hydroxide ion, and covalent bonding between the hydrogen and oxygen atoms.

Bond strength

There is no simple rule about which types of bonds are strongest.

Metallic bonds vary from the weak ones in mercury to the very strong ones in tungsten.

Ionic and covalent bonds also vary in strength.

STRUCTURE

After bonding takes place, there are different kinds of particle:

Atoms

- Metals are made of giant lattices of atoms held together by metallic bonds.
- Carbon (diamond or graphite) lattices are made of giant lattices of atoms covalently bonded together.
- Noble gas lattices (only formed at very low temperatures) are made of atoms held together by weak van der Waals' forces.

Ions

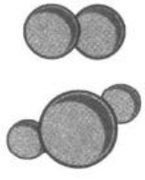
Compounds made from metals and non-metals exist in giant lattices made of ions. Ions are atoms which have gained or lost electrons and so have a charge.

Cations (metal ions) have positive charges because they have lost electrons.

Anions (non-metal ions) have negative charges because they have gained extra electrons.

Molecules

Elements and compounds of non-metals exist as groups of atoms covalently bonded together. These are called **molecules**. Molecules, like atoms, have no charge.



A **diatomic molecule** is made from only two atoms, e.g. H_2; N_2; O_2; Cl_2; I_2.

A **triatomic molecule** is made from three atoms, e.g. H_2O; CO_2.

Polyatomic molecules are made from many atoms, e.g. CH_4; CH_3CH_2OH.

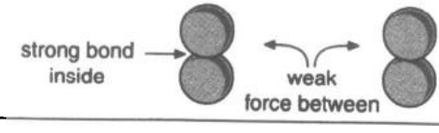
Bonding between molecules

Just as there are attractive forces between oppositely charged parts of next door atoms, there are also attractive forces between oppositely charged parts of next door molecules.

There are different kinds of forces between molecules. Some are called **polar forces** and some are called **van der Waals' forces**.

The most important thing to remember about these are:

- the forces inside molecules are much stronger than the forces between molecules
- the bigger the molecules are, the stronger the forces between them.



化学键和结构的初步知识

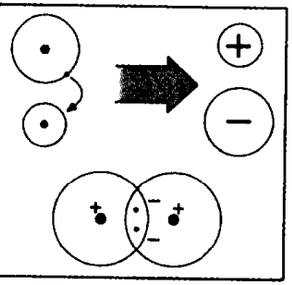
化学键

化学键是粒子之间的结合力

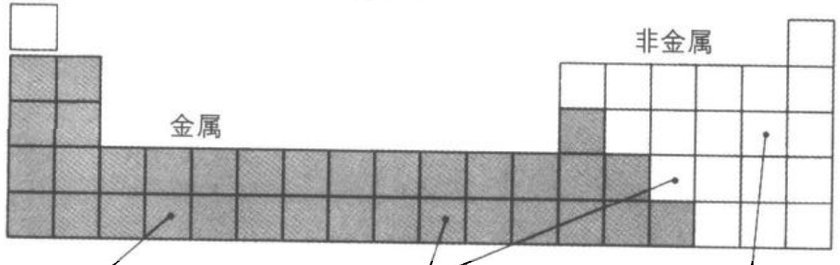
在每一种化学键里，带正电荷的粒子吸引带负电荷的粒子。

假如一个原子失去电子而被别的原子获得，那么这两个原子带有相反的电荷，并形成化学键。

假如电子由两个原子共有，那么这两个原子都吸引共有的电子，这时形成另一种形式的化学键。



周期表帮助我们知道形成哪一种化学键



如果两种原子都是*金属原子*，那么形成的化学键就是*金属键*。如铜或铝。

如果一种原子是*金属原子*而另一种原子是*非金属原子*，那么形成的化学键就是*离子键*。如氯化钠。

如果两种原子都是*非金属原子*，那么形成的化学键就是*共价键*。如二氧化碳、水或碘。

有些化合物像氢氧化钠有两种化学键：在钠离子和氢氧根离子之间的离子建以及氢原子和氧原子之间的共价键。

化学键力

没有简单的规律来决定，究竟哪种化学键更强。

金属键里的强弱差异很大，从很弱的汞到很强的钨。

离子键和共价键强弱差异也很大。

结构

化学键形成后，会生成不同种类的粒子：

原子

- 原子由金属键键合成巨大的晶格，形成金属。
- 碳（金刚钻或石墨）晶格是由原子由共价键键合形成巨大的晶格。
- 稀有气体晶格（仅在很低的温度下形成）是由原子靠弱范得华力结合形成的。

离子

化合物由巨大晶格上的金属离子和非金属离子形成。

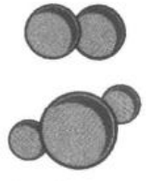
原子获得或失去电子成为离子，所以离子带有电荷。

⊕ **阳离子**（金属离子）因失去电子而带正电荷。

⊖ **阴离子**（非金属离子）因获得电子而带负电荷。

分子

非金属元素和非金属化合物以原子团的形式存在，而这些原子团以共价键结合在一起。这些原子团就叫分子，分子像原子一样不带电。



一个**双原子分子**仅由两个原子组成。

比如：H_2、N_2、O_2、Cl_2、I_2

一个**三原子分子**是由三个原子组成的，比如：H_2O、CO_2

多原子分子是由许多原子组成的，比如：CH_4、CH_3CH_2OH

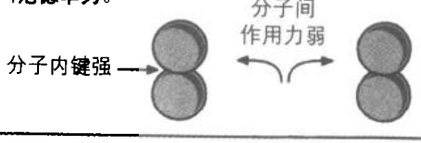
分子之间的键

正如十分靠近的原子所带的电荷如果相反的话，会互相吸引。那么十分靠近的分子所带的电荷如果相反的话，带电部分也会互相吸引。

有不同种类的分子间的力，有些叫**极性力**，有些叫**范德华力**。

记住以下的重要性质：

- 分子内部的力要比分子之间的力强得多。
- 分子越大，分子之间的力就越强。



Bonding and structure in metals

A theory of bonding must explain the properties of the substances.

KEY METALLIC PROPERTIES

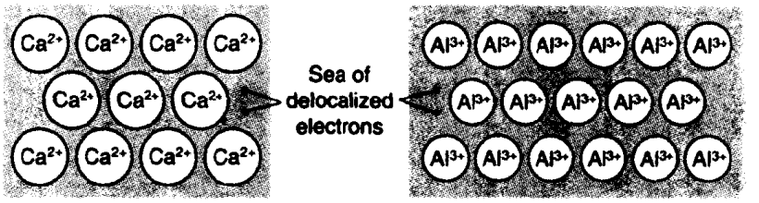
- good electrical conductivity
- malleable and ductile (can be bent and reshaped without suddenly snapping)

STRUCTURE IN METALS

In most metals the lattice of particles is arranged in the close-packed pattern shown below.

The lattice is formed of cations made of the nucleus and inner shell electrons. So the charge on the cations is always equal to the number of the group of the periodic table that the element is found in.

Between the cations there is a sea of outer electrons. These outer electrons are shared among all the atoms and can move anywhere in the lattice (they are **delocalized**).



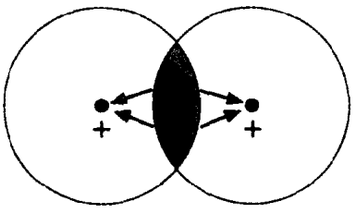
Calcium (Group 2) lattice

Aluminium (Group 3) lattice

BONDING IN METALS

Remember that metal atoms are large and attract outer electrons weakly.

In a metal, next door atoms overlap because the outer part of the atoms is mostly empty space.



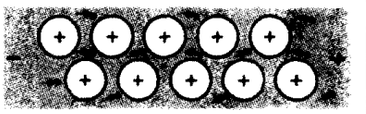
Both nuclei attract the electrons in the overlap area, so there is an attractive force between the atoms called a metallic bond.

Metallic bond: the electrostatic force of attraction that two neighbouring nuclei have for the shared electrons between them.

EXPLAINING THE KEY PROPERTIES

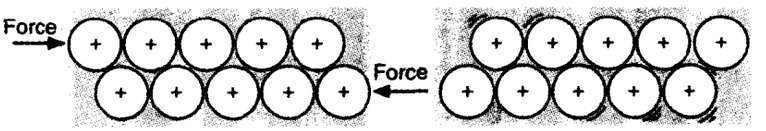
Electrical conductivity

Conduction is the movement of charge. In metals the delocalized electrons drift through the metal lattice carrying the charge.



Malleability and ductility

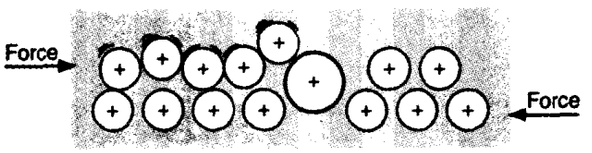
The shape of metals can be changed because the layers of atoms can slide past or over each other. When they do this, some bonds are broken, but an equal number are made.



CHANGING METALLIC PROPERTIES

Alloying

An alloy is a mixture of a metal and another element. Adding another element disturbs the pattern in the lattice so that the layers will not slide past each other so easily. Alloys are usually stronger and harder than the pure metal.



Heat treatment

If a liquid metal is cooled quickly, the crystals or grains in it have little time to grow. But if it is cooled slowly, large crystals or grains can grow. The crystal or grain size affects the strength of the metal. Metals with larger grains are softer than metals with smaller grains.

If a solid metal is slowly heated to red heat (so that the atoms have enough energy to rearrange) and then is suddenly cooled, the atoms are trapped in a new pattern. The strength and hardness of the metal will be changed.

Uses of metals

The physical properties of metals make them suitable for particular purposes:

- **electrical conduction**: copper and aluminium cables
- **thermal or heat conduction**: copper bottoms to saucepans
- **malleability**: copper pipes, steel car bodies, lead roofs, etc.

金属里的化学键和结构

化学键理论必须能解释物质的性质。

金属主要的性质

- 良好的导电性
- 有延展性

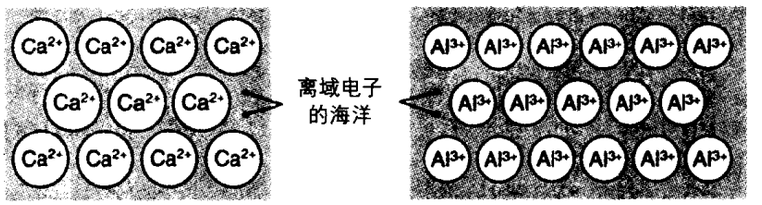
（能弯曲，变形而不会突然折断）

金属结构

在大多数金属里，粒子晶格紧密排列，见下图：

原子核及内层电子形成阳离子，而阳离子组成晶格。因此，阳离子所带的电荷数总是跟在周期表里该原素所处的族数相等。

在阳离子之间有一个外层电子的“海洋”，外层电子由所有的原子共享，并能在晶格里四处移动（它们是离域的）。

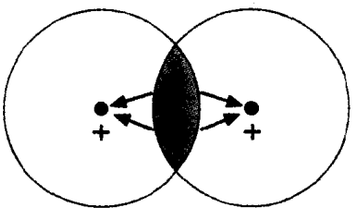


钙（第2族）晶格　　铝（第3族）晶格

金属里的化学键

记住：金属原子体积大，对外层电子的吸引力弱。

在金属里，互相紧靠的原子交叠在一起，因为它们的外层通常是空的。



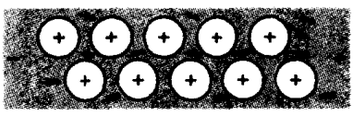
两个核都吸引互相交叠的地方的电子。所以，在原子之间有一种吸引力，这种力叫金属键。

金属键：两个相邻核由于共享电子而在它们之间产生的静电引力。

解释主要的性质

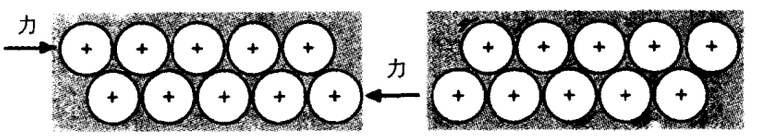
导电性

导电是由于电荷移动。在金属里，离域电子穿越金属晶格而移动电荷。



延展性

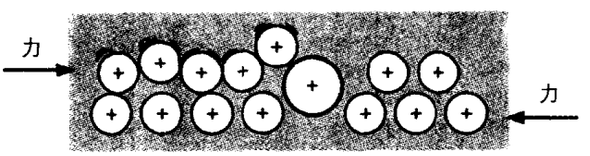
金属的形状可以改变。因为原子层相互之间可以滑动。当滑动发生时，有些键破裂，但相同数量的键又形成。



改变金属的性质

合金

合金是一种金属和其他元素的混合物，加入另外一种元素可以破坏原有晶格，这样原子层不会这么容易地互相滑动，合金通常比纯金属更坚硬。



热处理

假如液态金属快速冷却，内部的晶格或晶粒就没有时间生成。如果慢慢冷却，就会生成大的晶格或晶粒，晶体和晶粒的大小会影响金属的强度。晶粒较大的金属要比晶粒较小的金属软。

假如一种固体金属慢慢加热到红热（这样金属原子就有足够的能量重新排列），然后突然冷却，原子就会重排成新的晶格，金属的强度和硬度就会改变。

金属的应用

金属的物理性质使它们适宜于一些特殊的用途：

- **导电**：铜导线或铝导线。
- **导热**：用铜做锅子的底。
- **延展性**：铜管，钢制汽车车身，铅皮屋顶等。

Bonding and structure in ionic compounds

A theory of bonding must explain the properties of the substances.

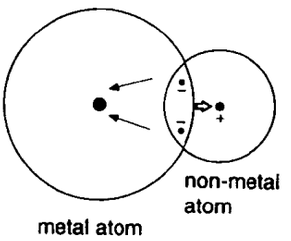
KEY IONIC PROPERTIES

- hard, high melting point solids
- insulators when solid, but conduct when molten or dissolved
- brittle – they break suddenly under load

BONDING IN IONIC COMPOUNDS

Remember that metal atoms are large and hold outer electrons weakly, but non-metal atoms are small and hold outer electrons strongly.

This means that when metal and non-metal atoms meet, electrons are lost by the metal atom and gained by the non-metal atom.



The metal atom loses the outer electrons leaving a positive ion.

The number of electrons lost is the number of electrons in the outer shell. This is the same as the group number, so the charge on the positive ion equals the group number.

e.g. Group 1 2 3
Na^+ Mg^{2+} Al^{3+}

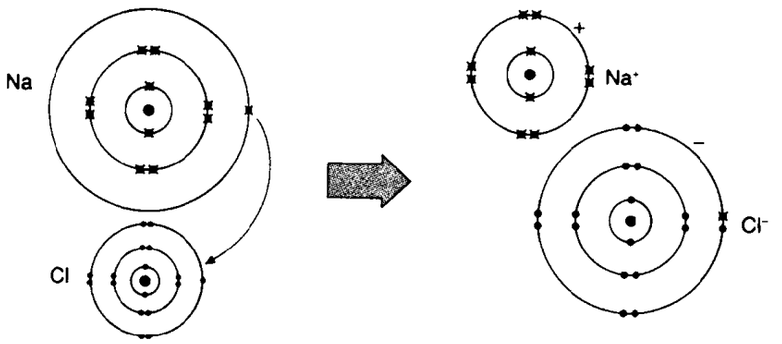
The non-metal atom gains new outer electrons making a negative ion.

Electrons are gained from the metal atom until the outer shell is full. So the charge on the ion is the same as the number of gaps in the outer shell. This is given by (8 – group number).

e.g. Group 6 7 0
O^{2-} F^- –

no gaps so no ions formed

For example, when sodium and chlorine react:



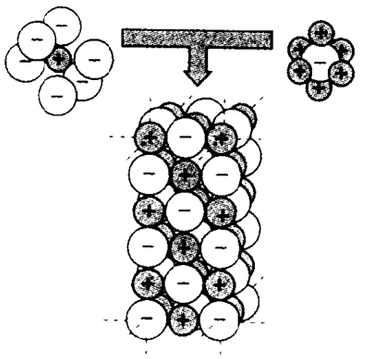
The ions formed have full outer shells. They have the same electronic structure as a noble gas.

The oppositely charged ions attract each other and an ionic bond is formed.

Ionic bond: the electrostatic force of attraction between two oppositely charged ions formed as the result of electron transfer. Ionic bonds are sometimes called electrovalent bonds.

STRUCTURE IN IONIC COMPOUNDS

The oppositely charged ions clump together and a lattice forms. When you draw an ionic lattice, do not draw lines between the ions: lines are used to represent covalent bonds. Remember that positive ions are nearly always smaller than negative ones.



EXPLAINING THE KEY PROPERTIES

Hardness, high melting point

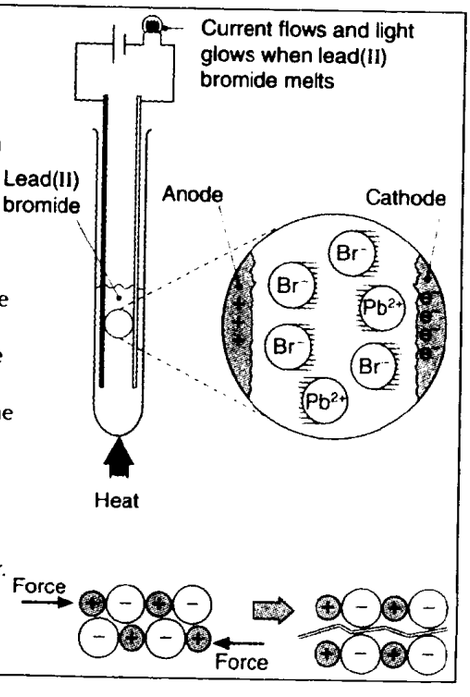
Oppositely charged ions attract each other strongly forming a lattice which is difficult to break up.

Electrical properties

In the solid state the ions are held in place and cannot move. Once the substance has melted or dissolved, the ions can move and carry charge. Positive ions are attracted towards the cathode: they are called cations. Negative ions are attracted towards the anode: they are called anions.

Brittleness

When a force is applied, the strongly bonded lattice resists. But eventually the layers start to slide past each other. Ions of the same charge move next to each other and repulsion replaces attraction. The solid breaks.



离子化合物的键和结构

化学键理论必须能解释物质的性质。

离子化合物的主要性质

- 坚硬，熔点高的固体。
- 固体时不导电，熔融或溶解时能导电。
- 脆性—在加压时，会突然碎裂。

离子化合物里的键

记住，金属原子大，对外层电子的吸引力弱；非金属原子小，对外层电子的吸引力强。

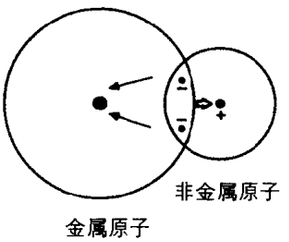
当金属原子跟非金属原子相遇时，金属原子失去电子，而非金属原子获得电子。

金属原子失去外层电子变成带正电荷的离子。

失去电子的数目就是外层上的电子数，它跟金属所在的族数相同。因此带正电荷的离子所带的电荷数也跟族数相等。

比如：族 1 2 3

Na^+ Mg^{2+} Al^{3+}



非金属原子获得新的外层电子变成带负电荷的离子。

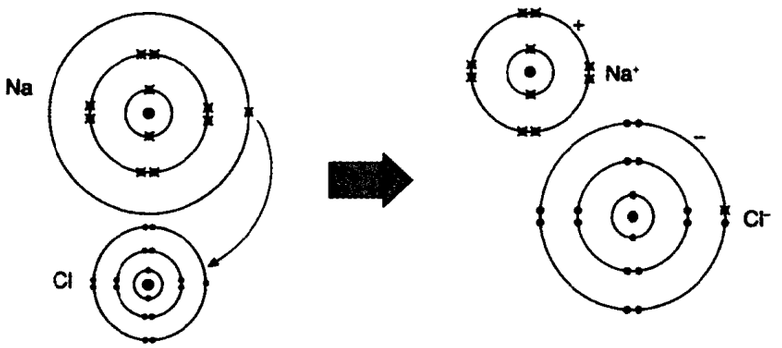
这些电子来自金属原子，直到外层充满为止。因此带负电荷的离子所带电荷数跟外层需充满还缺的电子数相同。可以用（8 − 族数）来求得。

比如：族 6 7 0

O^{2-} F^- −

（已饱和，没有离子生成）

比如，当钠跟氯反应：



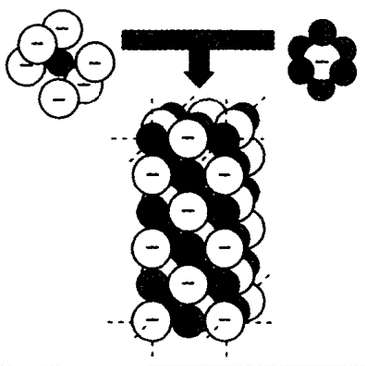
生成的离子外层已充满。
它们跟稀有气体的电子结构相同。

带有相反电荷的离子互相吸引形成离子键。

离子键：由于电子转移，形成带有相反电荷的离子，它们靠静电引力互相吸引，离子键有时也叫电价键。

离子化合物的结构

带有相反电荷的离子堆积在一起，形成晶格。当画一个离子晶格时，不要在离子之间画直线。直线用来代表共价键，记住带正电荷的离子，几乎总是比带负电荷的离子小。



解释主要的性质

坚硬，熔点高

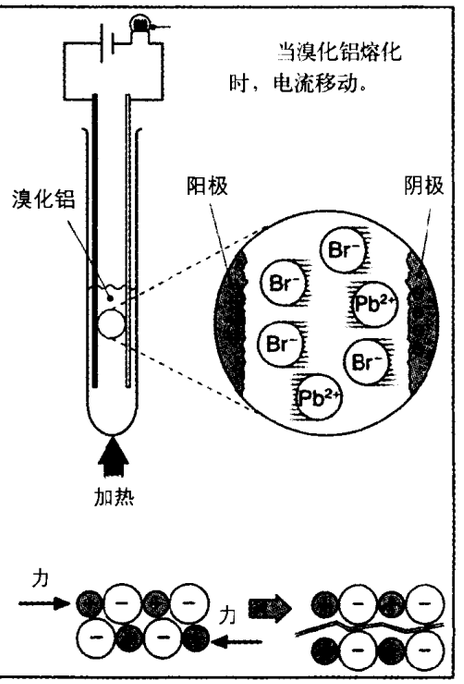
带有相反电荷的离子互相强烈吸引，形成一种晶格，这种晶格很难被打破。

导电性

在固体状态下，离子有固定的位置，不能移动。一旦物质熔化或溶解，离子就能移动并带有电荷。带正电荷的离子被阴极吸引而向阴极移动，它们叫阳离子。带负电荷的离子被阳极吸引而向阳极移动，它们叫阴离子。

脆性

当受到外力时，有强键构成的晶格就要抵抗，如外力到达一定程度，层与层之间开始互相滑动，带有相同电荷的离子经移动几乎正好相对，结果，斥力代替引力，固体碎裂。



Bonding in covalent substances

A theory of bonding must explain the properties of substances.

KEY COVALENT PROPERTIES

There are two different kinds of covalent substance:

- *either* gases, liquids, and soft solids, *or*
- hard, very high m.p. solids

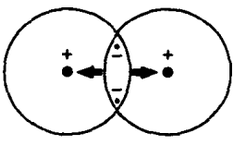
Both are insulators.
Both are brittle in the solid state.

Covalent bonding is found in non-metallic elements as well as compounds.

BONDING IN COVALENT SUBSTANCES

Remember that non-metal atoms are smaller than metal ones and attract their electrons strongly.

When two non-metal atoms touch and overlap, pairs of electrons in the area of overlap get attracted to both nuclei and a bond forms.



Covalent bond: the electrostatic force of attraction that two nuclei have for a shared pair of electrons between them.

A covalent bond can be drawn in a number of ways. For example, the bond between two hydrogen atoms can be drawn in three ways.

H:H or H:H or H–H

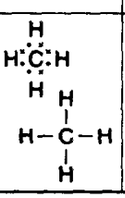
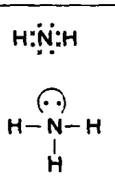
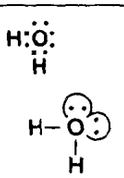
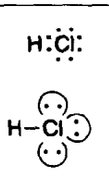
NUMBER OF BONDS FORMED

The number of covalent bonds an atom of an element makes depends on the position of the element in the periodic table.

Remember that to make a covalent bond an atom needs

- an electron to put into the bond, and
- a space or gap in its outer shell into which the other atom's electron can go.

The table shows this.

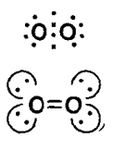
Group	3	4	5	6	7	8
Number of electrons in outer shell	3	4	5	6	7	8
Number of gaps in outer shell	5	4	3	2	1	0
Number of bonds made	3	4	3	2	1	0
Examples						

All these molecules have one or more shared pairs of electrons making the bonds. Some of them also have pairs of electrons belonging to one atom only. These are called **non-bonding pairs** or **lone pairs**.

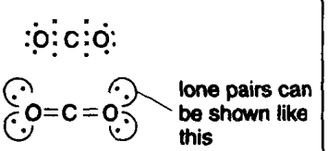
DOUBLE AND TRIPLE BONDING

Sometimes atoms can share more than one pair of electrons between them. When this happens, double or even triple bonds are made.

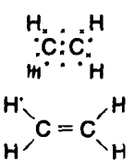
in oxygen, O_2



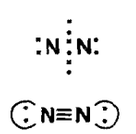
in carbon dioxide, CO_2



in ethene, C_2H_4



in nitrogen, N_2



It does not matter whether the bonds made are single, double, or triple: the total number of bonds made by an atom does not change. In the examples here, carbon still makes four bonds, nitrogen makes three, oxygen makes two, and hydrogen makes one.

共价物的键

化学键理论必须能解释物质的性质。

共价键化合物的主要性质

有两种不同类型的共价键物质：

- *无论是气体、液体和软的固体，还是*
- 硬的、高熔点的固体

它们都是绝缘体。

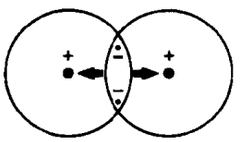
而且在固态时很脆。

共价键存在于非金属元素和化合物中。

共价物的键

记住非金属原子要比金属原子小，并能强烈吸引金属原子的电子。

当两个非金属原子碰撞并互相交叠，两个原子核共同吸引交叠区的电子对，并形成键。



共价键：两个原子核靠静电引力共享它们之间的电子对。

有许多画法来表示共价键，比如：两个氢原子之间的键可以用三种图示方法来描述。

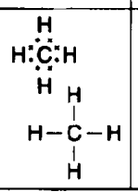
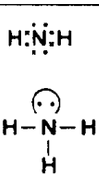
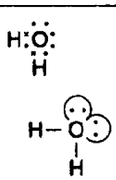
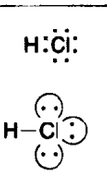
H:H　　或　　H:H　　或　　H−H

键生成的数目

一种元素的原子形成共价键的数目取决于该元素在周期表里的位置。

记住：要形成一个共价键，一个原子需要

- 一个电子供成键用。
- 外电子层有空穴使其他原子的电子能进入。

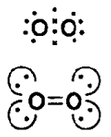
族	3	4	5	6	7	8
外电子层电子数	3	4	5	6	7	8
充满外电子层还需要的电子数	5	4	3	2	1	0
成键的数目	3	4	3	2	1	0
例						

所有这些分子都有一个或几个成键的共用电子对。其中有些分子里的电子对只属于一个原子，它们叫做**非成键电子对**或**孤对电子**。

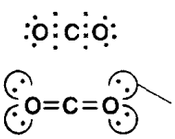
双键和三键

有时候原子之间共用的电子对不止一对，当发生这种情况时，形成了双键或三键。

在氧分子里，O_2

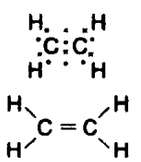


在二氧化碳分子里，CO_2

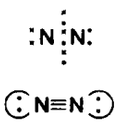


孤对电子可以画成这样

在乙烯分子里，C_2H_4



在氮分子里，N_2



不管形成的共价键是单键、双键或三键，一个原子成键的总数不会改变。比如：这里，碳形成四个键，氮形成三键，氧形成双键而氢形成单键。

Structure of covalent substances

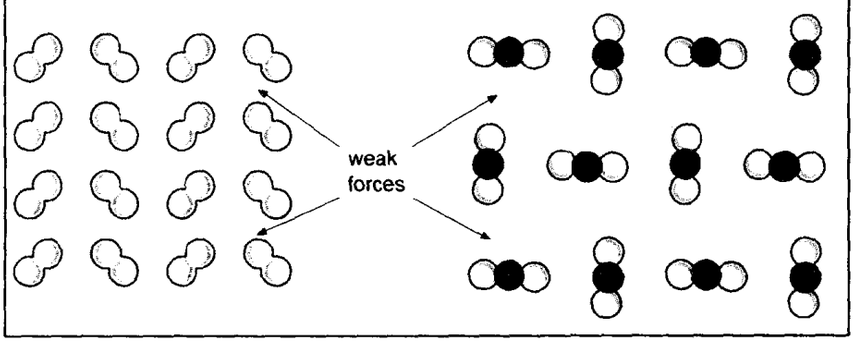
MOLECULAR COVALENT SUBSTANCES

These substances exist as separate, covalently bonded molecules. Molecules have no charge.

The covalent bonding *inside* each molecule is *very strong*, but the bonding *between* the molecules is much, much *weaker*. It is this weak bonding which is overcome when these substances are broken or melted.

The solid lattices are made of ordered arrangements of molecules.

e.g. iodine, I_2 — carbon dioxide, CO_2



EXPLAINING THE KEY PROPERTIES

Softness and low melting point

When a force is applied to these substances, or when they are heated, it is the weak forces *between* the molecules that are overcome. The strong forces inside the molecules are not overcome.

Because these intermolecular (between molecules) forces are so weak, the solids are soft and melt easily.

Insulators

There are no charged particles free to move in these substances. The electrons are localized in pairs and there are no ions. So they do not conduct.

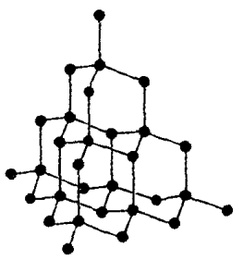
Brittleness

When force is applied and the weak forces are overcome, no new bonds are made. The substance suddenly breaks.

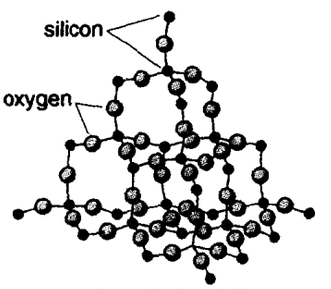
MACROMOLECULAR (GIANT COVALENT) SUBSTANCES

These substances exist in huge, covalently bonded lattices. A diamond is a single giant molecule with millions of bonds. Strong covalent bonding continues throughout the whole lattice. Here there are no weak forces to break, only strong covalent bonds.

e.g. diamond — silicon dioxide (quartz)



diamond lattice



silicon dioxide lattice

EXPLAINING THE KEY PROPERTIES

Hardness and high melting point

Breaking or melting these substances involves breaking strong covalent bonds. So these substances are very hard with very high m.p.s. Diamond is the hardest substance known.

Insulators

There are no charged particles free to move in these substances. The electrons are localized in pairs and there are no ions. So they do not conduct.

Brittleness

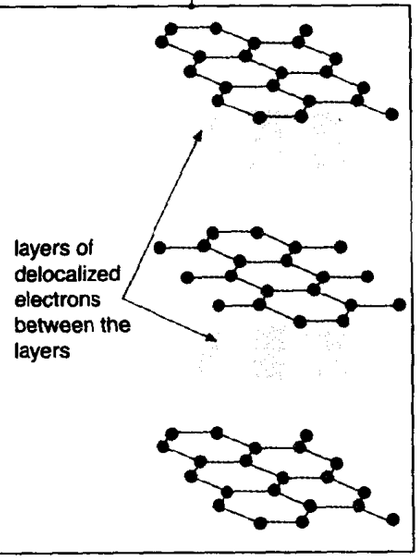
When force is applied and the weak forces are overcome, no new bonds are made. The substance suddenly breaks.

THE UNUSUAL PROPERTIES OF GRAPHITE

Graphite is a form of carbon. Although it is covalently bonded, it conducts electricity. Carbon rods used for electrolysis are made of graphite.

Graphite has a layered structure in which each carbon uses only three electrons for bonding. The fourth electron from each atom is delocalized and shared throughout the layer. Because graphite has delocalized electrons (like a metal), it conducts electricity (like a metal).

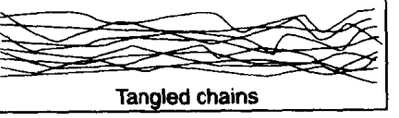
Carbon atoms also exist in cage-like lattices called fullerenes.



POLYMERS

Polymers are giant chains of covalently bonded atoms forming extremely long molecules. Like other covalent molecules, the forces between them are much weaker than the forces inside them. But these long molecules can tangle together like string or spaghetti. This tangling is made worse if the polymer molecules have side chains sticking out of them.

Plastics are polymers. Some plastics are bendy and flexible because of this tangling of long polymer chains.



Tangled chains

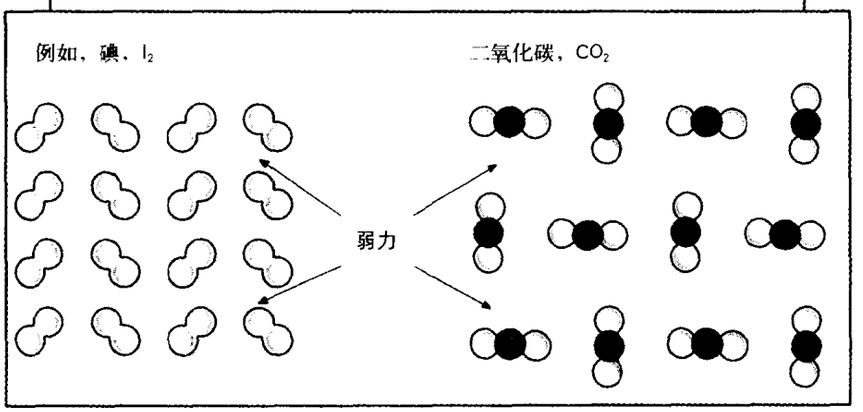
共价物的结构

共价物分子

这些物质以共价分子形式单独存在，分子不带电荷。

每个分子内的共价键很强，但是分子间的键弱得多，当这些物质碎裂或熔化的时候，正是这个弱键被克服的时候。

固体晶格是分子有规则地排列形成的。



解释主要的性质

柔软、熔点低

当这些物质受力或受热时，分子间的弱作用力被克服，而分子内的强作用力并没有被克服。

因为这些分子间的力很小，所以固体是柔软的，容易熔化。

绝缘体

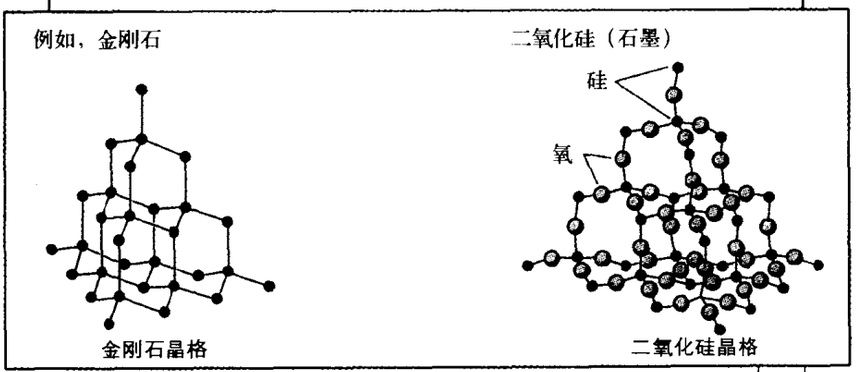
在这些物质中，没有可以自由移动的带电粒子。电子定域于电子对上，而没有离子，所以它们不导电。

脆性

当这些物质受力时，分子间的弱作用力被克服，没有新键生成。物质会突然断裂。

高分子（大共价键）物质

这些物质有巨大的共价键晶格，金刚石是一种单一的大分子，它有几百万个键。强共价键充满整个晶格，整个高分子里只有强共价键，而没有会断裂的弱作用力。



解释主要的性质

坚硬、熔点高

要打碎或熔化这些物质，就要打破强共价键。所以，这些物质很硬，且有很高的熔点。金刚石是已知的最硬的物质。

绝缘体

在这些物质中，没有可以自由移动的带电粒子。电子定域于电子对上，而没有离子，所以它们不导电。

脆性

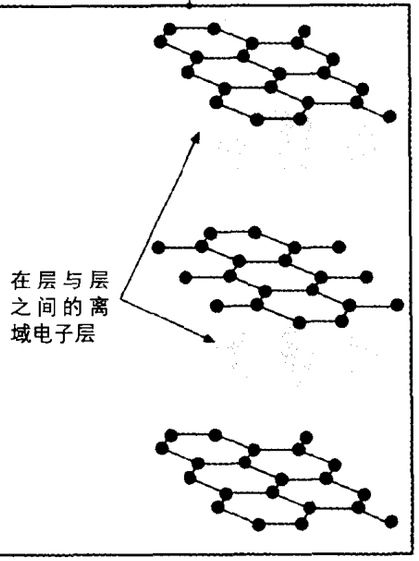
当这些物质受力时，分子间的弱作用力被克服，没有新键生成，物质会突然断裂。

石墨的特性

石墨是碳的一种存在形式，虽然以共价键结合，但它能导电，电解用的碳棒就是石墨做的。

石墨有一种层状结构，它的每一个碳原子只用三个电子成键，每个碳原子里的第四个电子是离域于整个层面的，正因为石墨有离域电子（像金属那样），所以它能导电（像金属那样）。

碳原子还以鸟笼状的晶格存在，这种晶格叫足球烯（C60）。



聚合物

聚合物是巨链状的以共价键结合的众多原子形成一种特别长的分子，像其他共价分子一样，它们分子之间的力要比分子内部的力小得多，但是这些长分子就像绳子或面条那样会缠结在一起。如果聚合物分子有支链伸出的话，这种缠结会更厉害。

塑料就是聚合物，正因为这种长聚合链的缠结，有些塑料可以弯曲，有挠性。


缠结的链

Bonding and structure in the main groups of the periodic table

								0
	H							He
	1	2	3	4	5	6	7	
	Li	Be	B	C	N	O	F	Ne
	Na	Mg	Al	Si	P	S	Cl	Ar

HYDROGEN

Hydrogen is a covalent molecular diatomic gas.

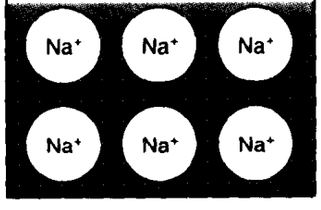
H:H or H–H

GROUP 0

The noble gases are all atomic gases. The atoms all have full outer shells of electrons, and attract their electrons very strongly. The forces between the atoms are weak, but increase down the group as the number of electrons in the atoms increases. So the m.p.s and b.p.s increase down the group.

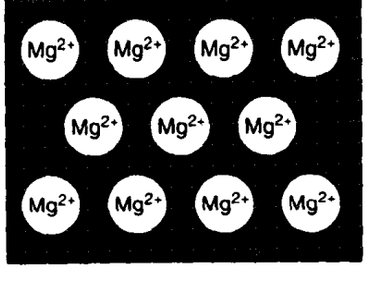
GROUP 1

Group 1 metals are metallically bonded in atomic lattices. The one outer electron from each atom is delocalized.



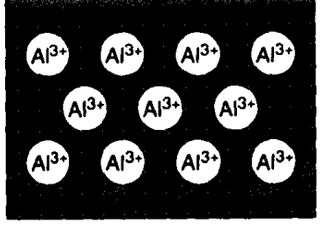
GROUP 2

Group 2 metals are metallically bonded in atomic lattices. Two outer electrons from each atom are delocalized. The double charge on the ions attracts the electrons more than a single charge can. So Group 2 metals are harder than Group 1 metals.



GROUP 3

Aluminium is metallically bonded in an atomic lattice. Three outer electrons from each atom are delocalized. They are strongly attracted to the triply charged cation.



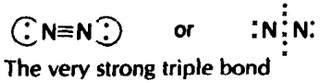
GROUP 4

Carbon exists in three structures in the solid state. This is an example of **allotropy**. All three structures are giant or macromolecular covalent lattices (see page 16).

Silicon has a diamond structure.

GROUP 5

Nitrogen is a covalent, molecular, diatomic gas



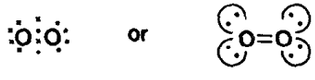
The very strong triple bond makes nitrogen very unreactive.

GROUP 6

Oxygen and sulphur both show allotropy. Each has two forms.

Oxygen

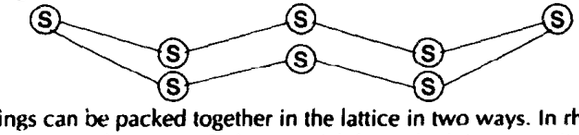
Oxygen is found in two gaseous forms. Dioxygen, O_2, is the common form.



Trioxygen or ozone, O_3, is found in the atmosphere in smaller quantities.

Sulphur

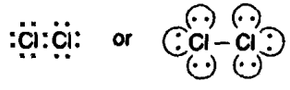
Sulphur is found in two solid forms. Both are molecular, covalent solids made of S_8 molecules.



The S_8 rings can be packed together in the lattice in two ways. In rhombic sulphur (which melts at 113°C) they are tightly packed. In monoclinic sulphur (which melts at 119°C) they are more loosely packed.

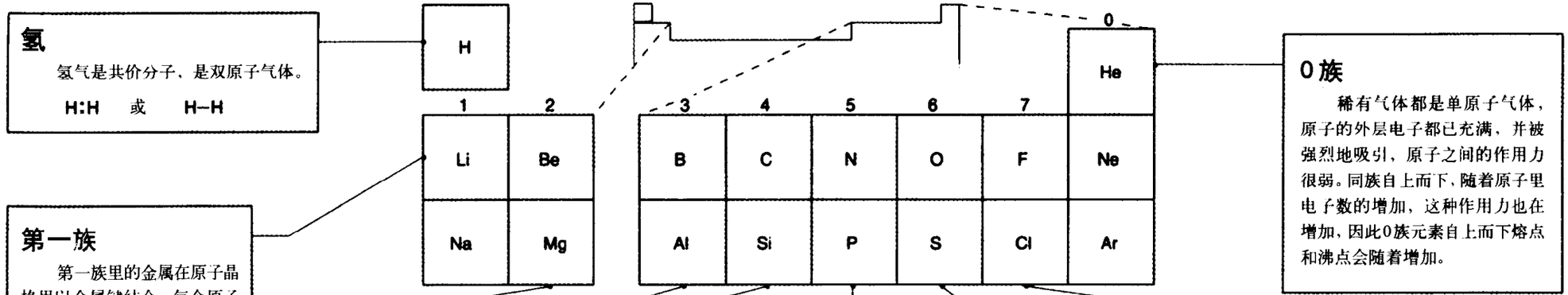
GROUP 7

The halogens are covalent, molecular, diatomic elements.



Going down the group, the bond *inside* the molecule gets weaker as the shared pair of electrons gets further from the nuclei. But the forces *between* the molecules gets stronger as the number of electrons increases. So fluorine and chlorine are gases, bromine is a liquid, and iodine is a solid.

周期表主族的键和结构



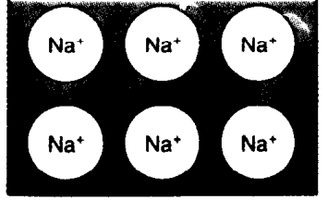
氢

氢气是共价分子，是双原子气体。

H:H　或　H–H

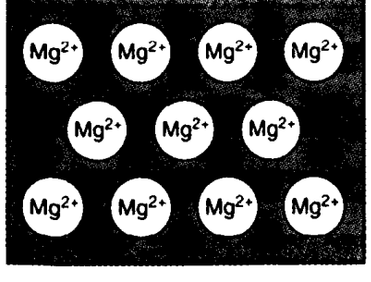
第一族

第一族里的金属在原子晶格里以金属键结合，每个原子的一个外层电子是离域的。



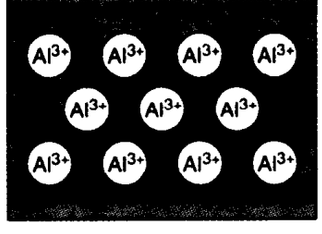
第二族

第二族的金属在原子晶格里以金属键结合，每个原子的外层电子是离域的。带2个电荷的离子要比带1个电荷的离子更能吸引电子，所以第二族金属要比第一族金属硬。



第三族

铝在原子晶格里以金属键结合，每个原子的三个外层电子是离域电子。带三个电荷的阳离子会强烈地吸引它们。

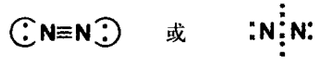


第四族

碳在固态时以三种状态存在，这是一种同素异形现象。这三种结构都是高分子或大分子共价晶体。硅有跟金刚石一样的结构。

第五族

氮气是共价分子，双原子气体。



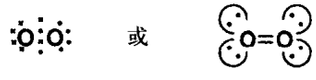
很强的三键使氮气很不活泼。

第六族

氧和硫都有同素异形现象，它们各有两种同素异形体。

氧

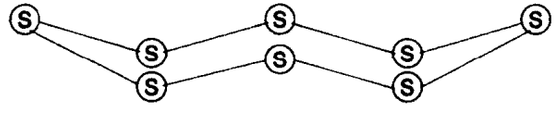
氧以气体形式存在，双原子氧 O_2 是它的常见形式。



三原子氧也叫臭氧，O_3，存在于大气中，量较小。

硫

硫以两种固体形式存在，两者都是分子共价固体，由 S_8 分子组成。



S_8 环可以用两种方式叠在一起成晶格，在菱形硫（熔点是113℃），它们是紧叠在一起的，而在单斜硫（熔点119℃）排列就疏松得多。

第七族

卤素是共价、双原子分子。

同族自上而下随着共用电子对逐渐远离原子核，分子内的键逐渐变弱，但由于电子数的增加，分子间的作用力却越来越强，因此，氟和氯是气体，溴是液体，而碘是固体。

0族

稀有气体都是单原子气体，原子的外层电子都已充满，并被强烈地吸引，原子之间的作用力很弱。同族自上而下，随着原子里电子数的增加，这种作用力也在增加，因此0族元素自上而下熔点和沸点会随着增加。

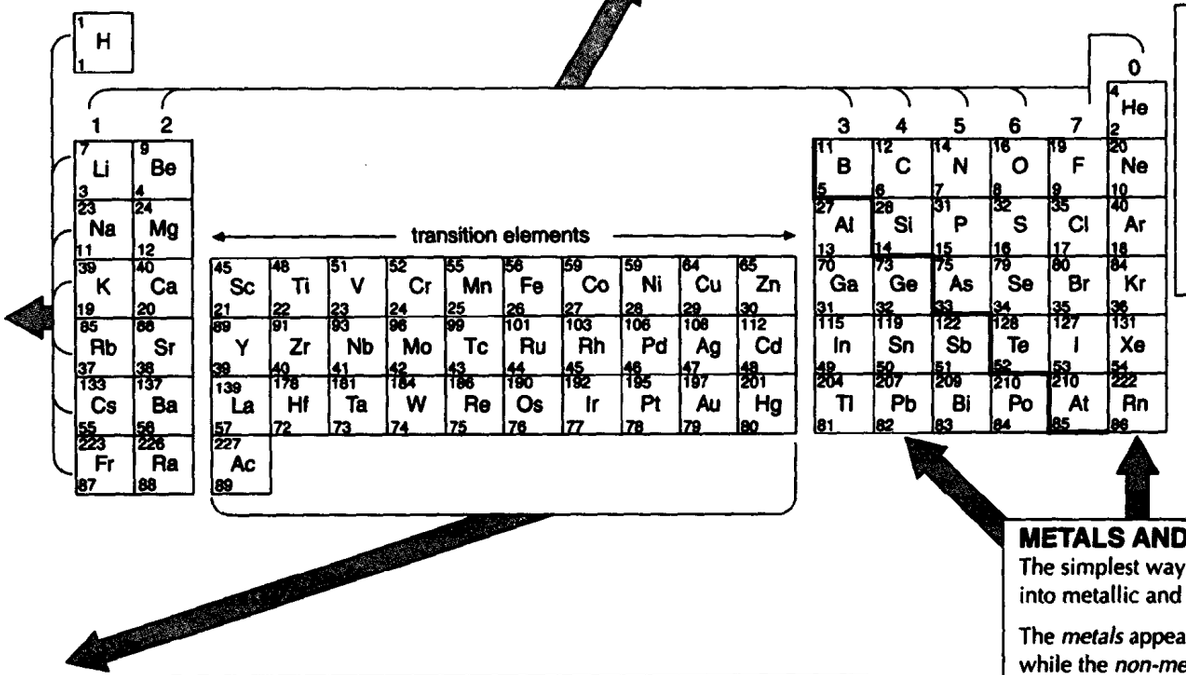
The periodic table

The periodic table is a list of the elements in order of their atomic numbers.
The list is set out so that elements with similar properties are in vertical columns.

GROUPS

- The long vertical columns of elements are called **groups**.
- The groups are numbered from 0 to 7.
- A group contains elements with similar properties.
- Going down a group, the elements show trends as the properties they share change slightly.

Hydrogen is the first element and is unlike any other. So hydrogen is in a box by itself and is not part of any of the groups.



PERIODS

Periods are horizontal rows of elements. A period contains elements with different properties. Each period, apart from the first one, starts with metals and changes to non-metals.

GROUP NAMES

Some groups have names as well as numbers.

- Group 0 is called the **noble gases**.
- Group 1 is called the **alkali metals**.
- Group 2 is called the **alkaline earth metals**.
- Group 7 is called the **halogens**.

METALS AND NON-METALS

The simplest way to divide up the periodic table is into metallic and non-metallic elements.

The *metals* appear on the *left* of the zig-zag line, while the *non-metals* are on the *right* of the line. You can see that there are many more metals than non-metals.

TRANSITION ELEMENTS

This is a large collection of elements between Groups 2 and 3. The elements in the main groups differ in properties from group to group. But the transition elements all have certain properties in common:

1. **They are metals with high m.p. and density**
   (Titanium is exceptional in being very light, zinc is exceptional in melting at a low temperature.)
2. **The elements and their compounds often act as catalysts**
   e.g. iron in the Haber process, vanadium(V) oxide in the Contact process, nickel in margarine manufacture.
3. **They form coloured compounds**
   e.g. potassium manganate(VII) is purple; potassium dichromate is orange; iron(II) sulphate is green; iron(III) nitrate is brown; copper(II) sulphate is blue.
4. **They can react with another element to form more than one compound**
   e.g. copper forms two oxides, copper(I) oxide, Cu_2O, and copper(II) oxide, CuO; iron forms two chlorides, iron(II) chloride, $FeCl_2$, and iron(III) chloride, $FeCl_3$.

METALLOIDS OR SEMI-METALS

Elements near the zig-zag line often show some metallic properties and some non-metallic properties. For example:

- carbon (graphite) is a non-metal, but conducts electricity
- silicon and germanium are called **semiconductors** and have resistances which change markedly with conditions
- aluminium oxide has both basic and acidic properties (**amphoteric**).

周期表

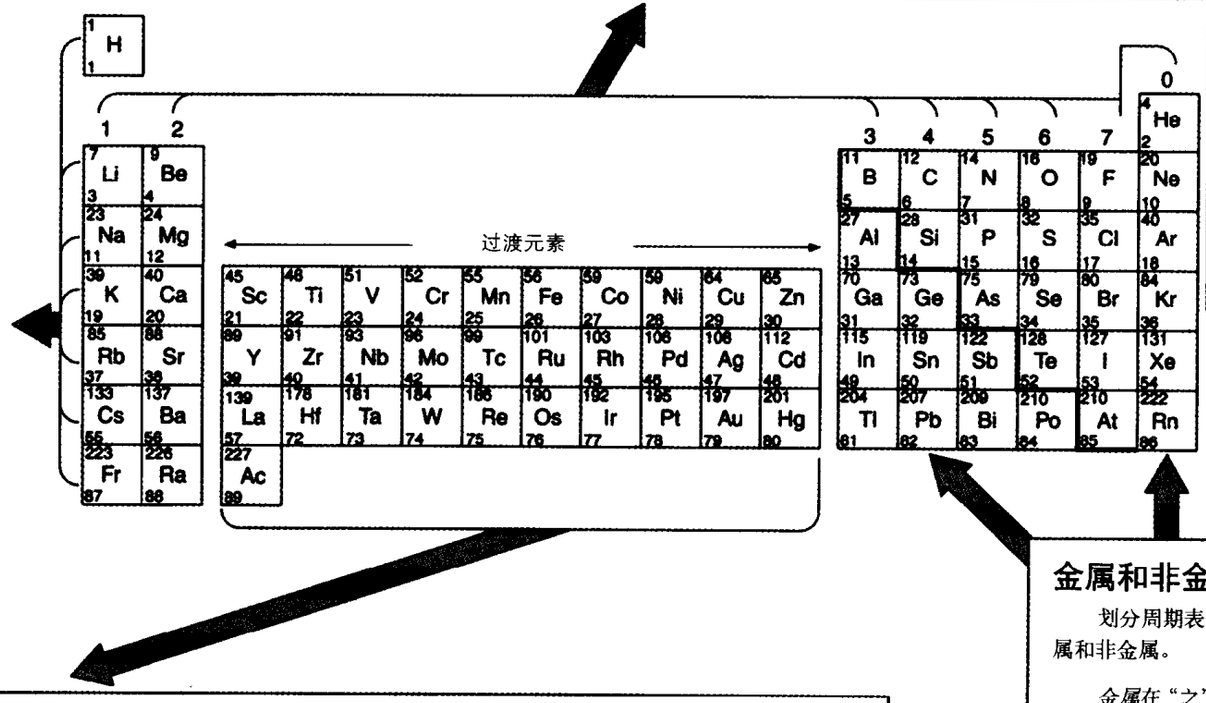
周期表是元素按它们的原子序数顺序排列的表。

这张表还设计成有相似性质的元素在同一列里。

族

- 排成垂直长列（一组）的元素叫**族**。
- 按顺序第一族到第七族。
- 同一族所含元素性质相似。
- 同一族自上而下，这些元素表现出它们的性质轻微变化的趋势。

氢是第一号元素，它跟其他元素不一样。因此，独占一格，不属于任何一族。



族的名称

有些族的名称就是它的族数。

- 0 族叫**稀有气体**。
- 第一族叫**碱金属**。
- 第二族叫**碱土金属**。
- 第七族叫**卤素**。

周期

周期是水平成行的（一组）元素。同一周期所含元素有不同的性质，每一周期除第一周期外，都由金属元素开头，然后向非金属元素变化。

金属和非金属

划分周期表的最简单的方法就是把元素分成金属和非金属。

*金属*在“之”字线的*左边*，而*非金属*在“之”字线的*右边*。从中可以看出金属要比非金属多。

过渡元素

在第二族和第三族之间有一大群元素。主族元素，族与族之间性质是不同的，但是过渡元素却有一定的共性：

1. 它们是熔点高、密度大的金属

（锑是例外，它很轻。锌也是例外，它在很低的温度下就能熔化）

2. 元素和它们的化合物通常用作催化剂

比如：铁在哈伯制氨法中，氧化钒在接触法（制硫酸）中，镍在人造黄油的生产中。

3. 它们能形成有色化合物

比如：高锰（Ⅶ）酸钾是紫色的；重铬酸钾是橙色的；硫酸亚铁是绿色的；硝酸铁是褐色的；硫酸铜是蓝色的。

4. 它们可以跟其他的元素反应，生成多种化合物

比如：铜生成两种氧化物：氧化亚铜 Cu_2O 和氧化铜 CuO；铁能生成两种氯化物：氯化亚铁 $FeCl_2$ 和氯化铁 $FeCl_3$。

类金属和半金属

靠近“之”字线的元素常既显示一些金属的性质，又显示非金属的性质：

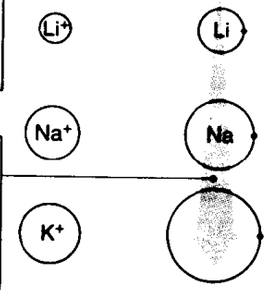
- 碳（石墨）是非金属，但能导电
- 硅和锗称为**半导体**，而且其电阻随条件改变而显著变化
- 氧化铝既有碱的性质又有酸的性质（**两性的**）

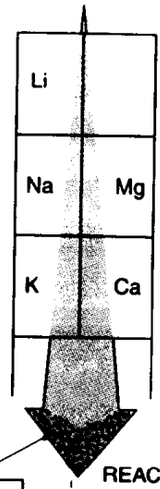
Group 1

All the elements in this group
- are soft, silvery metals
- are very reactive (they are kept under oil to stop them reacting with air or water)
- form ions with a single positive charge

Going down the group
- melting points decrease
- reactivity increases

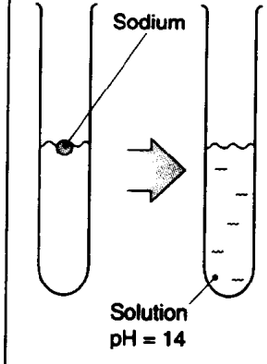
The reason for both these trends is the same. The attraction of the nucleus for the outer electron gets less as the atoms get bigger going down the group. So the metallic bond is weaker, and the atoms lose the outer electron more easily.





Reaction with water
The metals react with water rapidly in the cold. They make an *alkaline solution* and hydrogen.

e.g. $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$



Solubility of compounds
All their compounds are soluble in water. The compounds are ionic and split up into separate ions. The oxide, hydroxide, and carbonate are all alkaline because they increase the number of hydroxide ions:

$O^{2-}(aq) + H_2O(l) \rightarrow 2OH^-(aq)$

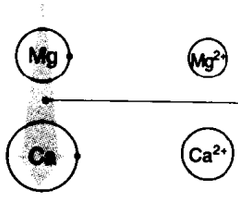
$CO_3^{2-}(aq) + H_2O(l) \rightarrow OH^-(aq) + HCO_3^{2-}(aq)$

Stability to heat
Nearly all of their compounds are stable when heated. Exceptions are:
- the nitrates
  $2NaNO_3(s) \rightarrow 2NaNO_2(s) + O_2(g)$
- the hydrogencarbonates
  $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g)$

Group 2

All the elements in this group
- are soft, but not as soft as Group 1, and silvery
- are reactive, but not as reactive as Group 1 (they are not kept under oil)
- form ions with a double positive charge

Going down the group
Like Group 1, reactivity increases down the group, for the same reason. The outer electrons get further and further away from the nucleus, so are less and less well held.

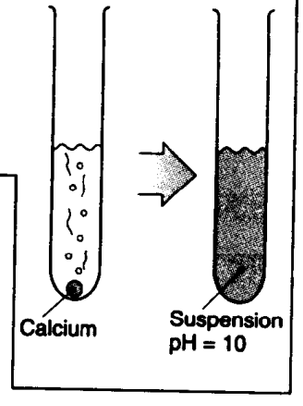


Compared with Group 1, they are:
- harder
- less reactive

because two outer electrons are involved in bonding instead of one. In the metal lattice doubly charged ions are attracting twice as many electrons. When the metal reacts, two electrons have to be removed from the pull of the nucleus.

Reaction with water
All react with water, but less rapidly than Group 1. Calcium reacts rapidly in the cold, but magnesium only slowly. Magnesium burns in steam. They make an *alkaline suspension* and hydrogen.

e.g. $Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$



Solubility of compounds
Many Group 2 compounds are insoluble, e.g. calcium carbonate (chalk and limestone).

Stability to heat
Many of their compounds are unstable when heated, e.g.
- the carbonates decompose to give the oxide and carbon dioxide
  $MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$
- the hydroxides decompose to give the oxide and water
  $Ca(OH)_2(s) \rightarrow CaO(s) + H_2O(g)$

第一族

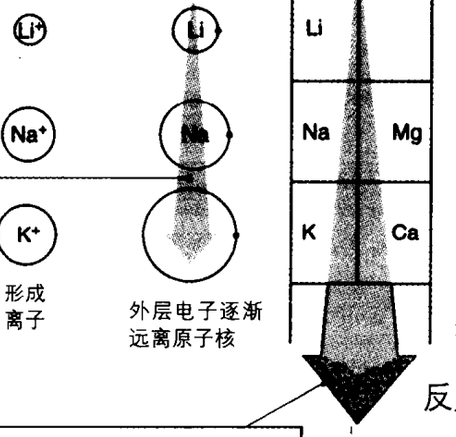
第一族所有元素

- 柔软，有银白色光泽金属
- (化学)反应性活泼(保存在煤油里，以免跟空气和水反应)
- 形成带一个正电荷的离子

第一族的元素自上而下

- 熔点降低
- 反应性增强

这两个变化趋势的原理是相同的。自上而下随着原子越来越大，原子核对外层电子的吸引力逐渐减弱，因此，金属键变弱，而原子更容易失去外层电子。



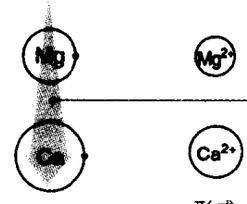
第二族

第二族所有元素

- 软，带有银白色光泽，但没有第一族那么柔软
- 反应性活泼，但比第一族差（它们不必保存在煤油里）
- 生成带两个正电荷的离子

第二族元素自上而下

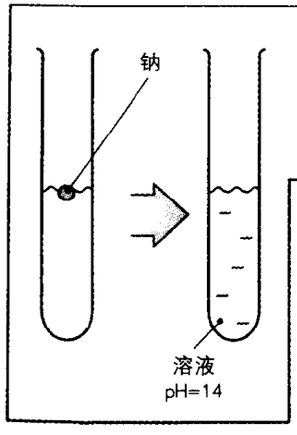
像第一族一样，同样的原因，反应性自上而下增强。外层电子离开原子核越来越远，所以，核对电子的束缚力越来越小。



跟第一族比较，它们

- 更硬
- 反应性较弱

因为参与成键的外层电子是两个而不是一个。在金属晶格里，带两个电荷的离子吸引的电子数也要加倍，当金属反应时，两个电子必须克服原子核的引力才能离去。



跟水反应

在冷水里，金属就能跟水迅速反应，形成碱溶液和氢气。

例如：$2Na(S)+2H_2O(l) \rightarrow 2NaOH(aq)+H_2(g)$

化合物的溶解性

所有它们的化合物都溶于水，这些化合物是离子化合物，能分离成单独的离子。氧化物、氢氧化物和碳酸盐都呈碱性，因为它们会增加氢氧根离子的数量：

$O^{2-}(aq)+H_2O(l) \rightarrow 2OH^-(aq)$

$CO_3^{2-}(aq)+H_2O(l) \rightarrow OH^-(aq)+HCO_3^{2-}(aq)$

热稳定性

当加热时，几乎所有它们的化合物都是稳定的。除了：

- 硝酸盐

$2NaNO_3(s) \rightarrow 2NaNO_2(s)+O_2(g)$

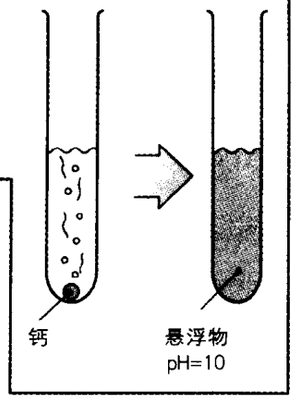
- 碳酸氢盐

$2NaHCO_3(s) \rightarrow Na_2CO_3(s)+H_2O(g)+CO_2(g)$

跟水反应

所有元素都能跟水反应，但反应不如第一族那么快，钙在冷水里能迅速反应，但镁只能缓慢反应。镁在蒸汽里能燃烧。它们生成*碱溶液*和氢气。

例如：$Ca(S)+2H_2O(l) \rightarrow Ca(OH)_2(aq)+H_2(g)$



化合物的可溶性

许多第二族元素的化合物是不溶于水的，比如，碳酸钙(白垩和石灰石)

热稳定性

当加热时，它们的许多化合物是不稳定的，比如：

- 碳酸镁分解生成氧化镁放出二氧化碳

$MgCO_3(s) \rightarrow MgO(s)+CO_2(g)$

- 氢氧化钙分解生成氧化钙和水

$Ca(OH)_2(s) \rightarrow CaO(s)+H_2O(g)$

Group 7, the halogens

All the elements in this group
- are coloured non-metals; the colour darkens down the group.
- exist as **diatomic molecules** (molecules made of two atoms): F_2; Cl_2; Br_2; I_2
- have melting and boiling points which increase down the group
- are very reactive

Going down the group
Reactivity *decreases* down the group, so each halogen displaces the ones below it from their compounds:

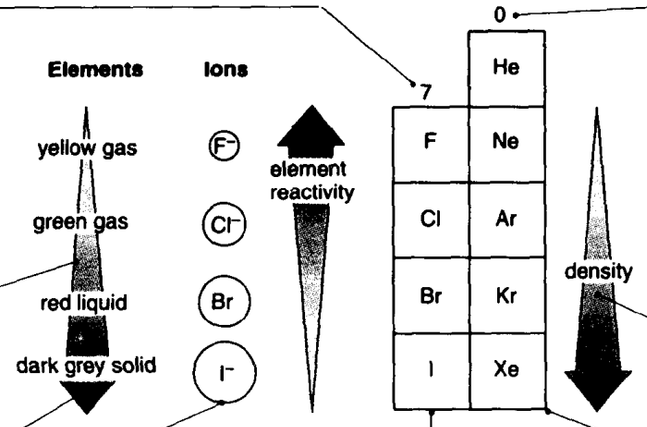
e.g. $Cl_2(g) + 2KBr(aq) \rightarrow Br_2(aq) + 2KCl(aq)$
$Cl_2(g) + 2KI(aq) \rightarrow I_2(aq) + 2KCl(aq)$
$Br_2(g) + 2KI(aq) \rightarrow I_2(aq) + 2KBr(aq)$

This trend in reactivity is opposite to that seen in Groups 1 and 2.

The reason for this is that these elements react by *gaining* electrons instead of losing them like metal atoms do. They usually react to form anions with a *single negative charge*. The smaller atoms at the top of the group attract electrons more strongly than the larger ones at the bottom. So the elements at the top of the group are more reactive than those below them.

Reactions
All the elements in this group
- react with hydrogen forming hydrogen halides which are acidic in water
  e.g. $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$
  $HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$
- react with metals forming ionic metal halides
  e.g. $Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$
  $2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$

Iron reacts similarly.



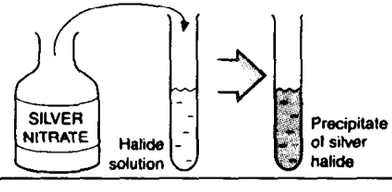
Uses
Halogens are very **reactive oxidizing agents**. Solutions of chlorine in water and iodine in alcohol are used to kill bacteria.

Fluoride ions are added to toothpaste; a fluorine compound is the surface on non-stick pans.

Chlorine forms many covalent compounds with many important uses:
- CH_3CCl_3, 1,1,1-trichloroethane, is a very good solvent, used in dry cleaning
- CCl_2F_2, a chlorofluorocarbon (CFC) used as an aerosol propellant, now discontinued because of damage to the ozone layer.

Other compounds are used as anaesthetics, drugs, pesticides, and herbicides.

Precipitation reactions of halide ions
Halide ions in solution react with silver ions to form insoluble precipitates:
$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ white
$Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$ cream
$Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$ yellow
These solids darken in light and form the basis of photographic film.



Group 0, the noble gases

All the elements in this group
- are colourless gases
- are found in small amounts in the air
- are very, very unreactive (helium and neon never react, the others only very rarely and under special conditions)

The atoms are relatively small with full shells. They hold on to the electrons they already have strongly and have no room to gain any new electrons

Going down the group
- the elements get more dense
- the boiling points increase

Uses
Their uses depend on their physical properties or their unreactivity.

Helium
- in balloons (very low density)
- for deep diving (unreactive)
- used for super-cooling (low b.p.)

Neon
- in advertising signs (glows in electric field)

Argon
- to fill light bulbs (unreactive and cheap)
- in welding (unreactive)

Xenon
- in flash bulbs (unreactive). The unreactive gas prevents the filament of the bulb reacting when it flashes and gets very hot, so the bulb can be used many times.

第七族，卤素

第七族所有元素

- 是有颜色的非金属，且自上而下颜色逐渐变深
- 以**双原子分子**形式存在（每个分子里由两个原子组成）：F_2；Cl_2；Br_2；I_2
- 自上而下熔、沸点升高
- 反应性强

同族内自上而下

反应性变弱，因此，卤素可以把在它下方的卤素化合物里的卤素取代出来。

例如：$Cl_2(g)+2KBr(aq) \rightarrow Br_2(aq)+2KCl(aq)$

$Cl_2(g)+2KI(aq) \rightarrow I_2(aq)+2KCl(aq)$

$Br_2(g)+2KI(aq) \rightarrow I_2(aq)+2KBr(aq)$

反应性强弱变化的趋势正好跟第一、二族里元素显示的相反。

原因是，这些元素（原子）反应时都要获得电子而不像金属原子那样失去电子。它们通常反应形成带一个负电荷的负离子，位置在顶上的较小的原子要比位置在底下的较大的原子更强烈地吸引电子，因此，在顶上的元素要比在底下的元素反应性强。

反应

这一族内所有元素

- 跟氢气反应生成卤化氢，它溶于水成酸

例如：$H_2(g)+Cl_2(g) \rightarrow 2HCl(g)$

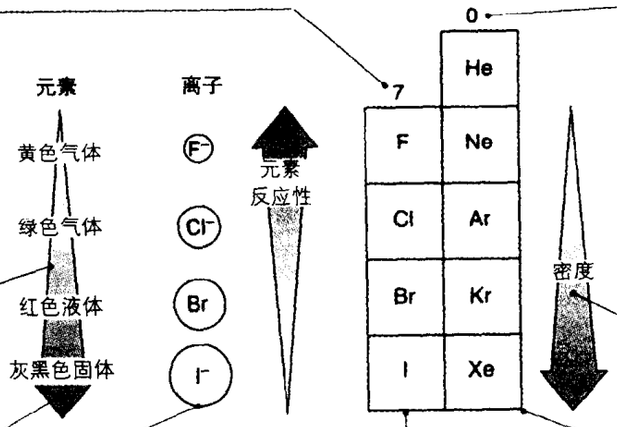
$HCl(g)+H_2O(l) \rightarrow H_3O^+(aq)+Cl^-(aq)$

- 跟金属反应生成金属卤化物

例如：$Na(s)+Cl_2(g) \rightarrow 2NaCl(s)$

$2Al(s)+3Cl_2(l) \rightarrow 2AlCl_3(s)$

跟铁的反应相似。



用途

卤素是**很活泼的氧化剂**。氯气的水溶液和碘的酒精溶液可以用来杀菌。

氟离子添加到牙膏里，不粘锅的表面涂有氟化物。

氯可以形成许多共价化合物，有许多重要的用途。

- CH_3CCl_3，三氯甲烷是一种良好的溶剂，用来干洗
- CCl_2F_2，氯氟化碳（CFC）可用作一种推进剂的气溶胶，但现在已停止使用，因它对臭氧层有害

其他卤素化合物用作麻醉剂、药、杀虫剂和除草剂。

卤离子的沉淀反应

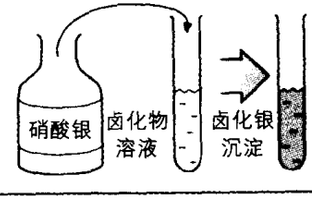
溶液里的卤离子跟银离子反应形成不溶性的沉淀物：

$Ag^+(aq)+Cl^-(aq) \rightarrow AgCl(s)$白色

$Ag^+(aq)+Br^-(aq) \rightarrow AgBr(s)$乳白色

$Ag^+(aq)+I^-(aq) \rightarrow AgI(s)$黄色

这些固体遇到光变黑，形成感光胶片的片基。



0族，稀有气体

这一族的所有元素

- 都是无色气体
- 在空气里少量存在
- 非常非常不活泼（氦、氖从不反应，其他的仅在特殊条件下难得才能反应）

原子相对较小，外层已充满，外层电子被强烈地吸引，且外壳层已没有空间再容纳新的电子。

同族自上而下

- 元素密度增大
- 沸点提高

用途

它们的用途取决于它们的物理性质或者它们的惰性。

氦

- 填充气球（密度很小）
- 深潜水（惰性）
- 用作深度冷冻（沸点低）

氖

- 广告（在电场里发出白热光）

氩

- 填充灯泡（惰性和便宜）
- 焊接（惰性）

氙

- 闪光灯泡（惰性），惰性气体能防止灯丝在闪烁和发热时起反应，因此，灯泡的使用寿命很长。

Sulphur chemistry

SULPHURIC ACID, H_2SO_4

Sulphuric acid is probably the most important industrial chemical made because it is used in so many processes. It is made from sulphur in the **Contact process**.

The Contact process

- **sulphur is melted and burnt in air**

  $S(l) + O_2(g) \rightarrow SO_2(g)$

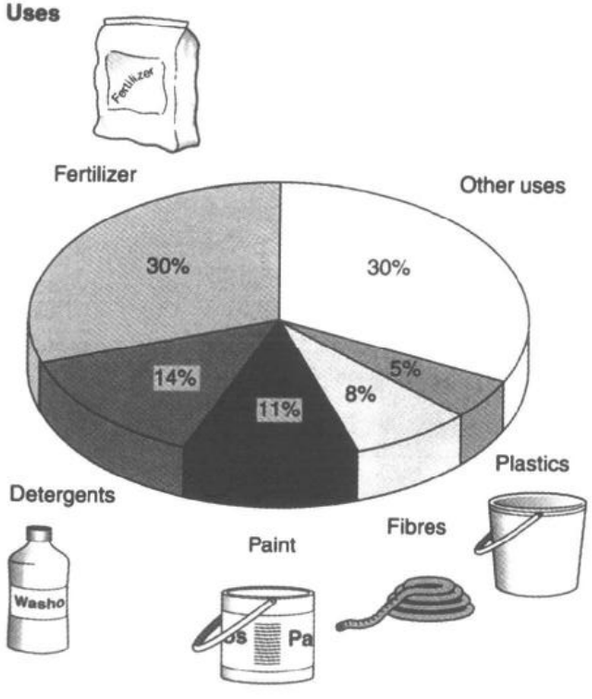
- **the sulphur dioxide is oxidized to sulphur trioxide**

  $2SO_2(g) + O_2(g) \overset{450°C}{\underset{V_2O_5}{\rightleftharpoons}} 2SO_3(g)$

- **the sulphur trioxide is hydrated with water**

  $H_2O(l) + SO_3(g) \rightarrow H_2SO_4(l)$

Uses



This is an exothermic combination reaction. The sulphur burns easily and the reaction goes to completion.

This is also an exothermic reaction, but it is reversible.

High rate would be produced by high pressure, high temperature, and a catalyst.

High yield would be produced by high pressure, but low temperature.

The actual conditions used are a compromise.

High pressure is too expensive so a pressure just above atmospheric is used. At 450°C, 97% conversion is achieved.

This is another very exothermic reaction. Just adding the sulphur trioxide gas to water would make the water boil, forming a stable acid mist. To stop this, the sulphur trioxide is bubbled into 98% sulphuric acid, 2% water. This mixture has a much higher boiling point. The water reacts making even more acid without making a mist. So no acid vapours escape from the plant.

SULPHUR

Sulphur is a non-metallic element in Group 6.
Its properties are typical of a non-metal.

- **Physical**: brittle, insulating, molecular solid, S_8.
- **Chemical**: forms an anion, S^{2-}, and an acidic oxide, SO_2.
  $SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$ sulphurous acid.

SULPHUR DIOXIDE, SO_2

Sulphur dioxide is a covalent, molecular substance, with weak forces between the molecules. It is a dense gas.

It can be oxidized or reduced depending on what it reacts with:

- hydrogen sulphide reduces it to sulphur
  $2H_2S(g) + SO_2(g) \rightarrow 3S(s) + 2H_2O(l)$
- potassium dichromate oxidizes it in solution; the colour of the dichromate changes from orange to green.

  $K_2Cr_2O_7(aq)$ (orange) $+ 3H_2SO_3(aq) + H_2SO_4(aq) \rightarrow Cr_2(SO_4)_3(aq)$ (green) $+ K_2SO_4(aq) + 4H_2O(l)$

Reactions of concentrated sulphuric acid

- **As a strong acid**
  $H_2SO_4(l) + 2H_2O(l) \rightarrow 2H_3O^+(aq) + SO_4^{2-}(aq)$
- **As an oxidizing agent**: it will oxidize both metals and non-metals.
  $Cu(s) + 2H_2SO_4(l) \rightarrow CuSO_4(aq) + SO_2(g) + 2H_2O(l)$
  $C(s) + 2H_2SO_4(l) \rightarrow CO_2(g) + 2SO_2(g) + 2H_2O(l)$
- **As a dehydrating agent**: it will remove water or the elements of water. It makes hydrated copper(II) sulphate into the anhydrous form
  $CuSO_4.5H_2O(s) \rightarrow CuSO_4(s)$
  It dehydrates sucrose
  $C_{12}H_{22}O_{11}(s) \rightarrow 12C(s)$

硫化学

硫酸 H_2SO_4

硫酸可以说是最重要的工业化学品，因为，在许多化工生产中都要用到硫酸。它是由**接触法**里的硫来生产的。

接触法

- **硫熔化，在空气里燃烧**

  $S(l)+O_2(g) \rightarrow SO_2(g)$

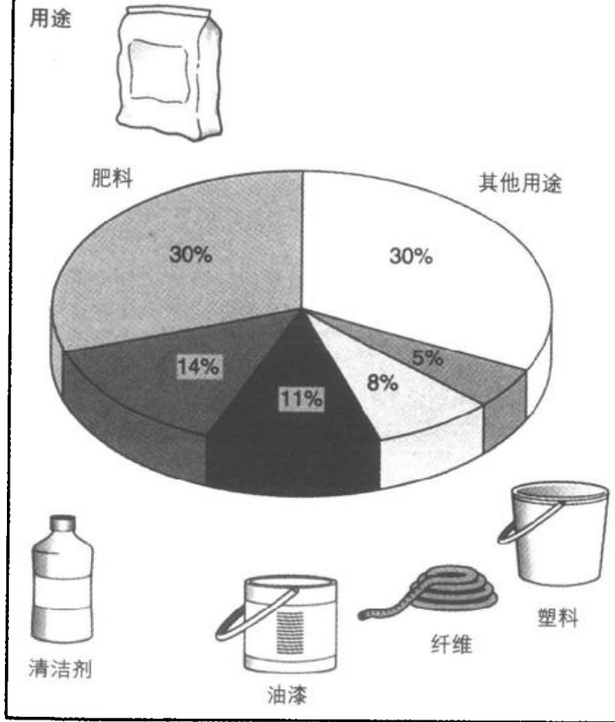
- **二氧化硫氧化成三氧化硫**

  $2SO_2(g)+O_2(g) \overset{450℃}{\underset{V_2O_5}{\rightleftharpoons}} 2SO_3(g)$

- **三氧化硫跟水化合**

  $H_2O(l)+SO_3(g) \rightarrow H_2SO_4(l)$

用途



这是一个放热的化合反应，硫很容易燃烧直到反应完成。

这也是一个放热反应，但反应是可逆的。

在高压、高温和催化剂条件下，反应速度很高。在高压、低温条件下，生成物产量高。实际反应条件是各种条件的折中。

高压很费钱，所以生产压力只比大气压高一些。

在450℃，转化率达97%。

这又是一个强放热反应，只要把三氧化硫通入水中，就能使水沸腾，，生成一种稳定的酸雾。为了防止这种现象，让三氧化硫气体溶入98%的硫酸，2%的水。这种混合物的沸点高得多，跟水反应制取到更多的酸，而不是变成酸雾，这样就没有酸气从生产车间里逃逸出来。

硫

硫是第六族非金属元素，它有典型的非金属性质。

- **物理性质**：脆、不导电、分子固体 S_8。
- **化学性质**：生成阴离子 S^{2-} 和一种酸性氧化物 SO_2。

  $SO_2(g)+H_2O(l) \rightarrow H_2SO_3(aq)$ 亚硫酸。

二氧化硫，SO_2

二氧化硫是一种共价分子物质，分子间作用力弱，是一种稠密的气体。

根据反应物的不同，它既能被氧化，又能被还原：

- 硫化氢还原成硫

  $2H_2S(g)+SO_2(g) \rightarrow 3S(s)+2H_2O(l)$

- 在溶液里硫被重铬酸钾氧化，重铬酸钾的颜色从橙色变成绿色。

  $K_2Cr_2O_7(aq)+3H_2SO_3(aq)+H_2SO_4(aq) \rightarrow Cr_2(SO_4)_3(aq)+K_2SO_4(aq)+4H_2O(l)$

  （$K_2Cr_2O_7$：橙色；$Cr_2(SO_4)_3$：绿色）

浓硫酸的反应

- **作为强酸**

  $H_2SO_4(l)+2H_2O(l) \rightarrow 2H_3O^+(aq)+SO_4^{2-}(aq)$

- **作为氧化剂**：它能氧化金属和非金属

  $Cu(s)+2H_2SO_4(l) \rightarrow CuSO_4(aq)+SO_2(g)+2H_2O(l)$

  $Cu(s)+2H_2SO_4(l) \rightarrow CO_2(g)+2SO_2(g)+2H_2O(l)$

- **做脱水剂**：它能吸水或脱去水分子。它使水合硫酸铜变成无水硫酸铜。

  $CuSO_4.5H_2O(s) \rightarrow CuSO_4(s)$

  它使蔗糖脱水。

  $C_{12}H_{22}O_{11}(s) \rightarrow 12C(s)$

Important ideas about chemical change 1: making new substances

In a chemical reaction
The starting substances – the reactants – react to give new, different substances – the products. The changes which take place in the reaction are usually written as an equation.

reactants → products

means 'reacts to give' (sometimes the reaction conditions are written over the arrow)

Word equations
These express in words what is reacting with what to make the products.

e.g. magnesium metal and gaseous oxygen → solid magnesium oxide

Symbol equations
These express in terms of chemical symbols the formulas of the substances taking part in the reaction. They are balanced in the sense that there are the same number of each atom on each side of the arrow.

e.g. $2Mg + O_2 \rightarrow 2MgO$

State symbols
These tell us even more about the reaction. After the formula of each substance there are state symbols which describe the state that the substance is in.

So using (s) for solid, (l) for liquid, (aq) for a solution in water, and (g) for gas, the equation becomes:
$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

DIFFERENT KINDS OF CHEMICAL CHANGE

Decomposition
Here a single substance is broken down into two or more simpler substances.

e.g. most metal carbonates decompose to give the oxide and carbon dioxide:
$CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$

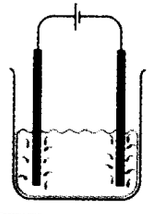
Remember, substances which cannot be decomposed because they contain only one kind of atom are called elements.

Heat in, so endothermic

Electrolysis
Electrolysis is a form of decomposition. It is used to extract very reactive metals from their ores. The ores of these reactive metals are very stable and cannot be decomposed in any other way.

The metal ions go to the cathode and the non-metal ions go to the anode.

e.g. in molten sodium chloride, the reaction is:
$2NaCl(l) \rightarrow 2Na(l) + Cl_2(g)$



Energy in, so endothermic

Combination
Here two substances (usually elements) react together to make a single new compound.

e.g. metal and non-metal: aluminium and iodine react to give aluminium iodide:
$2Al(s) + 3I_2(s) \rightarrow 2AlI_3(s)$

Sometimes two elements combine together in more than one way.

e.g. carbon can react with oxygen to make two different oxides: carbon monoxide, CO, and carbon dioxide, CO_2. Which one forms depends on how much oxygen is available for the reaction.

Heat out, so exothermic

Displacement
These are reactions in which one element takes the place of another. Both metals and non-metals can do displacements.

More reactive metals can displace less reactive ones from their solutions:
$Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$

Reactive metals can displace hydrogen from acids:
$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$

Very reactive metals can even displace hydrogen from water:
$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

More reactive non-metals can displace less reactive ones from their solutions:
$Cl_2(g) + 2KI(aq) \rightarrow I_2(s) + 2KCl(aq)$

Displacement reactions are a good way of comparing the reactivity of elements.

化学变化的重要概念 1：生成新物质

在化学反应里

起始物质——反应物——反应生成新的不同的物质——产物。反应中发生的变化通常用反应式表示。

反应物→产物

表示“反应—生成”（有时候反应条件写在箭头上方）

文字反应式

用文字表述什么跟什么反应，生成什么。

比如：金属镁跟气态氧气→固体氧化镁。

符号反应式

按照参加反应的物质的化学式来表达。从平衡的意义上说，在箭头两边每种原子的数目应该相等。

例如：$2Mg+O_2 \rightarrow 2MgO$

状态符号

这些符号告诉我们更多有关反应的信息。在每种物质的化学式后面有状态符号，它表示物质在反应中的状态。

如用（s）表示固体，（l）表示液体，（aq）表示水溶液，（g）表示气体，反应式变成：$2Mg(s)+O_2(g) \rightarrow 2MgO(s)$

不同类型的化学变化

分解反应

一种物质破裂变成两种或两种以上更简单的物质。

如：大多数金属碳酸盐分解生成氧化物和水

$CuCO_3(s) \rightarrow CuO(s)+CO_2(g)$

记住：

有些物质是不能分解的，因为它们只有一种元素的原子组成。

吸收热量，是吸热反应

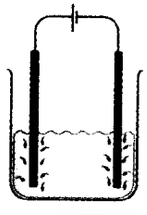
电解

电解是分解反应的一种形式，这种反应可以把非常活泼的金属从它们的矿物里提取出来。这些活泼金属的矿物是很稳定的，用其他办法是不能被分解的。

金属离子移向阴极，非金属离子移向阳极。

比如：熔融状态下的氯化钠电解反应：

$2NaCl(l) \rightarrow 2Na(l)+Cl_2(g)$



输入能量，是吸热反应

化合反应

两种物质（通常是两种元素）互相反应，生成一种新的化合物。

比如：金属和非金属，铝跟碘反应生成碘化铝：$2Al(s)+3I_2(s) \rightarrow 2AlI_3(s)$

有时候，两种元素可以用多种形式互相结合。

比如：碳跟氧气反应生成两种不同的氧化物，一氧化碳 CO 和二氧化碳 CO_2。至于生成哪一种氧化物，取决于反应中氧的多少。

放出热量，是放热反应

置换反应

反应里一种元素取代另一种元素，金属和非金属都能发生置换反应。

较活泼金属能把较不活泼的金属从它们的溶液里置换出来：

$Fe(s)+CuSO_4(aq) \rightarrow FeSO_4(aq)+Cu(s)$

活泼金属能把氢从酸溶液里置换出来：

$Mg(s)+H_2SO_4(aq) \rightarrow MgSO_4(aq)+H_2(g)$

非常活泼的金属甚至能把氢从水中置换出来：

$2Na(s)+2H_2O(l) \rightarrow 2NaOH(aq)+H_2(g)$

较活泼的非金属能把较不活泼的非金属从它们的溶液里置换出来：

$Cl_2(g)+2KI(aq) \rightarrow I_2(s)+2KCl(aq)$

置换反应是比较元素活泼性的一种好方法。

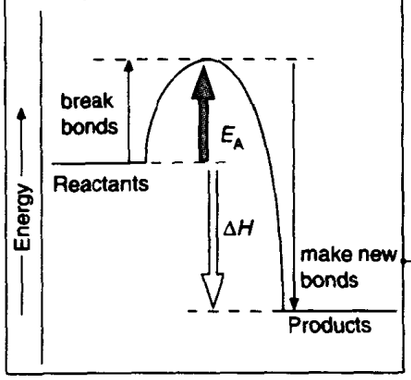
Important ideas about chemical change 2: energy

EXOTHERMIC CHANGES

The system (the reacting substances) *loses energy to the surroundings.*

e.g. the burning of carbon is an exothermic change.

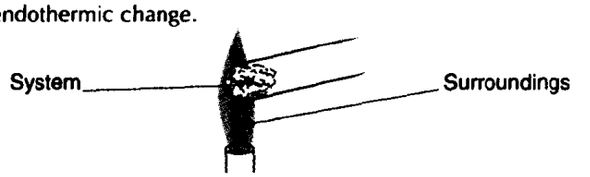
The system loses energy to the surroundings because *less* energy is needed to *break* the bonds in the reactants than to *make* the new bonds in the products.



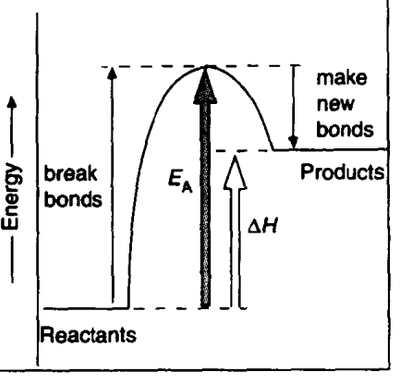
ENDOTHERMIC CHANGES

The system *gains energy from the surroundings.*

e.g. the decomposition of copper carbonate is an endothermic change.



The system gains energy from the surroundings because *more* energy is needed to *break* the bonds in the reactants than to *make* the new bonds in the products.



The energy content of the reactants and products is given the name **enthalpy**. It has the symbol *H*. The difference in enthalpy (the **enthalpy change**) is written mathematically as ΔH and is measured in kilojoules, kJ.

The energy needed to break the bond in the reactant is called the **activation energy**. It has the symbol E_A.

FUELS

Fuels are substances which react exothermically with air making safe products. They combust (burn) easily, so storing them can be a problem.

Hydrogen reacts exothermically and the product (water) is totally safe. But hydrogen is difficult and dangerous to store.

$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$

Bonds broken	Bonds made	Total energy change
2 H–H = 2 × 436	4 H–O = 4 × 463	
1 O=O = 496		
1368 kJ	1852 kJ	1852 – 1368 = 484 kJ

Methane (natural or North Sea gas) reacts exothermically. The products are carbon dioxide and water. These are safe, although carbon dioxide contributes to global warming.

$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$

Bonds broken	Bonds made	Total energy change
4 C–H = 4 × 412	2 C=O = 2 × 743	
2 O=O = 2 × 496	4 H–O = 4 × 463	
2640	3338	3338 – 2640 = 698 kJ

Comparing fuels

The most efficient fuel is one that gives out most energy per gram.

4 g of hydrogen produce 484 kJ, so 1 g → 121 kJ
16 g of methane produce 698 kJ, so 1 g → 43.6 kJ

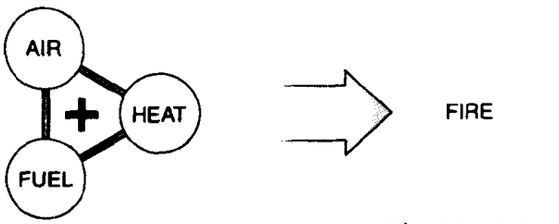
Hydrogen in the more efficient fuel.

FIRE

Fire triangle

For a fire to burn, fuel, air, and heat are needed. The heat provides the **activation energy**, E_A, to break existing bonds.

These three requirements are shown in the fire triangle.



REACTANTS + ACTIVATION ENERGY ⟹ REACTION

Preventing or putting out fires

A fire can be prevented by removing any one of the components of the fire triangle:

- remove the air (fire blankets, foam)
- remove the fuel (turn off fuel, use fire breaks in forests)
- remove heat (spray with water)

INCOMPLETE COMBUSTION

In the open air, a fuel reacts with oxygen until it is used up. The fuel is **completely combusted**.

If the supply of air is limited, the oxygen in the air may be used up before the fuel. The fuel is incompletely combusted.

If a hydrocarbon is **incompletely combusted**, the carbon in it may be:

- only partially oxidized, forming carbon monoxide
- unburnt, forming soot (as in a yellow Bunsen flame)

In car engines, turbos pump more air into the engine. This improves efficiency because it helps the fuel to combust completely.

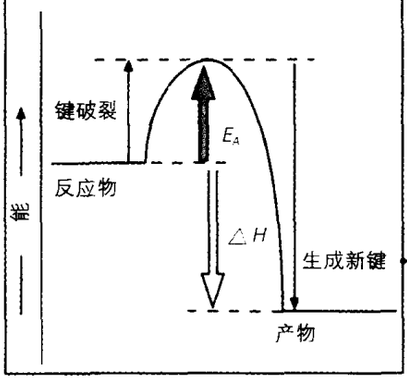
化学变化的重要概念 2：能

放热变化

系统（反应物质）*向环境释放能量*。

比如：碳燃烧就是一种放热变化。

系统向环境释放能量，因为，*破坏*反应物里的键需要的能量要比生成物里生成的新键所需的能量少。



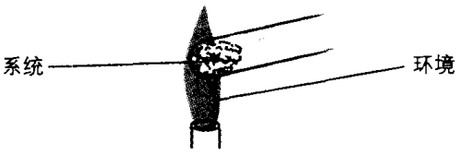
反应物和生成物的能量用**焓**来表示。它的符号是 H，焓的差别（**焓的变化**）写成数学式是 $\triangle H$，用千焦来度量。

用来破裂反应物里的键的能叫**活化能**。符号是 E_A。

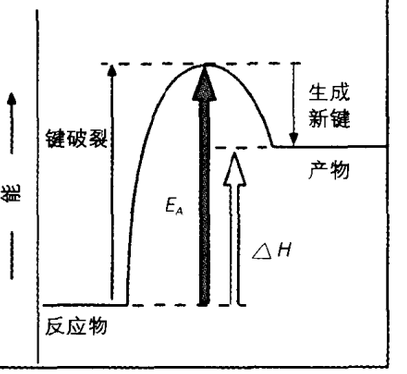
吸热变化

系统从环境获得能量。

比如：硫酸铜分解是一种吸热变化。



系统从环境获取能量。因为，使反应物的键*破裂*所需能量要比生成物的新键生成所需的能量多。



燃料

燃料能跟空气发生放热反应、生成安全的物质。燃料很容易燃烧，所以，怎么储存它们是一个难对付的问题。

氢气能发生放热反应，生成物（水）绝对安全，但是，储存氢气既困难又危险。

$2H_2(g)+O_2(g) \rightarrow 2H_2O(s)$

键破裂	键生成	整个能量变化
2H–H=2 × 436	4H–O=4 × 463	
1 O=O= 496		
1368 千焦	1852 千焦	1852–1368 =484 千焦

甲烷（天然气或叫北海气体）发生放热反应。产物是二氧化碳和水。它们是安全的，虽然二氧化碳使全球变暖。

$CH_4(g)+2O_2(g) \rightarrow CO_2(g)+2H_2O(g)$

键破裂	键生成	整个能量变化
4C–H=4 × 412	2C=O=2 × 743	
2 O=O= 2 × 496	4 H–O= 4 × 463	
2640 千焦	3338 千焦	3338–2640 =698 千焦

比较燃料

最有效的燃料就是每克燃料燃烧时释放出最大的能量。

4 克氢气产生 484 千焦，因此 1 克→ 121 千焦

16 克甲烷产生 698 千焦，因此 1 克→ 43.6 千焦

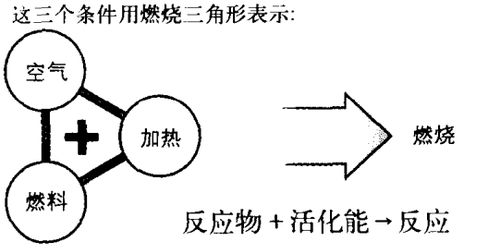
氢气是更有效的燃料。

燃烧

燃烧三角形

要燃烧发生，需要燃料，空气和加热。加热提供**活化能**，E_A，打破存在的键。

这三个条件用燃烧三角形表示：



反应物 + 活化能 → 反应

防火和灭火

去掉燃烧三角形中的任一个组成环节，就可以阻止燃烧：

- 去掉空气（灭火毯、泡沫）
- 去掉燃料（关掉燃料，在森林里建防火带）
- 去掉热（用水浇）

不完全燃烧

在敞开的空气中，燃料跟氧气反应，直到燃料用完，这时燃料在**完全燃烧**。

如果空气是有限的，空气里氧气就可能在燃料烧完以前就已经耗尽，这时燃料是不完全燃烧。

如果一种烃是**不完全燃烧**，烃里的碳可能：

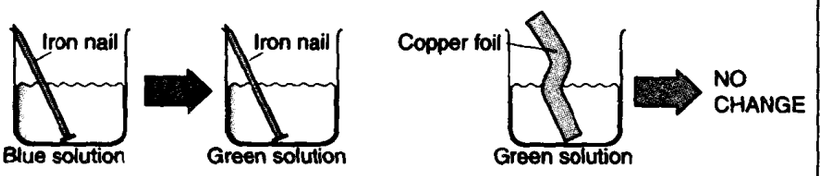
- 只有部分氧化，生成一氧化碳
- 燃烧不充分，形成煤烟（比如煤油灯呈黄色火焰）

在汽车发动机里，涡轮叶片把更多的空气打入发动机里，以提高效率。因为它使燃料充分燃烧。

Important ideas about chemical change 3: reactivity

DISPLACEMENT REACTIONS

Compare the reactivity of iron and copper by putting an iron nail into copper(II) sulphate solution and copper foil into iron(II) sulphate solution.



Observations
- the iron nail dissolves and gets smaller
- the solution changes from blue to green
- copper metal is deposited in the bottom of the beaker

Reaction

$Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$

or, because the sulphate ions do not take part and are only spectators:

$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$

Observations
- no change

Reaction

None

Conclusion

These two experiments tell us that
- iron metal is more reactive than copper metal
- copper ions are more reactive than iron ions

Results from experiments like this show us some important ideas

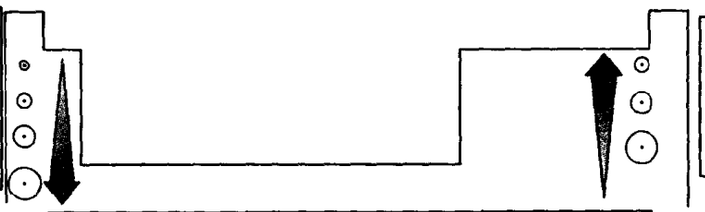
- **The more reactive an element is, the less reactive are its compounds (and vice versa)**

METALS	METAL IONS IN SOLUTION	HALOGENS	HALIDE IONS IN SOLUTION
sodium	Na^+	fluorine	F^-
iron	Fe^{2+}	chlorine	Cl^-
copper	Cu^{2+}	bromine	Br^-
		iodine	I^-

REACTIVITY

- **Reactivity patterns in the main groups of the periodic table can be related to atomic structure**

Metal atoms react by losing electrons. Bigger atoms, further down the group hold their outer electrons less well, so are more reactive.



Non-metal atoms react by gaining electrons. Smaller atoms, near the top of the group attract electrons more, so react more.

There is no clear pattern of reactivity in the transition elements. A different table is needed.

- **A reactivity list for all metals gives us a guide for the reactivity of the transition elements as well**
- **The position of a metal in the reactivity list gives a guide to its uses and the method used to extract it.**
- **The detailed chemistry of the metal and its compounds is related to its position in the reactivity list, as the table on the next page shows.**

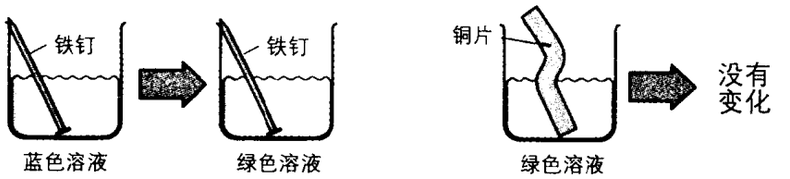
	Metal	Place in periodic table	Ion	
very reactive metals too reactive to be used	potassium	Group 1	K^+	**very unreactive ions** difficult to extract
	sodium	Group 1	Na^+	
	calcium	Group 2	Ca^{2+}	
less reactive metals many uses, especially aluminium, which is protected by an oxide layer	magnesium	Group 2	Mg^{2+}	
	aluminium	Group 3	Al^{3+}	
	zinc	transition element	Zn^{2+}	**more reactive ions** easier to extract
	iron	transition element	Fe^{2+}	
	lead	Group 4	Pb^{2+}	
unreactive metals many uses	copper	transition element	Cu^{2+}	**very reactive ions** metals found unreacted; used even by early humans
	silver	transition element	Ag^+	
	gold	transition element	Au^{2+}	

REACTIVITY

化学变化的重要概念 3：反应性

置换反应

把铁钉放入硫酸铜溶液里，把铜片放入硫酸亚铁溶液里，来比较铁和铜的反应性。



观察

- 铁钉溶解，变细小
- 蓝色溶液变成绿色溶液
- 金属铜沉淀在烧杯底部

反应

$Fe(s)+CuSO_4(aq) \rightarrow FeSO_4(aq)+Cu(s)$

硫酸根离子并没有参加反应，仅仅是“旁观者”：

$Fe(s)+Cu^{2+}(aq) \rightarrow Fe^{2+}(aq)+Cu(s)$

观察

- 没有变化

反应

没有反应

结论

这两个实验告诉我们

- 金属铁比金属铜活泼
- 铜离子比铁离子活泼

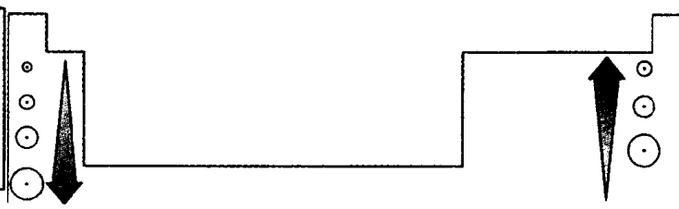
从这个实验导出的结果告诉我们一些重要的概念。

· 一种元素越是活泼，那么它的化合物就越不活泼（反过来也成立）

金属		溶液里的金属离子		卤素		溶液里的卤离子	
钠 铁 铜	反应性	Na^+ Fe^{2+} Cu^{2+}	反应性	氟 氯 溴 碘	反应性	F^- Cl^- Br^- I^-	反应性

· 元素周期表里主族里的反应模式可以用原子结构来解释

金属原子在反应中失去电子。同族中自上而下，原子越大对外层电子的吸引越弱，所以原子的活性越强。



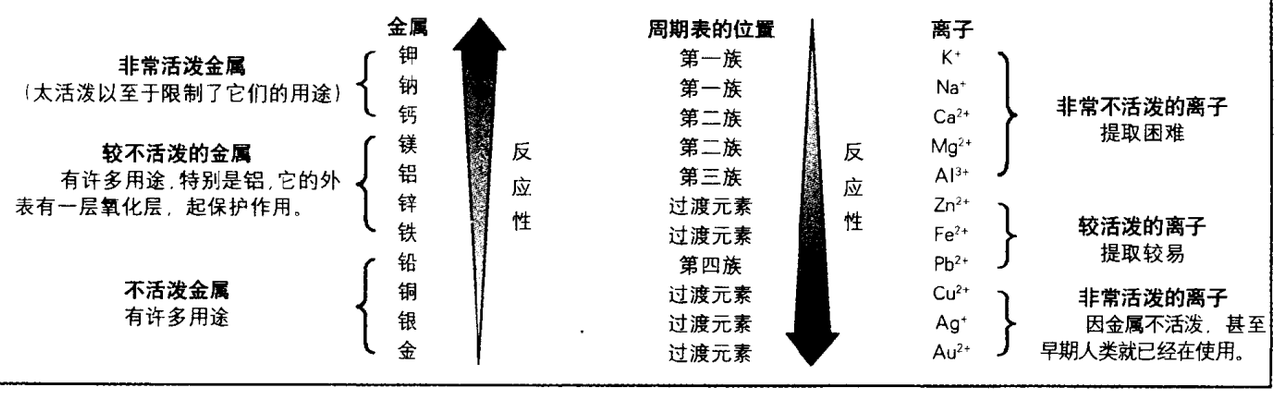
非金属原子在反应中获得电子。同族中越在上面的原子越小，越容易吸引电子，所以反应活性越强。

在过渡元素中没有明确的反应活性模式，需要一张不同的表。

· 所有金属的反应活性表也能告诉我们过渡元素的反应性

· 在反应活性表中，一种金属的位置能告诉我们它的用途以及提取它的方法

· 金属和它的化合物的详尽的化学性质跟它在反应活性表中的位置有关，这张表列在下面一页中



Metal reactivity and uses

METAL	REACTION WITH AIR	REACTION WITH WATER	REACTION WITH DILUTE ACID	EXTRACTION	USES	METAL
potassium	burn to form oxide	react quickly in cold water	all these metals displace hydrogen from dilute acids; reactivity increases up the list	electrolysis of molten compound		potassium
sodium					**street lamps:** sodium and its compounds give orange light when heated	sodium
calcium					**steel production:** calcium reacts with and removes oxygen	calcium
magnesium		burns in steam			**alloy with aluminium:** makes aluminium stronger **flares:** burns with a very bright light	magnesium
aluminium		oxide layer stops reaction			**major structural metal:** strong, but light; protected by oxide layer	aluminium
zinc		reacts in steam		reaction with carbon in **blast furnace**	**alloy with copper:** brass **sacrificial protection of steel:** galvanizing	zinc
iron		reacts reversibly in steam			**major structural metal:** cheap to extract and strong when alloyed with carbon, but it rusts	iron
hydrogen	react slowly when heated					hydrogen
copper		no reaction	metals below hydrogen never react with acids to displace hydrogen	decomposition by heat alone	**pipes:** ductile but unreactive **coinage:** colour, unreactive **electrical cables:** good conductor	copper
gold					**jewellery:** rare, attractive colour **electrical contacts:** good conductor, unreactive	gold

Notes
Hydrogen is in the list because many metal reactions involve the metal displacing hydrogen from water or acids.

Group 1 metals are kept under oil to stop reaction with air. Other metals form oxide layers which slow down further reaction.

The reactivity of aluminium appears *anomalous* or unexpected. It is a very reactive metal, but it appears to be unreactive because the oxide layer protects it.

Unreactive metals do not react to produce hydrogen. But some of them react with acids in other ways. For example, copper reacts with dilute nitric acid. In this reaction nitric acid is not acting as an acid (through the hydrogen ion) but as an oxidizing agent (through the nitrate ion).

The reactive metals have such unreactive compounds that they can only be decomposed by electrolysis.

The unreactive metals at the bottom of the list have such reactive compounds that the metals were discovered and used in prehistoric times.

Metal uses depend on a number of factors:

- **abundance of the metal:** aluminium is more abundant than iron; gold is very rare.
- **ease of extraction:** gold and iron are easy to extract; aluminium is expensive to extract because so much electricity is needed.
- **suitable physical and chemical properties:** these are listed above.

金属活性及用途

金属	跟空气反应	跟水反应	跟稀酸溶液反应	提取	用途	金属
钾	燃烧生成氧化物	在冷水中迅速反应	所有这些金属都能从稀酸溶液里置换出氢，表中自下而上反应性增强	电解熔融的化合物		钾
钠					路灯：钠和它的化合物在加热时发出桔黄色的光	钠
钙					炼钢：钙跟氧反应，从而把氧去掉	钙
镁		在蒸汽中燃烧			跟铝形成合金：使铝更坚固 照明：燃烧时发出一种非常强烈的光	镁
铝		有氧化层阻止反应			主要的结构金属：坚固、但轻、有氧化层保护	铝
锌		在蒸汽中反应		在鼓风炉里跟碳反应	跟铜形成合金：黄铜 钢铁的保护层：电镀	锌
铁		在蒸汽中可逆反应			主要的结构金属：容易提炼，熔合碳时坚固，但易生锈	铁
氢	加热，反应缓慢					氢
铜		不反应	氢以下的金属，不会从酸溶液里置换出氢	只有加热，才能分解	管材：导电，但不反应 镀层：有光泽，但不反应 电缆线：电的良导体	铜
金					首饰：稀有，漂亮的光泽 电插件：电的良导体，不反应	金

要点

因为许多金属反应都涉及金属从水里或碱里置换出氢，所以把氢列在其中。

第1族金属放置在煤油里，以防止它们跟空气反应。其他金属形成氧化层，以减缓进一步反应。

铝的反应性显得不规则或很特别。它是很活泼的金属，但由于有氧化层保护，它又显得不活泼。

不活泼金属不能反应制取氢气，但有些能靠别的途径跟酸反应。比如：铜跟稀硝酸反应，在这个反应里，硝酸并不是作为一种酸来反应（通过氢离子），而是作为一种氧化剂（通过硝酸根离子）。

活泼金属的化合物非常稳定，以致于活泼金属只能靠电解这些化合物来制取。

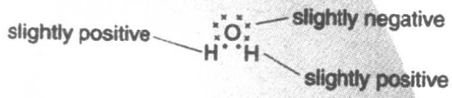
在表格底部的不活泼金属，它们的化合物非常活泼，以致于在史前时代，这些金属就已经发现及应用了。

金属的用途取决于以下一些因素：

- **金属的丰度**：铝比铁的储量大，金很稀少。
- **容易提取的程度**：金和铁容易提取，提取铝需要大量的电，所以很费钱。
- **合适的物理和化学性质**：这些性质已列在表中。

Water

BONDING AND STRUCTURE



The shared pairs in the covalent bonds are pulled nearer to the oxygen than the hydrogen.

This makes the hydrogen ends of the molecule a bit positive and the oxygen part a bit negative. This means the molecule is **polar**.

TESTS FOR WATER

Water can be recognized by

- its physical properties

It freezes at 0°C and boils at 100°C.

- its solvent properties

It dissolves anhydrous white copper sulphate turning it blue:

$CuSO_4(s) \rightarrow CuSO_4.5H_2O(aq)$
white blue

It dissolves anhydrous blue cobalt chloride turning it pink.

$CoCl_2(s) \rightarrow CoCl_2.7H_2O(aq)$
blue pink

SOLVENT PROPERTIES

The charged parts of each water molecule attract other molecules and ions making water a very good solvent.

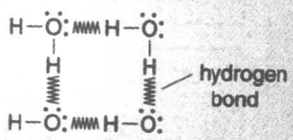
Ionic solids (like salt) and **covalent solids** (like sugar) all get *more* soluble as the temperature increases.

Gases (like oxygen, carbon dioxide, and hydrogen chloride) get *less* soluble as the temperature increases. The oxygen dissolved in water is essential to aquatic life.

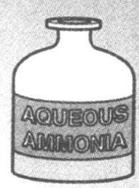
PURIFICATION

Because water is such a good solvent, it is difficult to find it pure. **Rainwater** contains dissolved gases. It dissolves gases like carbon dioxide (which occurs in the atmosphere naturally), and sulphur dioxide and nitrogen dioxide (which are in the atmosphere as a result of human activities).

PHYSICAL PROPERTIES



The charged parts of each molecule attract oppositely charged parts on nearby molecules strongly. These forces are called **hydrogen bonds**. They hold water molecules together tightly, so water is a liquid not a gas at room temperature.



AMMONIA IN SOLUTION

Ammonia gas is very soluble in water. It *takes a proton from water* (unlike the hydrogen halides which give a proton to water). The resulting solution is alkaline, because it contains hydroxide ions, OH^-.

$NH_3(g) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$

HYDROGEN CHLORIDE IN SOLUTION

Hydrogen chloride and the other hydrogen halides are very soluble in water. They react with the water making *strongly acidic* solutions because they *give a proton to water* making the hydroxonium ion, H_3O^+. This is usually written more simply as H^+. So the reaction equation is

$H_2O(l) + HCl(g) \rightarrow H_3O^+(aq) + Cl^-(aq)$

or $HCl(g) \xrightarrow{H_2O} H^+(aq) + Cl^-(aq)$

The resulting solution is called hydrochloric acid.

SALTS IN SOLUTION

Many ionic solids dissolve in water. Sea water is a source of these salts and the elements in them.

Sea water contains sodium chloride and small amounts of other metal halides. Bromine is extracted from the magnesium bromide in sea water by displacement with chlorine.

$Cl_2(g) + MgBr_2(aq) \rightarrow MgCl_2(aq) + Br_2(aq)$

CARBON DIOXIDE IN SOLUTION

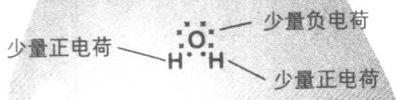
Carbon dioxide dissolves in water forming **carbonic acid.**

Rain is very dilute carbonic acid; soda water is a more concentrated solution.

$H_2O(l) + CO_2(g) \rightarrow H_2CO_3(aq)$

水

键和结构



共价键里的共用电子对比起氢原子来更靠近氧原子。

这便使分子里氢原子一端带少量正电荷，而氧原子部分带少量负电荷，这表示分子是有**极性**的。

水的测试

可以通过以下方法认识水

它的物理性质

水在0℃结冰，在100℃沸腾。

它的溶解性

它能溶解白色的无水硫酸铜，使其变成蓝色

$CuSO_4(s) \rightarrow CuSO_4.5H_2O(aq)$

白色　　蓝色

它能溶解蓝色的无水氯化钴，使其变成粉红色

$CoCl_2(s) \rightarrow CoCl_2.7H_2O(aq)$

蓝色　　粉红色

溶解性

每一个水分子带电部分吸引其他分子或离子，使水成为一种非常好的溶剂。

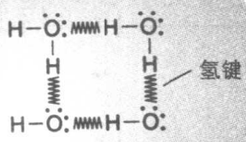
固体离子化合物（像盐）和**固体共价化合物**（像蔗糖）当水温越高越容易溶于水。

气体（像氧气、二氧化碳和氯化氢）在水温越高时越不容易溶解于水。溶解于水的氧气对水中的生命来讲是必要的。

净化

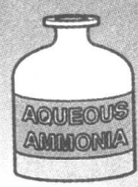
因为水是一种良好的溶剂，所以要找到纯净水是很困难的。**雨水**里有溶解的气体，它溶解的气体有二氧化碳（在大气里自然存在），二氧化硫和二氧化氮（它是由于人类的活动而释放到大气中去的）。

物理性质



每一个分子带电部分强烈地吸引附近分子带相反电荷的部分，这种力叫**氢键**。

氢键把水分子紧紧地聚合在一起，因此水在室温时是一种液体而不是气体。



溶液里的氨

氨气很容易溶解于水，它从水里*获取*一个质子（不像卤化氢，它向水里放出一个质子）。结果，溶液呈**碱性**，因为，它含有氢氧根离子。

$NH_3(g)+H_2O(l) \rightarrow NH_4^+(aq)+OH^-(aq)$

溶液里的氯化氢

氯化氢和其他卤化氢都很容易溶解于水，它们跟水反应生成强酸溶液，因为它们释放出一个质子，生成水合氢离子H_3O^+，通常简写成H^+，因此，反应方程式是：

$H_2O(l)+HCl(g) \rightarrow H_3O^+(aq)+Cl^-(aq)$

或 $HCl(g) \xrightarrow{H_2O} H^+(aq)+Cl^-(aq)$

形成的溶液叫盐酸。

溶液里的盐

许多固体离子化合物溶解于水。海水是这些盐以及盐中元素的源泉。

海水里有氯化钠和少量的其他金属卤化物，溴是用氯置换海水里溴化镁而提取出来的。

$Cl_2(g)+MgBr_2(aq) \rightarrow MgCl_2(aq)+Br_2(aq)$

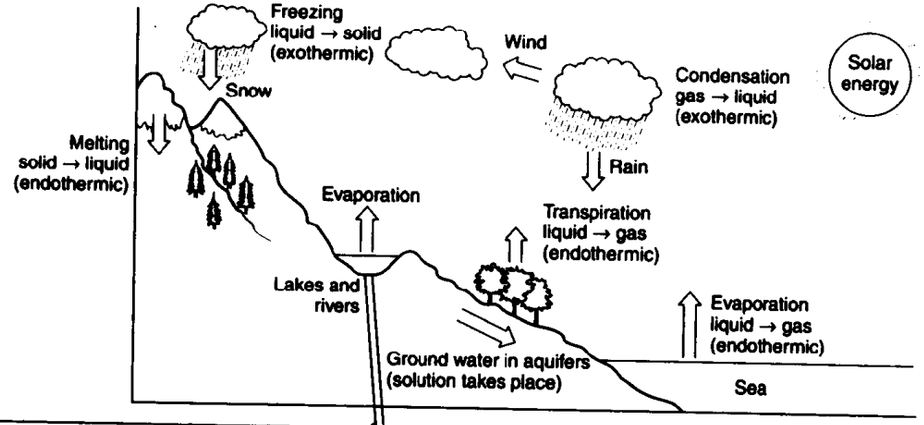
溶液里的二氧化碳

二氧化碳溶于水形成**硫酸**。

雨水是很稀的碳酸溶液。苏打水是比较浓的碳酸溶液。

$H_2O(l)+CO_2(g) \rightarrow H_2CO_3(aq)$

The water cycle



WATER AS A RESOURCE

Because water is cycled quickly it is a renewable resource. The time it spends in different parts of the cycle – the residence time – varies a lot. Water may be in the atmosphere for only a few hours; in a lake or river for days, weeks, or months; and in ice caps, glaciers, or oceans for thousands of years.

As water is cycled it dissolves

- gases like the oxides of carbon, nitrogen, and sulphur
- soluble solids from the ground it runs over or through.

These processes may be 'natural' (e.g. the formation of hard water) or 'unnatural' (e.g. dissolving pollutant gases to form acid rain).

Reservoir water
Contains clay, algae, bacteria.

WATER TREATMENT PLANT

Aerator
Dissolved iron is oxidized forming a precipitate.

Mixing tank
Aluminium sulphate added to precipitate clay; chlorine added to kill bacteria.

Sedimentation tank
Clay particles settle out.

Filtration
Water filtered through beds of fine sand.

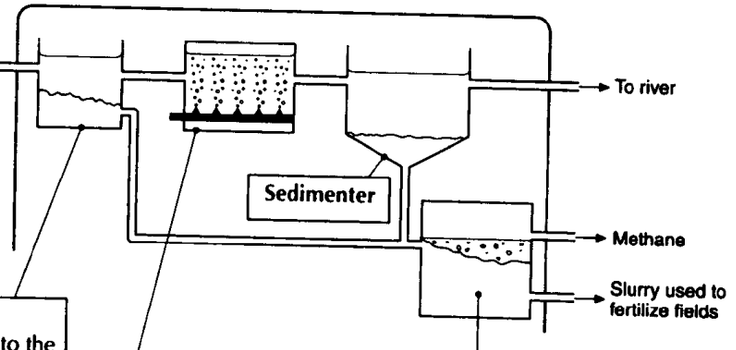
Chlorination tank
More chlorine added to kill all bacteria. Chlorine is a strong oxidizing agent and reacts with bacteria.

Water treatment plants cannot remove soluble impurities such as nitrates. So the water running off fields into rivers is monitored to check that leached nitrates stay below safe limits.

Toilets 33%
Washing and bathing 48%
Cleaning 10%
Cooking and drinking 1%

Storage tank

SEWAGE TREATMENT PLANT

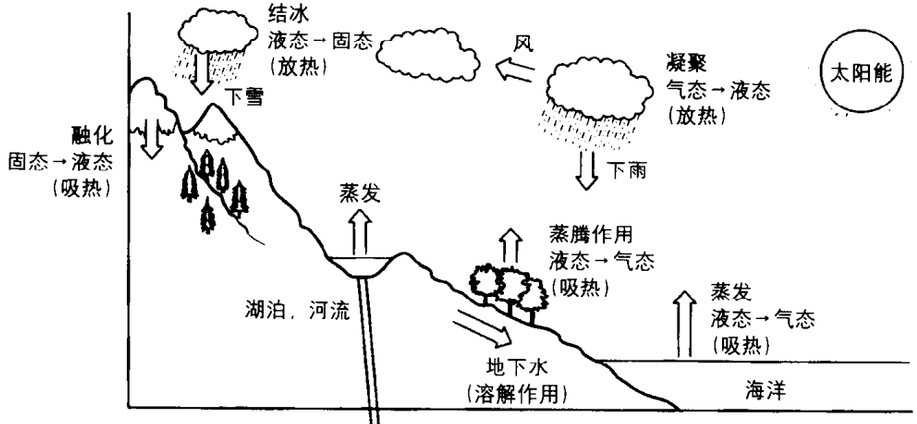


Settling tanks
Solid particles sink to the bottom making sludge.

Aeration tank
Air is blown through water. Aerobic bacteria contain enzymes which catalyse the decomposition of harmful substances in the water.

Sludge digester
Anaerobic bacteria contain enzymes which catalyse decomposition of harmful substances. Methane gas and fertilizer are produced.

水循环



水是一种资源

因为水不断地迅速循环，所以它是一种可以更新的资源。

整个循环的各个不同的环节，所需的时间是不同的。在大气里水也许只滞留几个小时，在河流湖泊里滞留几天，几个星期或几个月，而在极地冰盖里、冰川里或海洋里可以停留几千年。

当水循环时，它能溶解

- 气体，比如二氧化碳、二氧化氮和二氧化硫
- 它流经的地上或地下的可溶性固体

这些过程是很“自然”的（比如形成硬水）或“反自然”的（比如溶入污染气体形成酸雨）。

水库
含黏土、水藻、细菌。

充气室
溶解的铁氧化生成沉淀。

混合槽
加入硫酸铝使黏土沉淀，加入氯气杀死细菌。

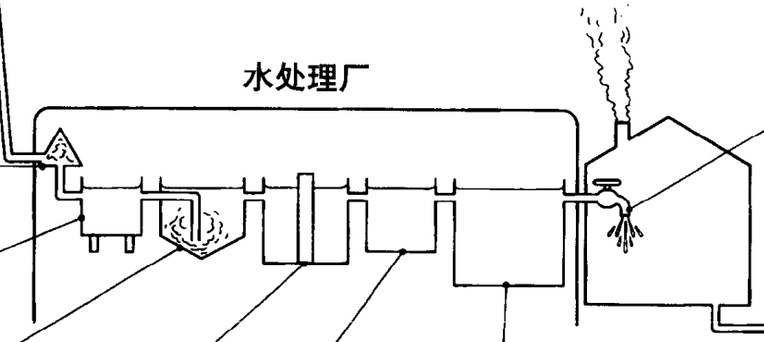
沉淀池
黏土沉降。

过滤池
水经过细沙过滤。

氯化池
进一步加入氯杀死细菌，氯是一种强氧化剂，跟细菌作用。

水处理厂不能除去可溶性的杂质，比如硝酸盐。因此，必须监测流过田野流入河里的水，以确定经过过滤的水里，硝酸盐含量在安全线以下。

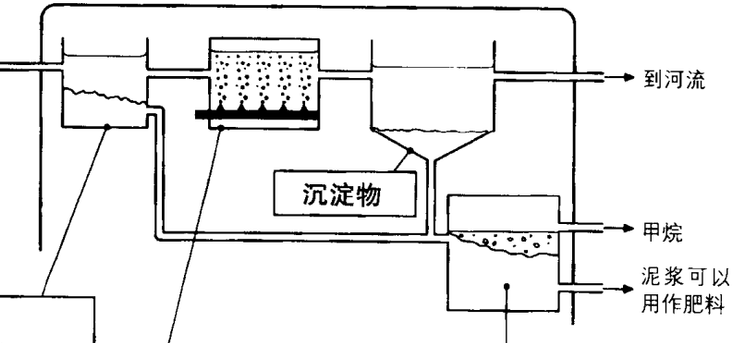
水处理厂



蓄水槽

盥洗 33%
洗澡 48%
清扫 10%
烧饭和喝水 1%

污水处理厂



沉淀池
固体颗粒沉降到底部形成烂泥。

充气槽
向水里鼓入空气，好氧细菌里有酶能催化分解水中的有害物质。

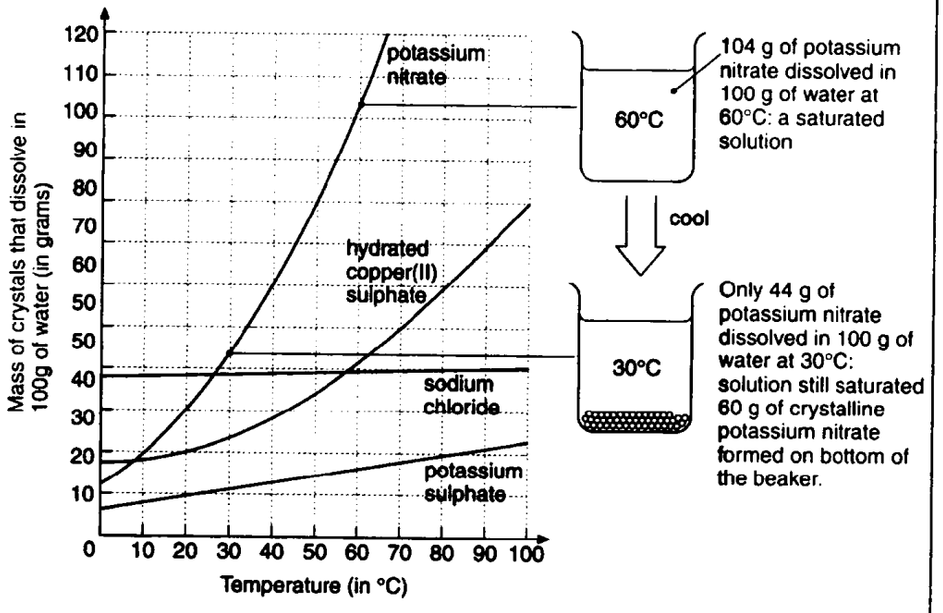
沉淀蒸发器
好氧细菌有酶能催化分解有害物质，制成甲烷和肥料。

Solubility and solutions in water

SOLUBILITY

The **solubility** of a substance is defined as the mass of that substance which will dissolve in 100 g of water at a defined temperature.

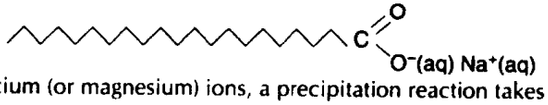
For most solids, the solubility **increases** with increasing temperature.



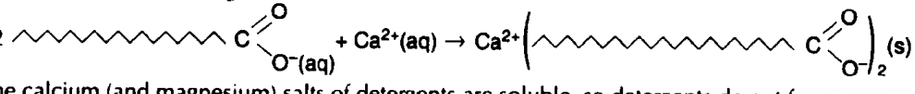
For gases, the solubility **decreases** with increasing temperature.

SOAP, SCUM, AND DETERGENT

Soaps are the sodium salts of long carbon chain carboxylic acids.



In the presence of calcium (or magnesium) ions, a precipitation reaction takes place and the insoluble calcium (or magnesium) salt forms.

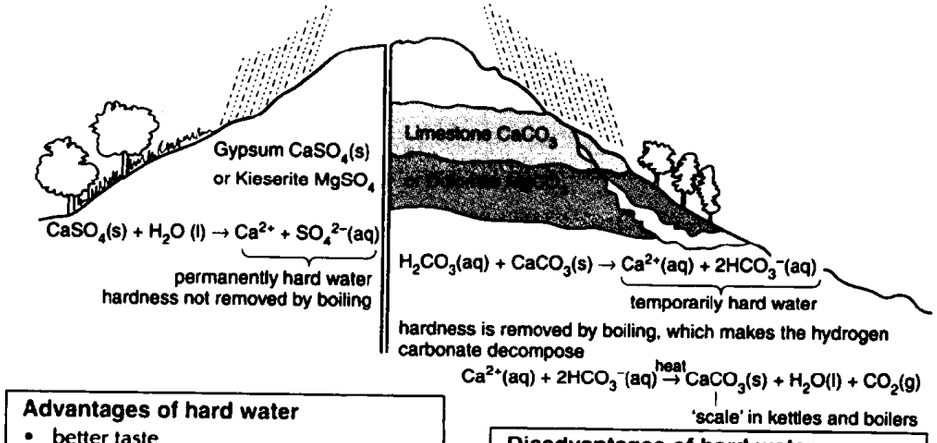


The calcium (and magnesium) salts of detergents are soluble, so detergents do not form scum with hard water.

HARD WATER

Water containing dissolved calcium or magnesium ions is said to be **hard**. In hard water soap does not lather as well and forms a scum. The calcium and magnesium ions get into the water in two ways.

1. Rain falls on soluble calcium or magnesium minerals and **dissolves** them.
2. Rain (which is slightly acidic) **reacts with** basic calcium or magnesium minerals. Rainwater is acidic because it contains dissolved carbon dioxide. So rain is dilute carbonic acid.



Advantages of hard water

- better taste
- healthier: less heart disease
  stronger bones and teeth
- better for brewing beer

Disadvantages of hard water

- forms a scum with soap
- forms a scale or 'fur' in hot water boilers and kettles

Softening water

Water which has had its hardness removed is described as softened water.
Water is softened by:

1. Precipitating out the calcium or magnesium ions by adding sodium carbonate:

   $Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$

2. Ion exchange. The hard water is run through a resin which replaces the calcium or magnesium ions with sodium ions:

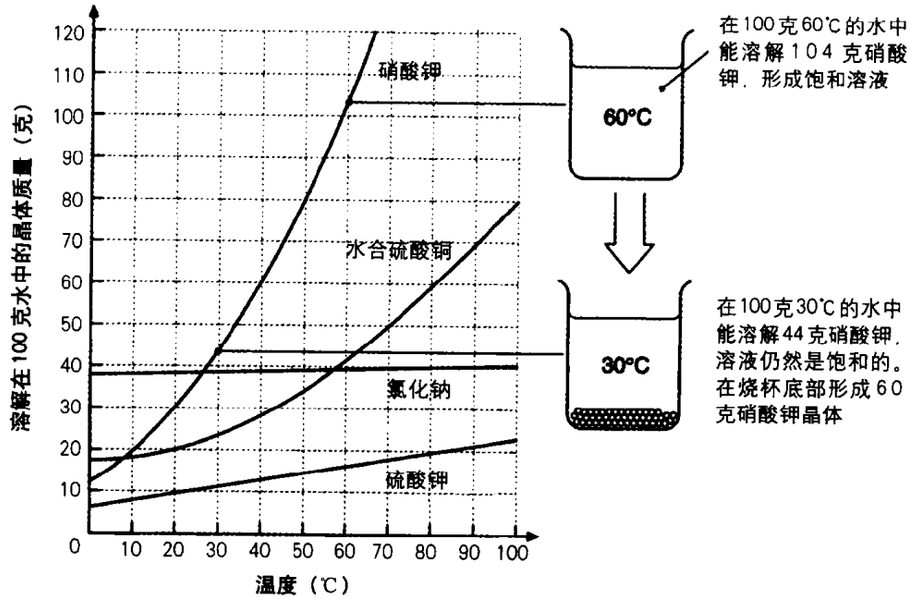
   $2Na\text{-resin} + Ca^{2+}(aq) \rightarrow Ca\text{-resin} + 2Na^{+}(aq)$

溶解度和水溶液

溶解度

一种物质的**溶解度**定义为：在一定温度下100克水中这种物质能溶解的克数。

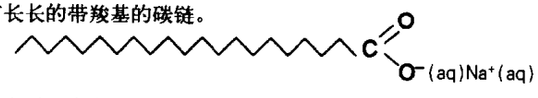
对大多数固体来说，溶解度随温度的**升高**而升高。



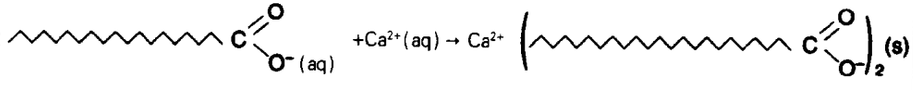
对气体来说，随着温度**升高**溶解度下降。

肥皂、浮渣和清洁剂

肥皂是钠盐，它有长长的带羧基的碳链。



当有钙或镁离子存在时，会发生沉淀反应，生成不溶性的钙盐或镁盐。



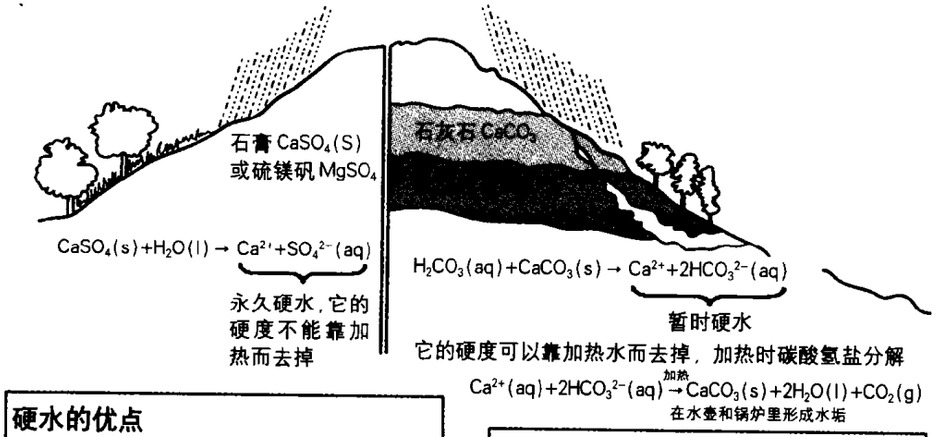
清洁剂里的钙盐和镁盐是可溶性的，所以清洁剂不会跟硬水反应生成浮渣。

硬水

水中含有溶解的钙或镁离子，就称这种水变**硬**。在硬水里，肥皂不易发泡、去污。钙、镁离子通过两种途径进入水中。

1. 雨水降落在钙或镁的矿物中，矿物**溶解**。

2. 雨水（稍带酸性）跟碱性的钙、镁矿**反应**，雨水因为含有溶解的二氧化碳，这雨水就成很稀的碳酸，所以雨水带酸性。



硬水的优点

- 口感好
- 有利健康，减少心脏发病，强骨骼和牙齿
- 有利于酿造啤酒

硬水的缺点

- 跟肥皂形成浮渣
- 在水壶和锅炉里生成水垢

水软化

使水去掉硬度叫水的软化。水的软化可以通过：

1. 加入碳酸钠生成沉淀，从而去掉钙、镁离子：

   $Ca^{2+}(aq)+CO_3^{2}(aq) \rightarrow CaCO_3(s)$

2. 离子交换，硬水流过一种树脂，树脂里的钠离子会取代钙、镁离子：

   $2Na-$ 树脂 $+Ca^{2+}(aq) \rightarrow Ca-$ 树脂 $+2Na^{+}(aq)$

Acids and bases

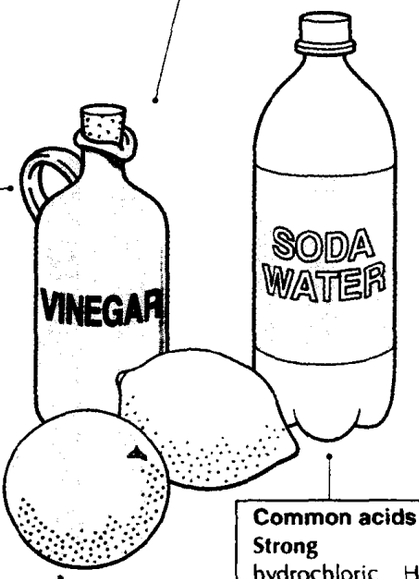
ACIDS

Acid properties

- sour taste: citric acid in lemons and grapefruits; ethanoic acid in vinegar (never taste acids in the lab)
- change the colour of indicators: litmus and universal indicators go red
- react with water to make hydrogen ions, H_3O^+, or more simply, $H^+(aq)$
  $H_2O(l) + HNO_3(g) \rightarrow H^+(aq) + NO^{3-}(aq)$
- react with reactive metals which displace the hydrogen in the acid
  $Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$
- react with metal oxides, metal hydroxides, and metal carbonates to make salts; when this happens the acid is *neutralized*.

Definition of an acid

An acid is a substance which contains hydrogen which can be displaced by a metal and which reacts with water to make hydrogen ions as the only positive ions.



Strong and weak acids

Some acids react completely with water forming hydrogen ions:

$H_2O(l) + HCl(g) \rightarrow H^+(aq) + Cl^-(aq)$

The solution made conducts strongly because it contains so many ions. These acids are called strong acids.

Other acids react incompletely with water, and only make a few hydrogen ions:

$H_2O(l) + CH_3COOH(l) \rightleftharpoons H^+(aq) + CH_3COO^-(aq)$
99.9% 0.1% 0.1%

Because there are so few ions present in the solution, it conducts weakly. Acids like this are called weak acids.

So

- **strong acids are fully ionized** in water
- **weak acids are only partially ionized** in water.

Bee stings are acidic – treat with sodium hydrogencarbonate.

Common acids

Strong	
hydrochloric	HCl
nitric	HNO_3
sulphuric	H_2SO_4
Weak	
carbonic	H_2CO_3
ethanoic	CH_3COOH
sulphurous	H_2SO_3

BASES

Bases and alkalis

Substances which neutralize acids are called **bases**.

Bases are the oxides, hydroxides, or carbonates of metals.

Most bases are insoluble, but some dissolve in water.

Soluble bases are called **alkalis**.

Common alkalis

Group 1 oxides, hydroxides, and carbonates: NaOH; K_2O; Na_2CO_3

Calcium hydroxide (lime water): $Ca(OH)_2$

Ammonia solution (aqueous ammonia): $NH_3(aq)$

Strong and weak alkalis

Some alkalis split up completely into ions:

$NaOH(s) + H_2O(l) \rightarrow Na^+(aq) + OH^-(aq)$

They are called strong alkalis.

Other alkalis react incompletely with water making only a few hydroxide ions:

$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

They are called weak alkalis.

Wasp stings are alkaline – treat with lemon juice or vinegar.

Alkaline solutions

The solution made from a soluble base:

- has a soapy, slippery feel – most soaps are alkaline
- changes the colour of indicators – litmus and universal go blue.

酸和碱

酸

酸的性质

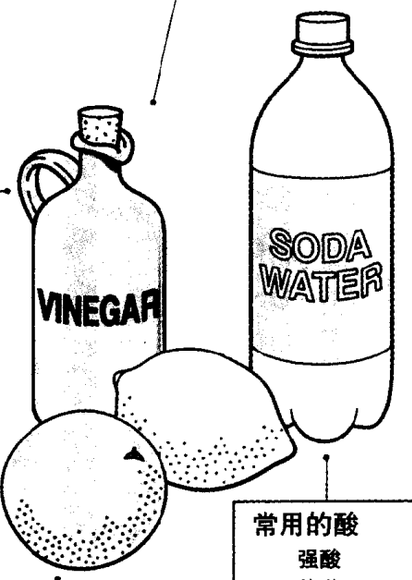
- 酸味：柠檬、葡萄柚里的柠檬酸，醋（绝对不能在实验室里尝酸）里的醋酸
- 改变指示剂的颜色，使石蕊和通用指示剂变红色
- 跟水反应生成水合氢离子 H_3O^+，简写成 $H^+(aq)$

  $H_2O(l)+HNO_3(g) \rightarrow H+(aq)+NO^{3-}(aq)$
- 跟活泼金属反应，金属置换出酸中的氢：

  $Mg(s)+H_2SO_4(aq) \rightarrow MgSO_4(aq)+H_2(g)$
- 跟金属氧化物、金属氢氧化物和金属碳酸盐反应生成盐，反应时酸变*中性*

酸的定义

酸是一种物质，它含有氢，氢能被金属置换。酸跟水反应，只生成一种带正电荷的离子，就是氢离子。



强酸和弱酸

有些酸跟水完全反应形成氢离子：

$H_2O(l)+HCl(g) \rightarrow H+(aq)+Cl^-(aq)$

由于含有大量的离子，所以溶液导电性加强，这些酸叫强酸。

有些酸跟水不完全反应，只生成少量氢离子：

$H_2O(l)+CH_3COOH(l) \rightleftharpoons H^+(aq)+CH_3COO^-(aq)$

99.9%　　0.1%　0.1%

由于含有的离子很少，所以溶液导电性弱，像这种酸叫弱酸。

所以：

- **强酸在水里全部离子化**
- **弱酸在水里部分离子化**

蜜蜂的蛰针放出的液体是酸性的，可以用碳酸氢钠处理伤口。

常用的酸

强酸	
盐酸	HCl
硝酸	HNO_3
硫酸	H_2SO_4
弱酸	
碳酸	H_2CO_3
乙酸	CH_3COOH
亚硫酸	H_2SO_3

碱

碱和可溶性碱

能中和酸的物质叫**碱**。

碱是金属的氧化物、氢氧化物或碳酸盐。

大多数碱是不溶于水的，但有些能溶于水。

溶于水的碱叫**可溶性碱**。

常见的碱

第一族里，氧化物、氢氧化物和碳酸盐：$NaOH$；K_2O；Na_2CO_3

氢氧化钙（熟石灰水）：$Ca(OH)_2$

氨溶液（氨水）：$NH_3(aq)$

强碱和弱碱

有些碱在水中全部变成离子：

$NaOH(s)+H_2O(l) \rightarrow Na^+(aq)+OH^-(aq)$

这些碱是强碱。

有些碱跟水发生不完全反应，只能生成少量的氢氧根离子：

$NH_3(aq)+H_2O(l) \rightleftharpoons NH_4^+(aq)+OH^-(aq)$

这些碱叫弱碱。

黄蜂叮刺后，释放的液体是碱性的，可以用柠檬酸或醋来处理。

碱溶液

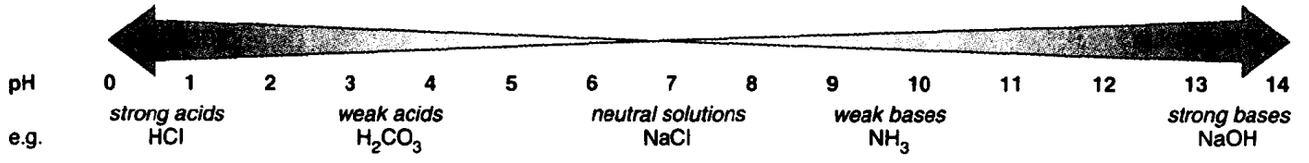
可溶性碱形成的溶液：

- 有一种像肥皂样滑腻的感觉，大多数肥皂是碱性的
- 能改变指示剂的颜色

  使石蕊和通用指示剂变蓝

Neutralization

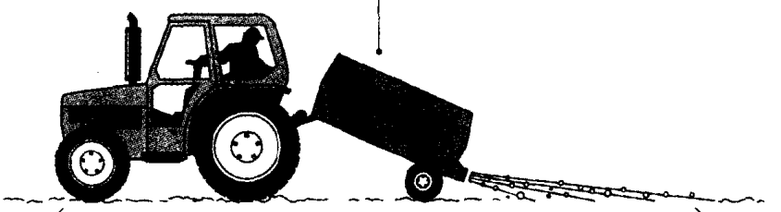
pH
The acidity or alkalinity of a solution can be measured on the pH scale, which goes from 0 to 14.



Acidic solutions have pH values less than 7.

Neutral solutions have pH values of 7 at room temperature.

Alkaline or basic solutions have pH values greater than 7.



NEUTRALIZATION

When an acid and a base react together they **neutralize** each other. The acid loses its acidic properties and the base loses its basic properties. The products of a neutralization reaction are a salt and water.

acid + base → salt + water (+ carbon dioxide if the base is a carbonate)

e.g. $NaOH + HCl \rightarrow NaCl + H_2O$
$MgO + H_2SO_4 \rightarrow MgSO_4 + H_2O$
$CaCO_3 + 2HNO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2$

During these reactions:

- the hydrogen ions from the acid react with the hydroxide ions from the base to make water molecules

  $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

- all the other ions are spectators and just stay in solution
- heat is produced because all neutralizations are exothermic
- the pH changes
- the colour of an indicator changes.

USING NEUTRALIZATIONS

There are a number of important examples of neutralization.

1. Adding lime (calcium hydroxide) to soil
Plants need nitrogen, phosphorus, and potassium compounds from the soil to grow well. Most plants take up these elements better when the soil is alkaline. Lime neutralizes acids in the soil making it alkaline.

2. Reducing acid rain and its effects
The coal burnt in power stations contains sulphur as an impurity. When the coal is burnt, the sulphur is burnt too. This produces sulphur dioxide, which dissolves in rain forming acid rain. By passing the burnt gases through lime, they are neutralized. The product, calcium sulphate, is used as plaster.

Many lakes have become acidic due to acid rain. All the fish in them die. Spraying powdered lime on to the lake neutralizes the water so that fish can once again survive.

3. Neutralizing stomach acids
The human stomach contains hydrochloric acid so that the enzyme pepsin can begin digesting protein. Sometimes too much acid is made and begins to attack the stomach wall causing pain. The extra acid can be neutralized by taking an 'ant-acid'. These always contain a base such as sodium or magnesium carbonate.

ACIDS WITH TWO HYDROGENS

Some acids like sulphuric, H_2SO_4, and carbonic, H_2CO_3, have two hydrogens in them. These acids can be

- **completely neutralized** when both hydrogens are replaced, e.g.
  $H_2CO_3 + 2NaOH \rightarrow Na_2CO_3 + 2H_2O$
  complete neutralization
- or **partly neutralized** when only one hydrogen is replaced, e.g.
  $H_2CO_3 + 1NaOH \rightarrow NaHCO_3 + 1H_2O$
  partial neutralization

The salt made by partial neutralization is called an **acid salt**. In this example the salt is called **sodium hydrogencarbonate**.

SALTS

Salts are substances in which the hydrogen of an acid has been replaced by a metal, e.g. NaCl or $MgSO_4$.

Each acid can produce a family of salts.

e.g.
hydrochloric acid produces **chlorides**
nitric acid produces **nitrates**
sulphuric acid produces **sulphates**
ethanoic acid produces **ethanoates**

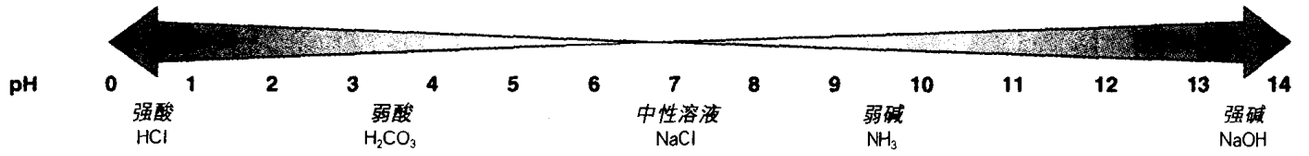
The first part of the salt, the metal part, is determined by the base used to react with the acid. So each base also produces a family of salts.

e.g.
sodium bases like sodium hydroxide produce **sodium salts**
magnesium bases like magnesium oxide produce **magnesium salts**

中和

pH

溶液的酸碱性可以用 pH 值来测量，pH 值从 0 到 14。

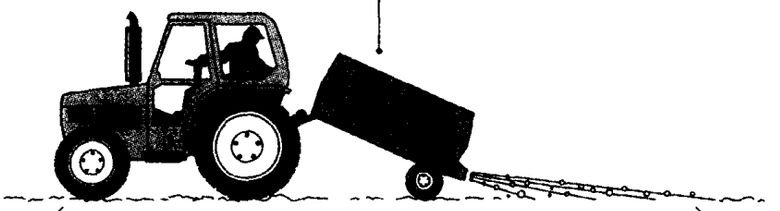


石蕊的颜色 红色 紫色 蓝色

酸性溶液 pH 值小于 7。

中性溶液在室温时 pH 值是 7。

碱性溶液在室温时 pH 值大于 7。



中和

当一种酸和一种碱反应时它们相互**中和**，酸失去酸的性质，而碱失去碱的性质。中和反应的产物是一种盐和水。

酸＋碱→盐＋水（＋如果碱是碳酸盐则放出二氧化碳）

如：$NaOH+HCl \rightarrow NaCl+H_2O$

$MgO+H_2SO_4 \rightarrow MgSO_4+H_2O$

$CaCO_3+2HNO_3 \rightarrow Ca(NO_3)_2+H_2O+CO_2$

在反应时：

- 酸里的氢离子跟碱里的氢氧根离子反应生成水分子

  $H^+(aq)+OH^-(aq) \rightarrow H_2O(l)$

- 所有的其他离子只是旁观者(没有参加反应)，仍在溶液里
- 因为所有的中和反应是放热反应，所以有热量产生
- pH 值改变
- 指示剂的颜色改变

中和反应的应用

有许多中和反应的重要例子。

1. 在泥土里加石灰（氢氧化钙）

植物需要从土壤里吸取氮、磷和钾的化合物才能生长良好。当土壤呈碱性时，大多数植物能较好地吸取这些元素，石灰能中和土壤里的酸，使土壤变碱性。

2. 减少酸雨和它的影响

发电厂里燃烧的煤炭含有杂质硫，当煤炭燃烧时，硫也燃烧，产生二氧化硫，它溶解在雨水里变成酸雨。如果让燃烧的气体通过石灰层，气体就被中和，产物是硫酸钙，用作石膏。

许多湖泊由于酸雨而呈酸性，湖里的鱼都死了。向湖里撒石灰粉能中和湖水，鱼能重新获得生机。

3. 中和胃酸

人的胃里有盐酸，这样胃蛋白酶就能消化蛋白质，有时胃里会形成过多的胃酸，并开始损伤胃壁引起胃痛。这时吃一种抗酸剂就能中和过多的胃酸。它们是一种像碳酸钠或碳酸镁那样的碱。

有两个氢原子的酸

有些酸像硫酸 H_2SO_4、碳酸 H_2CO_3 有两个氢原子，这些酸：

- 当两个氢原子都被置换时，能**全部中和**，比如：
  $H_2CO_3+2NaOH \rightarrow Na_2CO_3+2H_2O$
  全部中和
- 当只有一个氢原子被置换时，能**部分中和**，比如：
  $H_2CO_3+1NaOH \rightarrow NaHCO_3+1H_2O$
  部分中和

因部分中和而形成的盐叫**酸式盐**，在上例中，生成的盐叫**碳酸氢钠**。

盐

盐是酸里的氢被一种金属取代而形成的物质。比如：NaCl 或 $MgSO_4$。

每一种酸可以形成一族盐。

比如：
盐酸生成**氯化物**
硝酸生成**硝酸盐**
硫酸生成**硫酸盐**
醋酸生成**醋酸盐**

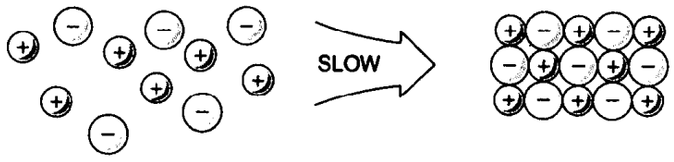
盐的前面部分，即金属部分是由用来跟酸反应的碱决定的。所以每一种碱也能形成一族盐。

比如：
像氢氧化钠（**钠碱**）生成**钠盐**
像氧化镁（**镁碱**）生成**镁盐**

Crystallization and precipitation

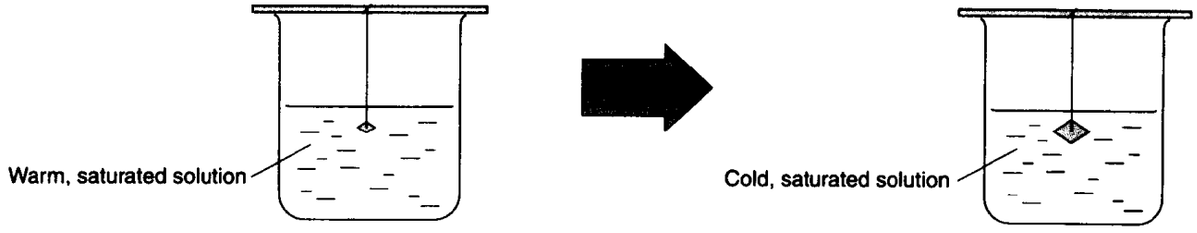
CRYSTALLIZATION

If the water in a solution is lost by evaporation, the ions that are left will clump together. The positive cations will attract the negative anions, and the ions will arrange themselves so that oppositely charged ions are next to each other. A lattice will slowly form. This process is called **crystallization**.



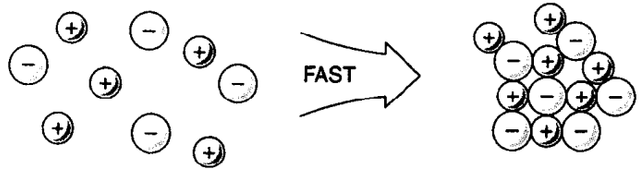
e.g. $Na^+(aq) + Cl^-(aq) \rightarrow NaCl(s)$

If the process happens slowly, big crystals have time to grow. If the process happens quickly, lots of small crystals form.



PRECIPITATION

If two solutions containing oppositely charged ions which attract each other very strongly are added together, the ions will immediately clump together. Because this happens very quickly, there is not time for an ordered lattice to form. So instead of crystals, a fine suspension is seen. This is called a **precipitate**.



Precipitation is the reaction between two solutions making an *insoluble* product.

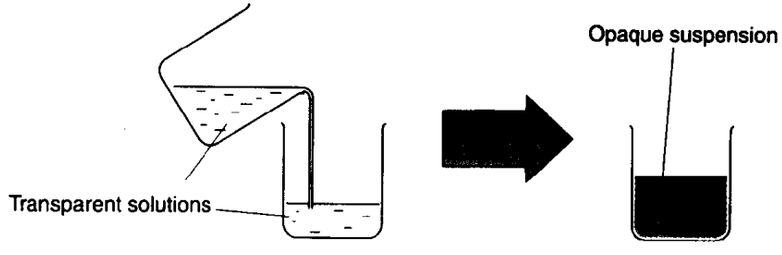
e.g.

$CaCl_2(aq) + Na_2CO_3(aq) \rightarrow CaCO_3(s) + 2NaCl(aq)$

or much better

$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$

because the other ions are spectators.



Using precipitation reactions

1. Making insoluble salts

Any insoluble salt can be made simply by adding together two solutions containing between them the ions in the salt.

So to make lead iodide, add any lead solution to any iodide solution, filter off and wash the precipitate, then dry it.

2. Testing for the presence of certain ions

Precipitation reactions can be used to test for both anions and cations.

Anion tests

Anions like the halides and sulphates can be tested for using precipitation reactions. For example, the presence of chloride ions in solution can be detected by adding silver ions. Silver ions attract chloride ions so strongly that if there are any chloride ions present a white precipitate of silver chloride will form.

(Equally, silver ions can be tested for using chloride ions.)

A systematic scheme for testing for anions is shown on page 67.

Cation tests

Many metals form insoluble hydroxides. So if a solution of sodium hydroxide is added to a solution of the metal, a precipitate of the hydroxide will be seen. Hydroxide precipitates vary in colour, and some redissolve when excess sodium hydroxide is added.

A systematic scheme for testing for cations is shown on page 66.

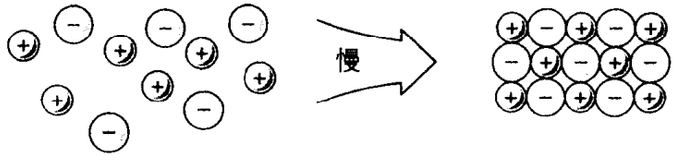
结晶和沉淀

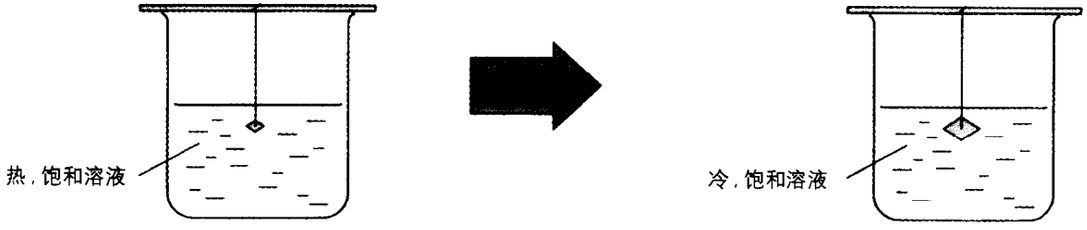
结晶

如果溶液里的水由于蒸发而消失，留下的离子会聚成团状，正离子会吸引负离子。带相反电荷的离子互相挨在一起排列，慢慢形成晶格。这一过程叫**结晶**。

比如：$Na^+(aq)+Cl^-(aq) \rightarrow NaCl(s)$

如果这一过程缓慢发生，就有充足的时间形成大晶体。
如果这一过程很快发生，就形成许多小晶体。





沉淀

如果两种溶液带有相反电荷的离子，它们互相强烈吸引并聚在一起，离子立刻聚成团状。由于这一过程发生快，根本没有时间形成有规则的晶格，所以，只看到一种细小的悬浮物，而看不到有晶体生成，这种悬浮物叫**沉淀物**。

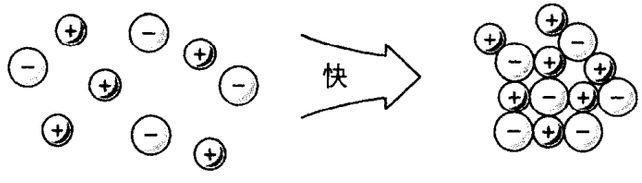
沉淀物是由于两种溶液互相反应生成一种不溶性的产物。

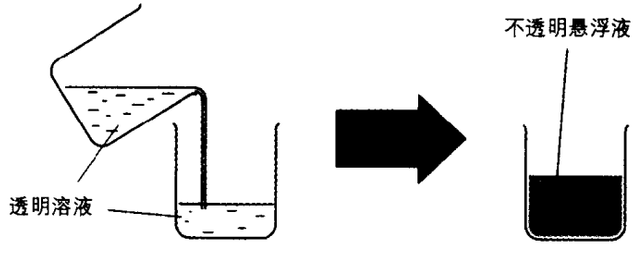
比如：
$CaCl_2(aq)+Na_2CO_3(aq) \rightarrow CaCO_3(s)+2NaCl(aq)$

或更本质的是：

$Ca^{2+}(aq)+CO_3^{2-}(aq) \rightarrow CaCO_3(s)$

因为其他离子没有参加反应。





沉淀反应的利用

1. 制造不溶性的盐

只要把两种分别含有盐的离子的溶液混合在一起，就能制得任何一种不溶性的盐。

比如要制取碘化铅，只要把任何一种铅溶液加入到一种碘溶液中，过滤，清洗沉淀，然后烘干。

2. 鉴别某些离子是否存在

沉淀反应可以用来检别阴离子和阳离子。

鉴别阴离子

可以用沉淀反应来检别卤离子和硫酸根离子等阴离子。比如，溶液里氯离子是否存在，可以通过加入银离子来检别，只要有氯离子存在，银离子就会强烈吸引氯离子，形成白色氯化银沉淀。

（相同地，银离子也可以用氯离子来鉴别）

系统地鉴别阴离子的方法见 63 页

鉴别阳离子

许多金属形成不溶性的氢氧化物。如果氢氧化钠溶液里加入一种金属溶液，就会有氢氧化物沉淀。各种氢氧化物沉淀的颜色是不同的。当加入过量的氢氧化物时，有些沉淀会重新溶解。

系统地鉴别阳离子的方法见 62 页

Reduction and oxidation

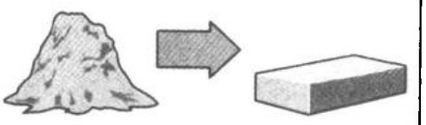
REDUCTION

Reduction is the removal of oxygen. The word was originally used to describe the process of changing a metal ore (often an oxide) into the metal.

e.g. $2CuO(s) + C(s) \rightarrow 2Cu(s) + CO_2(g)$

The metal oxide above would not have been reduced without the carbon, so the carbon is called a **reducing agent**.

Notice that in acting as a reducing agent, the carbon is itself oxidized. This means that the copper oxide was acting as an **oxidizing agent**.

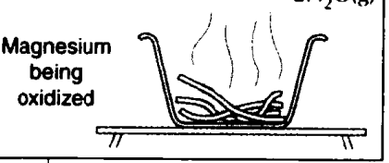


OXIDATION

Oxidation is the reaction of an element or compound with oxygen.

e.g. $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

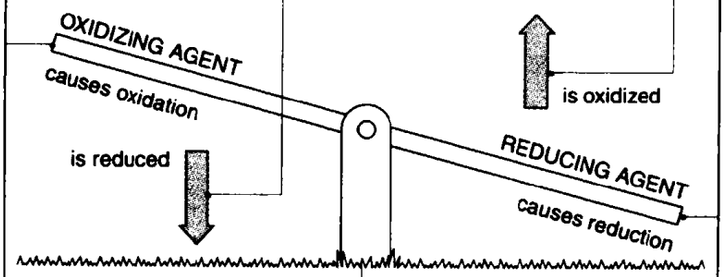
or $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$



Oxidizing agents

Oxidizing agents are substances that oxidize the substances they react with. They themselves are easily *reduced*.

Common oxidizing agents are: oxygen, the halogens, potassium dichromate(VI), potassium manganate(VII).



Reducing agents

Reducing agents are substances that reduce the substances they react with. They themselves are easily *oxidized*.

Common reducing agents are: reactive metals; carbon; carbon monoxide

REDOX

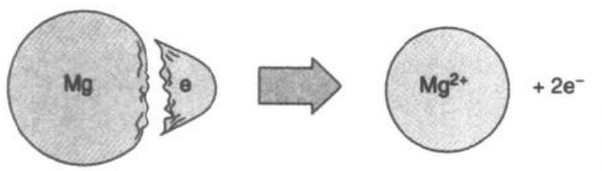
Reduction and oxidation take place together. All oxidation reactions involve the reduction of something else, so whether the process is called oxidation or reduction depends on which reactant is being referred to. So the whole process is often called **redox**.

Electron transfer

Magnesium atoms and oxygen molecules react to form magnesium oxide, an ionic solid. In this solid there are magnesium ions, Mg^{2+}, and oxide ions, O^{2-}.

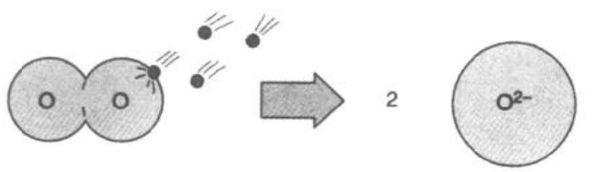
So the magnesium (which is oxidized) loses electrons as the atoms become positive cations:

$Mg \rightarrow Mg^{2+} + 2e^-$



while the oxygen (which is reduced) gains electrons as the molecules become negative anions:

$O_2 + 4e^- \rightarrow 2O^{2-}$



So, oxidation and reduction can also be defined in terms of electron loss and gain.

Oxidation is loss of electrons. **Reduction** is gain of electrons. **Redox** is electron transfer.

Remember **OIL RIG**! **O**xidation **I**s **L**oss, **R**eduction **I**s **G**ain.

ELECTROLYSIS

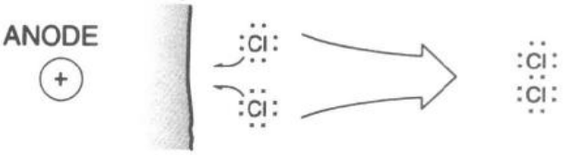
Electrolytic reactions are examples of redox reactions.

Anode reactions are **oxidations**.

At the positive anode, electrons are lost from anions:

e.g. $2Cl^- \rightarrow Cl_2 + 2e^-$

or $2O^{2-} \rightarrow O_2 + 4e^-$

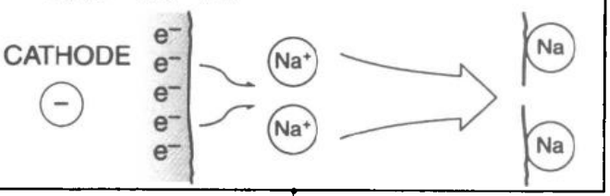


Cathode reactions are **reductions**.

At the negative cathode, electrons are gained by cations:

e.g. $Na^+ + e^- \rightarrow Na$

and $Al^{3+} + 3e^- \rightarrow Al$



DISPLACEMENT REACTIONS

Displacement reactions are also redox reactions. For example:

A more reactive metal is oxidized, while a less reactive one is reduced.

$Fe + Cu^{2+} \rightarrow Fe^{2+} + Cu$

A more reactive non-metal is reduced while a less reactive one is oxidized:

$Cl_2 + 2I^- \rightarrow 2Cl^- + I_2$

还原和氧化

还原

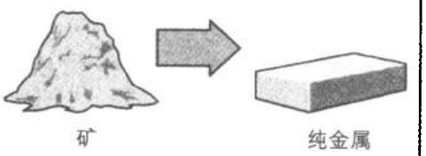
还原就是去掉氧。还原这个词最初被用来描述把金属矿物（通常是金属氧化物）变成金属的过程。

比如:

$2CuO(s)+C(s) \rightarrow 2Cu(s)+CO_2(g)$

上面的金属氧化物如果没有碳就不会被还原，所以碳就叫**还原剂**。

注意，在与还原剂作用时，碳本身被氧化。这意味着氧化铜起了**氧化剂**的作用。



氧化

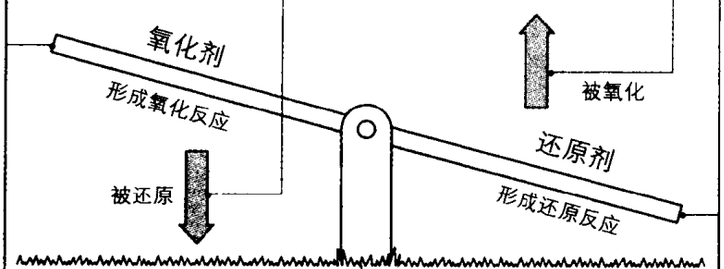
氧化是一种元素或化合物跟氧发生反应。比如:

$2Mg(s)+O_2(g) \rightarrow 2MgO(s)$

或 $CH4(g)+2O_2(g) \rightarrow CO_2(g)+2H_2O(g)$

氧化剂

氧化剂在反应时能氧化跟其反应的物质，它们本身很容易被还原。常用的氧化剂有：氧气、卤素、重铬酸钾、高锰酸钾。



还原剂

还原剂在反应时能还原跟其反应的物质，它们本身很容易被氧化。常用的还原剂有：活泼金属、碳、一氧化碳

氧化还原作用

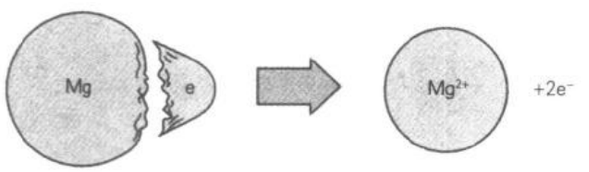
还原和氧化是一起发生的，所以氧化反应都包括其他一些物质的还原。因此，不管是把反应过程称作氧化还是还原，它取决于对哪种反应物而言，因此整个反应过程通常叫做**氧化还原作用**。

电子转移

镁原子跟氧分子反应生成氧化镁，这是一种离子化合物固体，这种固体里有镁离子 Mg^{2+} 或氧离子 O^{2-}。

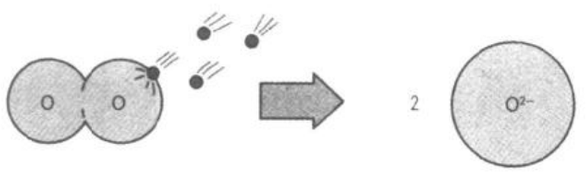
因此，镁（它被氧化）失去电子，变成带正电荷的阳离子:

$Mg \rightarrow Mg^{2+}+2e^-$



同时，氧（它被还原）获得电子，变成带负电荷的阴离子:

$O_2+4e^- \rightarrow 2O^{2-}$



因此，氧化和还原也能按照电子得失的概念来定义。

氧化就是失去电子。**还原**就是获得电子。氧化还原作用就是电子**转移**。

记住英文缩写 OIL RIG! Oxidation Is Loss, Reduction Is Gain。（氧化是失去，还原是获得）

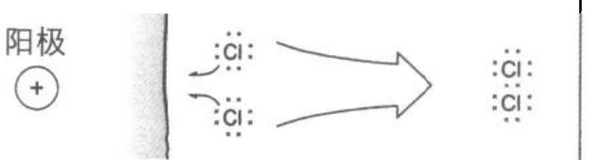
电解

电解反应是氧化还原反应的例子。

阳极上的反应是氧化反应。

在带正电荷的阳极，阴离子失去电子:

例如: $2Cl^- \rightarrow Cl_2+2e^-$ 或 $2O^{2-} \rightarrow O_2+4e^-$

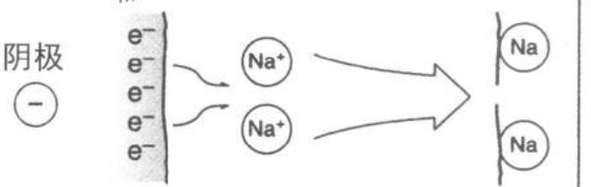


阴极上的反应是还原反应。

在带负电荷的阴极，阳离子获得电子:

例如: $Na^+ + e^- \rightarrow Na$

和 $Al^{3+}+3e^- \rightarrow Al$



置换反应

置换反应也是氧化还原反应。比如:

一种较活泼的金属被氧化，同时，一种较不活泼的金属被还原。

$Fe+Cu^{2+} \rightarrow Fe^{2+}+Cu$

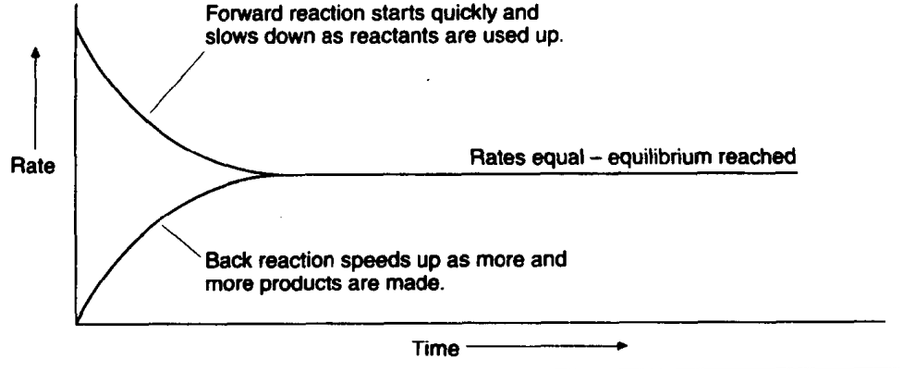
当一种较不活泼的非金属被氧化时，一种较活泼的非金属就被还原。

$Cl_2+2I^- \rightarrow 2Cl^-+I_2$

Reversible reactions

EQUILIBRIUM SYSTEMS

To begin with, reactants react making products. As the reactants get used up, the forward reaction slows down. As more and more product is made, the back reaction speeds up. Eventually the two rates are equal. Reactants are making products as quickly as products are making reactants. The system is said to be in **dynamic equilibrium**. Although reactions are going on, no visible change is seen because the two reactions in opposite directions cancel each other out.



The reaction from left to right is called the **forward reaction**.

In some reactions the products can react themselves, making the original reactants. In other words, the reaction can go both ways. It is **reversible**. This is shown in a written equation using the **equilibrium sign** ⇌.

forward reaction

reactants ⇌ products

back reaction

The substances on the *left* of the equation are called **reactants** and those on the *right* are called **products**, whichever reaction (forward or back) is being referred to.

The reaction from right to left is called the **back reaction**.

CHANGING CONDITIONS IN EQUILIBRIUM SYSTEMS

An equilibrium system does not appear to change from the outside, but inside both forward and back reactions are happening.

When the temperature or pressure changes, or when the amount of one of the reactants or products changes, the two rates change. They change by different amounts, so they no longer cancel each other out. *For a time* one reaction is faster than the other. The system is not at equilibrium, so changes can be detected as reactants are made faster than products, or products are made faster than reactants. Eventually, the system reaches a new equilibrium position, which is different from the first.

Le Chatelier's principle

The way an equilibrium system reacts when the conditions are changed can be predicted using a general rule called le **Chatelier's principle**.

This states that *when a change is applied to an equilibrium system, the system will alter in such a way as to oppose the change.*

Using the Haber process for making ammonia as an example, we can see how this rule works:

The reaction for the Haber process is:
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ + heat
(the reaction is exothermic)

Increasing the pressure

If the pressure is increased, the equilibrium system reacts to reduce the pressure. It does this by moving to the right because there are only 2 molecules on the right of the equation, but four on the left.

MORE MOLES → SQUEEZE → FEWER MOLES

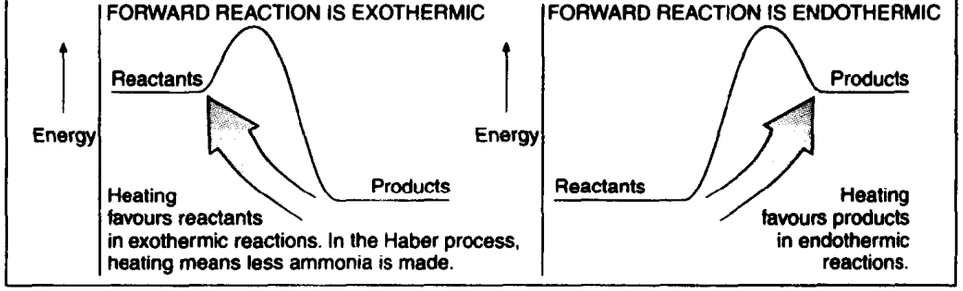
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ + heat

So an increase in pressure increases the yield of ammonia for a given amount of reactants.

Increasing the temperature

If the temperature is increased, the equilibrium system reacts to remove heat. It does this by moving in the endothermic direction. For an exothermic reaction like the Haber process, this means moving to the left. So increasing the temperature of the Haber process decreases the yield of ammonia.

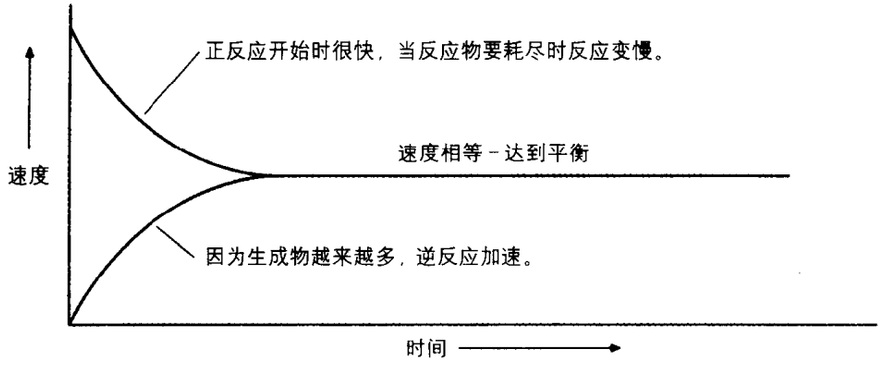
For a system where the forward reaction is endothermic, increasing the temperature increases the yield of product.

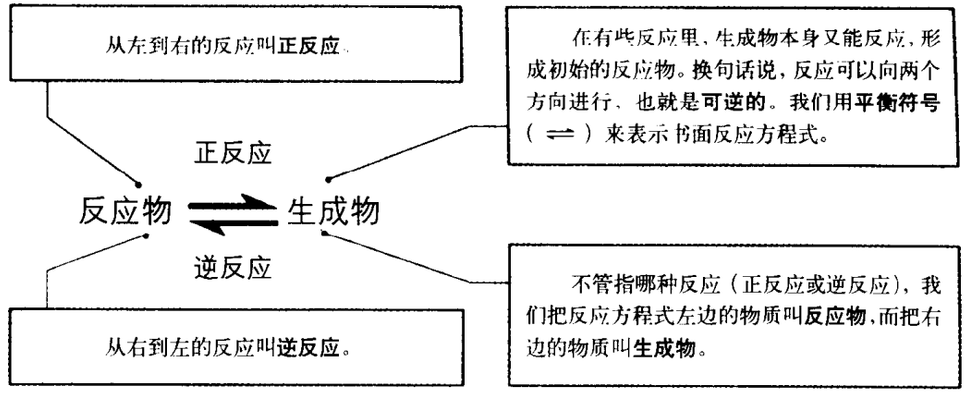


可逆反应

平衡系统

反应开始时，反应物反应形成生成物，当反应物将耗尽时，正反应变慢。由于生成物越来越多，逆反应加速。最后，正逆反应的速度相等，反应物形成生成物跟生成物形成反应物一样快，这一系统叫**做动态平衡**。虽然反应仍在进行，但已看不出有变化，因为两个方向相反的反应作用相互抵消。





改变平衡系统里的反应条件

从外部看，一个平衡系统似乎不发生变化，但从系统内部看，正逆反应会发生变化。

当温度或压力改变时，或当一种反应物的量或一种生成物的量改变时，正逆反应的速度会改变，而且速度改变的大小不一。这样，它们的反应作用不会互相抵消。一种反应比另一种反应快，系统不再平衡。这样通过检测，反应物形成比生成物快或生成物形成比反应物快，可以知道变化发生了。最后，系统达到一种新的跟第一个平衡不同的平衡位置。

勒沙特列原理

当条件改变时，可以用一种通用的规则称作**勒沙特列原理**来预测平衡系统的反应方向。

它表述为：*如果改变影响平衡系统的条件，平衡系统就向能减弱这种变化的方向变化。*

运用哈伯法生产氨就是一个例子，我们可以从中看到这一规则是怎样起作用的。

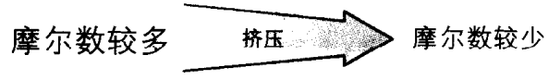
哈伯法的反应是：

$N_2(g)+3H_2 \rightleftharpoons 2NH_3(g)+$ 热

（反应是放热的）

提高压力

如果压力提高，平衡系统向降低压力的方向移动。因为在这个方程式的右边只有2个分子，而左边有4个分子。所以平衡向右边移动，以降低压力。



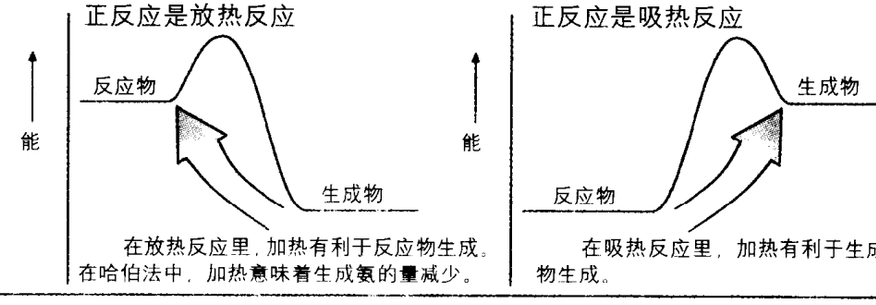
$N_2(g)+3H_2 \rightleftharpoons 2NH_3(g)+$ 热

所以，在反应物的量一定的情况下，提高压力可以增加氨的产量。

提高温度

如果提高温度，平衡系统反应要去掉热量，平衡向吸热方向移动。对于像哈伯法那样的放热反应，这意味着平衡向左移动。所以，提高哈伯法的温度，会减低氨的产量。

对于一个系统，当正反应是吸热反应时，提高温度可以提高生成物的产量。



Measuring rates of reaction

Rates of reaction
The rate of a chemical reaction is the **amount of reactant used up, or product made, in a given time**. Do not use the words 'speed' or 'how fast'.

The rate of a reaction can be measured in one of two general ways.

DISCONTINUOUS METHOD

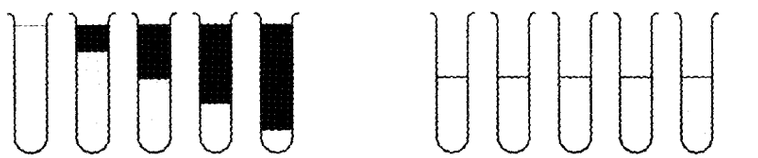
Here the reaction is started and timed until it is finished.

Each experiment produces **one** reading.

No readings are taken during the reaction.

e.g. Reaction between sodium thiosulphate and dilute acid:

$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow S(s) + SO_2(g) + 2NaCl(aq) + H_2O(l)$

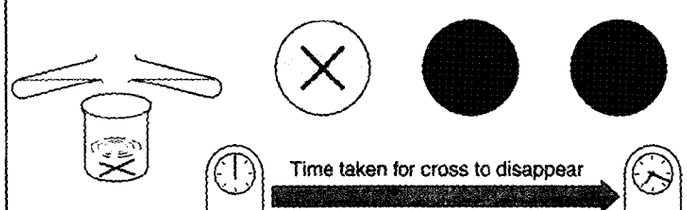


Water	0	5	10	15	20	cm^3
Thiosulphate	25	20	15	10	5	cm^3
Acid	15	15	15	15	15	cm^3

Sodium thiosulphate concentration steadily diluted

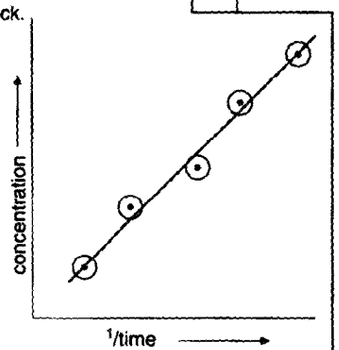
Acid concentration kept constant

Pour pairs of solutions into a beaker over a black cross and start the clock. When you can no longer see the cross, stop the clock.



The rate of the reaction is proportional to $\frac{1}{\text{time taken}}$.

Plot a graph of concentration against $\frac{1}{\text{time}}$.



CONTINUOUS METHOD

Here the reaction is started and readings are taken throughout the experiment.

Each experiment produces **many** readings.

With a chart recorder continuous readings could be taken.

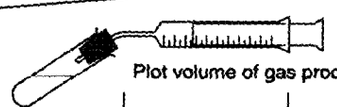
e.g. Reaction between marble chips and dilute hydrochloric acid:

$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

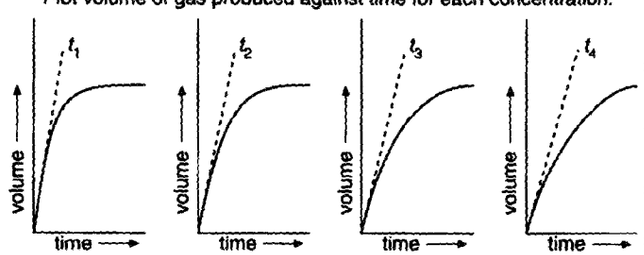
Water	0	10	20	30 cm^3
Acid	10	10	10	10 cm^3

Acid concentration steadily diluted

Large excess of marble is used



Plot volume of gas produced against time for each concentration.



The steeper the slope, the quicker the rate of reaction.

This method can also be used to study the rate of decomposition of hydrogen peroxide. Solid manganese(IV) oxide is used as a catalyst to speed up the decomposition.

$2H_2O_2(l) \xrightarrow{MnO_2} 2H_2O(l) + O_2(g)$

测量反应速度

反应速度

化学反应速度就是在一定时间里，**反应物消耗的量及生成物产生的量**。在英语里不用“speed”或“how fast”来表达。

反应速度可以用两种途径来测得。

不连续的办法

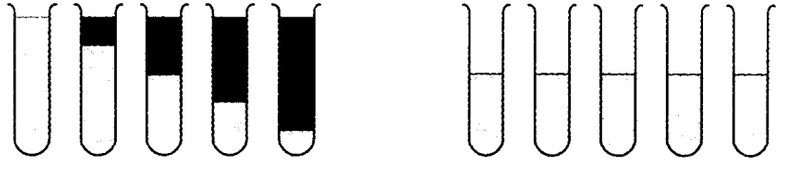
反应开始计时直到反应完成。

每一个实验只有一个读数。

在反应过程中不读数。

比如：硫代硫酸钠跟盐酸反应

$Na_2S_2O_3(aq)+2HCl(aq) \rightarrow S(s)+SO_2(g)+2NaCl(aq)+H_2O(l)$

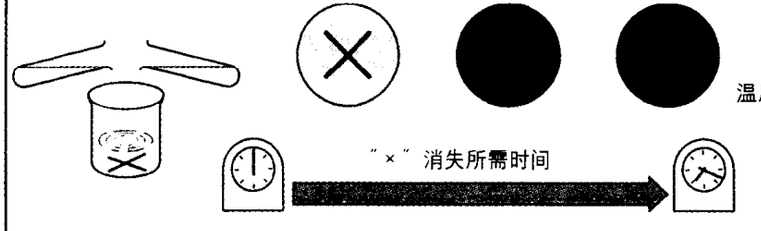


水	0	5	10	15	20	cm^3
硫代硫酸钠	25	20	15	10	5	cm^3
酸	15	15	15	15	15	cm^3

硫代硫酸钠浓度逐步减少

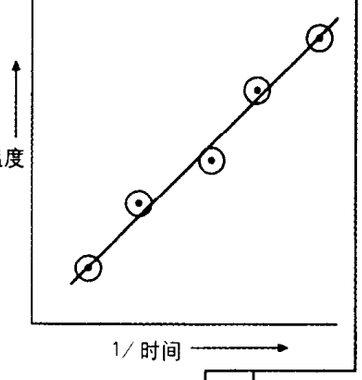
酸的浓度保持不变

把两种溶液倒入烧杯，烧杯底部有一个黑色的“×”，并开始计时，直到看不见“×”时，停止计时。



反应速度跟所用时间成反比。

绘制浓度跟时间倒数的曲线。



连续的办法

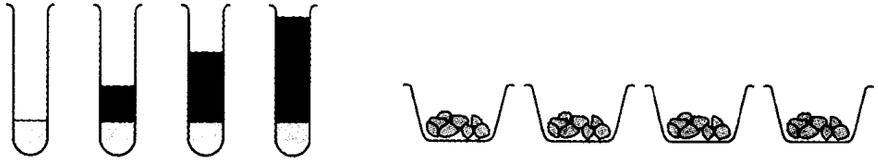
反应开始，整个实验过程中不断地读数。

每一个实验有许多读数。

用一张图表记录不断获得的读数。

比如：石灰石跟稀盐酸的反应

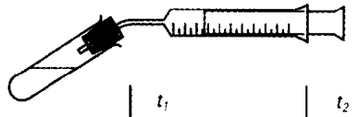
$CaCO_3(s)+2HCl(aq) \rightarrow CaCl_2(aq)+CO_2(g)+H_2O(l)$



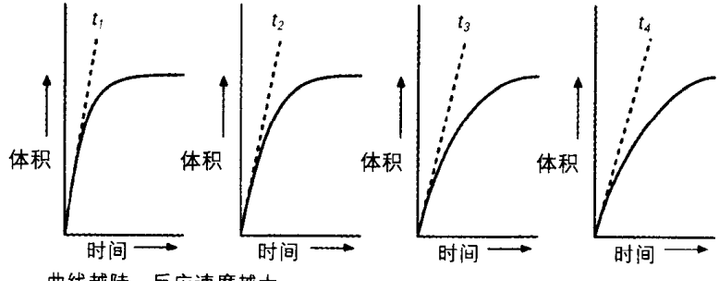
水	0	10	20	30	cm^3
酸	10	10	10	10	cm^3

酸浓度逐步减小

加入过量的石灰石



针对每一个浓度画出产生的气体体积跟所用时间的图表。



曲线越陡，反应速度越大。

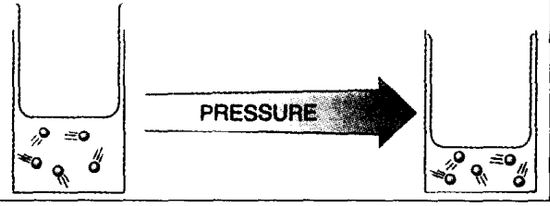
这种方法也可以用来研究过氧化氢的分解。固态二氧化锰用作催化剂加快分解反应。

$2H_2O_2(l) \xrightarrow{MnO_2} 2H_2O(l)+O_2(g)$

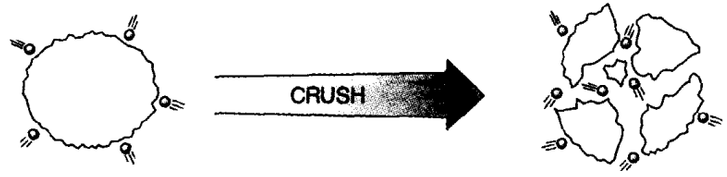
Factors affecting reaction rates

Concentration
Increasing the concentration increases the number of particles.
Increasing the number of particles increases the number of collisions.
Increasing the number of collisions increases the number of successful collisions.
This increases the rate of reaction.

Pressure
Increasing the pressure means that the gas molecules are squashed into a smaller volume.
The same amount of gas in a smaller volume has a greater concentration.
So the argument above applies. There will be more collisions, so there will be more successful collisions, so the rate will increase.

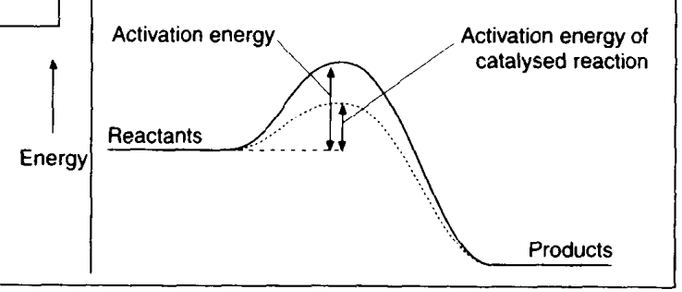


Surface area and particle size
Only the particles on the surface of a solid are exposed to collisions.
Breaking up the solid makes new surfaces which are exposed to collisions.
So there are more collisions with the surface, which increases the reaction rate.



Temperature
Not all collisions between reactants succeed in making products. Only those collisions with enough energy to break bonds in the reactants will lead to a reaction. The energy a collision needs to be successful is called the **activation energy**. Increasing the temperature of the reaction means more particles have the activation energy. This means more collisions are successful, so the rate of reaction increases.

Catalyst
A catalyst allows the reaction to go by a different pathway with a lower activation energy. More particles will have this lower activation energy, and so more collisions will be successful. More successful collisions means a higher rate.
e.g. iron is added as catalyst in the Haber process for making ammonia;
vanadium(V) oxide, V_2O_5, is added as a catalyst in the Contact process for making sulphuric acid; manganese(IV) oxide, MnO_2, catalyses the decomposition of hydrogen peroxide in the lab.



FACTORS AFFECTING RATE

The rate of a chemical reaction is affected by:

- **the concentration of the reactants**: increasing the concentration increases the rate
- **the pressure in gas state reactions**: increasing the pressure increases the rate
- **the surface area of solid reactions**: increasing the surface area increases the rate
- **the temperature of the reacting system**: increasing the temperature increases the rate enormously. For a typical chemical reaction, the rate *doubles for every 10°C rise in temperature.*
- **the addition of a catalyst**: adding a suitable catalyst increases the rate. A catalyst is a substance which *speeds up the rate of a reaction without itself being used up during the reaction.*

COLLISION THEORY

These facts can be explained using the **collision theory** which states:

For substances to react, their particles

- must collide
- with enough energy to break existing bonds.

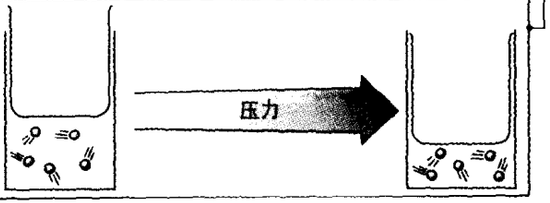
影响反应速度的因素

浓度

浓度增加，反应物的粒子数增加，粒子数增加则粒子之间的碰撞次数增加，碰撞次数增加，则有效碰撞次数也增加。这样反应速度就加大。

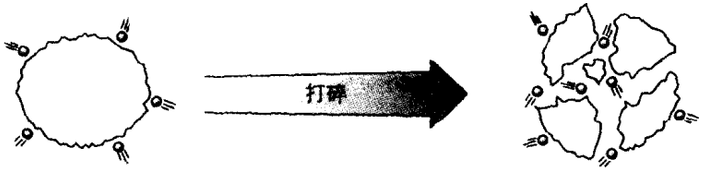
压力

压力增加表示气体分子被挤压进一个更小的空间。在一个较小的空间，同样数量的气体浓度就大了。这样，就适用于上述浓度因素，碰撞更多，有效碰撞也更多，反应速度加大。



表面积和粒子大小

一种固体只有它的表面的粒子才能引起碰撞。打碎固体，形成新的表面以引发碰撞。这样，随着表面增加，就有更多的碰撞，反应速度就加大。



温度

并不是反应物之间所有的碰撞都能导之生成产物，只有那些有足够能量以打破反应物内的化学键的碰撞才能引发反应。能引起有效碰撞的能量叫活化能。反应温度上升，表示有更多的粒子具有活化能，表示有更多的有效碰撞，这样反应速度就提高。

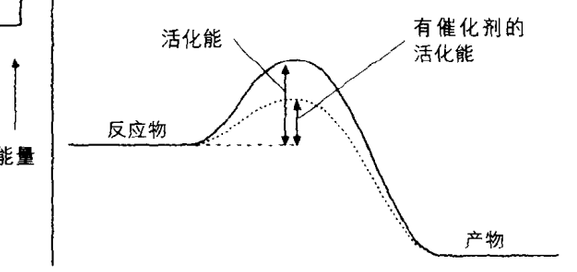
催化剂

催化剂能改变反应的途径，这种途径只要较低的活化能。由于更多的粒子具备这种较低的活化能，这样，更多的碰撞就会是有效的。更多的有效碰撞表示更高的反应速度。

比如：铁作为一种催化剂加到哈伯法中以生产氨。

五氧化二钒 V_2O_5 作为一种催化剂，加到接触法中以生产硫酸。

二氧化锰 MnO_2 能催化实验里过氧化氢的分解。



影响反应速度的因素

化学反应的速度受以下因素的影响：

- **反应物的浓度**：增加浓度能提高速度
- **气态反应的压力**：增加压力能提高速度
- **固体反应物的表面积**：增加表面积能提高反应速度
- **反应系统的温度**：升高温度能大大提高反应速度

  对一个典型的化学反应讲，每升高 10℃，反应速度会提高 1 倍。
- **加入催化剂**：加入合适的催化剂能提高反应速度，催化剂是一种物质，它能提高反应速度而自身在反应中没有消耗。

碰撞理论

这些事实可以用**碰撞理论**来解释：

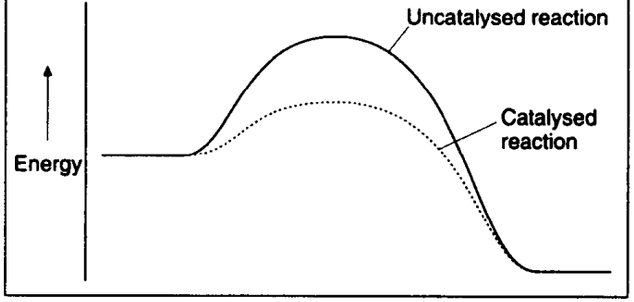
对于参加反应的物质，它们的粒子

- 必须碰撞
- 有足够的能量打破存在的化学键

Reactions involving enzymes

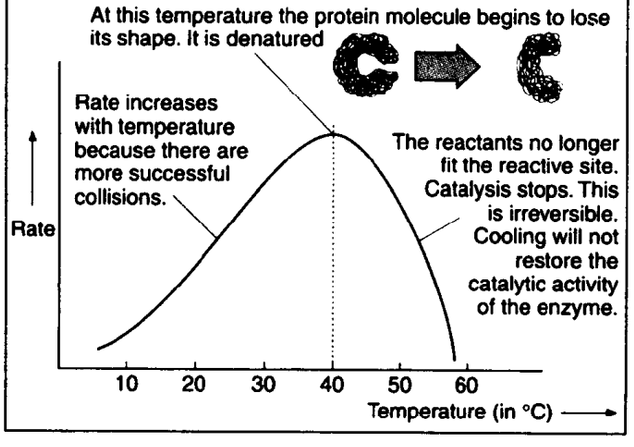
Enzyme structure
Enzymes are covalent macromolecules made of amino acids bonded together making a protein. The amino acid chains are folded and twisted forming globular proteins with specific reactive sites.

Enzyme catalysis
Enzymes catalyse specific reactions in living cells by providing a reaction pathway with a lower activation energy.

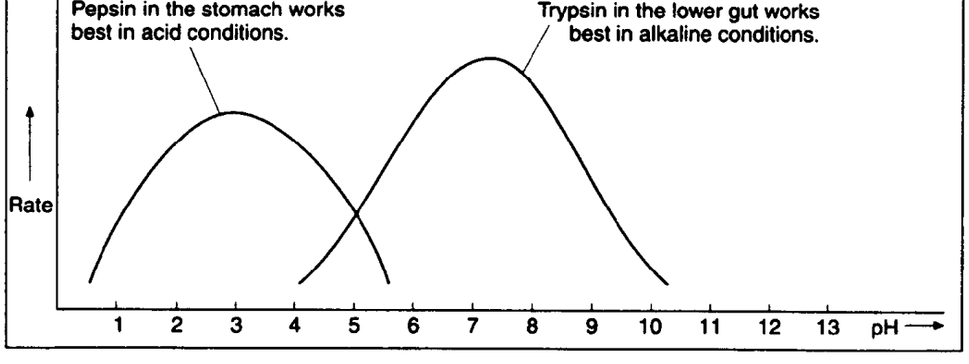


ENZYMES
- are all proteins found in living cells
- catalyse reactions in cells
- can each catalyse only one specific reaction
- act within a narrow pH range
- act within a narrow temperature range

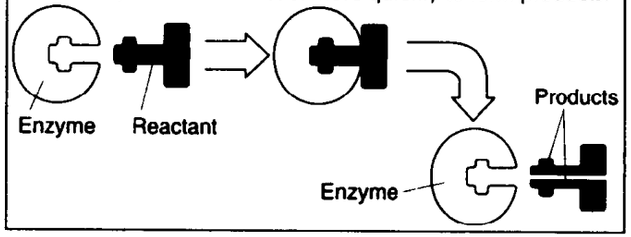
Temperature dependence



pH dependence
The shape of an enzyme depends on the hydrogen bonds between different parts of the amino acid chain, and hydrogen bonds are affected by pH. So each enzyme works best at a particular pH.



Enzyme lock and key mechanism
Reactant molecules fit into the reactive site of an enzyme like a key into a lock. Each reactive site only fits a particular reactant, so each enzyme catalyses only one reaction. Once in the site, the reactants react more quickly to form products.



USES OF ENZYMES

Digestion
Digestive enzymes convert insoluble substances in food into soluble substances which the body can absorb. They do this by breaking certain bonds one after another. Each bond is broken by a particular enzyme, and each enzyme needs particular conditions. This is why the pH changes through the gut.

Fermentation and baking
Fermentation is the anaerobic decomposition of simple carbohydrates into alcohol and carbon dioxide:

$$C_6H_{12}O_6 \rightarrow 2CO_2 + 2CH_3CH_2OH$$

This reaction is used in the brewing and wine making industries to make alcoholic drinks. In the baking industry the carbon dioxide produced makes the dough rise.

Yoghurt
Milk at 40°C is inoculated with bacteria. Enzymes in the bacteria convert the lactose in milk to lactic acid, which makes the milk thicken and curdle.

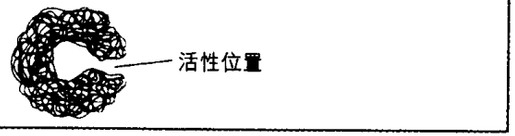
Detergents
Enzymes are added to detergents to help digest protein stains. Dirty washing is soaked in tepid water with a pH between 4 and 8, before being washed normally in hot water.

The enzymes used in detergents can sometimes cause allergic reactions such as asthma.

有酶参与的反应

酶的结构

酶是由氨基酸键合形成一种蛋白质而组成的共价高分子。氨基酸链交叠，扭转形成球状有特殊活性位置的蛋白质。

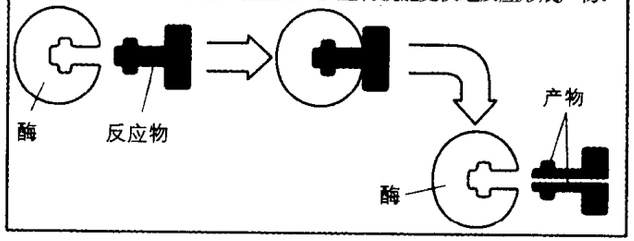


酶

- 都是蛋白质，存在于于生命细胞里
- 在细胞里催化反应
- 每一种酶只能催化一种特别的反应
- 仅在很窄的pH值范围内起反应
- 仅在很小的温度范围内起反应

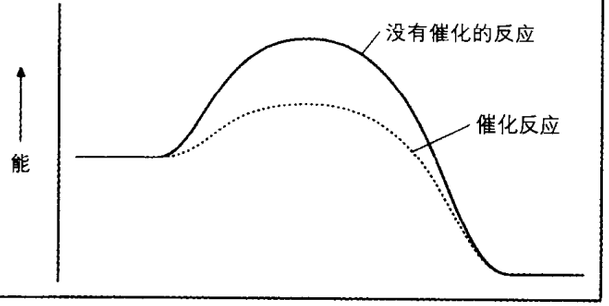
酶的“开关”机制

反应物分子对应一种酶的活性位置，就像一把钥匙开一把锁一样，每个活性位置只适应一种特殊的反应物。因此，每一种酶只能催化一种反应，一旦在这个位置上，反应物就能更快地反应形成产物。



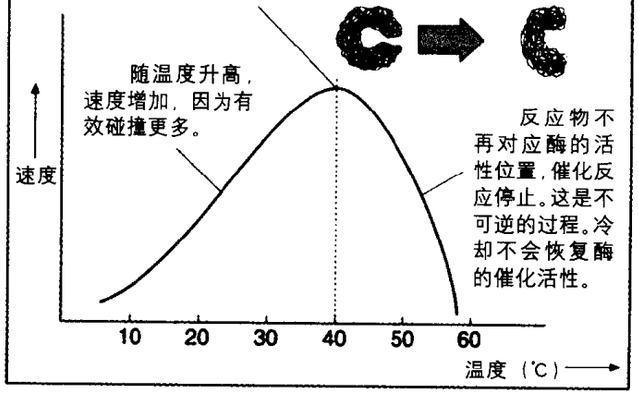
酶的催化

酶在生命细胞里以较低的活化能提供一种反应的途径来催化特殊的反应。



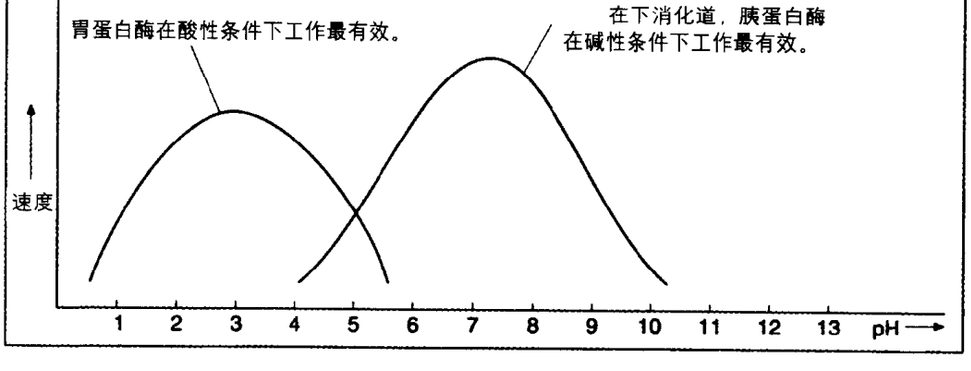
温度要素

在这一温度下，蛋白质分子开始变形、变性。



pH要素

酶的形状取决于氨基酸链不同部分之间的氢键，而氢键受pH值的影响。因此，每一种酶只有在特定的pH值时，作用最大。



酶的应用

消化

消化酶把食物里的不溶性物质变成可溶性物质，以便人体吸收。它们是通过打破一个又一个键来完成的。每种键由一种特殊的酶来打破，而每一种酶又需要特殊的条件，这就是为什么pH值在肠里会变化。

发酵与烘烤

发酵就是厌氧微生物把简单的碳水化合物分解成乙醇和二氧化碳。

$$C_6H_{12}O_6 \rightarrow 2CO_2+2CH_3CH_2OH$$

这一反应在酿酒业上用来制取含酒精的饮料。在面包烘烤业中，二氧化碳用来使面团发松。

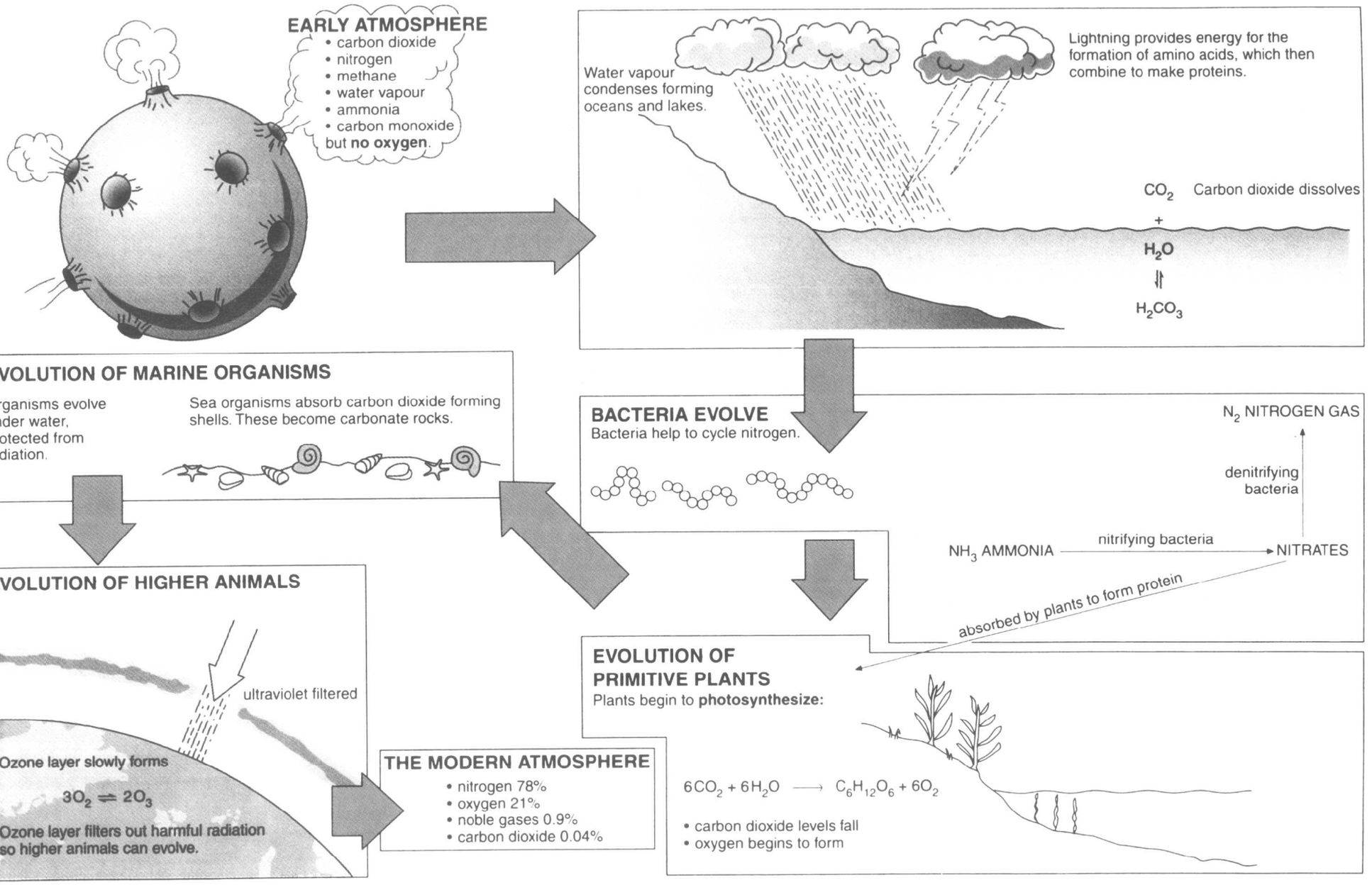
酸奶

在40℃时向牛奶中加入菌种，细菌中的酶会把牛奶中的乳糖变成乳酸，它使牛奶变稠、凝乳。

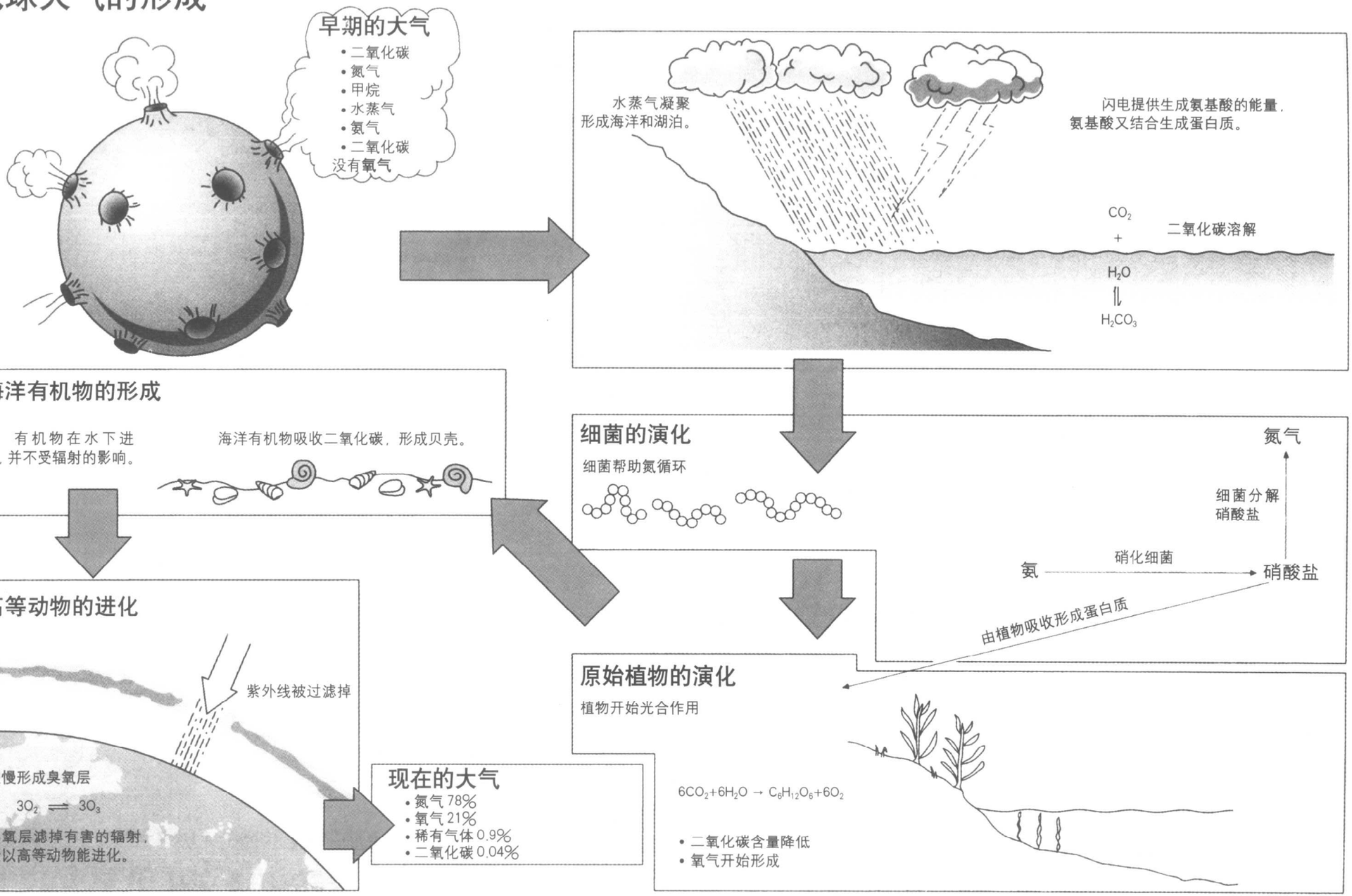
清洁剂

清洁剂中加入酶有助于化解蛋白质类的污垢，在热水中开始常规的清洗前，先把脏东西浸泡在pH值4～8范围里的微热的水中。有时候清洁剂里的酶会引起像哮喘这类过敏性反应。

Formation of Earth's atmosphere

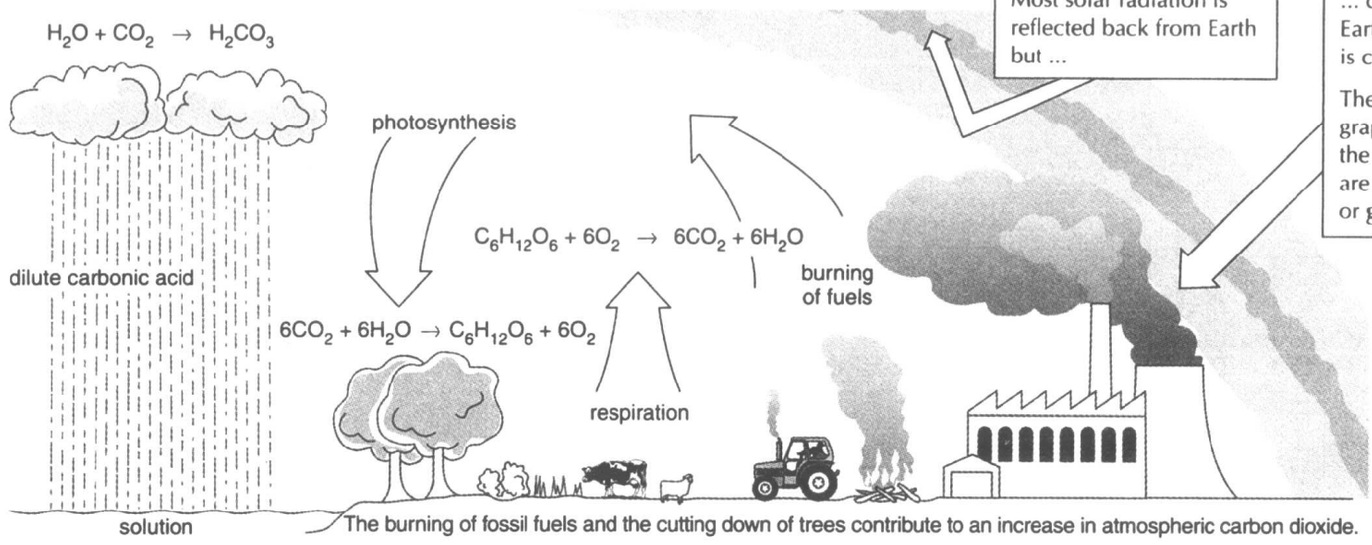


地球大气的形成


早期的大气
• 二氧化碳
• 氮气
• 甲烷
• 水蒸气
• 氨气
• 二氧化碳
没有氧气
水蒸气凝聚
形成海洋和湖泊。
闪电提供生成氨基酸的能量，
氨基酸又结合生成蛋白质。
CO_2
+
H_2O
H_2CO_3
二氧化碳溶解
海洋有机物的形成
有机物在水下进化，并不受辐射的影响。
海洋有机物吸收二氧化碳，形成贝壳。
细菌的演化
细菌帮助氮循环
氮气
细菌分解
硝酸盐
氨
硝化细菌
硝酸盐
由植物吸收形成蛋白质
高等动物的进化
紫外线被过滤掉
缓慢形成臭氧层
$3O_2 \rightleftharpoons 3O_3$
臭氧层滤掉有害的辐射，
所以高等动物能进化。
现在的大气
• 氮气 78%
• 氧气 21%
• 稀有气体 0.9%
• 二氧化碳 0.04%
原始植物的演化
植物开始光合作用
$6CO_2+6H_2O \rightarrow C_6H_{12}O_6+6O_2$
• 二氧化碳含量降低
• 氧气开始形成

Changes in the atmosphere

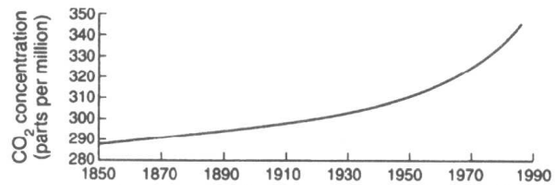
CARBON DIOXIDE AND THE GREENHOUSE EFFECT



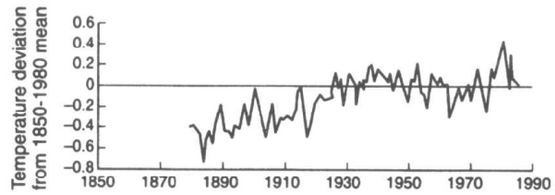
Most solar radiation is reflected back from Earth but ...

... carbon dioxide absorbs infrared radiation. This gives Earth its warm atmosphere, which makes life possible. This is called the greenhouse effect.

The increase in carbon dioxide in the atmosphere (top graph) has been accompanied by a rise in temperature of the atmosphere (bottom graph). Many scientists think these are linked. They call this the **enhanced greenhouse effect** or **global warming**.

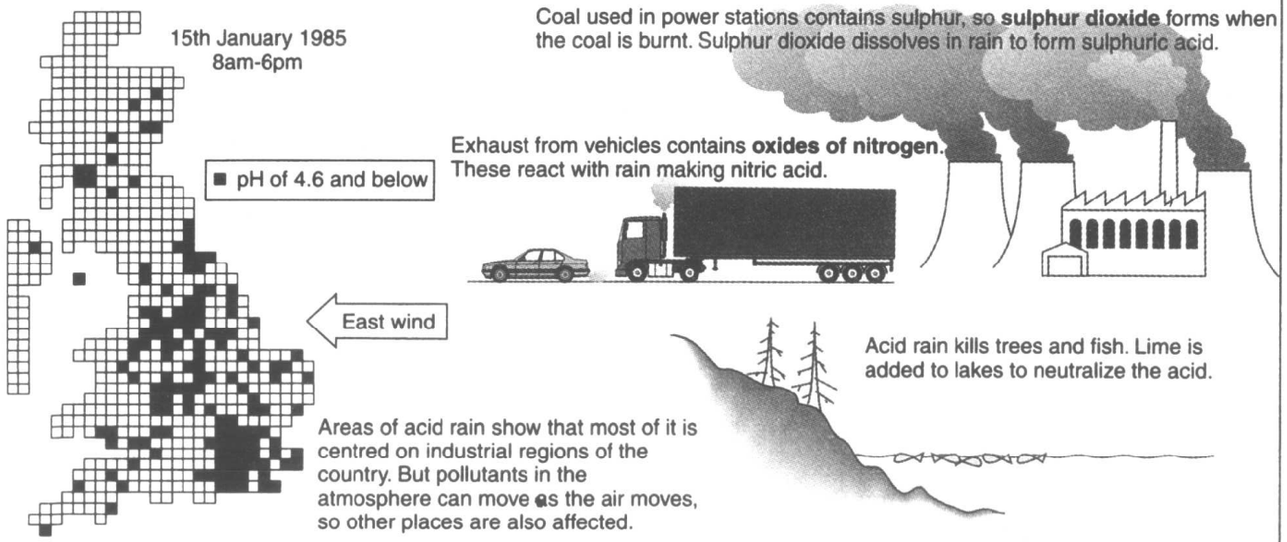


The increase in carbon dioxide since 1850



The rise in temperature since 1850

ACID RAIN



OZONE LAYER

The layer of ozone gas high in the atmosphere absorbs damaging high-energy radiation. The amount of ozone in the ozone layer is decreasing. This is caused by a number of gases, but especially chlorofluorocarbons (CFCs), which react with ozone. CFCs have been used in aerosols as propellants and in fridges as coolants. Thinning of the ozone layer leads to more skin cancer, cataracts, and damage to plants.

CFCs are being replaced with **hydrofluoroalkanes** (HFAs) which are more strongly bonded and do not react with ozone.

大气的变化

二氧化碳的温室效应

$H_2O+CO_2 \rightarrow H_2CO_3$

稀碳酸

溶液

光合作用

$6CO_2+6H_2O \rightarrow C_2H_{12}O_6+6O_2$

$C_2H_{12}O_6+6O_2 \rightarrow 6CO_2+6H_2O$

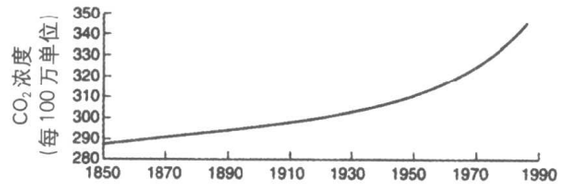
燃料燃烧

呼吸作用

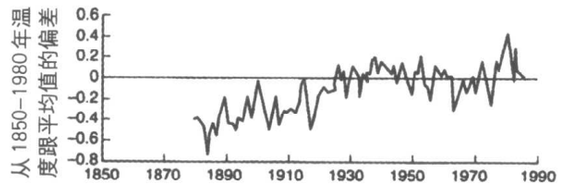
大多数太阳能辐射会被地球反射，但……

……二氧化碳会吸收远红外辐射，使地球有温暖的大气圈，产生生命，这就叫温室效应。

大气中二氧化碳的增加（见左上图）总是伴随着大气温度的增加（见左下图）。许多科学家认为，它们 是互相关联的。他们把这种现象叫做强温室效应或全球变暖。



自1850年以来二氧化碳增加



自1850年以来温度上升

燃烧化石燃料，砍伐树木会增加大气中二氧化碳的含量。

酸雨

1985年1月15日
早上8时－晚上6时

■ pH值4.6及以下

东风

酸雨区域显示它们大多数集中在国家的工业区。但是大多数的污染物会随着空气移动，所以其他地区也会受影响。

发电厂烧的煤里有硫，所以当煤燃烧时会形成**二氧化硫**。二氧化硫溶于雨水生成硫酸雨。

汽车的排放物里有**二氧化氮**，跟雨水反应生成硝酸。

酸雨杀死树木和鱼，向湖泊加入石灰来中和酸。

臭氧层

在大气高层里的臭氧层吸收有害的高能量的辐射。臭氧层里的臭氧在减少，它是由于一些气体，特别是跟臭氧发生反应的氯氟化碳（CFCs）造成的。

CFCs在气雾喷罐里用作压缩气体，在冰箱里用作冷凝剂。臭氧层变薄导致皮肤癌、白内障发病上升，并损伤植物。

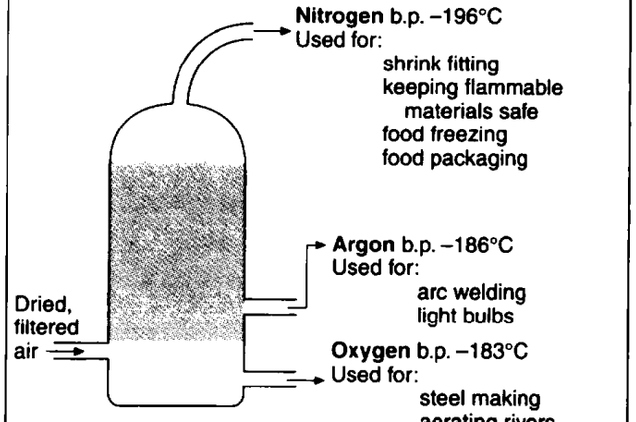
CFCs正由**氢氟烃**（HFAs）取代，后者的化学键更强，不会跟臭氧反应。

Products from air

FRACTIONAL DISTILLATION OF AIR

Air is a mixture so is separated by a physical process.

Because b.p.s are close together, **fractional distillation** is used.



FIXATION OF NITROGEN AND THE HABER PROCESS

- Plants are made of cells – cells have nuclei – nuclei contain proteins – proteins are made from amino acids – amino acids contain nitrogen.
- **Fixation** is the conversion of unreactive atmospheric nitrogen into reactive compounds that plants can absorb.

SYNTHETIC FIXATION – THE HABER PROCESS

Nitrogen is fixed synthetically by combining it with hydrogen to make ammonia, NH_3.

Raw materials

- water
- natural gas – source of hydrogen
- air – source of nitrogen

Reactions

$$CH_4 + H_2O \rightarrow CO + 3H_2$$

$$2CO + O_2 \rightarrow 2CO_2$$

$$N_2 \rightarrow N_2$$

(air)

NATURAL FIXATION

- thunderstorms

- bacterial nodules on roots of leguminous plants

Increasing demand for crops from a growing world population means these natural processes are no longer enough. **Fertilizers** are used to return nitrogen and other elements to the soil. The elements in fertilizers which plants need are **nitrogen**, **phosphorus**, and **potassium** (N,P,K).

HABER PROCESS

$3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g)$ + heat

Conditions

- Temperature: 300–500°C
- Pressure: 200–1000 atmospheres
- Catalyst: lumps of iron metal

Yield

About 15% conversion. Unreacted gases are recycled.

AMMONIA IS OXIDIZED TO NITRIC ACID

$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$

$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$

$4NO_2(g) + O_2(g) + 2H_2O(l) \rightarrow 4HNO_3(l)$

AMMONIA IS NEUTRALIZED

Some ammonia is used directly as fertilizer, but most fertilizers are ammonium salts.

$NH_3(aq) + HNO_3(aq) \rightarrow NH_4NO_3(s)$

$2NH_3(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(s)$

LEACHING OF FERTILIZERS

Fertilizers have to be soluble to be absorbed by plants.

Rain falling on fertilized ground dissolves the fertilizer and washes it from the soil into rivers and lakes. This is called **leaching**.

The leaching of fertilizers has two bad effects:

1. **Nitrates get into drinking water**. This is bad for health. A condition in young babies called blue baby syndrome has been linked to nitrate levels in drinking water.

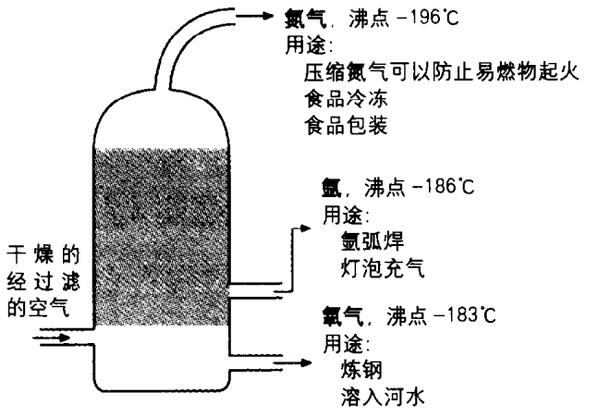
2. The leached fertilizer causes excessive growth of algae and other water plants. Bacteria use up all the oxygen in the rivers or lakes as they digest plant matter, and the river or lake water becomes black and foul smelling. This is called **eutrophication**.

从空气中获得产品

空气的分馏

空气是一种混合物，可以用物理方法来分离。

由于空气的各组分沸点很接近，所以采用**分馏**的办法。



固氮和哈伯法

- 植物由细胞组成，细胞有细胞核，细胞核含有蛋白质，蛋白质由氨基酸组成，氨基酸里有氮。
- 固氮就是把大气里不活泼的氮气转化成活泼的化合物，便于植物吸收。

人工固氮——哈伯法

氮气跟氢气结合生成氨，这是人工固氮。

原料

- 水
- 天然气——氢气的来源
- 空气——氮气的来源

反应

$$CH_4 + H_2O \rightarrow CO + 3H_2$$

$$2CO + O_2 \xrightarrow{\text{空气}} 2CO_2 + N_2$$

天然固氮

- 打雷

- 豆科植物根部的根瘤菌

随着世界人口的增长，对粮食的需求不断增加，这意味着天然固氮量远远不足，就需向土壤施肥以补充氮和其他元素。肥料里有植物需要的元素，**氮（N）磷（P）和钾（K）**。

哈伯法

$3H_2(g)+N_2(g) \quad 2NH_3(g)+$ 热量

反应条件

- 温度：300 − 500℃
- 压力：200 − 1000 大气压
- 催化剂：金属铁块

产率

约 15% 的转化率。没有反应的气体被循环使用。

氨氧化生成硝酸

$4NH_3(g)+5O_2(g) \rightleftharpoons 4NO(g)+6H_2O(g)$

$2NO(g)+O_2(g) \rightleftharpoons 2N_2O(g)$

$4NO_2(g)+O_2(g)+2H_2O(l) \rightleftharpoons 4HNO_3(l)$

氨被中和

有些氨直接用作肥料，但大多数肥料是铵盐。

$NH_3(aq)+HNO_3(aq) \rightarrow NH_4NO_3(s)$

$2NH_3(aq)+H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(s)$

化肥的沥滤

肥料必需是能溶于水的，植物才能吸收。

雨水降落在施过肥的土壤里，肥料溶解，被从土壤里冲走，流入河流、湖泊，这叫**肥料的沥滤**。

肥料的沥滤有两个负面作用：

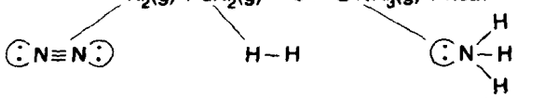
1. **硝酸盐溶入饮用水里**。这对健康有害。在一些婴儿中患有一种叫青紫婴儿综合症的就是跟饮用水的硝酸盐含量有关。

2. 沥滤的肥料会引起水藻和其他水生植物的过度生长。细菌在消化植物时，把河流、湖泊里的氧消耗殆尽，河水和湖水变黑、变臭，这就叫水体的**富营养化过程**。

Choosing conditions for the Haber process

REACTION

$N_2(g) + 3H_2(g) \rightleftharpoons 2\,NH_3(g) + heat$



very strongly bonded 944 kJ mol^{-1}

quite a strong bond 436 kJ mol^{-1}

weaker bonds than in the reactants 388 kJ mol^{-1}

THE PROBLEM

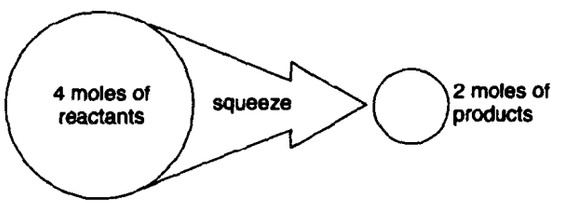
The reactant molecules (N_2 and H_2) are very strongly bonded. Only collisions with a huge amount of energy will be successful, because the activation energy is very high. This means that the rate of the forward reaction making ammonia will be very slow unless the temperature is high. But if the temperature is high, the relatively weak bonds in ammonia will break and the back reaction will speed up. So a high temperature is needed to supply the activation energy, but a high temperature makes the product decompose more quickly.

LE CHATELIER

Le Chatelier's principle predicts that the best yield of ammonia will be produced under high pressure and low temperature.

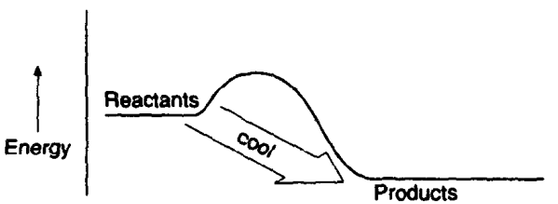
Pressure

There are more moles of reactants than products, so high pressure favours products.



Temperature

The reaction is exothermic (it produces heat), so cooling it will favour the forward reaction.

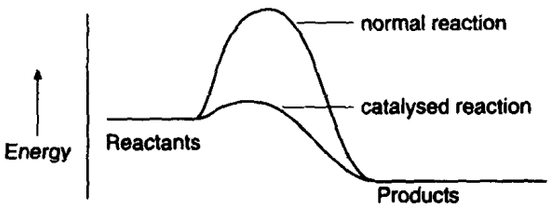


SOLVING THE PROBLEM

The actual conditions used in industry

1. Catalyst

Adding an iron catalyst lowers the activation energy, so a lower temperature can be used.

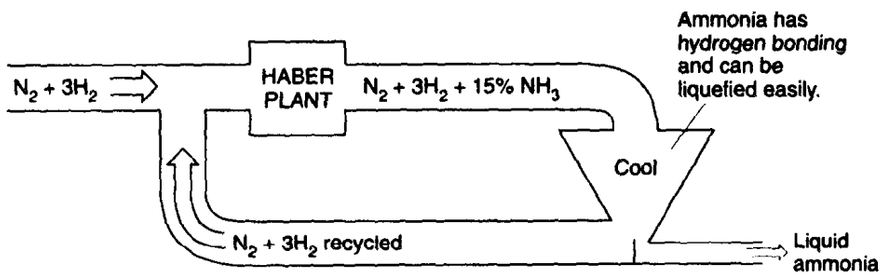


2. Pressure

Between 200 and 1000 atmospheres pressure are used. The higher the pressure the greater the yield but the costlier the plant. *Most operate at around 500 atmospheres.*

3. Temperature

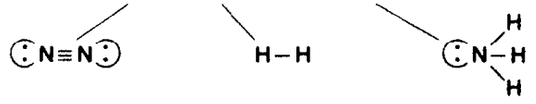
A temperature between 300 and 500°C is used. This reduces the yield to about 15%, but increases the rate. The unreacted nitrogen and hydrogen *gases are recycled.*



选择哈伯法的反应条件

反应

$N_2(g)+3H_2(g) \rightleftharpoons 2NH_3(g)+$加热



很强的键
944 千焦 / 摩尔

较强的键
436 千焦 / 摩尔

比反应物弱的键
388 千焦 / 摩尔

问题

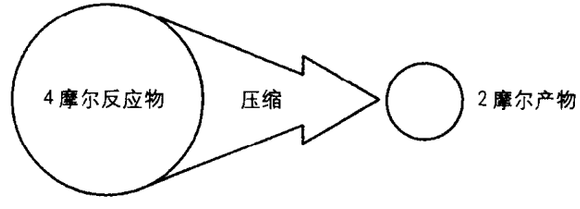
反应物分子里（N_2 和 H_2）有很强的键，只有用巨大的能量使它们碰撞，才能成功地使键破裂，因为活化能很高。这意味着生成氨的正反应速度很低，除非温度很高。但是如果升高温度，氨里面相对较弱的键就会破裂，逆反应要加快。因此，需要高温来供给活化能，但高温又使产物很快分解。

勒沙特列原理

从勒沙特列原理可以推测在高压和低温条件下，氨产量最高。

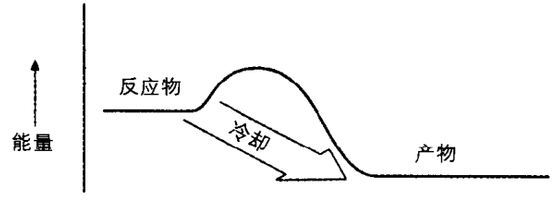
压力

反应物的摩尔数要比产物的多，所以高压有利于生成物。



温度

反应是放热反应（反应产生热量），所以降低温度有利于正反应。

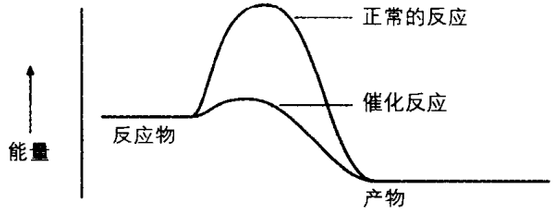


问题的解决

在工业上实际的生产条件

1. 催化剂

加入一种铁催化剂降低活化能，这样只需要较低的温度。

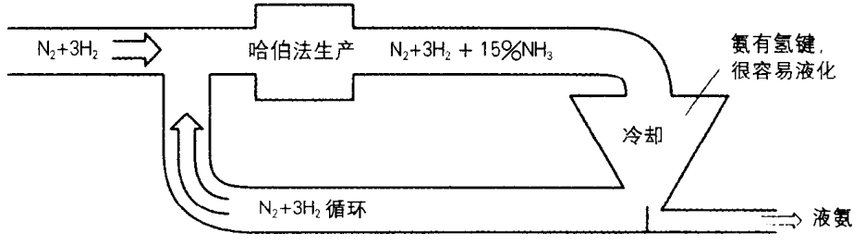


2. 压力

生产时压力在 200 ~ 1000 大气压之间，压力越高，产量越大。但工厂生产成本高。大多数生产压力在 500 大气压左右。

3. 温度

生产时温度在 300℃ ~ 500℃ 之间，这会减少 15% 的产量，但提高了反应速度。没有反应的氮气和氢气不断循环。



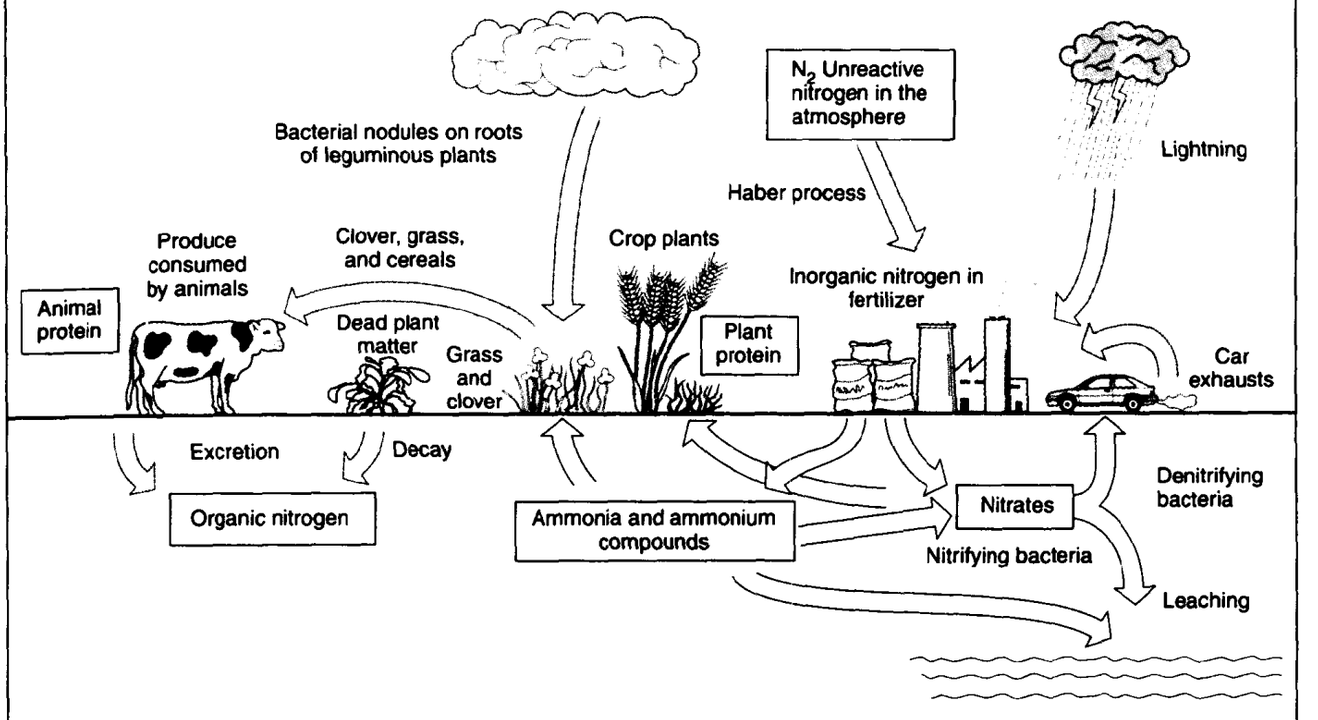
Natural cycles

Natural cycles are very important because:

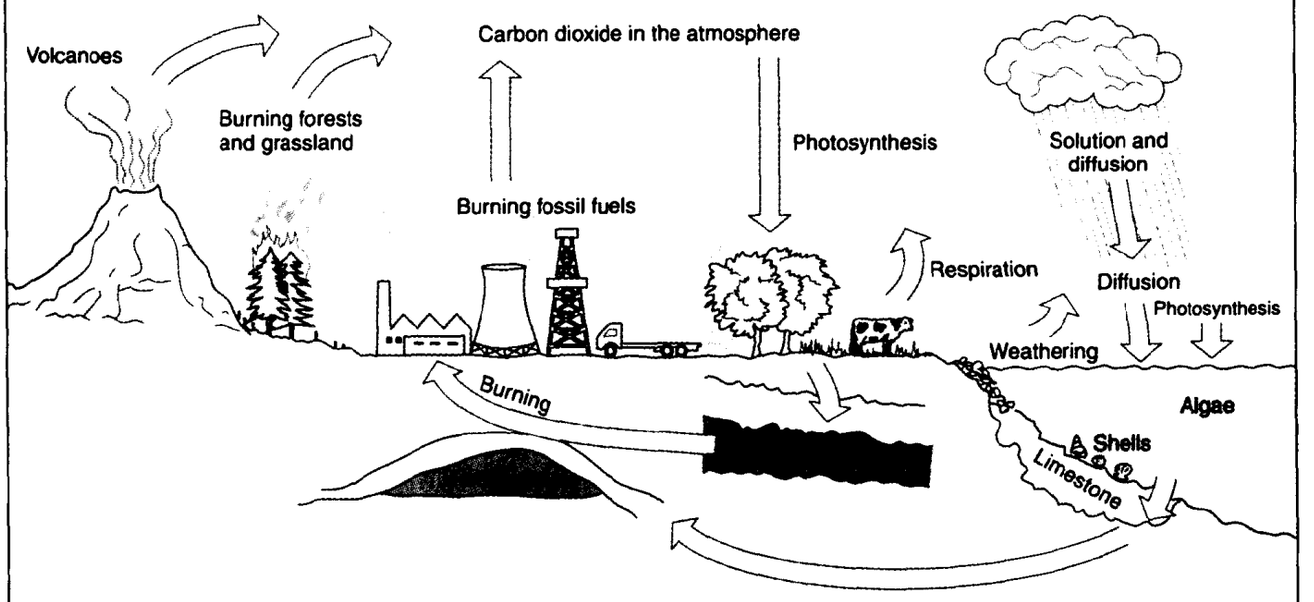
1. They maintain various elements so that they can be used again and again.
2. They maintain a balance or equilibrium in different parts of the cycle by replacing an element as it is used up.

When these cycles are disturbed by human activities, environmental problems build up. Either a resource runs out, or some substance builds up in concentration and causes pollution.

NITROGEN CYCLE



CARBON CYCLE



The burning of huge quantities of wood and fossil fuels increases the amount of carbon dioxide going **into** the atmosphere. The burning of grassland and cutting down of forests decreases the amount of carbon dioxide taken **out** of the atmosphere. So the cycle is disturbed and is no longer in balance or equilibrium. The result is **global warming** (the enhanced greenhouse effect), see p. 38.

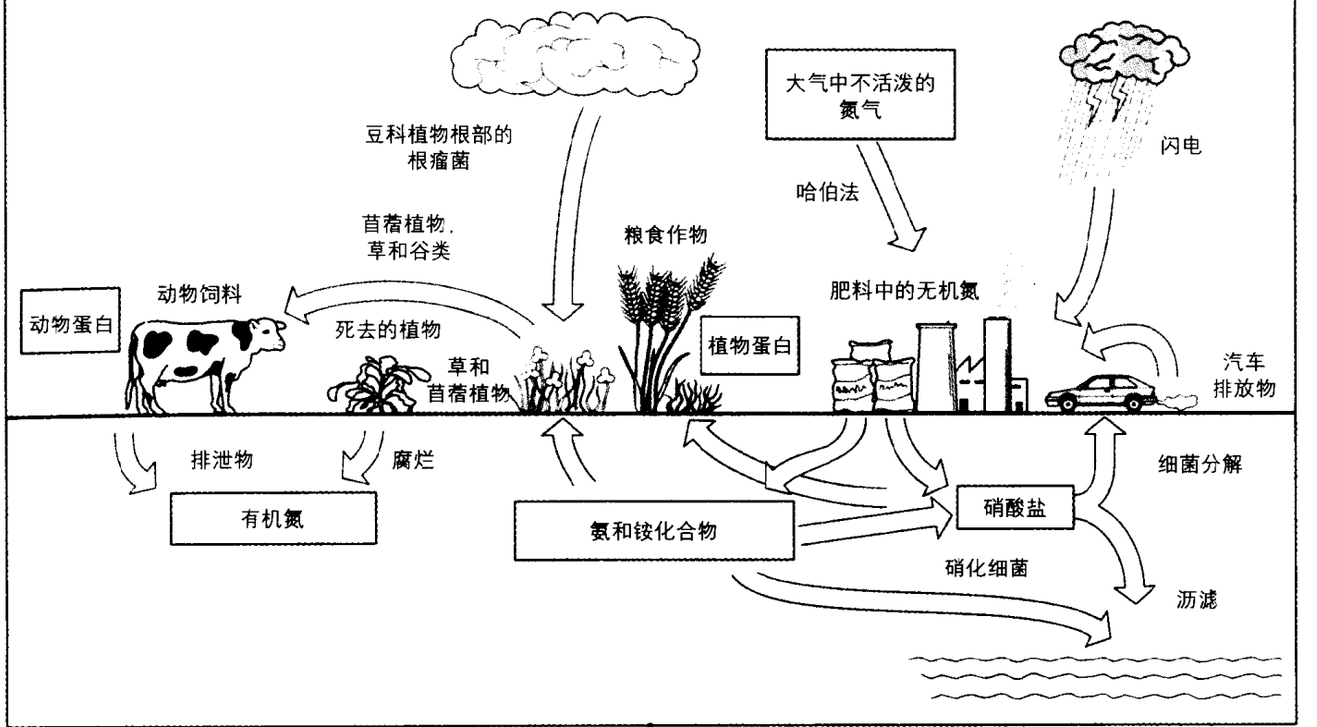
自然界的循环

自然界的循环非常重要。因为：

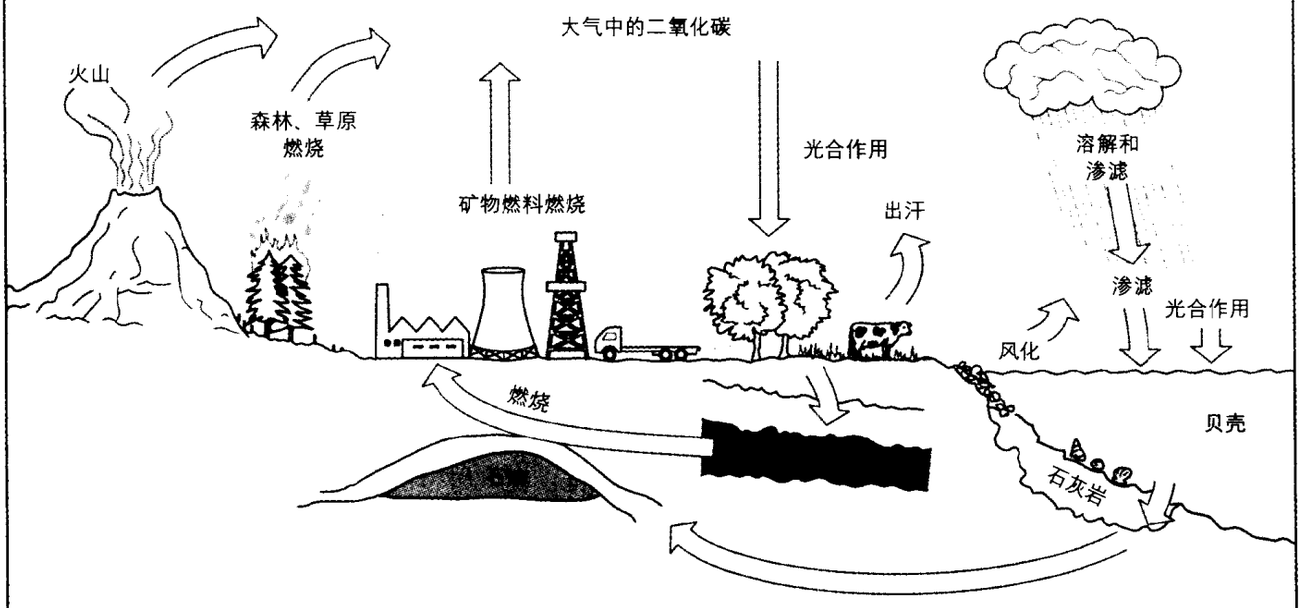
1. 它们能保持各种元素（含量稳定）能被反复使用。
2. 当一种元素耗尽时，通过置换的办法来保持循环里各个环节的平衡。

当这些循环由于人类的活动而被破坏时，不论是资源耗尽，还是某些物质高度集结浓缩而引起环境污染，环境问题就被提出来了。

氮循环



碳循环



燃烧大量的木材和化石燃料会**增加**大气中的二氧化碳的量。燃烧草地和砍伐森林，会减少从大气中**吸收**二氧化碳的量。这样循环被破坏，平衡也不复存在。结果**地球变暖**（温室效应增强），见 34 页。

The rock cycle and different kinds of rocks

Minerals are naturally occurring metal compounds.

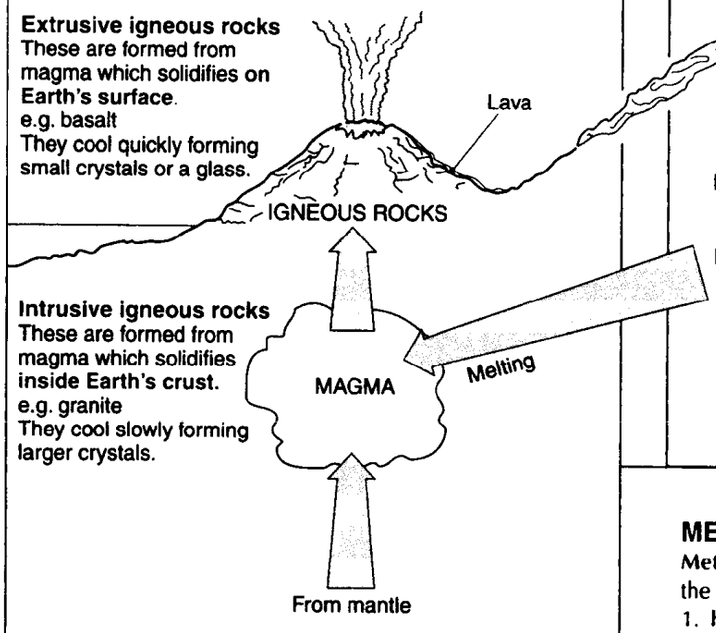
Ores are rocks from which metals can be extracted in economic quantities. Ores contain minerals or (sometimes) metals.

Iron ore contains the mineral **haematite**. **Aluminium ore** contains the mineral **bauxite**. **Gold ore** contains **gold metal**.

IGNEOUS ROCKS

Extrusive igneous rocks
These are formed from magma which solidifies on Earth's surface.
e.g. basalt
They cool quickly forming small crystals or a glass.

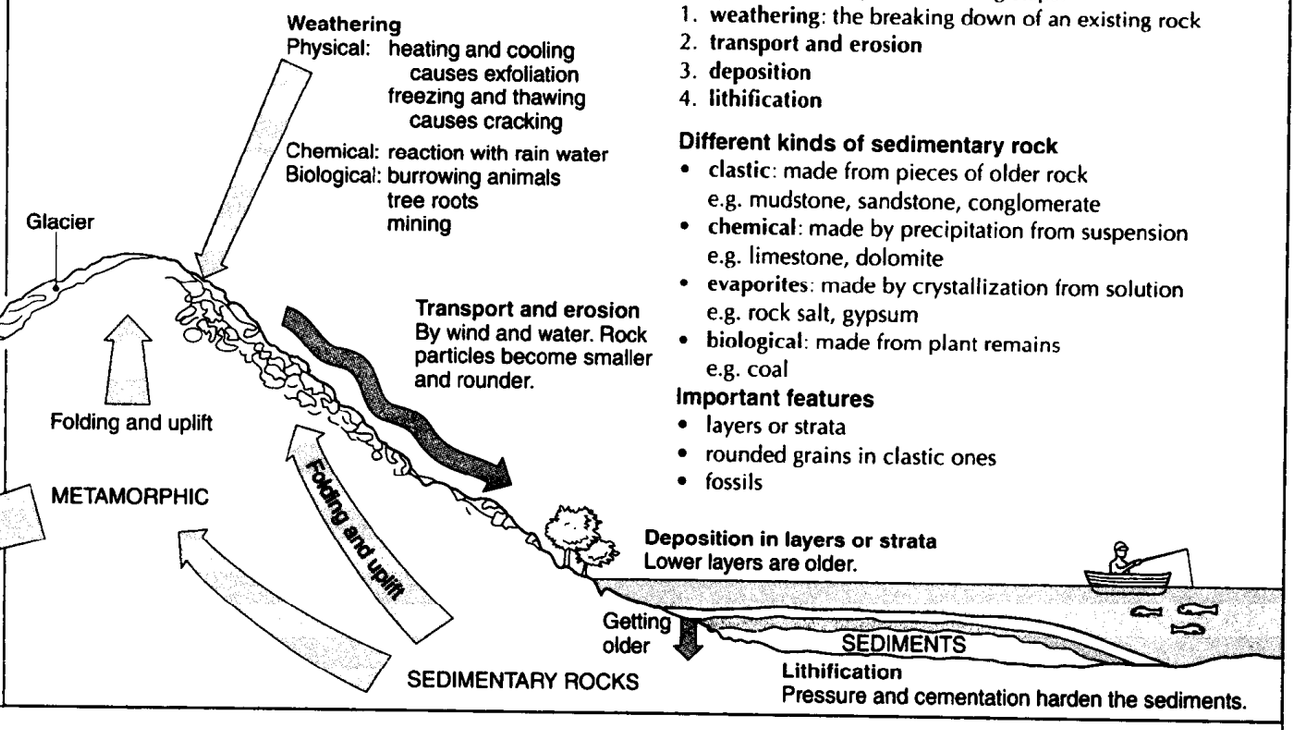
Intrusive igneous rocks
These are formed from magma which solidifies inside Earth's crust.
e.g. granite
They cool slowly forming larger crystals.



Igneous rocks are rocks of volcanic origin. They form when magma (molten rock from inside Earth) cools and solidifies. The speed of cooling controls the crystal size.

Important features
- crystalline

SEDIMENTARY ROCKS



Sedimentary rocks are rocks formed by **deposition**.
They are formed by the following steps:
1. **weathering**: the breaking down of an existing rock
2. **transport and erosion**
3. **deposition**
4. **lithification**

Different kinds of sedimentary rock
- **clastic**: made from pieces of older rock
  e.g. mudstone, sandstone, conglomerate
- **chemical**: made by precipitation from suspension
  e.g. limestone, dolomite
- **evaporites**: made by crystallization from solution
  e.g. rock salt, gypsum
- **biological**: made from plant remains
  e.g. coal

Important features
- layers or strata
- rounded grains in clastic ones
- fossils

METAMORPHIC ROCKS

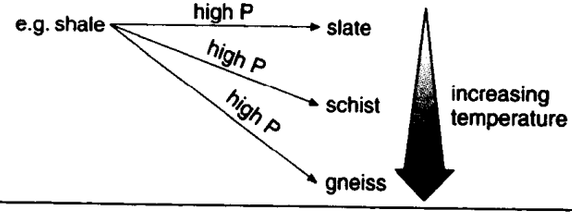
Metamorphic rocks are rocks which have been changed by the effects of
1. **high pressure**
2. **high temperature**

Both igneous and sedimentary rocks can become metamorphic.
e.g. limestone is changed into marble
mudstone or shale into slate

Under conditions of high pressure and temperature:
1. layers or strata become **folded bands**
2. rounded grains become **crystals**.

Important features
- banding
- crystals of various sizes

Changes depend on conditions
High pressure is always needed for metamorphosis, but the temperature may vary.



岩石循环和不同类型的岩石

矿物里有天然存在的金属化合物。

矿石是岩石，从中可以提炼出有经济价值的金属。

铁矿含有**赤铁矿**。**铝矿**里含有**铝土矿**。**金矿**里有**金**。

沉积岩

沉积岩是一种由**沉降**形成的岩石。
它们按以下步骤生成：
1. **风化**：现存的岩石碎裂
2. **运动和腐蚀**
3. **沉降**
4. **形成岩石**

风化
物理因素：加热和冷却引起页状剥落，冰冻和融化引起爆裂
化学因素：跟雨水反应
生物因素：钻进地洞里的动物、树根，采矿

不同类型的沉积岩

- **碎屑型**：是由原有的岩石碎块形成的
  比如：泥岩、砂岩和烁岩
- **化学型**：是从悬浮液沉降形成的
  比如：石灰岩、白云岩
- **蒸发型**：是从溶液结晶形成的
  比如：岩盐、石膏
- **生物型**：是从植物遗骸形成的
  比如：**煤**

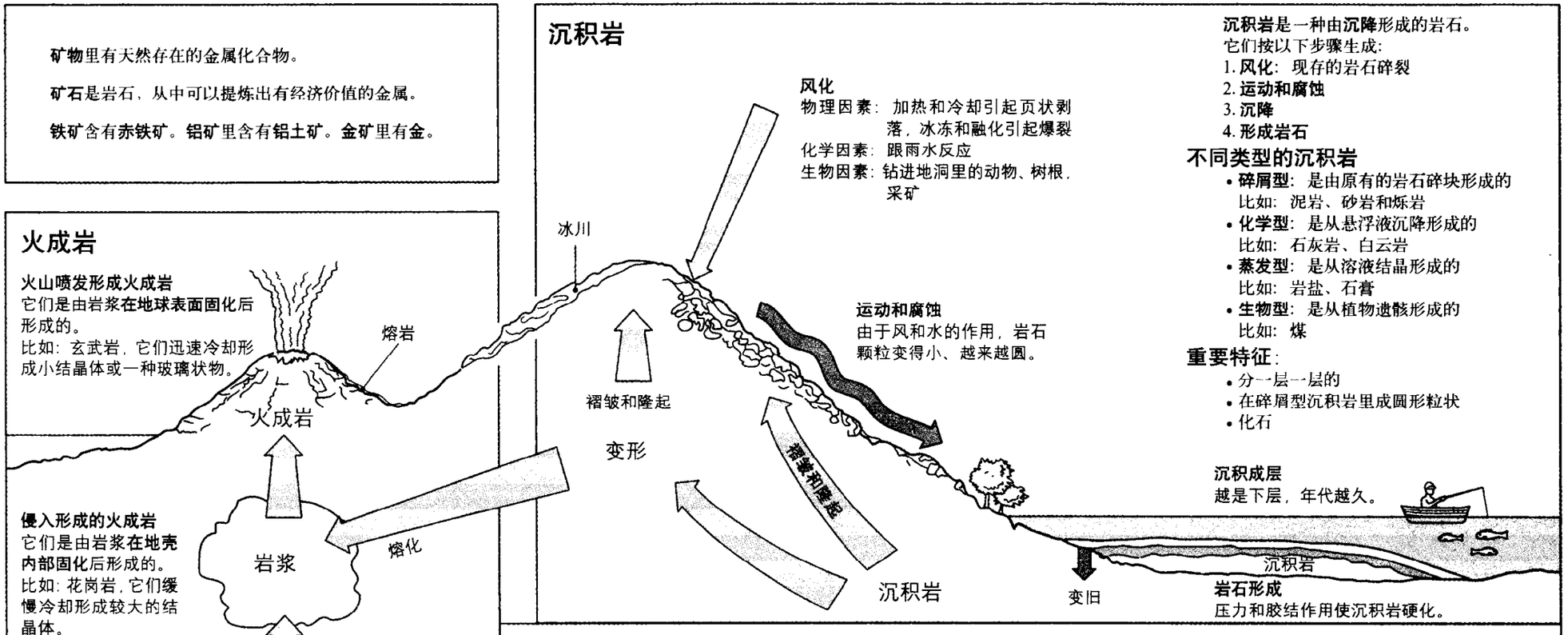
重要特征：

- 分一层一层的
- 在碎屑型沉积岩里成圆形粒状
- 化石

运动和腐蚀
由于风和水的作用，岩石颗粒变得小、越来越圆。

沉积成层
越是下层，年代越久。

岩石形成
压力和胶结作用使沉积岩硬化。



火成岩

火山喷发形成火成岩
它们是由岩浆**在地球表面固化**后形成的。
比如：玄武岩，它们迅速冷却形成小结晶体或一种玻璃状物。

侵入形成的火成岩
它们是由岩浆**在地壳内部固化**后形成的。
比如：花岗岩，它们缓慢冷却形成较大的结晶体。

火成岩是火山岩。是在岩浆（地球内部熔化的岩石）冷却和固化时形成的。冷却的速度决定了结晶体的大小。

重要的特征

- 结晶状

变质岩

变质岩是由以下因素作用变化而来的岩石
1. **高压**
2. **高温**

火成岩和沉积岩都能变成变质岩。比如：石灰石变成大理石、泥岩或页岩变成板岩。

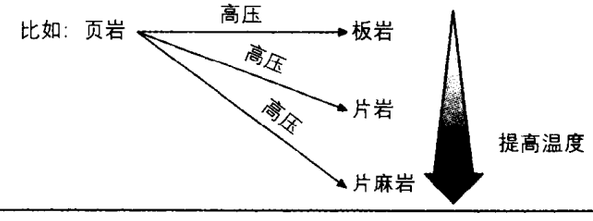
在高温和高压下：
1. 一层层的地层变成褶皱的**带状**
2. 圆粒状岩石变成**结晶状**

重要特征：

带状
多种大小的结晶

根据情况改变结果

对形成变质岩来讲，高压是必需的，但温度可以是不同的。



The structure of Earth and the theory of tectonic plates

TECTONIC PLATE THEORY

This states that the continents are made of less dense crustal rock floating on plates of the mantle. These plates move because there are convection currents in the inner part of Earth.

Evidence for tectonic plate theory

1. Continental coastlines fit together like bits of a jigsaw.
   e.g. the coasts of Africa and South America match each other.
2. There are similar rocks on either side of the oceans which match when the continents are moved together.
   e.g. similar rocks and fossils are found in Africa and South America.
3. Geological evidence of climatic change suggests that plates have moved.
   e.g. desert sands, tropical fossils, and glacial deposits show that Britain has moved on Earth's surface.
4. Position of mountain chains and island arcs.
   e.g. Japan and the Philippines show where plate margins are meeting.
5. Magnetic record preserved in rocks: magnetic stripes and wandering north pole.
   e.g. parallel lines of magnetism on either side of mid-ocean ridges show that there has been sea-floor spreading.

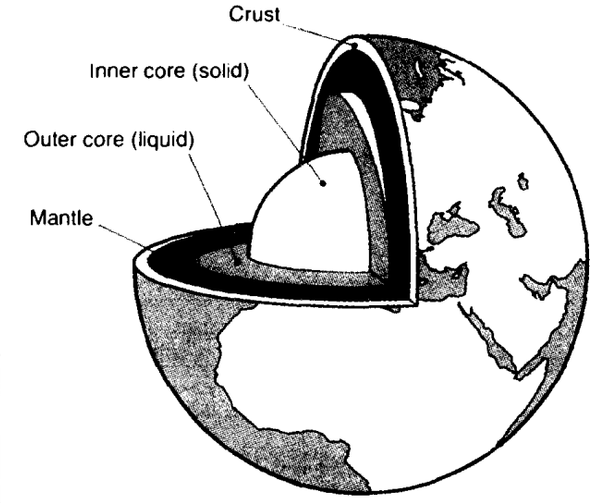
EVIDENCE FOR EARTH'S STRUCTURE

1. **Volcanoes**
   They indicate that the inside of Earth is hot and under pressure.
2. **Earthquakes**
   A pattern of shock waves spreads out through Earth from an earthquake. The pattern made by the waves tells us about the structure of Earth.

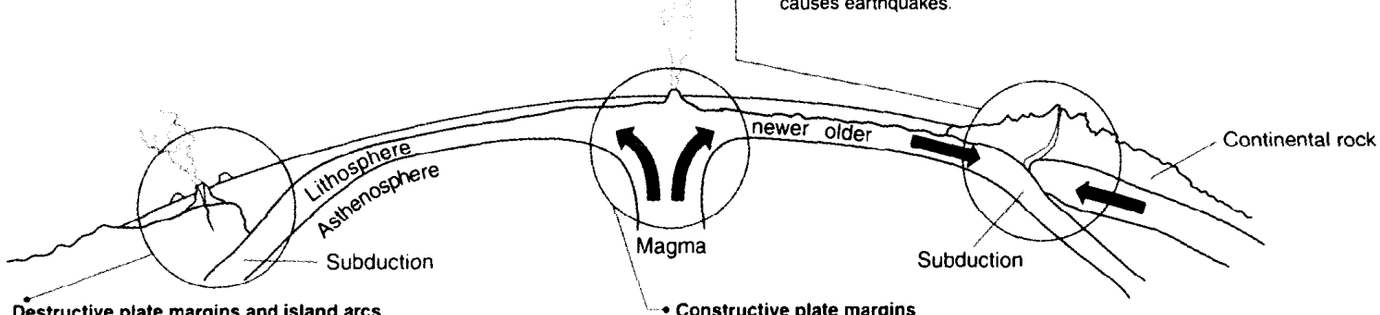
EARTH'S STRUCTURE

Studying earthquake waves tells us that Earth has a layered structure made of:

- a **very thin crust** a few tens of kilometres thick
- the **mantle** of underlying rock about 6000 km thick
- a **liquid core** about 2000 km thick
- a **solid core** about 1000 km thick in the centre.

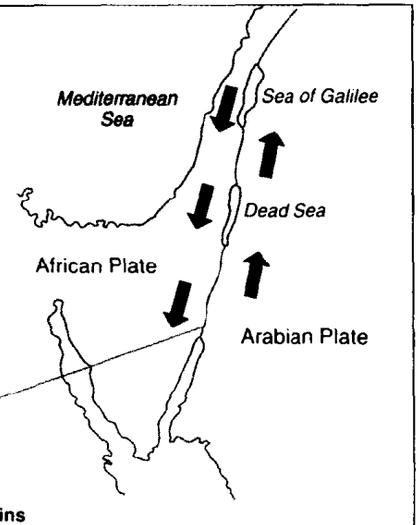


Destructive plate margins and mountain building
At these margins two plates moving in the opposite direction meet. One plate is forced under the other in a process called **subduction**. Lighter continental rock floating on the plates also collides. It piles up making mountains (e.g. the Himalayas). The movement of one plate past the other causes earthquakes.



Destructive plate margins and island arcs
Sometimes two plates collide under the sea where the continental crust is very thin. Here the dense basaltic rock slides under the lighter continental rock (subduction). This causes earthquakes. Volcanoes also form because the crust is so thin. These volcanoes produce rocks which are lighter in colour and density than those in the mid-ocean ridges (e.g. granite). The volcanoes lie in an arc along the line of the plate collision. Because they are in the ocean they form an arc of islands (e.g. Japan, the Philippines).

Constructive plate margins
At these margins new, dense, dark, igneous rock (basalt) rises from the mantle forming ridges of new mountains and volcanoes in the middle of the oceans. These are called **mid-ocean ridges**. Iceland is the northern end of a mid-ocean ridge which runs down the middle of the Atlantic Ocean.
The new, hot, liquid rock rises up and pushes older rock aside causing **sea-floor spreading**. As the molten rock solidifies, its magnetism is set in the direction of the north pole. Because Earth's magnetism has reversed a number of times, earlier rocks have their magnetism set in the opposite direction. So the rocks contain a striped pattern of magnetism.



Conservative margins
When the edges of two plates move past each other without either plate going underneath, faults and earthquakes happen. No plates are destroyed or made, so this boundary between plates is called a conservative margin. Examples include the San Andreas fault in California, and the Jordan Valley.

地球结构和板块理论

板块理论

这一理论认为大陆是由较薄的岩石壳层组成的。而地壳在地幔板块上漂浮，这些板块之所以能移动，是因为在地球内部有能对流的流体。

板块理论的证据

1. 大陆的海岸线能像锯条的锯齿那样互相吻合。比如：非洲和南美洲的海岸线互相吻合。

2. 大洋两边的大陆如果互相靠拢的话，可以发现这两边的岩石是相似的。例如：在非洲和南美洲可以发现相同的岩石和化石。

3. 气候变化造成的地质学上的证据显示，板块发生过移动。比如：沙砾、热带化石以及冰川沉积物表明，英伦三岛在地球表面移动过。

4. 山脉的位置以及岛屿的弧形。比如：日本和菲律宾表示板块的边缘是连接在一起的。

5. 在岩石里保存着磁记录：磁力线以及北极的漂移。比如：在海洋中心的山脊两边的平行磁力线表明海洋曾发生过海底扩展。

地球结构的证据

1. 火山

它们表示在地球内部是热的，并且是有压力的。

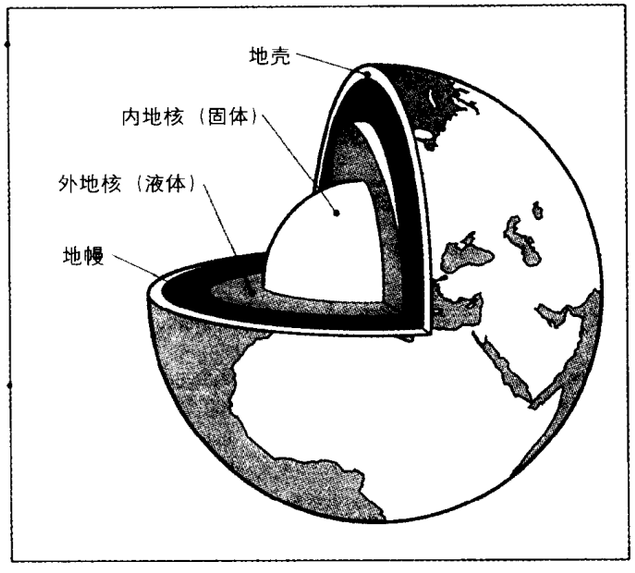
2. 地震

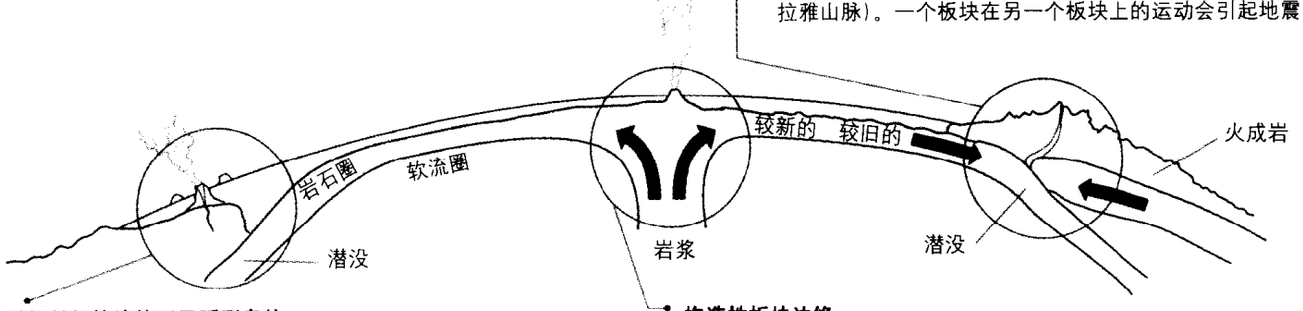
发生地震时，从地球内部发出的典型的震动波。从波的形状、可以告诉我们有关地球的构造。

地球结构

研究地震波可以告诉我们，地球由一种层结构组成：

- **非常薄的地壳**约几十千米厚
- 在下面由岩石构成的**地幔**约6000千米厚
- **液态的地核**约2000千米厚
- 位于中心的**固态的地核**约1000千米厚





破坏性板块边缘以及山脉的形成

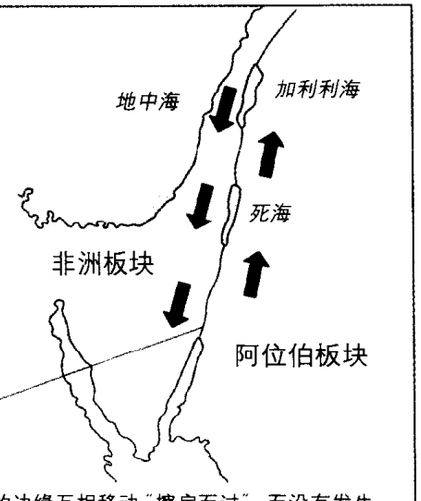
在这些边缘上，两个板块相向移动、相遇，一个板块被压在另一板块下面，这一过程叫**潜没**。较轻的大陆岩石漂浮在另一板块上也发生碰撞，板块隆起形成山脉（比如：喜玛拉雅山脉）。一个板块在另一个板块上的运动会引起地震。

破坏性板块边缘以及弧形岛屿

有时候在地壳很薄的海洋底部两个板块互相碰撞，结果较重的玄武岩下滑到较轻的火成岩下面（潜没）。这就引发地震，由于地壳很薄，还会发生火山爆发。这些火山爆发产生的岩石比大洋海脊的岩石（比如花岗岩）颜色较淡，密度较小。这些火山位于沿板块碰撞产生的弧形线上，因为它们是在大洋里，所以它们组成了许多岛屿（比如，日本和菲律宾）。

构造性板块边缘

在这些边缘，新生的、坚硬的深色火成岩（玄武岩）从地幔中凸起，形成海洋中部新的山脊和火山，它们被称作**海脊**。冰岛处于一条大洋海脊的北端，这条海脊一直延伸到大西洋中部。新生而灼热的熔岩隆起，推挤原先的岩石，引起**海底扩展**。熔岩凝固后，磁性指向北极。由于地球的磁力几经颠倒，原先岩石的磁性便指向相反方向。因此，岩石含有磁力线的条纹。



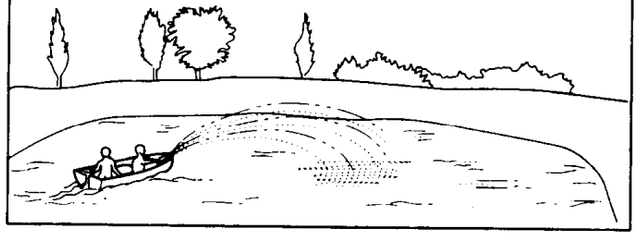
边缘保存

当两个板块的边缘互相移动"擦肩而过"，而没有发生一个板块滑到另一个板块下面时，会形成断层和地震。老的板块既没有破坏，也没有生成新的板块，这时，两个板块之间的分界线就叫边缘保存线。比如：在加利福尼亚的圣安德列斯断层以及约旦峡谷。

Materials from rocks: limestone and its uses

NEUTRALIZING LAKES

Limestone (calcium carbonate) is a **base**. It neutralizes lakes made acid by acid rain. Powdered limestone can be sprayed onto lakes for this purpose.



MAKING LIME FOR AGRICULTURE

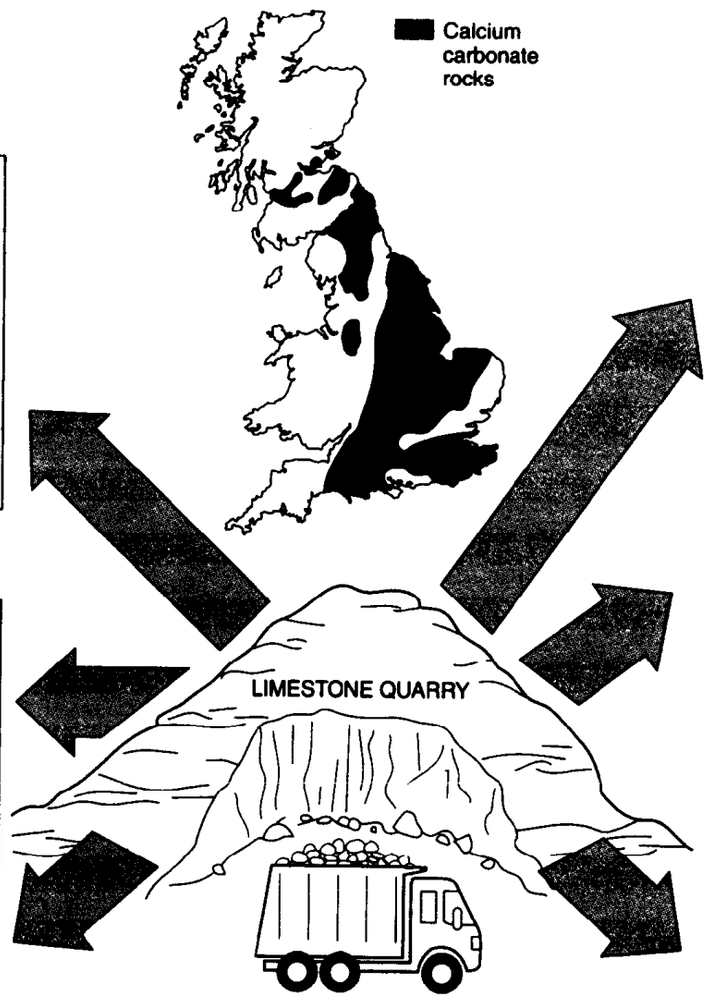
Metal carbonates decompose on heating.
Heating limestone produces **quicklime** which reacts with water to make **slaked lime.**

$$CaCO_3(s) \xrightarrow{\text{heat}} CaO(s) + CO_2(g)$$
(quicklime)

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$$
(slaked lime)

MAKING IRON

Limestone is mixed with iron ore and coke to form the 'charge' which is loaded into a **blast furnace** (see p. 45). The limestone reacts with the high melting point non-metal impurities in the iron ore. It forms a molten slag which floats on top of the iron.



MINING AND QUARRYING

These processes:

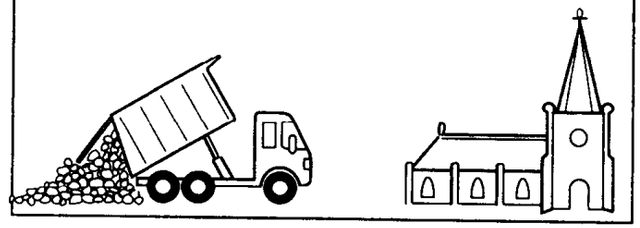
- create ugly slag heaps and scar the landscape
- generate a lot of heavy traffic
- cause dust and smoke pollution

but also

- provide jobs and income
- provide valuable raw materials.

BUILDING MATERIAL

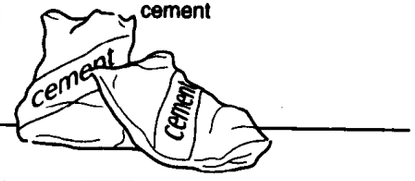
Limestone is a **hard sedimentary rock**. It is used for road foundations and to make buildings.



MAKING CEMENT

Limestone and clay are heated together in a furnace to make cement.

$$4CaCO_3(s) + Al_2Si_2O_7(s) \rightarrow 2CaSiO_3(s) + Ca_2Al_2O_5(s) + 4CO_2(g)$$
(cement)



MAKING GLASS

Limestone, sand, and sodium carbonate are heated together to make glass. This **soda glass** is used in windows. Soda glasses have the follow range of compositions:

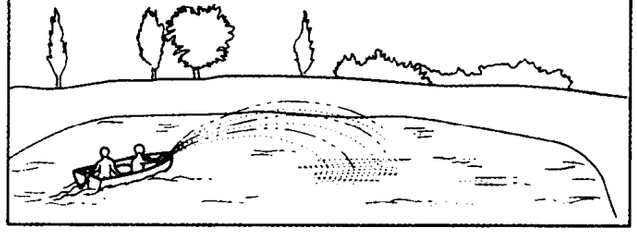
SiO_2	70–75%
Na_2O	12–16%
CaO	5–11%

If boron oxide is added to the reaction mixture, a **borosilicate glass** is produced. Borosilicate glasses are harder than soda glasses and can be heated without softening. Pyrex is a borosilicate glass.

来自岩石的材料：石灰石和它的用途

中和湖水

石灰石（碳酸钙）是一种**碱**，能中和由酸雨造成的酸性湖水，可以向湖里抛撒粉状的石灰石。



为农用制取石灰

加热分解金属碳酸盐。

加热石灰石生成**生石灰**。

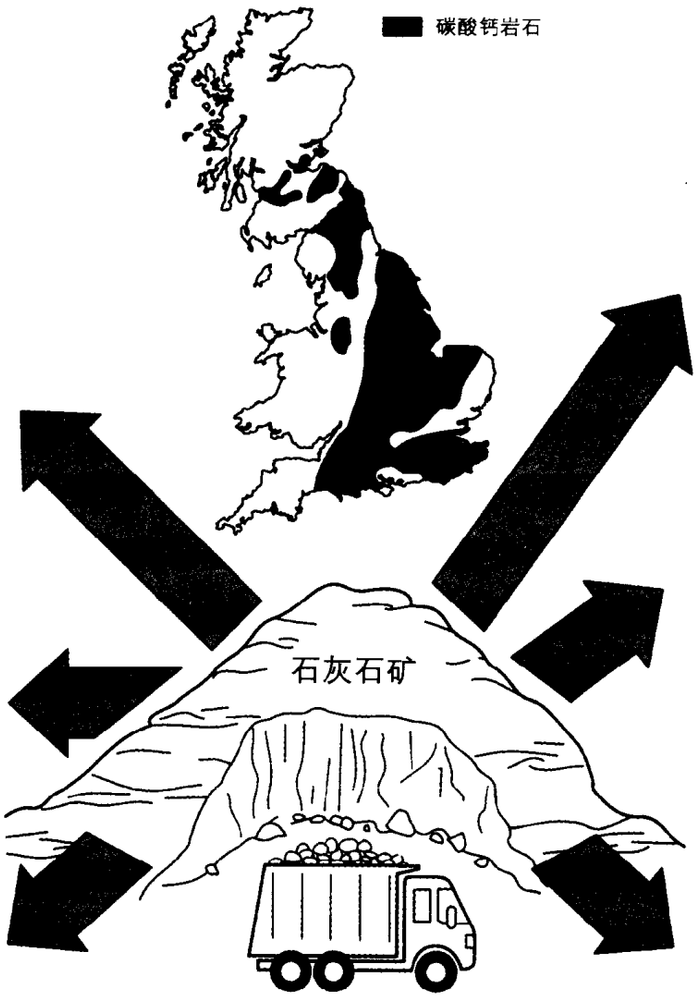
生石灰跟水反应生成**熟石灰**。

$$CaCO_3(s) \xrightarrow{\text{加热}} \underset{\text{生石灰}}{CaO(s)} + CO_2(g)$$

$$CaO(s) + H_2O(l) \rightarrow \underset{\text{熟石灰}}{Ca(OH)_2(s)}$$

炼铁

石灰石跟铁矿和焦碳混合组成物料，投入**高炉**，石灰石跟铁矿里高温融化的非金属杂质反应，形成熔融的炉渣，浮在铁水的表面。



开采矿石

采矿时：

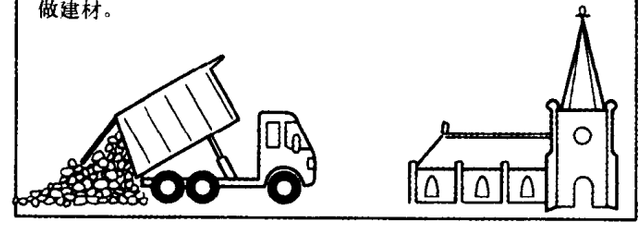
- 会造成麻烦的矿渣堆，在大地上留下“伤痕”
- 产生很沉重的运输量
- 造成灰尘和烟雾污染

但同时：

- 提供工作岗位和收入
- 提供有用的原材料

建筑材料

石灰石是一种**坚硬的沉积岩**。可以用来筑路基和做建材。



制水泥

石灰石和黏土一起在炉内加热，生成水泥。

$$4CaCO_3(s) + Al_2Si_2O_7(s) \rightarrow \underbrace{2CaSiO_3(s) + Ca_2Al_2O_5(s)}_{\text{水泥}} + 4CO_2(g)$$

制玻璃

石灰石、沙砾和碳酸钠一起加热，制成玻璃。用这种**钠玻璃**做窗。钠玻璃的组成如下：

SiO_2	70 ~ 75%
Na_2O	12 ~ 16%
CaO	5 ~ 11%

如向反应混合物加入硼，就制成一种**硼酸盐玻璃**，硼酸盐玻璃比钠玻璃硬，加热时不会变软。派莱克耐斯耐热玻璃就是一种硼酸盐玻璃。

Iron and steel

MANUFACTURE OF IRON

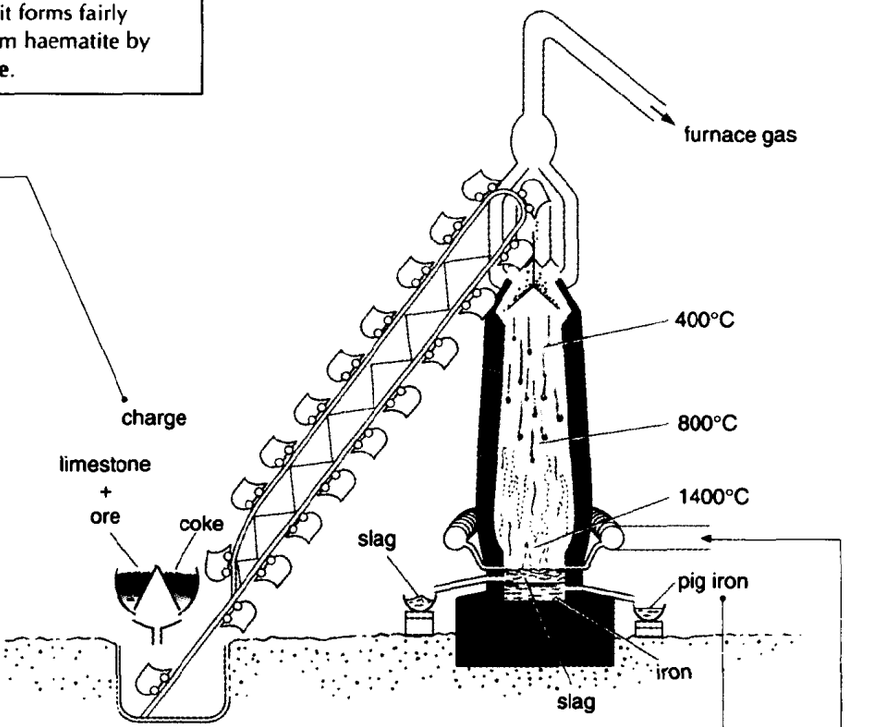
There is less iron than aluminium in Earth's crust, but it is easier and cheaper to extract.

The main ore is **haematite**, Fe_2O_3.

Iron is below zinc in the reactivity list so it forms fairly reactive compounds. Iron is extracted from haematite by **reducing it with carbon in a blast furnace**.

The **charge** is loaded into the top of the furnace.

The charge contains:
- iron ore – source of iron
- coke – fuel and reducing agent
- limestone – to form a **slag** by dissolving the high melting point non-metal impurities.



A **blast of hot air** goes into the bottom.

REACTIONS

1. **The coke burns**
   $C(s) + O_2(g) \rightarrow CO_2(g)$
2. **More coke reduces the carbon dioxide**
   $CO_2(g) + C(s) \rightarrow 2CO(g)$
3. **Carbon monoxide reduces iron ore**
   $Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(l) + 3CO_2(g)$
4. **Carbon reduces iron ore**
   $2Fe_2O_3(s) + 3C(s) \rightarrow 4Fe(l) + 3CO_2(g)$
5. **Limestone decomposes**
   $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
6. **Slag forms**
   $CaO(s) + SiO_2(s) \rightarrow CaSiO_3(l)$

'Pig' iron is produced. This contains C, Si, S, P. It is very brittle.

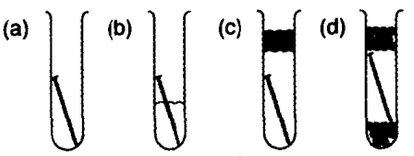
RUSTING

$4Fe(s) + 3O_2(g) + 6H_2O(l) \rightarrow 4\ Fe(OH)_3(s) \rightarrow 2\ Fe_2O_3.6H_2O(s)$ (rust)

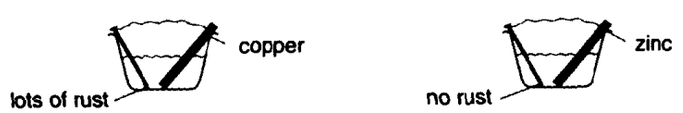
Simple lab experiments show:

1. That air and water are needed for iron to rust. So rusting is an **oxidation reaction**.

(a) control
(b) air and water – nail rusts
(c) boiled water with oil on top – no rust
(d) drying agent + air – no rust



2. Iron rusts when in contact with a less reactive metal, but not when in contact with a more reactive metal.



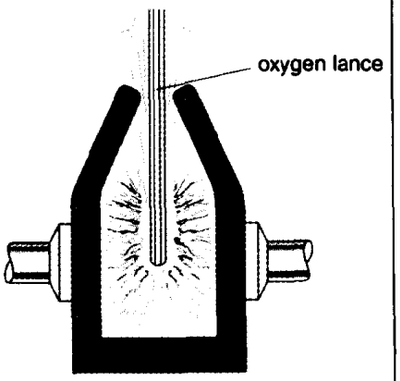
Stopping rust

1. **Coat the iron**: paint, oil or grease, chrome plate. This prevents air and water meeting the iron.
2. **Sacrificial protection**: galvanizing (zinc plating) or zinc anodes. The zinc reacts instead of the iron, so the iron is protected.
3. **Alloying**: e.g. stainless steel. Alloying modifies the reactivity of the iron.

STEEL MAKING

Pig iron is too brittle to be useful. It is turned into steel by:

1. mixing the molten iron with 30% scrap steel
2. blowing oxygen through to burn out impurities
3. adding weighed amounts of alloying elements.



铁和钢

铁的制取

在地壳里铁的含量比铝少，但是铁比铝能更容易、更便宜地提炼。

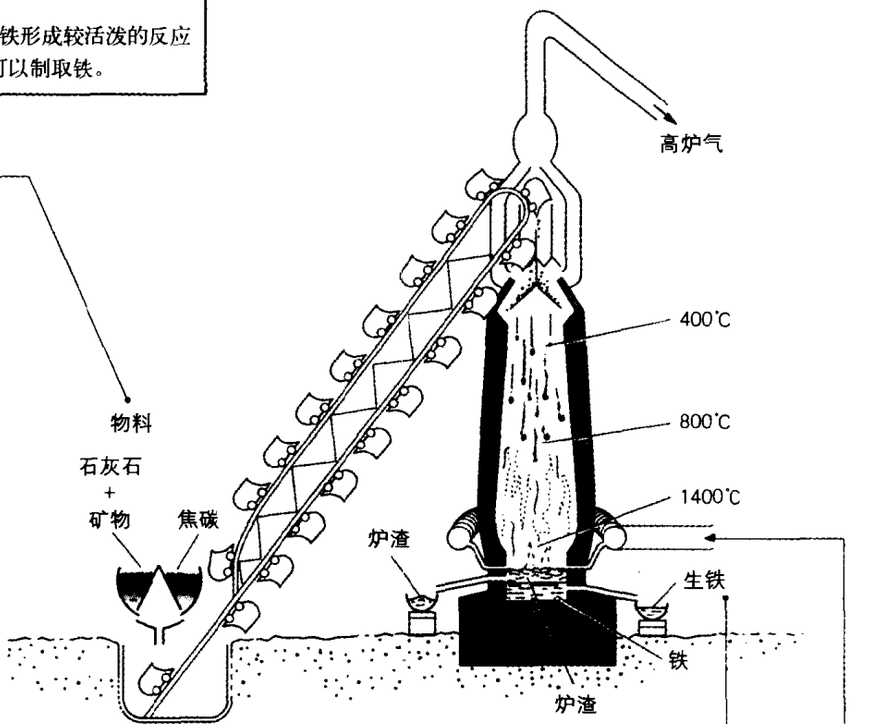
主要的矿物是**赤铁矿**，Fe_2O_3。

在活动性顺序表里铁在锌的后面，所以铁形成较活泼的反应化合物。**在高炉里，用碳来还原赤铁矿**，可以制取铁。

物料从高炉顶部加入。

物料包含：

- 铁矿——铁的来源
- 焦碳——燃料和还原剂
- 石灰石——熔化高熔点的非金属杂质，生成**炉渣**



热空气鼓入炉底。

生成**生铁**，它含有碳、硅、硫、磷，很脆。

反应

1. **焦碳燃烧**
   $C(s)+O_2(g) \rightarrow CO_2(g)$
2. **更多的焦碳还原二氧化碳**
   $CO_2(g)+C(s) \rightarrow 2CO(g)$
3. **一氧化碳还原铁矿石**
   $Fe_2O_3(s)+3CO(g) \rightarrow 2Fe(l)+3CO_2(g)$
4. **碳还原铁矿石**
   $2Fe_2O_3(s)+3C(s) \rightarrow 4Fe(l)+3CO_2(g)$
5. **石灰石分解**
   $CaCO_3(s) \rightarrow CaO(s)+CO_2(g)$
6. **形成炉渣**
   $CaO(s)+SiO_2(s) \rightarrow CaSiO_3$

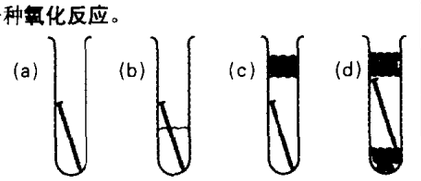
锈蚀

$$4Fe(s)+3O_2(g)+6H_2O(l) \rightarrow \underset{\text{铁锈}}{4Fe(OH)_3(s)} \rightarrow 2Fe_2O_3.6H_2O(s)$$

简易的实验室实验表明：

1. 铁锈蚀需要空气和水，因此锈蚀是一种**氧化反应**。

(a) 对照（铁钉）
(b) 空气和水——铁钉锈蚀
(c) 上层有油的沸水——不锈蚀
(d) 干燥剂 + 空气——不锈蚀



2. 当铁跟一些不活泼金属接触时，铁会锈蚀，但当铁跟一些比它活泼的金属接触时，铁不会锈蚀。

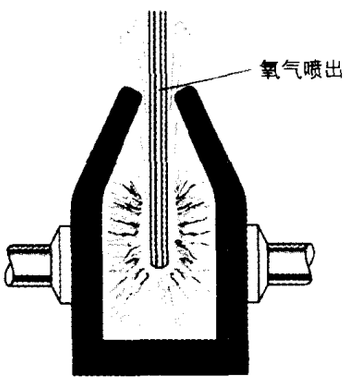
防止生锈

1. **给铁涂上保护层**：油漆、涂油、镀铬。这些能防止空气和水跟铁接触。
2. **牺牲保护法**：镀锌，也就是说使锌变成阳极，锌取代铁发生反应。这样，铁就得到了保护。
3. **合金**：比如不锈钢，合金能降低铁的反应性。

炼钢

生铁太脆，用处不大。通过以下方法，可以把生铁变成钢：

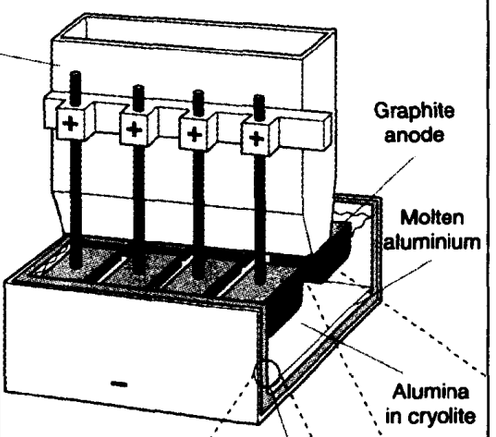
1. 在融熔的铁水中加入30%的废钢。
2. 吹入氧气，使杂质烧掉。
3. 加入一定量的合金元素。



Aluminium extraction

Conditions
950°C
4–5 volts
100 000 amps

HALL CELL



Aluminium is a reactive metal so it is extracted using **electrolysis**. (Aluminium appears to be unreactive, but only because it is protected by an oxide layer.)

The ore of aluminium is the mineral **bauxite**, Al_2O_3. It is purified in its country of origin to reduce transport costs.

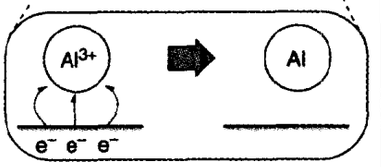
Alumina, purified aluminium oxide, has a very high melting point (2045°C). This is lowered by adding an impurity called **cryolite**, Na_3AlF_6.

The impure aluminium oxide is electrolysed in the **Hall cell**. The electrolyte is kept molten by the heating effect of the huge current.

Inputs
- bauxite: source of aluminium
- carbon: for anodes, which get burnt
- cryolite: to lower m.p. (this is mainly recycled)
- electricity: which makes this an expensive process

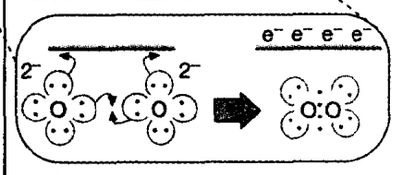
USES OF ALUMINIUM
The uses of aluminium depend on its properties:
- it is strong but light: used for planes, window frames
- conducts quite well: used for cables
- protected by oxide layer: boat fittings, saucepans

CATHODE REACTION



$Al^{3+}(l) + 3e^- \rightarrow Al(l)$

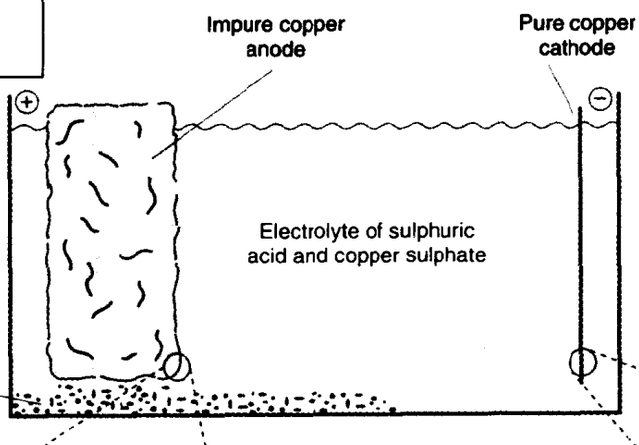
ANODE REACTION



$2O^{2-}(l) \rightarrow O_2(g) + 4e^-$
$C(s) + O_2(g) \rightarrow CO_2(g)$

Copper extraction and purification

Conditions
0.25 volts
800 amps



Copper is an unreactive metal so its compounds are quite reactive.

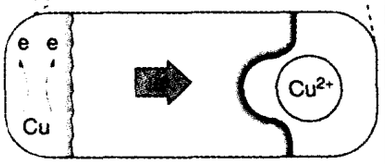
Copper is **extracted by smelting** – roasting or heating – the ore in a furnace.

Unlike a blast furnace the ore does not come into contact with the carbon fuel.

The copper produced is very impure.

Most of the properties of copper, such as electrical conduction and malleability, depend on the metal being very pure. So copper is **purified using electrolysis**.

ANODE REACTION
Copper atoms are oxidized to ions

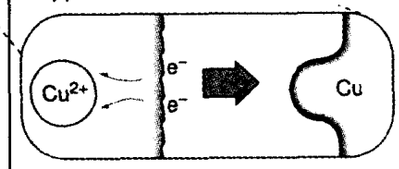


$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$

Each reaction is the exact reverse of the other. So the result is that copper is transferred from the impure anode to the 99.99% pure cathode. This method can also be used to plate copper onto other metals.

If the voltage is accurately controlled, only copper is deposited on the cathode. Other metals fall to the bottom forming anode sludge. Platinum, gold, silver, molybdenum, selenium, and tellurium are all extracted from the sludge.

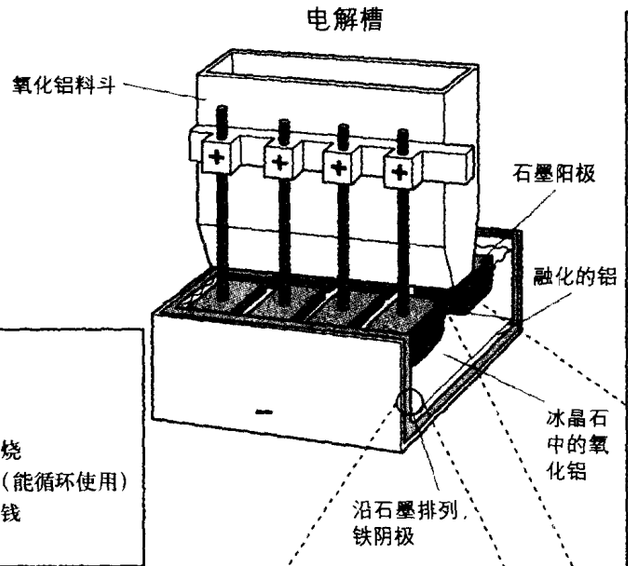
CATHODE REACTION
Copper cations are reduced to metal



$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

铝的提炼

反应条件
950℃
4—5伏
100 000安培



铝是一种活泼金属，所以要用**电解法**来提炼铝。

（铝看起来很不活泼，只是因为它有一层氧化膜保护）

铝矿是一种**铝土矿**，Al_2O_3。它先在产地纯化，以减少运费。

氧化铝，纯净的氧化铝有很高的熔点（2045℃）。加一种叫**冰晶石** Na_3AlF_6 的杂质，可以降低熔点。

不纯的氧化铝在**电解槽**里电解，由于强大的电流作用，电解液一直保持熔融状态。

加入

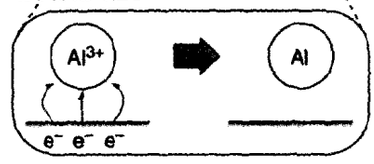
- 铝土矿：铝的来源
- 碳：做阳极，耐燃烧
- 冰晶石：降低熔点（能循环使用）
- 电：它使提炼很费钱

铝的用途

铝的用途由它的性质决定：

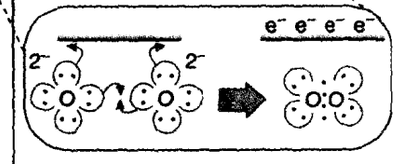
- 坚固但很轻：用来造飞机、窗框
- 良好的导电性：制造电线、电缆
- 有氧化层保护：船的外壳、锅子等

阴极反应



$Al^{3+}(l)+3e^- \rightarrow Al(l)$

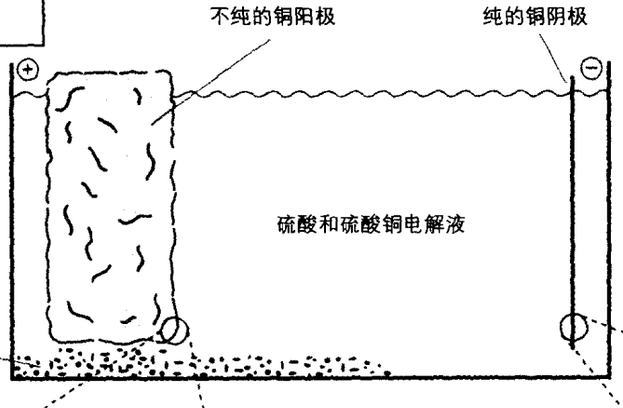
阳极反应



$2O^{2-}(l) \rightarrow O_2(g)+4e^-$
$C(s)+O_2(g) \rightarrow CO_2(g)$

铜的提炼和提纯

反应条件
0.25伏
800安培



铜是一种不活泼金属，因此它的化合物就相当活泼。

可以用**熔融**的办法来提炼铜——焙烧或加热炉里的矿石。

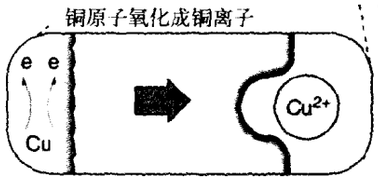
不像鼓风炉那样，矿石并不跟碳燃料接触。

生成的铜是很不纯的。

铜的大多数性质，像导电性和延展性，取决于金属铜是不是很纯。因此，用**电解法来提纯**铜。

阳极反应

铜原子氧化成铜离子



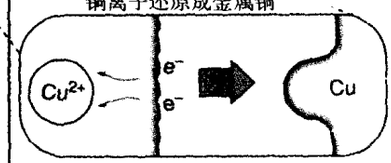
$Cu(s) \rightarrow Cu^{2+}(aq)+2e^-$

每一个反应正好是另一个反应的逆反应，因此，最后不纯的阳极上的铜变成阴极上的99.99%纯铜。这种方法也能用来在其他金属上镀铜。

如果精确控制电压，在阴极上只有铜沉淀下来，其他金属沉入槽底，形成阳极淤泥。铂、金、银、钼、硒、碲都是从淤泥中提炼出来的。

阴极反应

铜离子还原成金属铜



$Cu^{2+}(aq)+2e^- \rightarrow Cu(s)$

Transition elements

TITANIUM

Extraction

Titanium is very expensive to extract because it is extracted by a batch process instead of a continuous one.

Titanium is displaced from purified titanium chloride by magnesium, a more reactive metal.

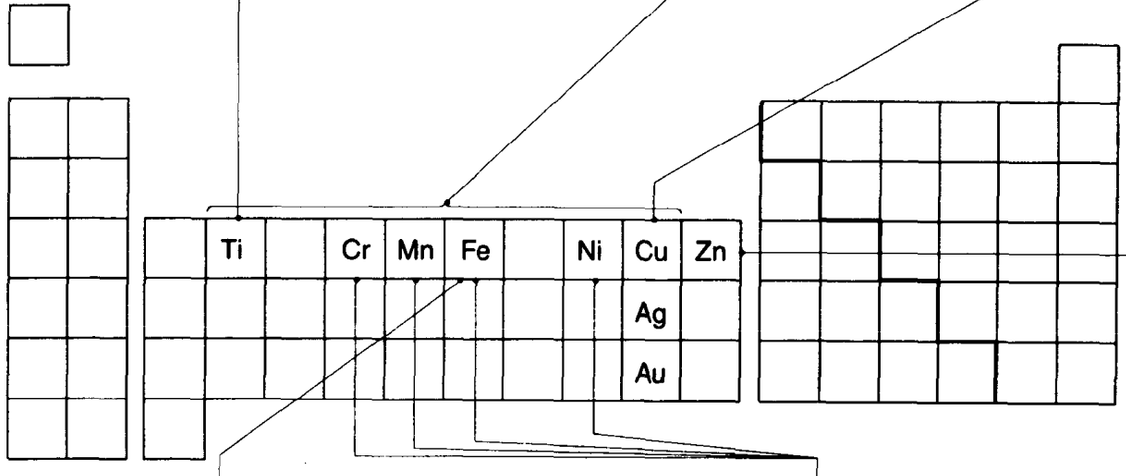
$TiCl_4(l) + 2Mg(l) \rightarrow Ti(s) + 2\ MgCl_2(l)$

Uses

Titanium is light but very strong. It is used in making turbine blades, aeroplane parts, and artificial limbs.

Once a **continuous process** is started up, metal is made continuously until the process is stopped. In a **batch process**, the furnace is loaded and heated up, reaction takes place, then the furnace is cooled down and unloaded. This whole process is then repeated. This wastes energy and time.

The transition elements are found between Groups 2 and 3 of the periodic table. They have characteristic properties (see p. 18). They also have a wide range of uses which depend on these properties.



COPPER, SILVER, AND GOLD

These are all easy to extract, but silver and gold are rare and so expensive. They all show typical metallic properties (good electrical conductivity, malleable, ductile). Their uses follow from their properties.

Copper

- is widely used as an electrical conductor (cheap, good electrical conductivity). But it is now being replaced by aluminium – which is cheaper and lighter– for cables in the electricity grid.
- is used for pipes (unreactive, ductile)
- is used for coins (unreactive, has a distinctive colour)

Silver and gold

- are sometimes used to coat electrical contacts, where the heat of sparking would cause copper to oxidize (unreactive, good electrical conductivity)
- are used for jewellery (rare, precious, attractive colours)

ZINC, CHROMIUM, NICKEL, AND COPPER

The biggest disadvantage of iron and steel is that they rust. Replacing or repairing rusting structures costs huge amounts every year. Rusting can be prevented by:

- galvanizing or coating the iron with zinc
- alloying the iron with a less reactive metal (e.g. chromium or nickel)
- chrome-plating steel, which provides a decorative, unreactive surface. But the steel will rust badly if the chrome layer is scratched through, because chromium is less reactive than iron.

Brass is sometimes used instead of iron. It is an alloy of copper and zinc.

IRON

Cast iron is brittle but hard because of the impurities it contains. It is used for making manhole covers.

Steel

When iron is purified and alloyed with small amounts of carbon, steel is made. The amount of carbon changes the properties of the steel.

- **mild steel** (0.09–0.2% carbon): malleable and not very hard; used for car bodies, cans, nails, wire
- **high carbon steel** (0.4–0.9% carbon): harder and less malleable; used for tools, masonry nails

Alloy steels

The properties of steel can be further changed by adding other transition metals:

- **stainless steel** is 18% chromium, 8% nickel
- **manganese steel** is very strong and hard; used for drill bits, cutting tools, springs.

过渡元素

钛

提炼

提炼钛代价很大，因为生产过程不是连续的，而是批量投料生产的。

用一种活泼金属镁来置换纯净的氯化钛中的钛。

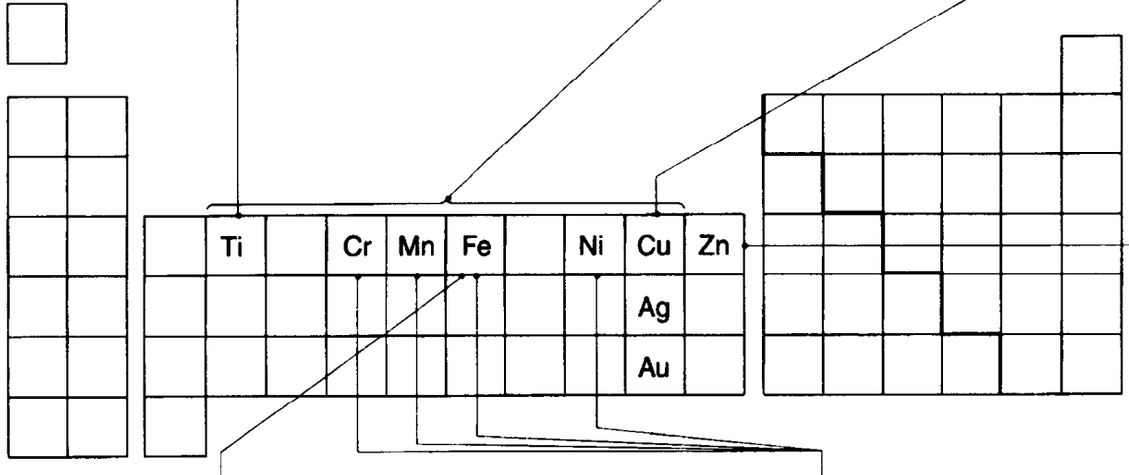
$TiCl_4(l)+2Mg(l) \rightarrow Ti(s)+2MgCl_2(l)$

用途

钛轻而坚硬，用来制造涡轮机的叶片、飞机部件和人工关节。

在**连续生产**中，一旦生产过程开始，金属就不断地生成，直到这一过程停止。在**批量生产**中，反应炉装料、加热、反应发生，然后让反应炉冷却、卸料，整个过程再重复。这种生产费能、费时。

过渡元素在元素周期表的第二族和第三族之间，它们有自己的特性（见14页）。根据这些性质，它们有广泛的用途。



铜、银和金

这些金属很容易提炼，但是银和金很稀少，所以很贵。它们都有典型的金属特性（电的良导体、锤性、延展性好）。它们的用途是由它们的性质决定的。

铜

- 广泛地被用作导体（便宜、导电性好）。但是，如今它正由铝取代——因为铝更便宜、更轻——比如：在输电线路上用的电缆
- 用来制造管道（反应性差，延展性好）
- 用来制造钱币（反应性差，有特殊的颜色）

银和金

- 有时用来在电器的接触点上镀金、镀银。因为电火花自燃会使铜触点氧化（金、银反应性差，导电性好）
- 用来做首饰（稀有、珍贵、光彩夺目的颜色）

铁

铸铁由于含有杂质而很脆但很坚硬。用它来制造（锅炉、下水道等）检修孔的盖子。

钢

当铁纯化，跟少量的碳熔合后，生成钢。碳的含量不同，钢的性质也不同

- **低碳钢**（含碳0.09—0.2%）：延展性好，不很硬。用来制造汽车车身、罐头、钉子或线材
- **高碳钢**（含碳0.4—0.9%）：较硬，延展性差。用来制造工具、建筑钢结构等

合金钢

加入某些过渡元素，可以进一步改变钢的性质：

- **不锈钢**含18%的铬，8%的镍
- **锰钢**很坚硬，用来做钻头、切削工具、弹簧等

锌、铬、镍和铜

铁和钢的最大缺点是会锈蚀，每年要耗费大量的资金来置换或修复锈蚀的结构。可以用以下的办法来防止锈蚀：

- 给钢、铁镀锌
- 加入较不活泼的金属（比如铬和镍）生成合金
- 镀铬，形成一层有装饰作用的不活泼的表面。但如果铬层穿孔，钢铁会锈蚀得更快，因为铬的活泼性比铁差

黄铜有时可以用来取代铁，它是铜和锌的合金。

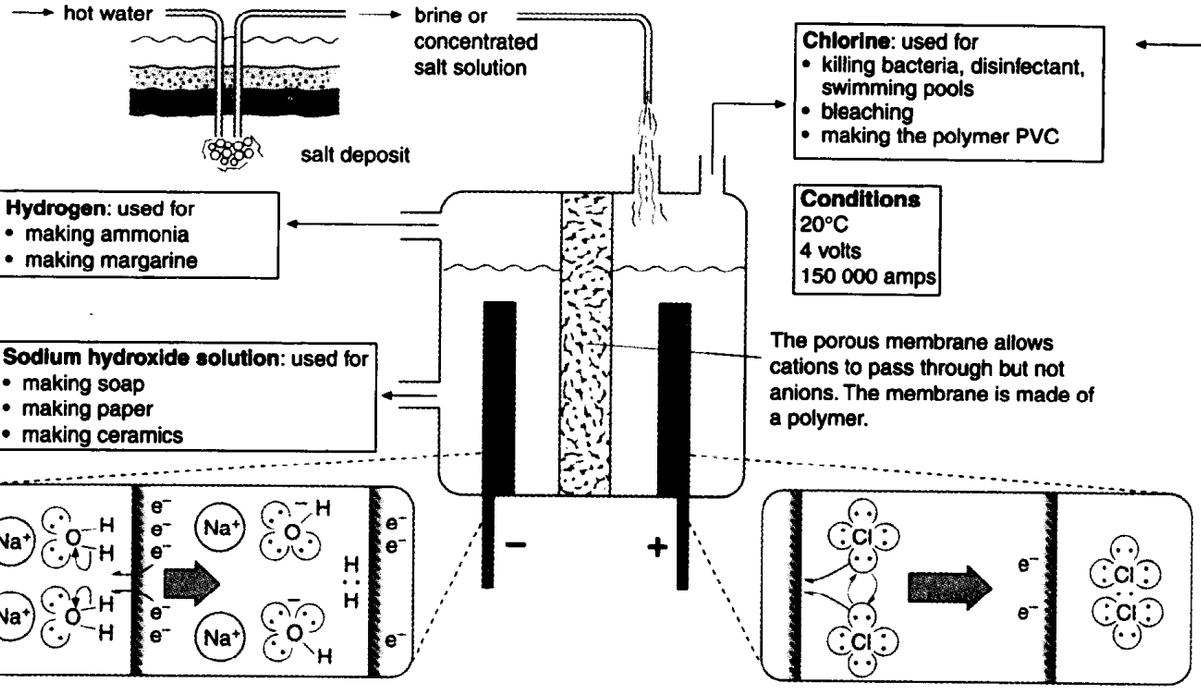
Chemicals from salt

Common salt, sodium chloride, is found naturally:
1. dissolved in **sea water** (about 2.6% in a typical sample) from which it is extracted by **evaporation**;
2. as **rock salt**, a sedimentary evaporite. There are huge deposits of rock salt in Cheshire. These are extracted by **solution mining**.

Uses of sodium chloride
- added to food to preserve it (ham)
- put on icy roads to melt the ice
- a source of sodium, chlorine, and sodium hydroxide

Sodium is a very reactive metal so it is extracted by **electrolysis**. Chlorine is also very reactive. The cells used for electrolysis are designed to keep the very reactive products apart.

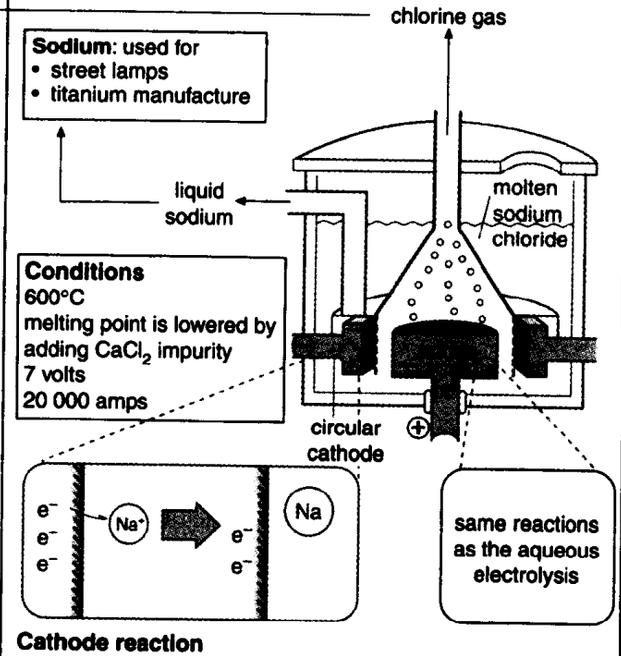
EXTRACTION AND ELECTROLYSIS OF BRINE



Cathode reaction
At the steel cathode:
- positively charged hydrated sodium cations are attracted to the negatively charged cathode
- the hydrogens on the water molecules are more reactive than sodium ions, so they are reduced (gain an electron). Hydroxide ions and hydrogen gas form:
  $2H_2O(l) + 2e^- \rightarrow 2OH^-(aq) + H_2(g)$

Anode reaction
At the titanium anode:
- negatively charged chlorine anions are attracted to the positively charged anode
- each anion loses one electron (it is oxidized)
- chlorine molecules form
  $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

ELECTROLYSIS OF MOLTEN SODIUM CHLORIDE



Cathode reaction
- positively charged sodium ions are attracted to the negative cathode
- sodium ions are reduced to sodium metal (there is no hydrogen to react, as there is in the electrolysis of brine)
  $Na^+(l) + e^- \rightarrow Na(l)$

Anode reaction
- exactly the same as for aqueous electrolysis:
  $2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$

来自盐的化合物

食盐、**氯化钠**，天然存在的方式：

1. 溶解在**海水**里（百分含量通常在2.6%）。**蒸发**海水可以提取食盐。

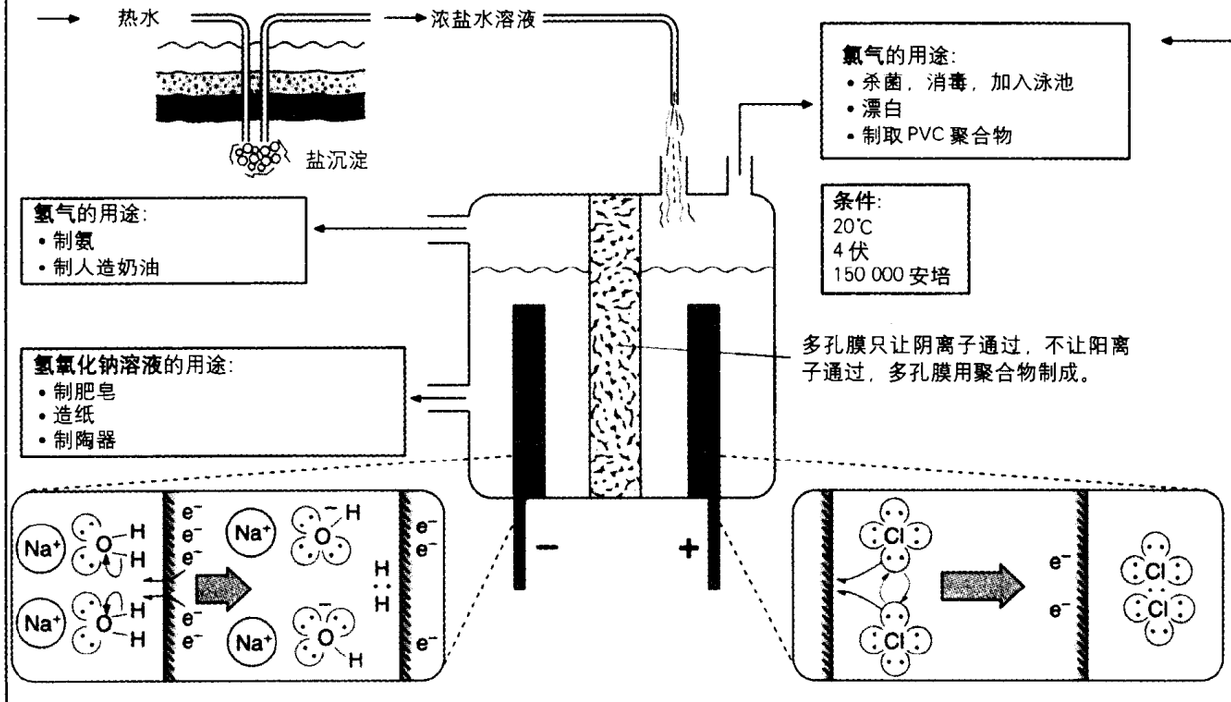
2. **岩盐**，沉积岩蒸发去除水分。在柴郡有大量的岩盐矿，通过**溶化矿藏**的方法来提取食盐。

氯化钠的用途

- 加到食品中腌制食品（火腿）
- 撒在结冰的路面上，以溶解冰
- 制取钠、氯和氢氧化物的原料

钠是一种非常活泼的金属，因此它需用**电解法**来制取。氯也很活泼，用来电解的电解槽要设计成把两种活泼的产物分开。

电解浓盐水



阴极反应

在铁阴极

- 带正电荷的水合钠阳离子被吸引到带负电荷的阴极
- 水分子里的氢比钠离子更活泼，因此，它们被还原（获取一个电子）生成氢氧化根离子和氢气

$2H_2O(l)+2e^- \rightarrow 2OH^-(aq)+H_2(g)$

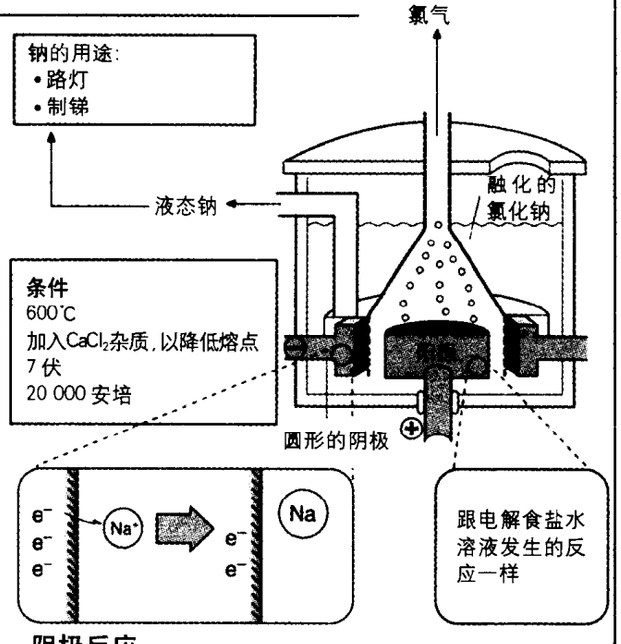
阳极反应

在铑阳极

- 带负电荷的氯阴离子被吸引到带正电的阳极
- 每个阴离子失去一个电子（它被氧化）
- 生成氯气分子

$2Cl^-(aq) \rightarrow Cl_2(g)+2e^-$

电解熔融的氯化钠



阴极反应

- 带正电荷的钠离子被吸引到带负电的阴极
- 钠离子被还原成金属钠（不像电解食盐水时那样，没有氢参与反应）。

$Na^+(l)+e^- \rightarrow Na(l)$

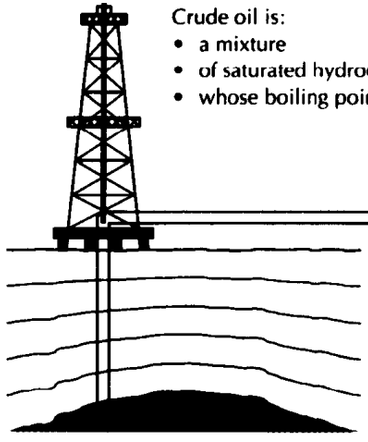
阳极反应

- 跟电解食盐水溶液完全相同

$2Cl^-(l) \rightarrow Cl_2(l)+2e^-$

Chemicals from crude oil

EXTRACTION

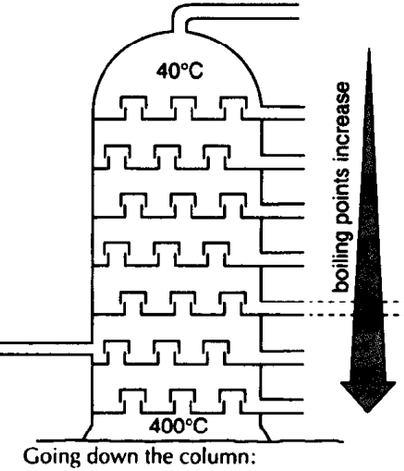


Crude oil is:
- a mixture
- of saturated hydrocarbons
- whose boiling points are close together.

Crude oil or petroleum
- a fossil fuel – the remains of marine organisms
- **a non-renewable resource** – but new reserves continue to be found.

PHYSICAL SEPARATION OF MIXTURE: FRACTIONAL DISTILLATION

Fractions: groups of compounds with similar boiling points.



PETROLEUM GASES	bottled gas
PETROL	car fuel
PARAFFIN	jet fuel
DIESEL	truck, bus fuel
LIGHT OIL	lubricants
FUEL OIL	heating fuel
WAX	candles
BITUMEN	roads

Three main kinds of use:

1 **Fuels**
React exothermically

2 **For physical properties**
Viscous, waxy, tarry

3 **Source of petrochemicals**
Can be decomposed

Going down the column:
- b.p.s increase, compounds become less volatile
- viscosity increases
- colour darkens
- molecules get bigger
- fractions burn less easily

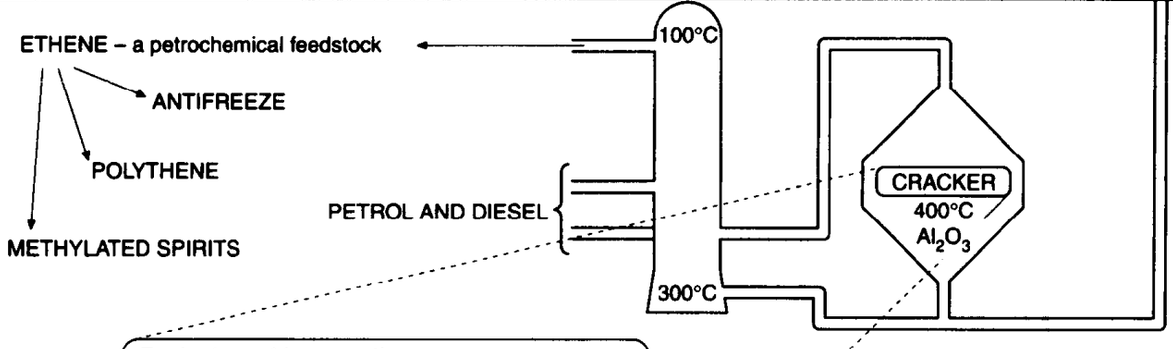
SUPPLY/DEMAND MISMATCH PROBLEM

The demand for petrol and diesel is high and there is not a high enough proportion of these fractions in crude oil.

The demand for fuel oil is low and there is more than enough of this fraction in crude oil.

So the supply of fractions does not match the demand for them.

So fuel oil is cracked to meet demand.



Typical cracking reaction

$C_{14}H_{30} \longrightarrow C_{12}H_{26} + C_2H_4$

fuel oil → diesel + ethene

750–900°C
for between 0.1 and 0.4 seconds

CHEMICAL DECOMPOSITION OF COMPOUNDS: CRACKING

The mismatch problem is solved by decomposing some of the fuel oil to make more petrol or diesel. This is called cracking.

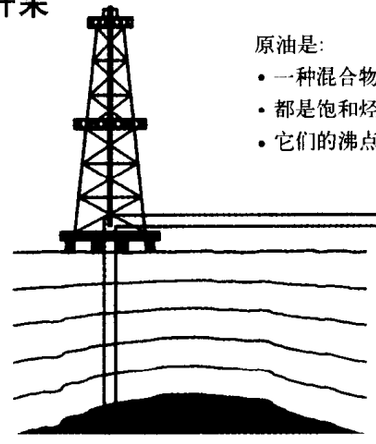
The large molecules are broken down or cracked:
- either by heat: **thermal cracking**
- or by catalyst and heat: **catalytic cracking**

Cracking also has the benefit of making reactive, unsaturated compounds with double bonds.

These compounds are important **petrochemical feedstocks**. This means other useful substances can be made from them.

来自原油的化学品

开采

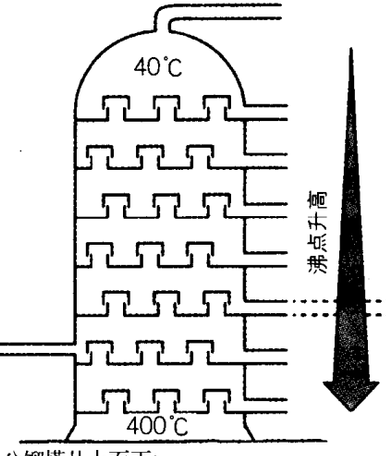


原油是:
- 一种混合物
- 都是饱和烃
- 它们的沸点很接近

原油或石油:
- **是一种化石燃料**——海洋有机物的残骸
- **是一种不能再生的资源**——但新的储存不断地被发现

用物理方法分离混合物——分馏

馏分: 有相同沸点的一组化合物。



石油气	瓶装天然气
汽油	汽车燃油
煤油	喷气飞机燃油
柴油	载重汽车、大客车燃油
轻油	润滑油
燃油	加热燃油
蜡	蜡烛
沥青	铺路

三种主要用途:
1. **燃油** 放热反应
2. **物理性质** 粘性，蜡质，柏油状
3. **石油化工的原料** 可以被分解

分馏塔从上而下:
- 沸点增加，化合物变得不易挥发
- 粘性增加
- 颜色加深
- 分子变大
- 馏分较不易燃烧

供需矛盾

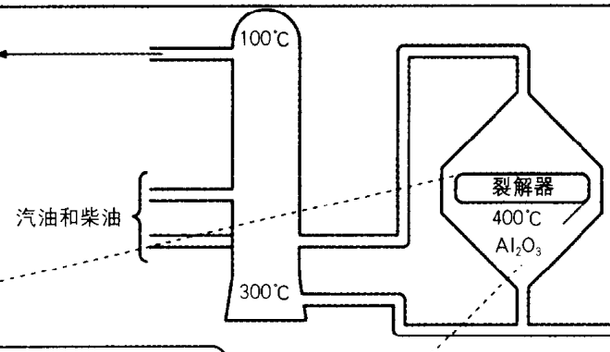
汽油和柴油需求量很大，但原油的馏分中，这两种馏分的比例不是很高。

对燃油的需求却很低，而在原油里这种馏分的比例却很高。

因此，馏分的组成无法满足实际需求。

所以，要将燃油**裂解**以满足需求。

乙烯 – 石油化工原料
- 防冻剂
- 聚乙烯
- 甲醇变性酒精



典型的裂解反应

$C_{14}H_{30} \longrightarrow C_{12}H_{26}+C_2H_4$

燃油　750–900°C 在 0.1 ~ 0.4 秒间　柴油　乙烯

用化学方法分解化合物: 裂解

通过分解一些燃油，以制取更多的汽油和柴油来解决供需矛盾。这种分解方法叫裂解。

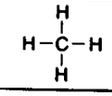
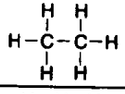
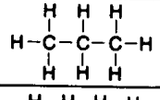
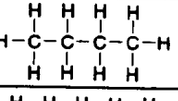
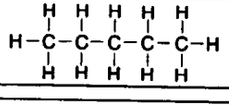
大分子被打开或断裂
- 或是采用加热的方法: **热裂解**
- 或是采用催化加热的方法: **催化裂解**

裂解还有一个好处，就是能制取较活泼的不饱和的含双键的化合物。

这些化合物是重要的**石油化工原料**，它表示，其他一些有用的物质可以从这些化合物中制取。

Alkanes

- contain only carbon and hydrogen
- contain only single covalent bonds
- have the maximum amount of hydrogen bonded to the carbon skeleton
- are described as saturated

Name	Molecular formula	Structural formula
methane	CH_4	
ethane	C_2H_6 or CH_3CH_3	
propane	C_3H_8 or $CH_3CH_2CH_3$	
butane	C_4H_{10} or $CH_3CH_2CH_2CH_3$	
pentane	C_5H_{12} or $CH_3CH_2CH_2CH_2CH_3$	

NAMING IN ORGANIC CHEMISTRY

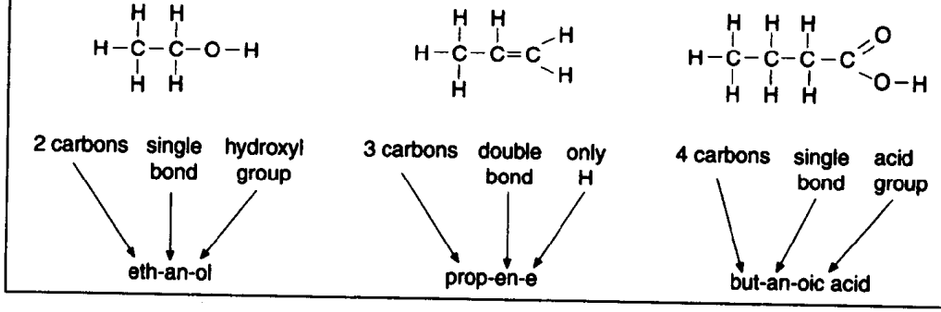
The names of compounds have three parts:

First part: gives the length of the carbon chain
1 carbon → meth-; 2 carbons → eth-; 3 carbons → prop-; 4 carbons → but-

Second part: tells whether there are any double or triple bonds in the carbon chain
all single bonds → -an-; a double bond → -en-; a triple bond -yn-

Third part (ending): tells what is joined to the carbon chain
only hydrogen → -e; a hydroxyl group → -ol; an acid group → -oic acid.

e.g.

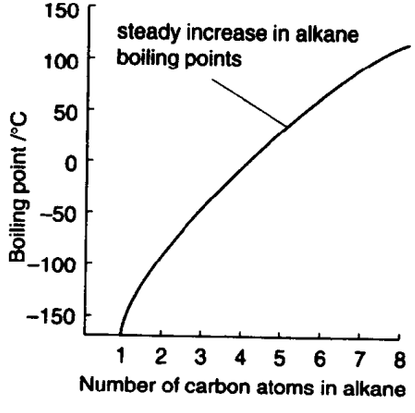


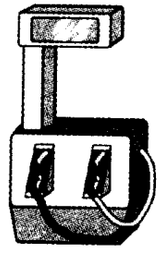
HOMOLOGOUS SERIES

The alkanes are an example of a **homologous series**.

A homologous series is a group of compounds:
1. with the same general formula – the alkanes have the formula C_nH_{2n+2} where n is the number of carbon atoms
2. each of which differs from the next by $-CH_2-$
3. which show a gradual trend in physical properties
4. which have the same chemical reactions.

All the alkanes burn in air.
e.g. $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

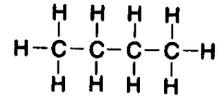




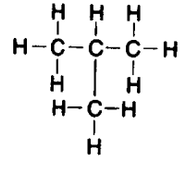
ISOMERISM

The atoms of alkanes from butane upwards can be bonded together in more than one way. This is called **isomerism**.

Isomers are molecules with the *same molecular formula but different structural formulas.*
e.g. butane C_4H_{10} can be: 1. a straight chain



2. a branched chain



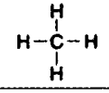
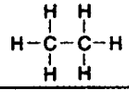
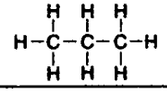
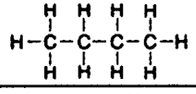
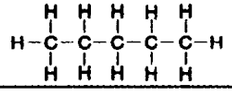
STRUCTURE AND BOILING POINTS

As the graph shows, the longer the chain of carbon atoms, the higher the boiling point. This is because longer chain molecules have bigger forces holding them together.

But the more branched the chain the lower the boiling point, because branched chains cannot pack together so tightly.

烷烃

- 只有碳和氢
- 只有单键
- 跟碳键键合的氢达到最大数量
- 是饱和的

名称	分子式	结构式
甲烷	CH_4	
乙烷	C_2H_6 或 CH_3CH_3	
丙烷	C_3H_8 或 $CH_3CH_2CH_3$	
丁烷	C_4H_{10} 或 $CH_3CH_2CH_2CH_3$	
戊烷	C_5H_{12} 或 $CH_3CH_2CH_2CH_2CH_3$	

有机化合物的命名

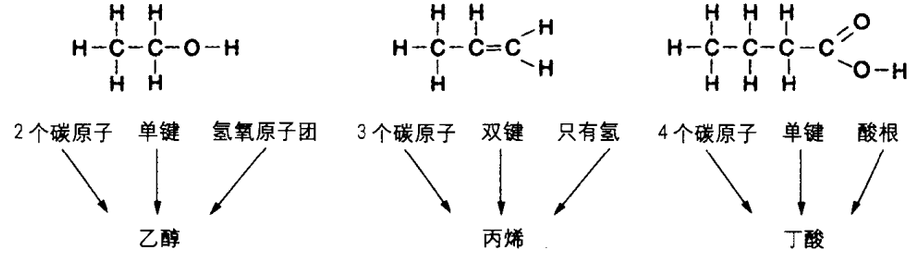
化合物的命名有三部分:

第一部分: 给出碳链的长度
1 个碳原子→甲; 2 个碳原子→乙; 3 个碳原子→丙; 4 个碳原子→丁

第二部分: 在碳链中有没有双键或三键
全部是单键→烷; 一个双键→烯; 一个三键→炔

第三部分(结尾): 在碳链上连接着什么
只有氢→烷; 一个氢氧原子团→醇; 一个酸根→羧酸

比如:



同系物

烷烃是**同系物**的一个实例。

同系物是一组化合物:

1. 有相同的通式——烷烃的通式是 C_nH_{2n+2}, n 是碳原子的数目。

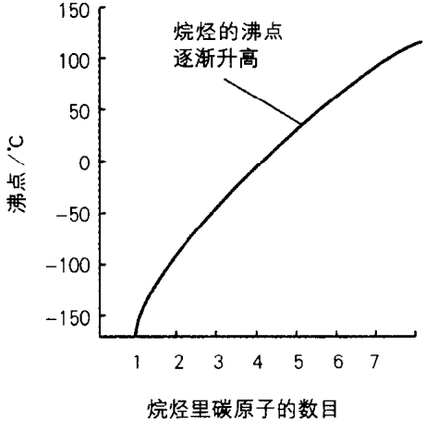
2. 其中每一种烷烃跟相邻的烷烃相差 $-CH_2-$。

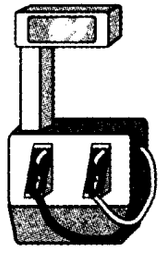
3. 在物理性质上表现出一种逐渐变化的趋势。

4. 它们有相同的化学反应。

所有的烷烃在空气中燃烧。

比如: $C_3H_8+5O_2 \rightarrow 3CO_2+4H_2O$



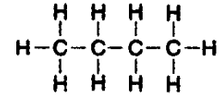


异构现象

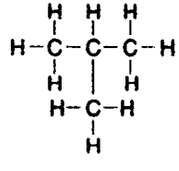
从丁烷起, 烷烃里的原子可以用多种途径键合在一起, 这就叫**异构现象**。

异构现象是指有*相同的分子式但结构式不同的分子*。

比如: 丁烷 C_4H_{10} 可以是: 1. 直链:



2. 一个支链:

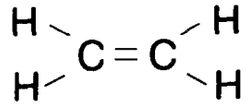


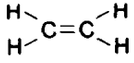
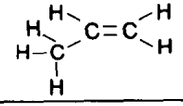
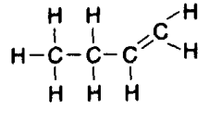
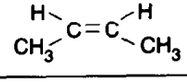
结构和沸点

如图所示, 碳链越长, 沸点越高, 因为分子链越长, 把分子聚合在一起的力就越大。支链越多, 沸点越低, 因为, 支链不能紧密地叠合在一起。

Alkenes

- contain only carbon and hydrogen
- have a double bond between two of the carbon atoms
- do not have the maximum amount of hydrogen bonded to the carbon skeleton
- are described as unsaturated



Name	Molecular formula	Structural formula
ethene	C_2H_4 or $CH_2{=}CH_2$	
propene	C_3H_6 or $CH_3CH{=}CH_2$	
butene	C_4H_8 or $CH_3CH_2CH{=}CH_2$ or $CH_3CH{=}CHCH_3$	 and 

ANOTHER HOMOLOGOUS SERIES

- general formula C_nH_{2n} where n is the number of carbon atoms
- physical properties show a steady trend as chain length increases
- more stable than alkanes when heated alone (stronger bonding)
- more reactive than alkanes when added to other substances.

OILS AND FATS

Vegetable oils and animal fats are similar compounds but with one important difference. Vegetable oils contain carbon–carbon double bonds: they are **unsaturated**. Animal fats contain only carbon–carbon single bonds: they are **saturated**.

Vegetable oils are turned into fats by reacting them with hydrogen. This makes them saturated like animal fats. The process is called **hardening**.

It is cheaper to make fat from vegetable oils in this way than to get fats from animals.

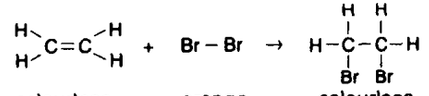
'Hardened' vegetable oils are sold as margarine.

ADDITION REACTIONS

Alkenes combine with bromine, hydrogen, water, and even themselves. These combination reactions are called **additions**.

1. Reaction with bromine

If an alkene is shaken with bromine water, the orange colour of the bromine disappears as the bromine reacts with the alkene.

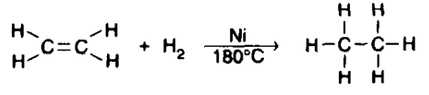


colourless orange colourless

This reaction is used to distinguish between alkanes and alkenes. If an alkane is shaken with bromine water the colour of the bromine does not go.

2. Reaction with hydrogen

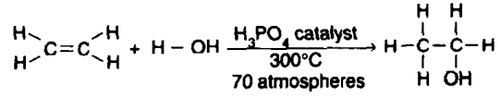
In the presence of a nickel catalyst, hydrogen adds on to an alkene making an alkane.



This reaction is important for making vegetable oil into fat.

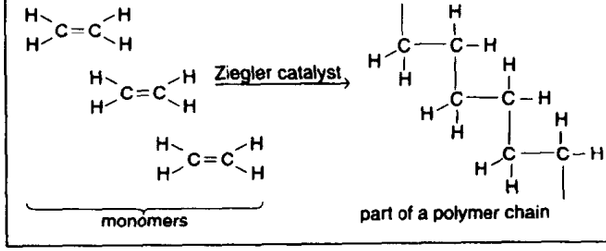
3. Reaction with water

Ethene reacts with water making ethanol (an alcohol).



4. Reaction with more ethene

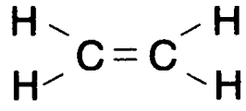
Under suitable conditions, ethene molecules react with each other, linking up to form a long chain molecule. This process is called **polymerization**. The ethene reactants are monomers; the long chain product is a polymer.

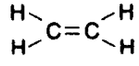
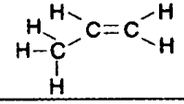
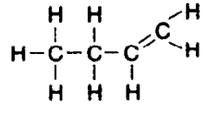
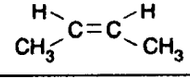


monomers part of a polymer chain

烯烃

- 只有碳和氢
- 在碳原子之间有一双键
- 跟碳链键合的氢未达到最大数量
- 是不饱和



名称	分子式	结构式
乙烯	C_2H_4 或 $CH_2=CH_2$	
丙烯	C_3H_6 或 $CH_3CH=CH_2$	
丁烯	C_4H_8 或 $CH_3CH_2CH=CH_2$ 或 $CH_3CH=CHCH_3$	 和 

另一种同系物

- 通式是 C_nH_{2n}，n 是碳原子的数目
- 随着碳链增长，物理性质表现出一种逐渐变化的趋势
- 当加热时，比烷烃更稳定（键更强）
- 当加入其他物质时，比烷烃活泼

油和脂肪

植物油和动物脂肪是相同的化合物。有一个重要的不同点，植物油有碳—碳双键，它们是**不饱和的**。动物脂肪只有碳—碳单键，它们是**饱和的**。

当跟氢反应时，植物油变成脂肪，使植物油变成像动物脂肪一样不饱和的，这一过程叫**硬化**。

用植物油制取脂肪比从动物身上得到脂肪便宜。

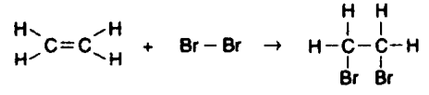
“硬化的”植物油就是商店里出售的麦淇淋。

加成反应

烯烃可以跟溴、氢、水以及烯烃自身化合。这些化合反应称为**加成反应**。

1. 跟溴反应

如果烯烃跟溴水混摇，当溴跟烯烃反应时，溴水橙色消失。

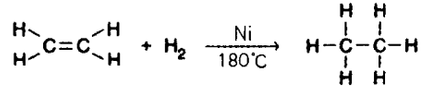


无色　　橙色　　无色

用这个反应，可以区别烷烃和烯烃，如烷烃跟溴水混摇，溴的颜色不会消失。

2. 跟氢反应

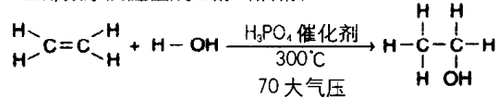
在镍催化剂存在的情况下，氢加到烯烃上生成烷烃。



这个反应是利用植物油制取脂肪的重要反应。

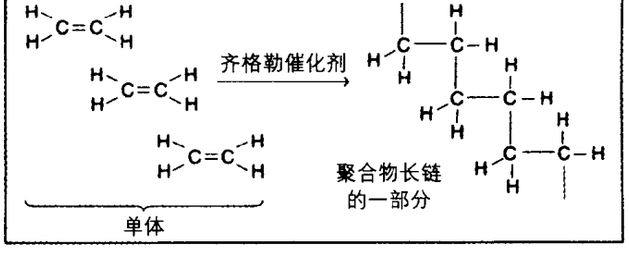
3. 跟水反应

乙烯跟水反应生成乙醇（酒精）。



4. 跟更多的乙烯反应

在合适的条件下，乙烯分子互相反应，链接起来，生成一个长长的分子链，这个过程叫做**聚合**。乙烯反应物叫单体，有长链的产物叫聚合物。



单体　　聚合物长链的一部分

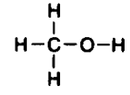
Alcohols

HOMOLOGOUS SERIES

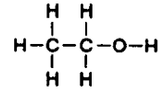
Alcohols are a homologous series with the general formula $C_nH_{2n+1}OH$.

The first three members are:

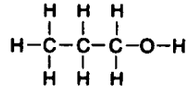
methanol CH_3OH



ethanol CH_3CH_2OH



propanol $CH_3CH_2CH_2OH$



Ethanol is the most important alcohol.

Hydrocarbon chain with an end like water

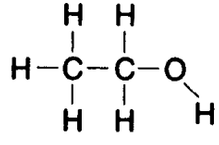
- Like water it has hydrogen bonding. So it is miscible with (soluble in) water.
- Like water it reacts with sodium giving off hydrogen:
  $2CH_3CH_2OH(l) + 2Na(s) \rightarrow 2CH_3CH_2ONa(s) + H_2(g)$

FUEL

- Like ethene, ethanol burns making carbon dioxide and water and giving out energy:
  $CH_3CH_2OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

This is **complete oxidation** or **combustion**.

ETHANOL



PARTIAL OXIDATION

In aqueous solution ethanol can be **partially oxidized** to ethanoic acid.

- In the home this happens when wine is left open to the air (the wine goes sour).
- In the lab this happens when ethanol is warmed with an oxidizing agent, e.g. potassium dichromate(VI) in dilute acid.

$$\underset{\text{ethanol}}{CH_3CH_2OH(l)} \xrightarrow{K_2Cr_2O_7/H^+} \underset{\text{ethanoic acid}}{CH_3COOH(l)}$$

INDUSTRIAL MANUFACTURE OF ETHANOL

Ethanol is made by adding water to ethene. This reaction is called **hydration** and is an *addition* reaction.

$$CH_2{=}CH_2(g) + H_2O(g) \xrightarrow[\text{70 atmospheres}]{H_3PO_4,\ 300°C} CH_3CH_2OH(l)$$

This process:

- is continuous
- produces pure ethanol
- uses finite resources (crude oil)
- produces large volumes cheaply

The alcohol produced by this method is '**methylated**' by adding methanol. This makes it undrinkable so people cannot drink industrial ethanol and avoid paying duty on the alcohol they drink.

Uses of methylated spirits

Industrial ethanol is sold as methylated spirits. It is used:

- as a fuel
- as a solvent

FERMENTATION

Alcohol for drinking is made by **fermenting** carbohydrates. This is an example of an enzyme-catalysed reaction.

$$\underset{\text{sucrose}}{C_{12}H_{22}O_{11}(s)} + H_2O(l) \xrightarrow{\text{yeast}} 2\underset{\text{glucose}}{C_6H_{12}O_6(aq)}$$

$$\underset{\text{glucose}}{C_6H_{12}O_6(aq)} \xrightarrow{\text{yeast}} 2CH_3CH_2OH(l) + 2CO_2(g)$$

This process:

- is a batch process
- produces impure alcohol
- uses renewable resources
- produces relatively small volumes
- is enzyme-catalysed anaerobic decomposition of the carbohydrate

The impurities produced give drinks like beer, wine, and whisky their own special tastes and flavours.

ALCOHOL CONTENT OF DRINKS

Spirits	~40%
Fortified wine	>17%
Wine	8–17%
Beer	~5%

Many people enjoy alcoholic drinks. But it is important to keep alcohol consumption within sensible limits, as it can have some harmful effects.

- Alcohol affects people's reaction times and co-ordination. So there is a legal limit on the amount of alcohol which may be drunk before driving.
- Alcohol can be damaging to health. Too much causes dizziness and vomiting. Over time it can damage the liver. Some people become dependent on alcohol.

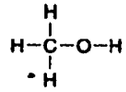
醇

同系物

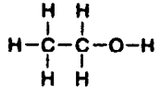
醇是通式为 $C_nH_{2n+1}OH$ 的同系物。

前三个成员是:

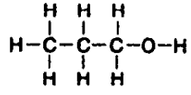
甲醇 CH_3OH



乙醇 CH_3CH_2OH



丙醇 $CH_3CH_2CH_2OH$



乙醇是最重要的醇。

碳氢链的一端跟水相似

- 像水一样，它有氢键。所以它可以跟水混溶（溶入水）
- 像水一样，跟钠反应放出氢

$2CH_3CH_2OH(l)+2Na(s) \rightarrow 2CH_3CH_2ONa(s)+H_2(g)$

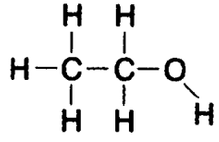
燃料

跟乙烯一样，乙醇燃烧生成二氧化碳和水，放出能量:

$CH_3CH_2OH+3O_2(g) \rightarrow 2CO_2(g)+3H_2O(l)$

这是**完全氧化**或**燃烧反应**。

乙醇



不完全氧化

在水溶液里，乙醇**不完全氧化**生成乙酸。

在家庭里，当葡萄酒敞开在空气里，就会发生这种现象（酒变酸）

在实验室里，当加热乙醇和氧化剂，比如: 在重铬酸钾的稀酸性溶液里，就会发生这种不完全氧化

$$CH_3CH_2OH(l) \xrightarrow{K_2Cr_2O_7/H^+} CH_3COOH(l)$$

乙醇　　乙酸

乙醇的工业制法

乙烯中加水生成乙醇，这个反应叫**水合**反应，是一种加成反应。

$$CH_2=CH_2(g)+H_2O(g) \xrightarrow[\substack{70\text{大气压}\\300^\circ C}]{H_3PO_4} CH_3CH_2OH(l)$$

反应过程是:

- 连续的
- 产物只有乙醇
- 采用有限的资源（原油）
- 生产量大，成本低

由于加入甲醇，用这种方法生产的乙醇是**甲基化**了的。使这种乙醇不能饮用。所以人们不能饮用工业乙醇，也不用为这种酒精付通常喝酒时要付的税。

甲基化的酒精的用途

工业乙醇作为一种替代的酒精出售，它用作:

- 燃料
- 溶剂

发酵

饮用酒里的乙醇是由碳水化合物**发酵**生成的。这是一个酶催化反应的例子。

$$C_{12}H_{22}O_{11}(s)+H_2O(l) \xrightarrow{\text{酒曲}} 2C_6H_{12}O_6(aq)$$

蔗糖

$$C_6H_{12}O_6(aq) \xrightarrow{\text{酒曲}} 2CH_3CH_2OH(l)+2CO_2(g)$$

葡萄糖

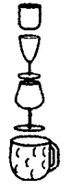
这个反应过程

- 是一个批量生产的过程
- 产品是不纯的乙醇
- 用能再生的资源
- 产量相对较小
- 碳水化合物经酶—催化厌氧分解

产生的杂质使乙醇带有啤酒、葡萄酒、威士忌等特有的味道和气味。

酒里乙醇的含量

烈性酒	~40%
掺了酒精的葡萄酒	>17%
葡萄酒	8~17%
啤酒	~5%



许多人喜欢喝酒，但是喝酒的量保持在一定的限度内非常重要，因为喝酒有危害:

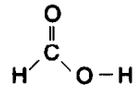
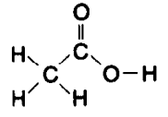
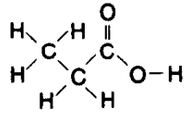
- 酒精会影响人的及时反应和协调力。因此，驾车前，酒精含量有法定限制，以防酒醉驾车
- 酒精对健康有害，饮酒过度使人头晕、呕吐。长期饮酒会损坏肝脏。有些人变得离不开酒

Carboxylic acids

HOMOLOGOUS SERIES

The carboxylic acids form a homologous series.

The first three are:

methanoic acid	CHOOH	
ethanoic acid	CH_3COOH	
propanoic acid	CH_3CH_2COOH	

MAKING ETHANOIC ACID

Ethanoic acid is made by the partial oxidation of ethanol. Compare this with the complete oxidation.

Partial oxidation

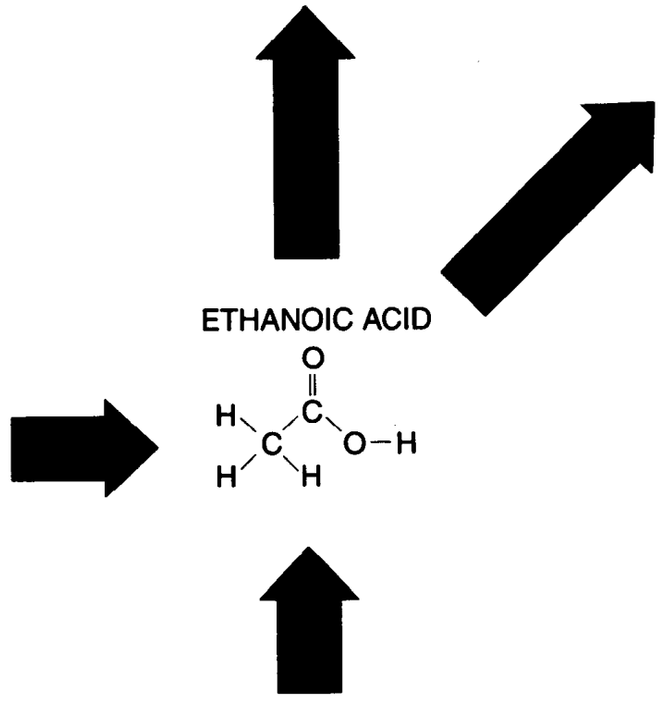
$CH_3CH_2OH(l) + 2[O] \rightarrow CH_3COOH(l) + H_2O(l)$

Complete oxidation

$CH_3CH_2OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

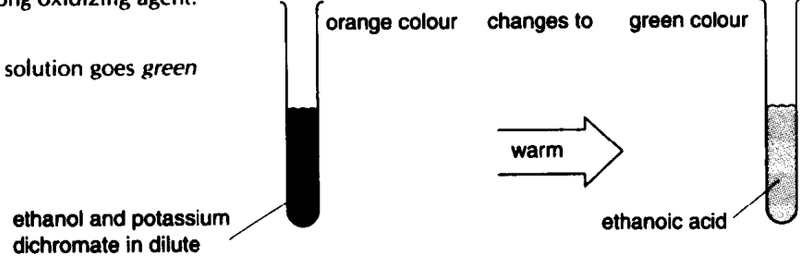
USES

- used in making textiles
- vinegar is impure ethanoic acid.



Partial oxidation is performed in solution in a test tube or beaker. The oxygen for the oxidation is supplied by acidified potassium dichromate(VI), which is a strong oxidizing agent. The reaction is slow unless it is heated.

Potassium dichromate(VI) is orange. The solution goes *green* during the reaction.



TYPICAL REACTIONS

1. With water

Carboxylic acids react with water forming hydrogen ions. They are *weak acids*, so they only form a few ions; most of the molecules remain as molecules.

e.g. $CH_3COOH(l) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$

99.9% molecules 0.1% ions

So the dissociation of the acid in water is incomplete.

2. With universal indicator

Carboxylic acids change the colour of universal indicator. They are weak acids so the indicator goes *orange*. (With strong acids the indicator goes red.)

3. With reactive metals

Carboxylic acids react with reactive metals like magnesium:

$Mg(s) + 2CH_3COOH(aq) \rightarrow Mg(CH_3COO)_2(aq) + H_2(g)$

4. With bases

Carboxylic acids are neutralized by bases such as sodium hydroxide or sodium carbonate:

$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$

$2CH_3COOH(aq) + Na_2CO_3(aq) \rightarrow 2CH_3COONa(aq) + CO_2(g) + H_2O(l)$

5. With alcohols

Carboxylic acids react with alcohols. A molecule of acid reacts with a molecule of alcohol, splitting out water and making a substance called an **ester**.

$CH_3COOH(l) + HOCH_2CH_3(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l)$

acid + alcohol ester + water

This reaction is *reversible* and *very slow*. It is catalysed by concentrated sulphuric acid.

Esters have fruity smells and flavours. They are used in the food industry.

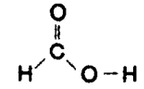
羧酸

同系物

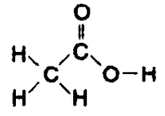
羧酸形成一组同系物。

前三个是:

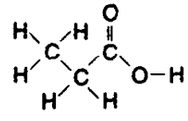
甲酸 CHOOH



乙酸 CH_3COOH



丙酸 CH_3CH_2COOH



制取乙酸

乙酸由乙醇不完全氧化制得。请跟完全氧化相比较。

不完全氧化

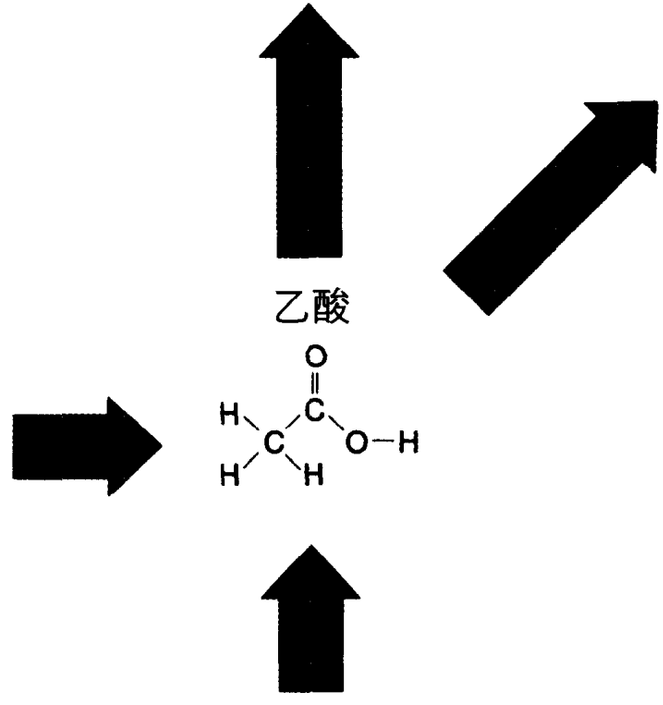
$CH_3CH_2OH(l)+2[O] \rightarrow CH_3COOH(l)+H_2O(l)$

完全氧化

$CH_3CH_2OH(l)+2O_2(g) \rightarrow 2CO_2(g)+3H_2O(l)$

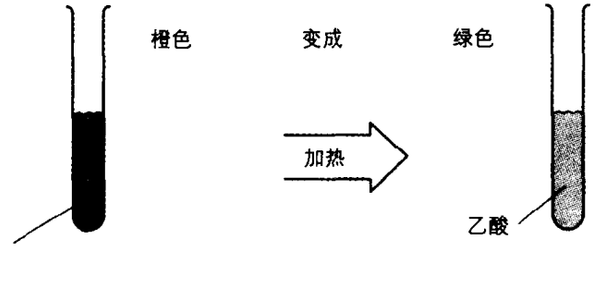
用途

- 用来制取纺织品
- 醋就是不纯的乙酸



在一个试管或烧瓶的溶液里演示**不完全氧化**。氧化用的氧是由酸化的重铬酸钾提供的。它是一种强氧化剂。如果不加热，反应很慢。

重铬酸钾是橙色的，反应过程中，溶液变成绿色。



典型反应

1. 跟水

羧酸跟水反应生成氢离子。它们是弱酸，所以只生成少量离子，大多数以分子形式存在。

比如: $CH_3COOH(l)+2H_2O \rightleftharpoons CH_3COO^-(aq)+H^+(aq)$

99.9%分子　　0.1%离子

所以，酸在水里的离解是不完全的

2. 跟通用试剂

羧酸能使通用试剂的颜色发生变化。它们是弱酸，所以指示剂变成橙色（遇强酸指示剂变成红色）。

3. 跟活泼金属

羧酸跟活泼金属，比如镁反应:

$Mg(s)+2CH_3COOH(aq) \rightarrow Mg(CH_3COO)_2(aq)+H_2(g)$

4. 跟碱

羧酸被碱，比如氢氧化钾或碳酸钠中和:

$CH_3COOH(aq)+NaOH(aq) \rightarrow CH_3COONa(aq)+H_2O(l)$

$2CH_3COOH(aq)+Na_2CO_3(aq) \rightarrow 2CH_3COONa(aq)+CO_2(g)+H_2O(l)$

5. 跟醇

羧酸跟醇反应，一个酸分子跟一个醇分子反应，分裂出水，并生成一种叫**酯**的物质。

$CH_3CO\overline{OH}(l)+H\overline{OCH_2CH_3}(l) \rightleftharpoons CH_3COOCH_2CH_3(l)+H_2O(l)$

酸 + 醇　　酯 + 水

这个反应是可逆的，且很慢，用浓硫酸催化。

酯有水果香味，它们用在食品工业中。

NATURAL POLYMERS

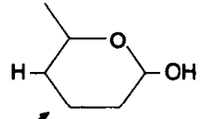
Plants take in small molecules and build large molecules from them. Animals take in large molecules (by eating plants or other animals), break them down by digestion, then build new large molecules from them.

Carbohydrates

Glucose is made by photosynthesis:

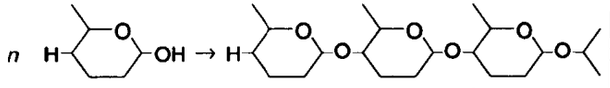
$$6\,CO_{2(g)} + 6\,H_2O_{(2)} \rightarrow 6\,O_{2(g)} + C_6H_{12}O_6$$

or



glucose

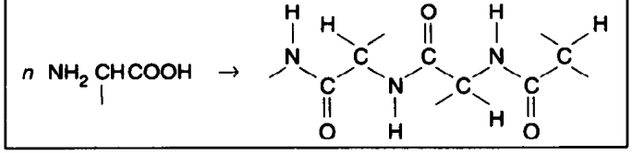
Glucose is then linked to make starch or cellulose:



starch

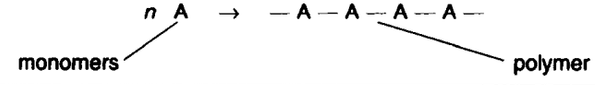
Proteins

Amino acids link up to make **proteins**:



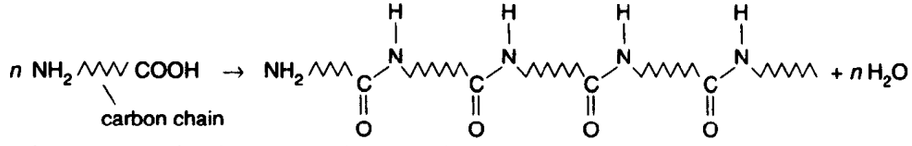
Polymers

These are very large, usually long-chain molecules made by linking together huge numbers of small molecules called **monomers**.



CONDENSATION POLYMERS

This group of polymers is made by linking up molecules which are reactive at each end, such as amino acids:



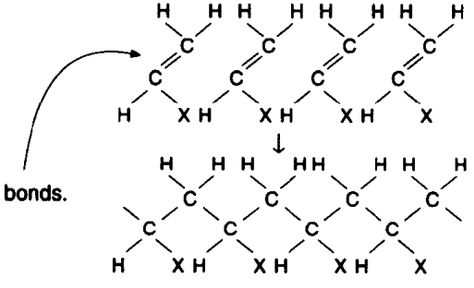
Each time two molecules join together, a small molecule (often water) is also formed as atoms are pushed out to make room for new bonds. This water condenses on the walls of the reaction vessel, so these are called **condensation polymers**.

Nylon and **polyester** are examples of condensation polymers.

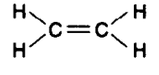
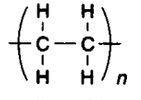
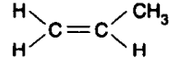
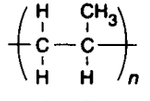
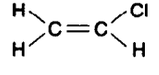
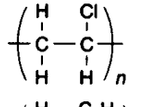
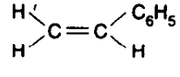
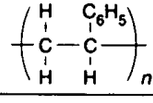
ADDITION POLYMERS

Chemists have imitated nature by linking together small molecules to make new materials.

Addition polymers are made from *unsaturated* monomers.



double bond is made into two single bonds.

MONOMER		POLYMER	
	ethene		polythene – poly(ethene) – used for bags, sheets, bottles
	propene		polypropene used for crates, ropes
	vinyl chloride (chloroethene)		polyvinylchloride(PVC) used for coats, hoses, bottles
	styrene		polystyrene used for foams, electrical insulation

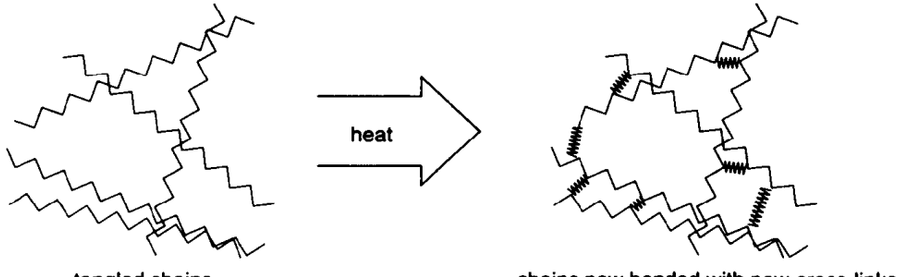
THERMOSOFTENING AND THERMOSETTING POLYMERS

Thermosoftening plastics

Some polymers (e.g. polythene, nylon) soften when heated and harden when cooled. This process can be repeated as often as needed. These are called **thermosoftening** plastics.

Thermosets or thermosetting plastics

Other polymers soften when heated but then new bonds form between the chains and the polymer hardens permanently. It will not soften again. These are called **thermosetting** polymers.



天然聚合物

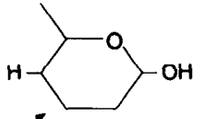
植物吸收小分子、用小分子构成大分子。动物吸收大分子（吃植物或其他动物），通过消化，打碎这些大分子，然后构成新的大分子。

碳水化合物

葡萄糖是通过光合作用得到的:

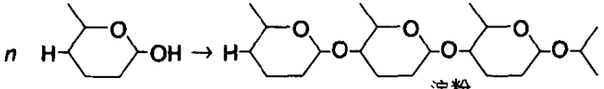
$$6CO_{2(g)}+6H_2O_{(2)} \rightarrow 6O_{2(g)}+C_6H_{12}O_6$$

或



葡萄糖

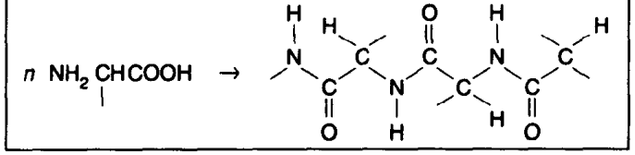
葡萄糖然后链接起来生成淀粉和纤维素:



淀粉

蛋白质

氨基酸链接起来生成**蛋白质**:

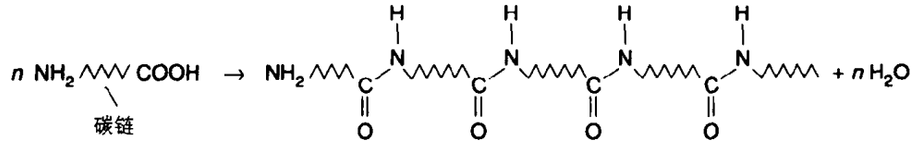


聚合物

它们是很大的分子，通常有很长的链，由大量的叫做**单体**的小分子链接在一起形成的。

缩聚物

这类聚合物是由许多分子，由它们分子端头反应活性较大的部分互相链接生成的。比如氨基酸:

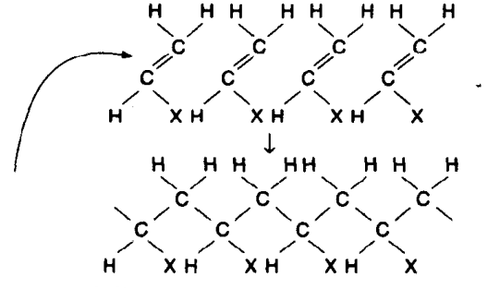


每次，两个分子结合在一起，当原子被挤出，以留出空间形成新键时，同时还生成一个小分子（通常是水）。水凝结在容器壁上，所以生成物叫**缩聚物**。

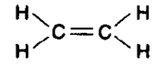
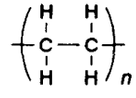
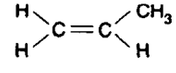
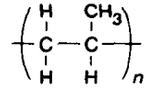
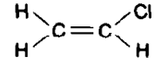
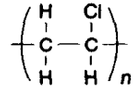
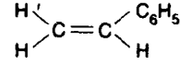
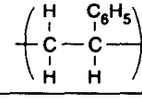
尼龙和**聚酯**是缩聚物的实例。

加聚物

化学家效法天然聚合物，通过把小分子链接起来制成新的物质。加聚物由不饱和的单体制成。



双键变成两个单键

单体		聚合物	
	乙烯		聚乙烯，用来做塑料袋、布、瓶
	丙烯		聚丙烯，用来做箱子、绳子
	氯乙烯		聚氯乙烯（PVC）用来做衣服、袜子、瓶子
	苯乙烯		聚苯乙烯，用来做泡沫塑料、绝缘体

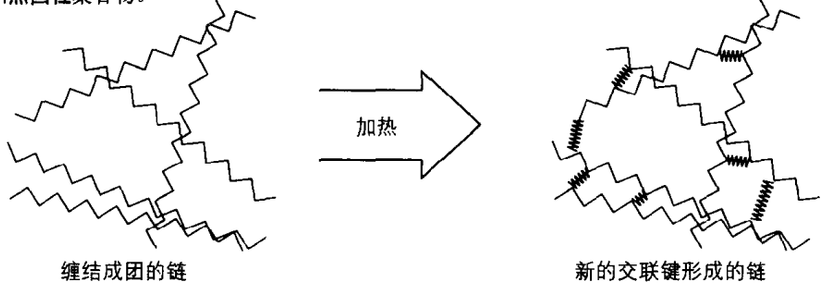
热塑性和热固性聚合物

热塑性塑料

有些聚合物（比如：聚酯、尼龙），当加热时会软化，冷却时会硬化，只要需要，这个过程可以反复进行。它们叫**热塑性**塑料。

热固性塑料

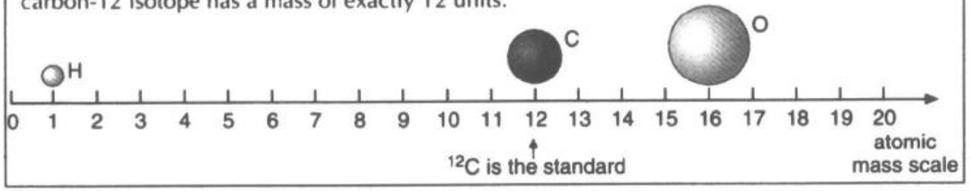
有些聚合物加热时会软化，但是链之间形成了新键，聚合物就永久硬化，它不会再软化。它们叫**热固性**聚合物。



Relative masses and moles

MASS NUMBER

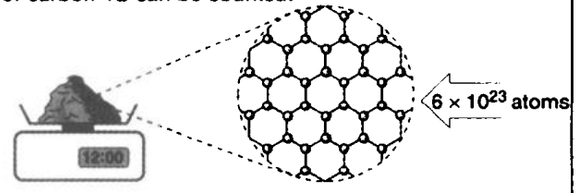
These are the masses of atoms compared to each other expressed on a scale on which the carbon-12 isotope has a mass of exactly 12 units.



AVOGADRO NUMBER OR AVOGADRO CONSTANT

The number of atoms in exactly 12 g of carbon-12 can be counted.

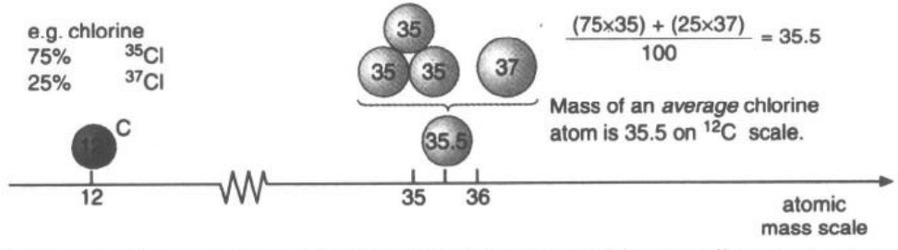
The **Avogadro number** is the number of atoms in exactly 12 g of the isotope ^{12}C. It is found to be $\mathbf{6 \times 10^{23}}$.



NATURALLY OCCURRING ELEMENTS AND RELATIVE ATOMIC MASS

All naturally occurring elements are mixtures of isotopes.

e.g. chlorine
75% ^{35}Cl
25% ^{37}Cl



$$\frac{(75\times35) + (25\times37)}{100} = 35.5$$

Mass of an *average* chlorine atom is 35.5 on ^{12}C scale.

Relative atomic mass is the weighted average of the masses of the naturally occurring isotopes of an element on the ^{12}C scale. These values are usually rounded off to the nearest whole number. Symbol A_r.

THE MOLE

Chemists measure the **amount** of any substance in moles.

A **mole** of any substance is the amount which contains the same number of particles of the substance as there are atoms in 12 g of ^{12}C.

i.e. it is the Avogadro number of particles of that substance.

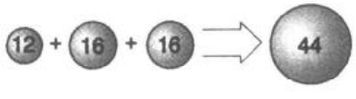
Amount	1 mole of carbon	1 mole of magnesium	1 mole of water
	contains	contains	contains
Number	6×10^{23} carbon atoms	6×10^{23} magnesium atoms	6×10^{23} water molecules
	have mass	have mass	have mass
Mass	12 g of carbon	24 g of magnesium	18 g of water

The mass of 1 mole (the **molar mass**) is the same as the *formula mass in grams.*

RELATIVE FORMULA MASS AND PERCENTAGE COMPOSITION

The relative formula mass is the sum of the relative atomic masses in the formula. Symbol M_r.

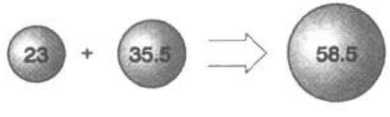
e.g. carbon dioxide, CO_2



% Composition

$$\%\ C = \frac{12}{44} \times 100 = 27.3\%$$

e.g. sodium chloride, NaCl



$$\%\ O = \frac{16 + 16}{44} \times 100 = 72.7\%$$

i.e. $\dfrac{\text{mass of element}}{\text{total mass}} \times 100$

KEY RELATIONSHIP

$$\text{Amount of substance in moles} = \frac{\text{mass of substance in g}}{\text{mass of 1 mole in g}}$$

相对质量和摩尔

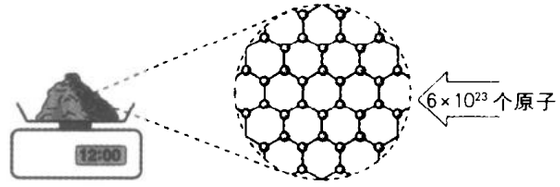
质量数

这些是原子的质量，它们是以碳-12同位素为12个质量单位作为基准，互相比较而得出的。

阿伏加得罗数或阿伏加得罗常数

12 克碳—12 里所含的原子数。

阿伏加得罗数正好是12克^{12}C同位素里原子的数目。它是 6×10^{23} 个。



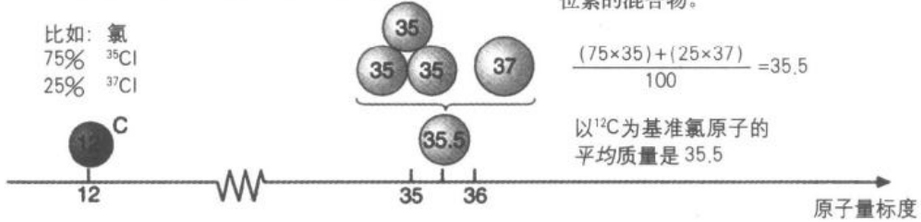
天然存在的元素和相对原子量

所有天然存在的元素都是它们同位素的混合物。

比如：氯
75% ^{35}Cl
25% ^{37}Cl

$$\frac{(75\times35)+(25\times37)}{100}=35.5$$

以^{12}C为基准氯原子的平均质量是 35.5



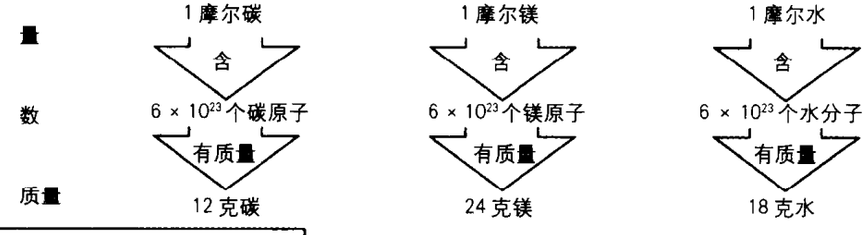
相对原子量是一种元素天然存在的同位素以^{12}C作为基准测得的平均质量。这些数值通常用舍入法凑成最接近的整数，用 Ar 表示。

摩尔

化学家用摩尔计算任何物质的量。

一**摩尔**任何物质所含的物质粒子数跟 12 克^{12}C 所含的原子数相同。

也就是说，那种物质的粒子数就是阿伏加得罗数。

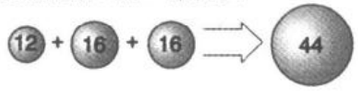


1 摩尔质量（**摩尔质量**）跟用克表示的*分子量相等*。

相对分子量和百分组成

相对分子量是分子式里相对原子量的总合。用 Mr 来表示。

比如：二氧化碳，CO_2



比如：氯化钠，NaCl

百分组成

$$\%C=\frac{12}{44}\times100=27.3\%$$

$$\%O=\frac{16\ 16}{44}\times100=72.7\%$$

就是：$\frac{\text{元素质量}}{\text{总质量}}\times100$

重要关系

$$\text{物质的量（摩尔）}=\frac{\text{物质的质量（克）}}{\text{摩尔质量（克）}}$$

Using moles

CHANGING MOLES TO MASS

Key relationship

number of moles × molar mass = mass in g

N.B. **A mole of oxygen** can mean two things. It can mean
- 1 mole of oxygen atoms which weighs 16 g or
- 1 mole of oxygen molecules which weighs 32 g.

So *always say what particles you are referring to.*

WORKED EXAMPLES

What is the mass of 1.5 moles of magnesium?

$1.5 \times 24 = 36$ g

What is the mass of 0.75 moles of copper(II) oxide?

$0.75 \times (64 + 16) = 0.75 \times 80 = 60$ g

CHANGING MASS TO MOLES

Key relationship

$$\frac{\text{mass in grams}}{\text{molar mass}} = \text{number of moles}$$

WORKED EXAMPLES

How many moles in 10 g of calcium?

$\frac{10}{40} = 0.25$ mol

How many moles in 10 g of calcium carbonate, $CaCO_3$?

$\frac{10}{40 + 12 + (16 \times 3)} = \frac{10}{100} = 0.1$ mol

FINDING FORMULAS FROM PERCENTAGE COMPOSITION FIGURES

Use the relationship above to work out the relative number of moles of each element. Then work out the ratio of moles of each element. This formula, which only gives you the *whole number ratio* of atoms is called the **empirical formula**.

To work out the *actual* number of atoms in the molecule (the **molecular formula**), you also have to know the relative formula mass.

Process

1. Assume you have 100g and turn % figures into grams.
2. Convert these masses into moles.
3. Divide these figures by the smallest to get formula.

WORKED EXAMPLES

What is the empirical formula of a hydrocarbon which is 85.7% carbon and 14.3 % hydrogen? Its relative molar mass is 42. What is its molecular formula?

Assume you have 100 g of the hydrocarbon.

The masses are:

carbon 85.7 g hydrogen 14.3 g

The moles are:

carbon 85.7/12 = 7.14 mol hydrogen 14.3/1 = 14.3 mol

The simplest ratio of moles is found by dividing by the smallest:

7.14/7.14 = 1 14.3/7.14 = 2

so the empirical formula is C_1H_2.

The formula mass of $C_1H_2 = 12 + 2 = 14$.

The formula mass of the hydrocarbon is 42 which = 3 × empirical formula mass,

so the molecular formula is C_3H_6.

A compound has the percentage composition: sodium 29.1%; sulphur 40.5 %; oxygen 30.4%. Its relative formula mass is 158. What is its formula?

	Na	S	O
% composition	29.1	40.5	30.4

Assume you have 100 g of the compound.

The masses are:

29.1 g	40.5 g	30.4 g

The moles are:

29.1/23 = 1.27 mol	40.5/32 = 1.27 mol	30.4/16 = 1.9 mol

Divided by the smaller number :

1.27/1.27 = 1	:	1.27/1.27 = 1	:	1.9/1.27 = 1.5

There must be whole numbers of atoms, so this becomes

2 : 2 : 3

The empirical formula is $Na_2S_2O_3$. This has a formula mass of 158 so the molecular formula is also $Na_2S_2O_3$.

摩尔的应用

从摩尔到质量

重要的关系

摩尔数 × 摩尔质量 = 质量(g)

注意：**1 摩尔氧**表示两个意思。它表示
- 1 摩尔氧原子重 16 克
- 1 摩尔氧分子重 32 克。

所以必须指出你讲的是什么粒子。

实例

1.5 摩尔镁的质量是多少？

$1.5 \times 24=36g$

0.75 摩尔氧化铜的质量是多少？

$0.75 \times (64+16)=0.75 \times 80=60g$

从质量到摩尔数

重要的关系

$$\frac{\text{质量（克）}}{\text{摩尔质量}} = \text{摩尔数}$$

实例

10 克钙里有几摩尔钙？

$$\frac{10}{40}=0.25mol$$

10 克硫酸钙是几摩尔？

$$\frac{10}{40+12+(16\times3)}=\frac{10}{100}=0.1mol$$

从百分组成数据写出分子式

利用上述关系，可以求出每种元素的相对摩尔数。然后算出每种元素的摩尔数比。这个化学式，仅给出全部的原子比例数，所以叫**经验式**。

要求出在分子（**分子式**）里实际的原子数，你还需知道相对分子量。

方法如下：

1. 假如你有 100 克，然后把百分数转化成克数。
2. 把这种质量变成摩尔数。
3. 把这些数约到最小，得到分子式。

实例

一种碳氢化合物含 85.7% 碳，14.3% 氢，求它的经验式。它的相对摩尔质量是 42，求它的分子式。

假设你有 100 克这种碳氢化合物。

质量是:

碳 85.7 克　　氢 14.3 克

摩尔数是:

碳 85.7/12 =7.14mol　　氢 14.3/1 =14.3mol

用约分求得最简摩尔比:

7.14/7.14=1　　14.3/7.14=2

因此，经验式是 C_1H_2。

式量是 C_1H_2=12+2=14

碳氢化合物的分子量是 42

它 =3 × 经验式的式量

所以分子式是 C_3H_6。

一种化合物有以下百分组成：钠 29.1%；硫 40.5%；氧 30.4%。它的相对分子量是 158，求它的分子式。

	Na	S	O
百分组成	29.1	40.5	30.4
假如你有 100 克化合物:			
质量是:	29.1g	40.5g	30.4g
摩尔数是:	29.1/23 =1.27mol	40.5/32 =1.27mol	30.4/16 =1.9mol
约简:	1.27/1.27 : 1 =1	1.27/1.27 : 1	1.9/1.27 : 1.5
原子数必须是整数，所以变成	2	: 2	: 3

经验式是 $Na_2S_2O_3$。它的式量是 158，分子式也是 $Na_2S_2O_3$。

Moles and concentrations of solutions

Concentration is a measure of how much solute is dissolved in a solvent.

Concentrations are measured in **moles per unit volume**. The unit of volume used may be the dm^3 or the litre. This is not as confusing as it seems because 1 dm^3 = 1 litre.

So **concentration = mol / dm^3** (sometimes written mol dm^{-3}) or **mol / litre** (sometimes written mol l^{-1}).

Concentration in mol / litre is sometimes known as **molarity** (written as M).

It is important to remember that:

1 dm^3 = 1000 cm^3 = 1 litre = 1000 ml which means that

concentration = mol / dm^3 = mol × 1000 / volume in cm^3

To calculate the amount of solute in solution, you need to know both the concentration and volume of the solution.

MASS AND VOLUME TO CONCENTRATION

Process

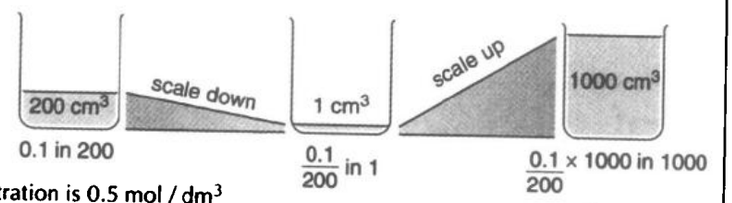
1. Calculate moles of solute
2. Scale volume to 1 dm^3

WORKED EXAMPLES

5.85 g of sodium chloride is dissolved in 200 cm^3 of water. Calculate the concentration in mol / dm^3.

5.85 g of sodium chloride is 5.85 / (23 + 35.5) = 0.1 mol

so logically:



so concentration is 0.5 mol / dm^3

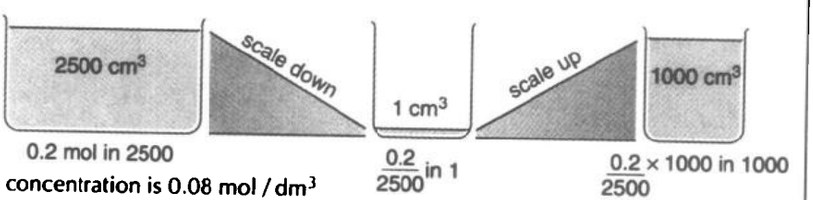
or using the equation:

$$\text{concentration} = \frac{\text{mol} \times 1000}{\text{volume in cm}^3} = \frac{0.1 \times 1000}{200} = 0.5 \text{ mol / dm}^3$$

8 g of sodium hydroxide are dissolved to make 2500 cm^3 of solution. What is the concentration?

8 g of sodium hydroxide is 8 / (23 + 16 + 1) = 0.2 mol

so logically:



so concentration is 0.08 mol / dm^3

or using the equation:

$$\text{concentration} = \frac{\text{mol} \times 1000}{\text{volume in cm}^3} = \frac{0.2 \times 1000}{2500} = 0.08 \text{ mol / dm}^3$$

CONCENTRATION AND VOLUME TO MASS

Process

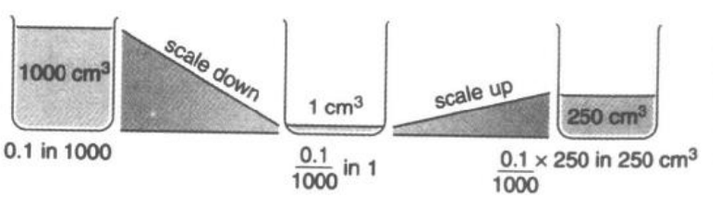
1. Write down the number of moles in 1 dm^3
2. Scale moles to the volume in the question
3. Convert from moles to mass

WORKED EXAMPLE

What mass of ammonium chloride is dissolved in 250 cm^3 of a 0.1 molar (0.1 mol / dm^3) solution?

In 1 dm^3 there is 0.1 mol

so logically:



1 mole has a mass of (14 + 4 + 35.5) = 53.5 g

0.0250 mole has mass 0.0250 × 53.5 = 1.34 g

摩尔和溶液的浓度

浓度用来量度一种溶液里溶解了多少溶质。

浓度用**单位体积里的摩尔数**来量度。体积单位是立方分米或升。它不会混淆，因为1立方分米=1升。

浓度=摩尔／立方分米（有时写成摩尔·分米$^{-3}$）或**摩尔／升**（有时写成摩尔·升$^{-1}$）。

用摩尔／升表示浓度，有时就叫**摩尔浓度**（写成M）。

必须记住：

1立方分米=1000立方厘米=1升=1000毫升 它表示

浓度=摩尔／立方分米=摩尔×1000／立方厘米（体积）。

为了计算溶液里溶质的量，你既要知道浓度还要知道溶液的体积。

从质量和体积求浓度

过程：

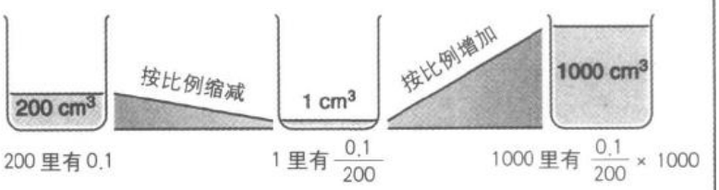
1. 计算溶质的摩尔数
2. 把体积按比例推算到1立方分米

实例

5.85克氯化钠溶解在200立方厘米水里，求溶液浓度（摩尔／立方分米）

5.85克氯化钠是5.85/(23+35.5)=0.1摩尔

因此可以推算：



所以，浓度是0.5mol/dm³

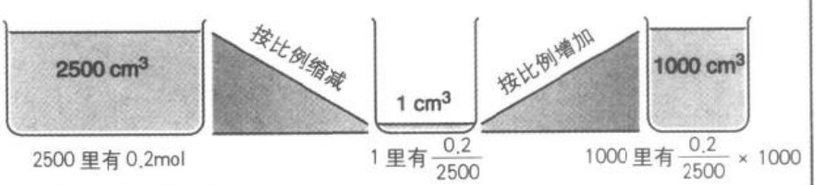
或用算式：

$$\text{浓度}=\frac{\text{摩尔}\times 1000}{\text{体积}\ (\text{cm}^3)}=\frac{0.1\times 1000}{200}=0.5\text{mol/dm}^3$$

8克氢氧化钠溶解配制2500立方厘米溶液，浓度是多少？

8克氢氧化钠是8/（23+16+1）=0.2mol

因此可以推算：



因此浓度是0.08mol/dm³

或用算式：

$$\text{浓度}=\frac{\text{摩尔}\times 1000}{\text{体积}\ (\text{cm}^3)}=\frac{0.2\times 1000}{2500}=0.08\text{mol/dm}^3$$

从浓度和体积求质量

过程：

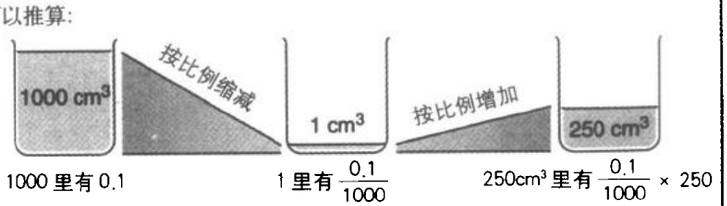
1. 写出在1立方分米体积的摩尔数
2. 根据问题，按比例算出跟体积相对应的摩尔数
3. 把摩尔数换算成质量

实例

多少克质量氯化铵溶解在250立方厘米0.1摩尔（0.1摩尔／立方分米）溶液里？

在1立方分米里有0.1摩尔

因此可以推算：



1摩尔的质量是(14+4+35.5)=53.5克

0.0250摩尔的质量是0.0250 × 53.5=1.34克

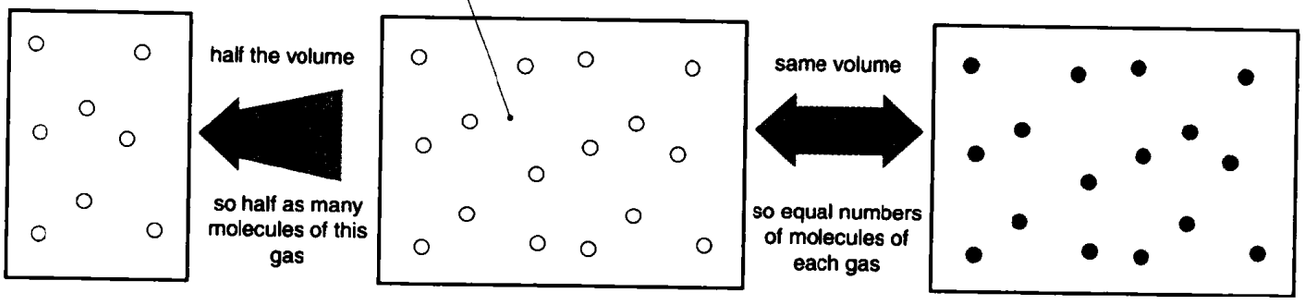
Moles and volumes of gases

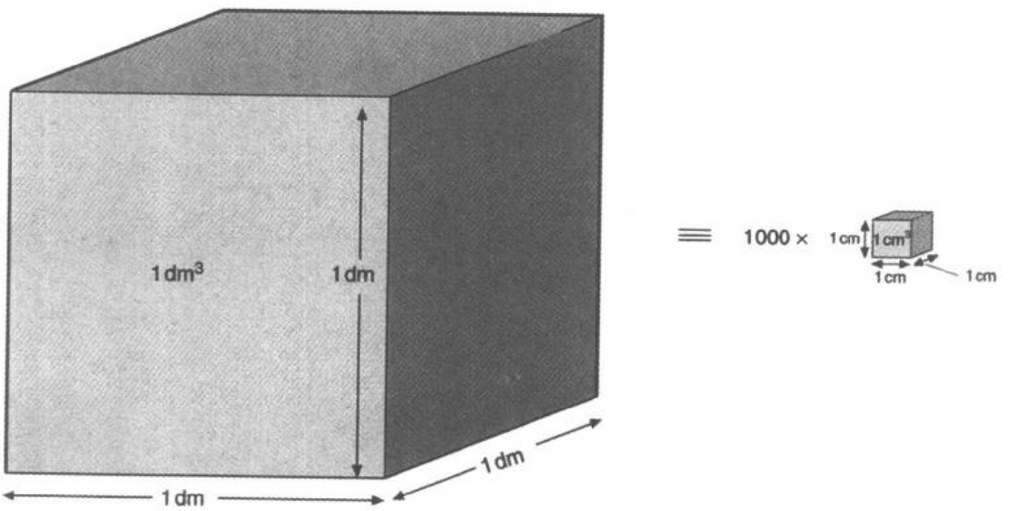
MOLAR VOLUME

Experiments show that **1 mole of any gas has a volume of 24 dm³** (24 000 cm³) **at room temperature and atmospheric pressure** (r.t.p.).

This is an application of **Avogadro's Law** which states that **equal volumes of gases under the same conditions contain equal numbers of particles.**

At **standard temperature and pressure** (s.t.p.) 1 mole of a gas has a volume of 22.4 dm³.





CHANGING VOLUMES TO MOLES

Key relationship

$$\frac{\text{Volume of the gas in dm}^3}{24} = \text{number of moles of the gas}$$

$$\frac{\text{Volume of gas in cm}^3}{24\,000} = \text{number of moles of the gas}$$

WORKED EXAMPLES

How many moles are there in 0.08 dm³ of hydrogen at r.t.p.?

0.08/24 = 0.00333 mol

How many moles in 125 cm³ of hydrogen chloride at r.t.p.?

125/24 000 = 0.00521 mol

CHANGING MOLES TO VOLUMES

Key relationship

Number of moles × 24 = volume of gas in dm³

Number of moles × 24 000 = volume of gas in cm³

WORKED EXAMPLES

What is the volume of 1.5 moles of air at r.t.p.?

1.5 × 24 = 36 dm³

What is the volume of 0.05 moles of chlorine at r.t.p.?

0.05 × 24 000 = 1200 cm³ or 1.2 dm³

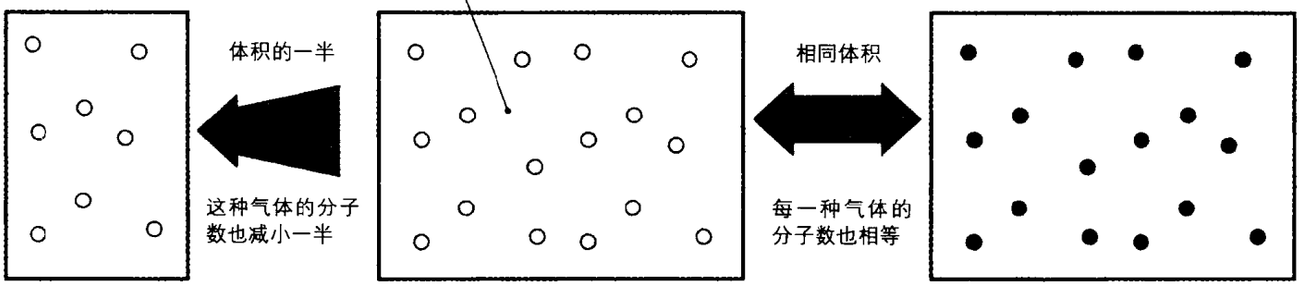
摩尔和气体体积

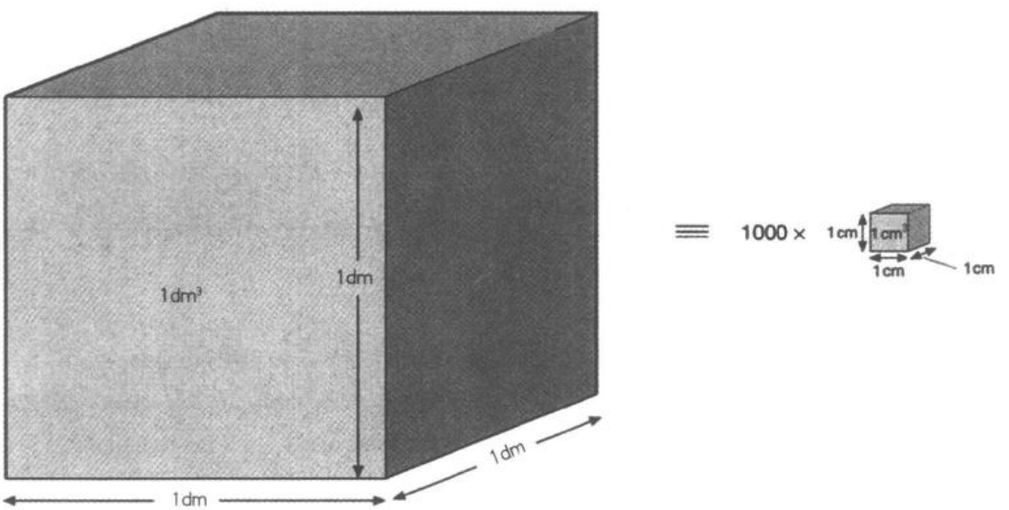
摩尔体积

实验表明：**1摩尔任何气体的体积在室温和1个大气压下**（r.t.p）**是24分米³**（24000厘米³）。

这是**阿伏加得罗定律**的应用。阿伏加得罗定律认为：**在相同条件下，在体积相等的各种气体里粒子数是相等的。**

在**标准温度和压力下**（标准状态）1摩尔气体有22.4分米³体积。





从体积求摩尔数

重要的关系

$$\frac{\text{气体体积 (dm}^3\text{)}}{24} = \text{气体的摩尔数}$$

$$\frac{\text{气体体积 (cm}^3\text{)}}{24\,000} = \text{气体的摩尔数}$$

实例

在标准状况下*，在0.08dm³氢气里有多少摩尔氢气？

0.08/24=0.00333mol

在标准状况下，在125cm³氯化氢气体里有多少摩尔氯化氢？

125/24 000=0.00521mol

从摩尔数求体积

重要的关系

摩尔数 × 24= 气体体积（dm³）

摩尔数 × 24 000= 气体体积（cm³）

实例

在标准状况下，1.5摩尔空气体积是多少？

1.5 × 24=36dm³

在标准状况下，0.05摩尔氯气体积是多少？

0.05 × 24 000=1200cm³ 或 1.2dm³

*注意，原文是r.t.p，下同。

Calculations from equations 1

In a **balanced equation** the mass of the reactants always equals the mass of the products. The equation shows matter being rearranged. Matter cannot be destroyed, so the mass of the products must be the same as the mass of the reactants.

An equation can be interpreted in two ways. For example, the equation:
$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

- can be seen as representing the particles which take part in the reaction:
  2 hydrogen molecules react with **1 oxygen molecule** to make **2 water molecules**
- or can be seen as relating the number of moles which have reacted:
  2 moles of hydrogen react with **1 mole** of oxygen to make **2 moles** of water.

Of course one equation is just a scaled up version of the other, the scale factor being the Avogadro number.

2 hydrogen molecules react with **1 oxygen molecule** to make **2 water molecules**

scale up by the Avogadro constant

scale up by the Avogadro constant

scale up by the Avogadro constant

2 moles of hydrogen react with **1 mole of oxygen** to make **2 moles of water.**

In the laboratory we think of equations in terms of moles, because we can turn moles into masses of solids (which we can weigh out) or into volumes of gases (which we can measure with a gas syringe).

So equations can be used to calculate reacting quantities.

PROCESS

1. Write out the balanced equation
2. Write out the mole ratios
3. Work out the moles of the known or given substance
4. Rewrite the mole ratio using the molar amount found in 3 above
5. Work out the moles of the unknown or wanted substance

MASS/MASS CALCULATIONS

e.g. What mass of sulphur reacts with 1.12 g of iron to make iron(II) sulphide?

1. Balanced equation — Fe(s) + S(s) → FeS(s)
2. Mole ratios — 1 mol of Fe 1 mol of S 1 mol of FeS
3. Number of moles of known substance — 1.12 g of iron is 1.12/56 = 0.02 moles of iron
   (remember that $\frac{\text{mass (g)}}{\text{formula mass}}$ = number of moles)
4. Mole ratios — 0.02 mol of Fe 0.02 mol of S 0.02 mol of FeS
5. How much unknown substance — 0.02 mol of sulphur = 0.02 × 32 = 0.62 g of sulphur

根据方程式计算 1

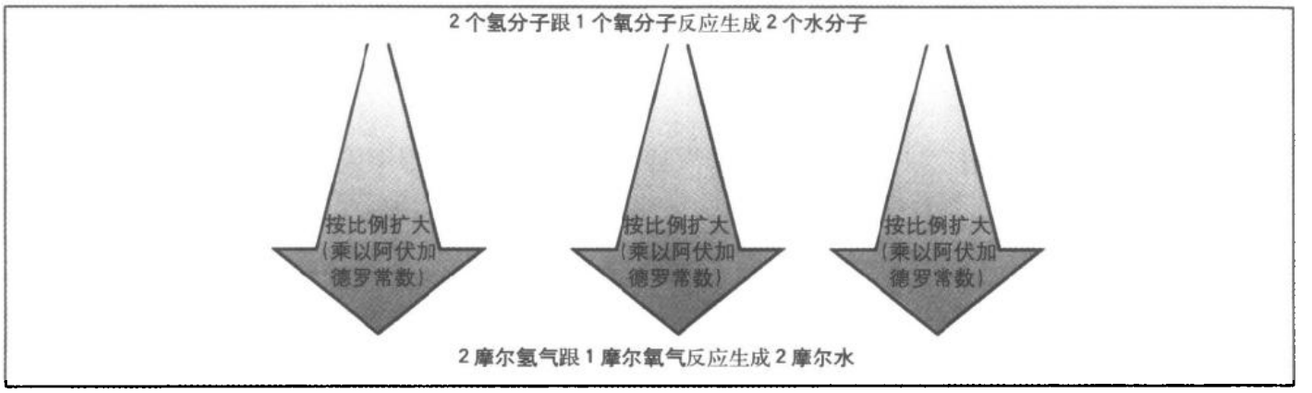
在**配平的化学方程式**里，反应物的质量总是跟生成物的质量相等。方程式表明，物质重新组合，物质不会消灭。所以产物的质量一定等于反应物的质量。

一个化学方程式可以有两种含义。比如：

$2H_2(g)+O_2(g) \rightarrow 2H_2O(l)$

- 可以理解为代表参加反应的粒子：
  2 个氢气分子跟 1 个氧气分子反应生成 **2 个水分子**。
- 也可以理解为发生反应的有关的摩尔数：
  2 摩尔氢气跟 1 摩尔氧气反应生成 2 摩尔水。

当然，同一个方程式只是由一种描述按比例增加转到另一种描述，而换算因子正是阿伏加得罗常数。



在实验室里，我们按照摩尔数来理解反应方程式。因为我们可以把摩尔数换算成固体质量（我们可以称量）或气体体积（我们用气体注射器来测量）。

因此，反应方程式可以用来计算反应量。

方法步骤：

1. 写出配平的方程式
2. 写出摩尔比
3. 算出已知的或给出的物质的摩尔数
4. 用 3 求出的摩尔数再列出摩尔比
5. 求出未知的或要求的摩尔数

质量 / 质量计算

比如：多少质量硫能跟 1.12 克铁反应生成硫化亚铁？

1. 配平方程式

$$Fe(s) + S(s) = FeS(s)$$

2. 摩尔比

1 摩尔铁　　1 摩尔硫　　1 摩尔硫化铁

3. 算出已知物质的摩尔数

1.12 克铁是 1.12/56=0.02 摩尔铁

（记住 $\frac{\text{质量（克）}}{\text{分子量}}$ = 摩尔数）

4. 摩尔比

0.02 摩尔铁　　0.02 摩尔硫　　0.02 摩尔硫化亚铁

5. 求得未知物质的克数

0.02 摩尔硫 =0.02 × 32=0.62 克硫

Calculations from equations 2

MASS/MASS CALCULATIONS

e.g. What mass of aluminium powder will burn in 1.6 g of oxygen?

1. Balanced equation

$$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$$

2. Mole ratios

4 mol of Al 3 mol of O_2 2 mol of Al_2O_3

3. Number of moles of known substance

1.6 g of oxygen is $\frac{1.6}{32} = 0.05$ mol

(remember that $\frac{\text{mass (g)}}{\text{formula mass}}$ = number of moles)

4. Mole ratios

From step 2:

	4 mol	3 mol	2 mol
so	4/3 mol	1 mol	2/3 mol
so	4/3 × 0.05 mol	0.05 mol	2/3 × 0.05 mol

5. How much unknown substance

4/3 × 0.05 mol of aluminium is 0.067 mol. This has a mass of 0.067 × 27 = 1.8 g.

MASS/VOLUME CALCULATIONS

e.g. What volume of ammonia reacts with 4 g of copper oxide?

1. Balanced equation

$$3CuO(s) + 2NH_3(g) \rightarrow 3Cu(s) + 3H_2O(g) + N_2(g)$$

2. Mole ratios

3 mol of CuO 2 mol of NH_3 3 mol of Cu 3 mol of H_2O 1 mol of N_2

3. Number of moles of known substance

4 g of copper oxide is $\frac{4}{(64 + 16)} = 0.05$ mol

(remember that $\frac{\text{mass (g)}}{\text{formula mass}}$ = number of moles)

4. Mole ratios

Step 2 gave

	3 mol	2 mol	3 mol	3 mol	1 mol
so	1 mol	2/3 mol	1 mol	1 mol	1/3 mol
so	0.05 mol	2/3 × 0.05 mol	0.05 mol	0.05 mol	1/3 × 0.05 mol

5. How much unknown substance

2/3 × 0.05 mol of ammonia has a volume of 2/3 × 0.05 × 24000 = 800 cm^3

VOLUME/VOLUME CALCULATIONS FOR GASES

e.g. What volume of oxygen is needed for the complete combustion of 50 cm^3 of propane, C_3H_8?

1. Balanced equation

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

2. Mole ratios

1 mol of C_3H_8 5 mol of O_2 3 mol of CO_2 4 mol of H_2O

3. Now remember Avogadro's law. Equal volumes of gases contain equal numbers of particles. That means that equal numbers of molecules occupy equal volumes. So we can simply convert from a mole ratio to a volume ratio.

1 volume 5 volumes 3 volumes 4 volumes

and so 50 cm^3 of C_3H_8 5 × 50 cm^3 of O_2 3 × 50 cm^3 of CO_2 4 × 50 cm^3 of H_2O

so the volume of oxygen needed is 250 cm^3.

根据方程式计算 2

质量 / 质量计算

比如：多少克铝粉能在 1.6 克氧气里燃烧？

1. 配平方程式

$$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$$

2. 摩尔比

4 摩尔铝　　3 摩尔氧气　　2 摩尔氧化铝

3. 已知物质的摩尔数

1.6 克氧气是 $\frac{1.6}{32}$ =0.05 摩尔

（记住 $\frac{\text{质量（克）}}{\text{分子量}}$ = 摩尔数）

4. 摩尔比

从第二步：

	4 摩尔	3 摩尔	2 摩尔
因此	4/3 摩尔	1 摩尔	2/3 摩尔
因此	4/3 × 0.05 摩尔	0.05 摩尔	2/3 × 0.05 摩尔

5. 求出未知物质的质量

4/3 × 0.05 摩尔铝是 0.067 摩尔，质量是 0.067 × 27=1.8 克。

质量 / 体积计算

比如：多少体积的氨可以跟 4 克氧化铜反应？

1. 配平方程式

$$3CuO(s) + 2NH_3(g) \rightarrow 3Cu(s) + 3H_2O(g) + N_2(g)$$

2. 摩尔比

3 摩尔氧化铜　2 摩尔氨　3 摩尔铜　3 摩尔水　1 摩尔氮气

3. 已知物质的摩尔数

4 克氧化铜是 $\frac{4}{(64+16)}$ =0.05 摩尔

（记住 $\frac{\text{质量（克）}}{\text{分子量}}$ = 摩尔数）

4. 摩尔比

第二步给出

	3 摩尔	2 摩尔	3 摩尔	3 摩尔	1 摩尔
因此	1 摩尔	2/3 摩尔	1 摩尔	1 摩尔	1/3 摩尔
因此	0.05 摩尔	2/3 × 0.05 摩尔	0.05 摩尔	0.05 摩尔	1/3 × 0.05 摩尔

5. 未知物是多少

2/3 × 0.05 摩尔氨的体积是 2/3 × 0.05 × 24 000=800cm^3。

（气体）体积 / 体积计算

比如：完全燃烧 50 厘米^3 丙烷 C_3H_8 要多少体积的氧气？

1. 配平方程式

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

2. 摩尔比

1 摩尔 C_3H_8　5 摩尔氧气　3 摩尔二氧化碳　4 摩尔水

3. 记住阿伏加得罗定律。体积相等的气体含有的粒子数相等。这表明，分子数相等的气体占有相同的体积。因此我们只要简单地把摩尔比转换成体积比就可以了。

	1 体积	5 体积	3 体积	4 体积
因此	50cm^3 的 C_3H_8	5 × 50cm^3 的 O_2	3 × 50cm^3 的 CO_2	4 × 50cm^3 的水

因此所需氧气的体积是 250cm^3。

Calculations from equations 3

MASS/VOLUME CALCULATIONS FOR SOLUTIONS

e.g. What volume of 2 mol / dm³ sulphuric acid is needed to react with 3 g of magnesium?

1. Balanced equation

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$$

2. Mole ratios

1 mol of Mg 1 mol of H_2SO_4 1 mol of $MgSO_4$ 1 mol of H_2

3. Number of moles of known substance

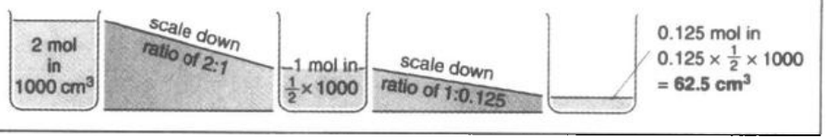
3 g of magnesium is 3/24 = 0.125 mol

(remember that $\frac{\text{mass (g)}}{\text{formula mass}}$ = number of moles)

4. Mole ratios

0.125 mol 0.125 mol 0.125 mol 0.125 mol

5. How much unknown substance



VOLUME/VOLUME CALCULATIONS FOR SOLUTIONS (USED IN TITRATIONS)

e.g. What volume of 0.15 mol / dm³ sodium carbonate solution is needed to neutralize 20 cm³ of 0.1 mol / dm³ hydrochloric acid?

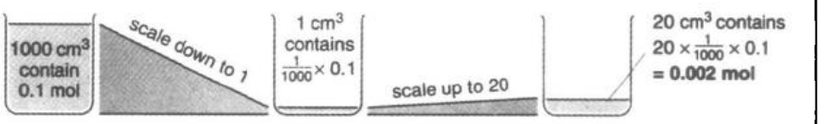
1. Balanced equation

$$2HCl(aq) + Na_2CO_3(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

2. Mole ratios

2 mol of HCl 1 mol of Na_2CO_3 2 mol of NaCl 1 mol of H_2O 1 mol of CO_2

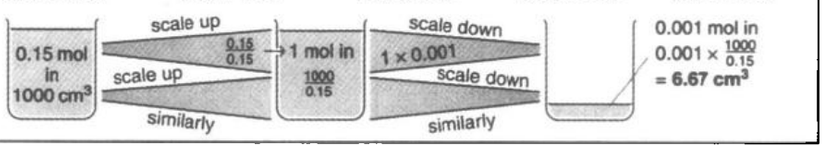
3. Number of moles of known substance



4. Mole ratios

0.002 mol 0.001 mol 0.002 mol 0.001 mol 0.001 mol

5. How much unknown substance



SAMPLE TITRATION CALCULATION

20 cm³ of sodium hydroxide was pipetted into a conical flask and titrated against 0.10 mol / dm³ sulphuric acid using methyl orange as indicator. The indicator changed colour when 15.6 cm³ of acid had been added from the burette. Calculate the concentration of the sodium hydroxide solution.

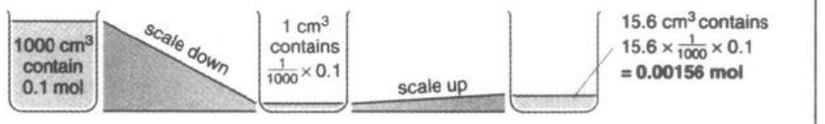
1. Balanced equation

$$H_2SO_4(aq) + 2\,NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

2. Mole ratios

1 mol of H_2SO_4 2 mol of NaOH 1 mol of Na_2SO_4 2 mol of H_2O

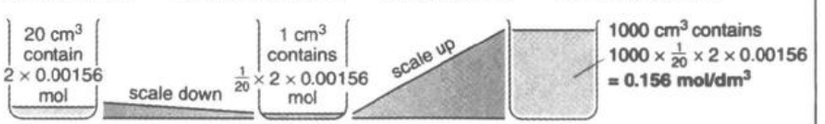
3. Number of moles of known substance



4. Mole ratios

0.00156 mol 2 × 0.00156 mol 0.00156 mol 2 × 0.00156 mol

5. How much unknown substance



根据方程式计算 3

溶液质量／体积计算

比如：跟 3 克镁反应需要多少体积 2 摩尔／分米³ 的硫酸？

1. 配平方程式

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$$

2. 摩尔比

1 摩尔镁　1 摩尔硫酸　1 摩尔硫酸镁　1 摩尔氢气

3. 已知物质的摩尔数

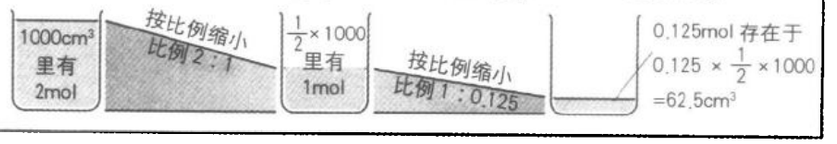
3 克镁是 $\frac{3}{24}$ =0.05 摩尔

（记住 $\frac{\text{质量（克）}}{\text{分子量}}$ = 摩尔数）

4. 摩尔比

0.125 摩尔　0.125 摩尔　0.125 摩尔　0.125 摩尔

5. 求出未知物质的质量



溶液体积／体积计算（用于滴定）

比如：中和 20 厘米³ 0.1 摩尔／分米³ 的盐酸，需要多少体积 0.1 摩尔／分米³ 的碳酸钠？

1. 配平方程式

$$2HCl(aq) + Na_2CO_3(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

2. 摩尔比

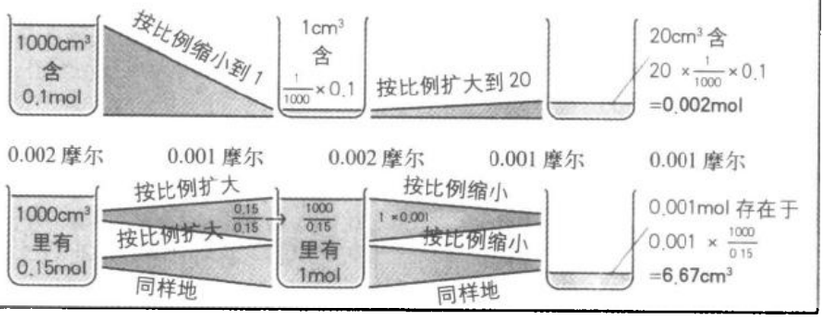
2 摩尔盐酸　1 摩尔碳酸钠　2 摩尔氯化钠　1 摩尔水　1 摩尔二氧化碳

3. 已知物质的摩尔数

4. 摩尔比

0.002 摩尔　0.001 摩尔　0.002 摩尔　0.001 摩尔　0.001 摩尔

5. 求出未知物质的质量



滴定计算实例

用移液管把 20 厘米³ 的氢氧化钠移入一个锥形瓶，并用 0.10 摩尔／分米³ 的硫酸滴定，用甲基橙作指示剂。当从滴定管滴入 15.6 厘米³ 硫酸时，指示剂变色。计算氢氧化钠溶液的浓度。

1. 配平方程式

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

2. 摩尔比

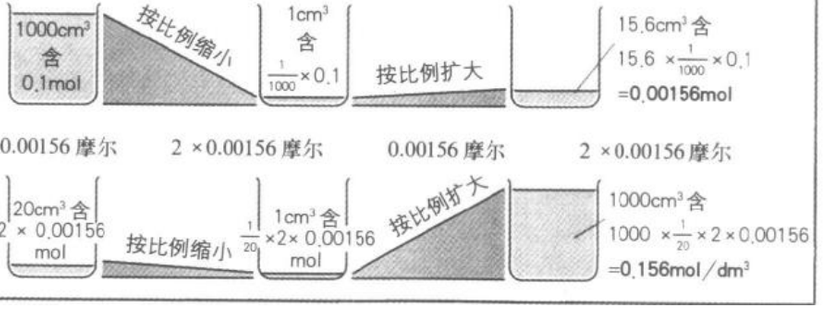
1 摩尔硫酸　2 摩尔氢氧化钠　1 摩尔硫酸钠　2 摩尔水

3. 已知物质的摩尔数

4. 摩尔比

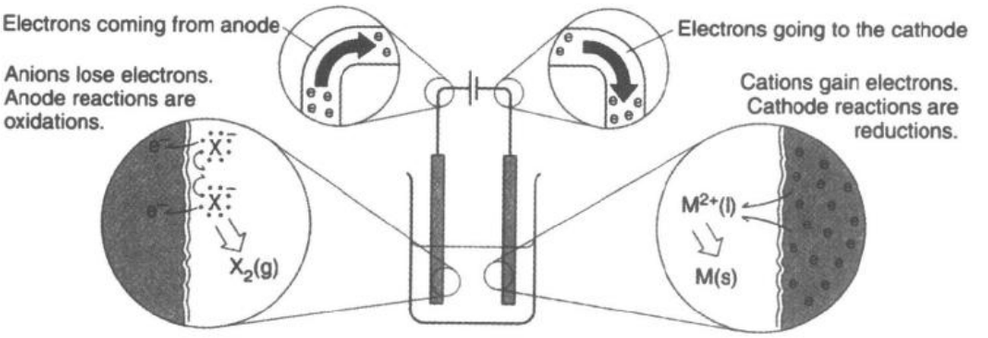
0.00156 摩尔　2 ×0.00156 摩尔　0.00156 摩尔　2 ×0.00156 摩尔

5. 求出未知物质的质量



Electrolysis calculations

ELECTROLYSIS
In electrolysis electrons are lost and gained by ions at the electrodes. These electrons are pumped round the circuit by a battery or power pack.



The amount of electrolysis depends on the number of electrons which flow round the circuit, i.e. the amount of **charge**. Charge is measured in **coulombs**. The relationship between current, time, and charge is:

amps x seconds = coulombs

The charge carried by **1 mole of electrons** is called the **Faraday**.

1 Faraday is 96 500 coulombs.

The mass of substance discharged at an electrode depends on:

- **the current flowing**
- **the time the current flows for**
- **the charge on the ion**
  Ions with a double charge need twice as many electrons to discharge them as ions with a single charge.
  $Ca^{2+} + 2e^- \rightarrow Ca$ compared with $Na^+ + 1e^- \rightarrow Na$

ELECTROLYSIS CALCULATIONS

Follow the same five steps as in other calculations from equations.

e.g. A current of 12 amps flows through molten lead bromide for 15 minutes. Calculate the masses of lead and bromine produced at the electrodes.

1. Balanced equations — **Anode:** $2Br^-(l) \rightarrow Br_2(g) + 2e^-$ **Cathode:** $Pb^{2+}(l) + 2e^- \rightarrow Pb(l)$

2. Mole ratios — 2 mol : 1 mol : 2 mol 1 mol : 2 mol : 1 mol

3. Number of moles of electrons — charge = 12 x 15 x 60 (current x time *in seconds*)
   = 10 800 coulombs
   which is 10 800/96 500 = 0.112 mol of electrons (Faraday)

4. Mole ratios — 0.112 : 0.5 x 0.112 : 0.112 0.5 x 0.112 : 0.112 : 0.5 x 0.112

5. How much unknown substance — 0.5 x 0.112 mol of bromine = 0.5 x 0.112 x 79 x 2 = 8.84 g of bromine
   0.5 x 0.112 mol of lead = 0.5 x 0.112 x 208 = 11.6 g of lead

e.g. A current of 100 000 amps is passed through the Hall cell in an aluminium plant for 1 hour. What mass of aluminium is deposited and what volume of oxygen is produced?

1. Balanced equations — **Anode:** $2O^{2-}(l) \rightarrow O_2(g) + 4e^-$ **Cathode:** $Al^{3+}(l) + 3e^- \rightarrow Al(l)$

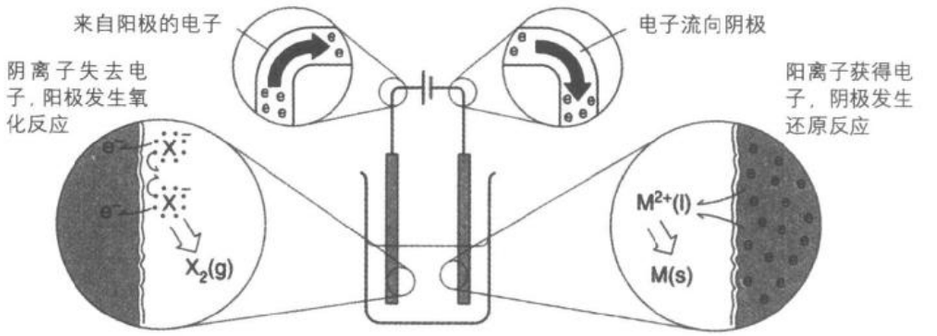
2. Mole ratios — 2 mol : 1 mol : 4 mol 1 mol : 3 mol : 1 mol

3. Number of moles of electrons — charge = 100 000 x 60 x 60 (current x time in seconds)
   = 360 000 000 coulombs
   which is 360 000 000/96 500 = 3730 mol of electrons

4. Mole ratios — 1/2 x 3730 : 1/4 x 3730 : 3730 1/3 x 3730 : 3730 : 1/3 x 3730

5. How much unknown substance — 1/4 x 3730 mol of oxygen = 1/4 x 3730 x 24 dm^3
   = 21 500 dm^3
   1/3 x 3730 mol of aluminium = 1/3 x 3730 x 27 g
   = 33 200 g
   = 33.2 kg

电解计算



电解

在电解时，在电极上离子失去或者获得电子。这些电子靠电池组或电力被送入电路。

电解的量取决于电路里流过的电子数，也就是**电量**。电量用**库仑**来计量。电流、时间和电量之间的关系是：

安培 × 秒 = 库仑

1 摩尔电子所带电荷叫**法拉第**。

1 法拉第是 96500 库仑。

一个电极上一定量物质所需电荷取决于：

- **电流（强度）**
- **通电时间**
- **离子所带电荷**

带两个单位电荷的离子放电需要的电子数是带一个电荷的离子所需电子数的两倍。

$Ca^{2+}+2e^- \rightarrow Ca$ 请比较 $Na^++1e^- \rightarrow Na$

电解计算

像其他根据方程式计算那样，同样按五个步骤计算。

比如：12 安培电流流过熔融的溴化铅 15 分钟，请计算在电极上产生铅和溴各多少？

1. 平衡方程式

阳极： $2Br^-(l) \rightarrow Br_2(g) + 2e^-$　　**阴极：** $Pb^{2+}(l) + 2e^- \rightarrow Pb(l)$

2. 摩尔比

2 摩尔　1 摩尔　2 摩尔　　1 摩尔　2 摩尔　1 摩尔

3. 电子的摩尔数

电量 =12 × 15 × 60 [电流强度 × 时间（秒）]
=10800 库仑
即：10800/96500=0.112 摩尔电子（法拉第）

4. 摩尔比

0.112　0.5 × 0.112　0.112　　0.5 × 0.112　0.112　0.5 × 0.112

5. 求未知物是多少？

0.5 × 0.112 摩尔溴 =0.5 × 0.112 × 79 × 2=8.84 克溴
0.5 × 0.112 摩尔铅 =0.5 × 0.112 × 208=1.16 克铅

比如：在铝厂里有 100 000 安培电流流过电解槽 1 个小时，问有多少质量铝沉积下来，并生成多少体积氧气？

1. 平衡方程式

阳极： $2O^{2-}(l) \rightarrow O_2(g) + 4e^-$　　**阴极：** $Al^{3+}(l)$　$3e^-$　$Al(l)$

2. 摩尔比

2 摩尔　1 摩尔　4 摩尔　　1 摩尔　3 摩尔　1 摩尔

3. 电子的摩尔数

电量 =10 000 × 60 × 60 [电流强度 × 时间（秒）]
=360 000 000 库仑
即：360 000 000/96500=3730 摩尔电子

4. 摩尔比

1/2 × 3730　1/4 × 3730　3730　　1/3 × 3730　3730　1/3 × 3730

5. 求未知物是多少？

1/4 × 3730 摩尔氧气 =1/4 × 3730 × 24dm^3
=21 500dm^3
1/3 × 3730 摩尔铝 =1/3 × 3730 × 27g
=33 200g
=33.2kg

Making salts in the laboratory

SOLUBILITY RULES FOR SALTS

- all Group 1 compounds are soluble
- all nitrates are soluble
- all chlorides are soluble except silver and lead
- all sulphates are soluble except calcium, barium, and lead
- all carbonates are insoluble except Group 1

SOLUBILITY RULES FOR BASES

- all Group 1 bases are soluble
- in Group 2, calcium and barium salts are soluble
- ammonia is soluble

SAFETY!

- follow instructions precisely
- wear safety glasses
- acids and alkalis are corrosive: handle them carefully and mop up any spills
- take care with hot objects

DECIDE IF THE SALT IS SOLUBLE USING SOLUBILITY RULES

Salt is insoluble

Salt is soluble

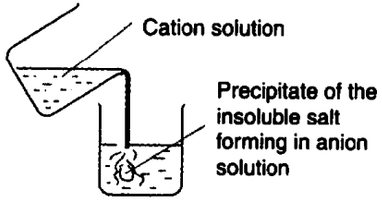
If you are adding a soluble base

If you are adding a metal or insoluble base

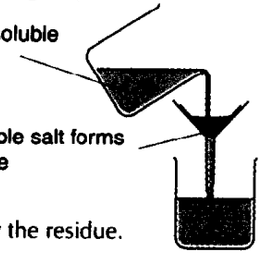
MAKE THE SALT BY PRECIPITATION

Use the solubility rules to think of two solutions, one having the cation, the other the anion.

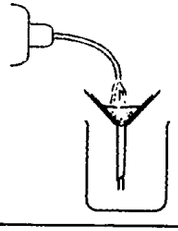
1. Add the cation solution to the anion solution.



2. Filter the resulting suspension.



3. Wash then dry the residue.

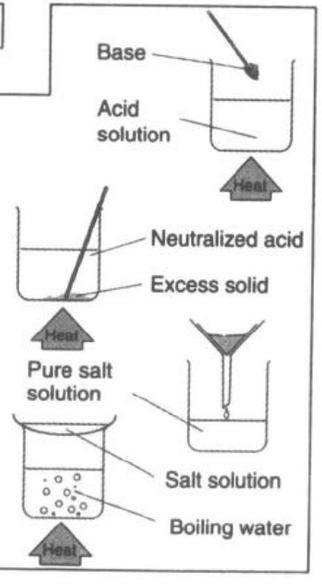


MAKE THE SALT BY NEUTRALIZATION

- Choose the appropriate acid, e.g. HCl for chlorides, HNO_3 for nitrates, H_2SO_4 for sulphates
- add either
  (a) a reactive metal: Mg, Al, Fe, Zn
  or (b) a base: a metal oxide, hydroxide, or carbonate
- if you are adding a base, decide whether it is soluble

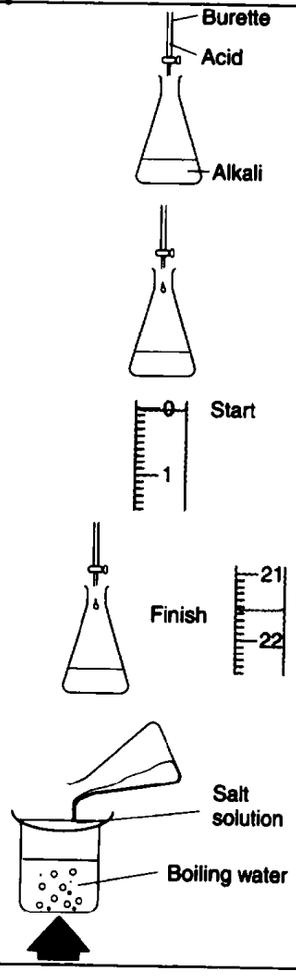
USE EXCESS BASE METHOD

1. Measure out a volume of acid solution. Add a spatula full of solid: metal, metal oxide, metal hydroxide, or metal carbonate. Warm the beaker.
2. Continue adding solid reactant to the solution until no more dissolves. Warm and stir the solution to make sure the reaction is complete.
3. Filter off the excess solid and collect the filtrate, which is a pure salt solution.
4. Evaporate off most of the water from the solution over a warm bath. Leave the remaining solution to cool, so that the salt can crystallize out. Dry off the crystals on filter paper.



USE TITRATION

1. Measure out a volume of alkaline solution, say 20 cm^3. Add some phenolphthalein indicator, then run acid into the flask from a burette.
2. Continue adding acid until one more drop of acid is just enough to turn the solution from pink to colourless. The base has now been neutralized.
3. Note the volume of acid needed for the neutralization (this is the reading on the burette).
4. Repeat the process, this time without adding indicator. Run the measured volume of acid from the burette into the 20 cm^3 of alkali in the flask.
5. Evaporate off most of the water from the solution over a water bath. Leave the remaining solution to cool, so that the salt can crystallize out. Dry off the crystals on filter paper.



实验室制盐

盐的溶解规律

- 所有第一族的化合物都是可溶的
- 所有硝酸盐是可溶的
- 除了氯化银和氯化铅外，所有盐酸盐都是可溶的
- 除了硫酸钙、钡和铅外，所有的硫酸盐都是可溶的
- 除了第一族的碳酸盐外，其他所有碳酸盐都是不溶的

碱的溶解规律

- 所有第一族的碱是可溶的
- 在第二族里，氢氧化钙、钡是可溶的
- 氢氧化铵是可溶的（或氨是可溶的）

用溶解规律决定盐是不是可溶性的

盐是可溶性的

盐是不溶性的

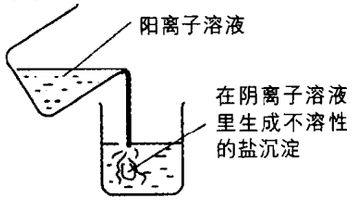
如果加入一种可溶性碱

如果加入一种金属或不溶性碱

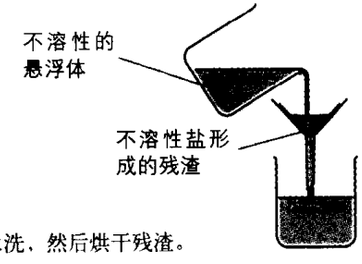
用沉淀法制盐

运用溶解规律，考虑两种溶液，一种含阳离子，一种含阴离子。

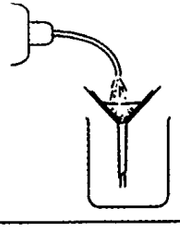
1. 加阳离子溶液到阴离子溶液里去。



2. 过滤生成的盐溶液。



3. 水洗，然后烘干残渣。



用中和法制盐

- 选择合适的酸，比如盐酸HCl、硝酸HNO_3、硫酸H_2SO_4
- (a) 加入一种活泼金属：镁、铝、铁、锌或(b)一种碱，一种金属氧化物、氢氧化物或碳酸盐
- 如果加入碱，要看是不是可溶性碱

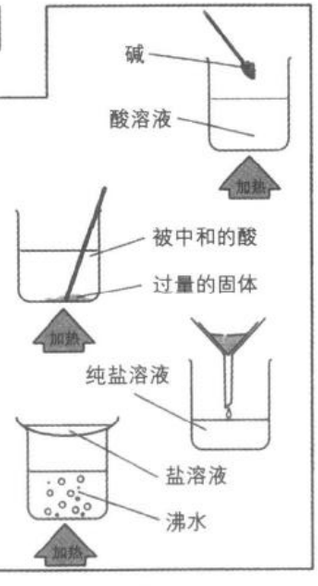
运用过量碱的方法

1. 量取一定体积的酸溶液，加入一些固体：金属、金属氧化物、金属氢氧化物或金属碳酸盐，加热烧杯。

2. 继续向溶液里加入固体反应物，直到固体不再溶解。加热并搅拌溶液，确保反应完全。

3. 滤去过量的固体，收集滤液，这是纯的盐溶液。

4. 在热的水浴上蒸去溶液里的大部分水，使剩余的溶液冷却。这样盐就会结晶析出，在滤纸上烘干晶体。



注意安全！

- 严格按操作要求做
- 戴防护眼镜
- 酸和碱有腐蚀性，小心处理。用抹布擦掉溅出来的液滴
- 小心加热过的物品

用滴定法

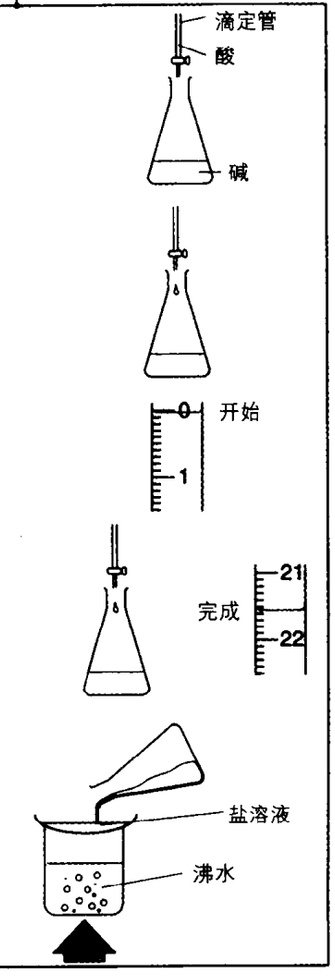
1. 量取一定量的碱溶液，假设20厘米^3，加入少许酚酞指示剂。然后把酸从滴定管里滴入锥形瓶。

2. 继续滴加酸，直到再滴入一滴酸时，正好使溶液从粉红色变成无色，这时酸被中和。

3. 记下根据滴定管上的刻度中和所需酸的体积。

4. 重复这一过程，这次不必加指示剂。向盛有20厘米^{3}碱溶液的烧杯里滴入已测出所需体积的酸溶液。

5. 在热的水浴上蒸去溶液里的大部分水，使剩余的溶液冷却。这样盐就会结晶析出，在滤纸上烘干晶体。



Measuring solubility

It is easier to see the first crystals forming as a saturated solution cools than it is to judge when the very last crystal dissolves as the solution is heated. So to measure solubility, you cool solutions of different concentrations and record the temperature when the first crystals appear on the surface (the coolest part of the solution) and then sink to the bottom. If you miss this moment, you can always reheat the solution and repeat the reading.

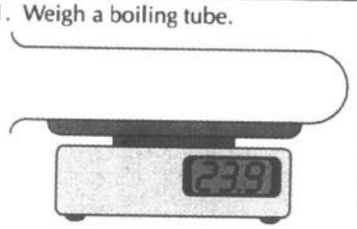
The different solutions are made by adding more and more water to the same mass of solute.

SAFETY!

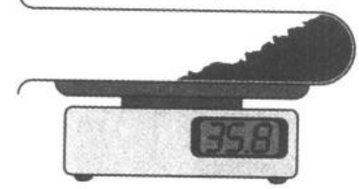
- follow instructions precisely
- wear safety glasses
- take care with hot objects
- wipe up any spilled substances

PROCEDURE FOR POTASSIUM NITRATE

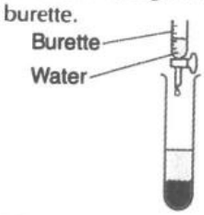
1. Weigh a boiling tube.



2. Add about 12 g of potassium nitrate, and re-weigh.

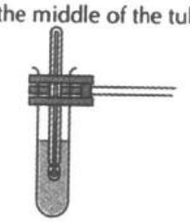


3. Add 10 cm^3 (10 g) of water from a burette.

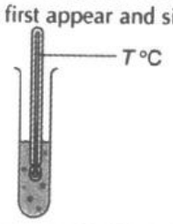


4. Heat until all the crystals of potassium nitrate have dissolved.

5. Clamp a thermometer so that it hangs in the middle of the tube.



6. Record the temperature at which crystals first appear and sink.



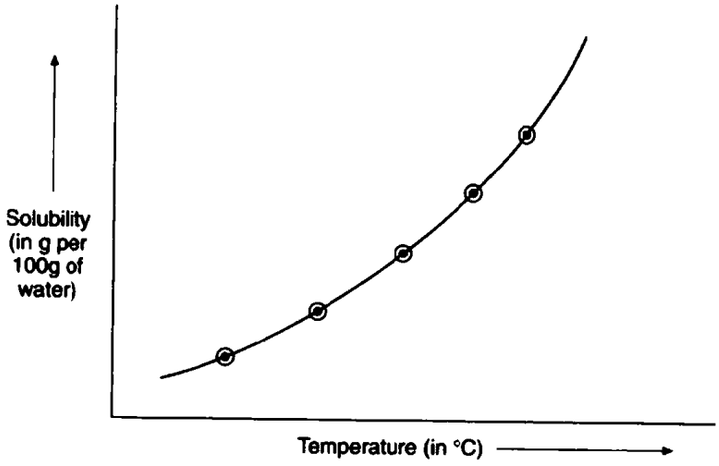
7. Add 2 cm^3 (2 g) more water to the solution in the tube.

8. Repeat steps 4, 5, and 6.

9. Repeat steps 7 and 8 until 20 cm^3 (20 g) water in all have been added.

10. Tabulate readings and calculate solubility in g / 100 g for each temperature.

11. Plot the results to give a solubility curve.



测量溶解度

当饱和溶液冷却时，最先形成的结晶比较容易观测到。而当溶液加热时，什么时候晶体最终溶解就较难观察到。因此要测量溶解度，就采用冷却不同浓度的溶液，同时记录晶体在溶液表面（溶液里最冷部分）刚刚析出，然后沉入底部时的温度。假如你错过这一时刻，你可以重新加热溶液，然后重新记录。

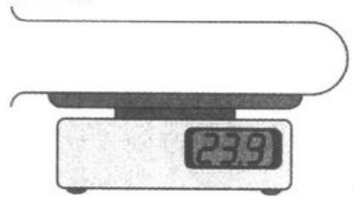
在相同质量的溶质里加入越来越多的水可以配成不同的溶液。

注意安全！

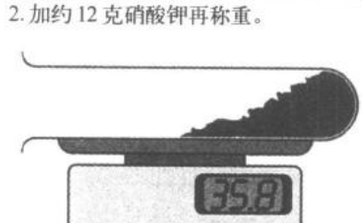
- 严格按操作规程做
- 戴防护眼镜
- 小心热的物体
- 擦掉溅出来的物质

测硝酸钾（溶解度）的步骤

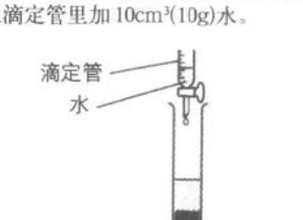
1. 称重试管。



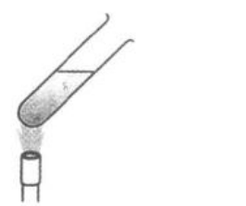
2. 加约 12 克硝酸钾再称重。



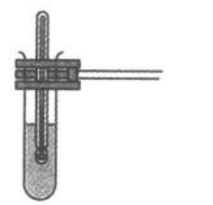
3. 从滴定管里加 10cm³(10g)水。



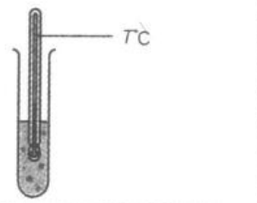
4. 加热，直到所有硝酸钾晶体全部溶解。



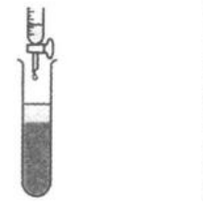
5. 夹紧一支温度计，使它能悬在试管中间。



6. 当晶体刚刚出现并下沉时，记下这时的温度。



7. 再向试管里的溶液加 2cm³(2g)水。

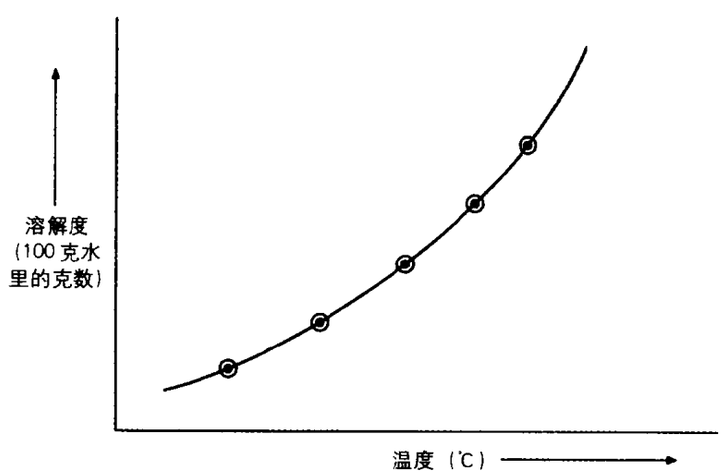


8. 重复步骤 4、5、6。

9. 重复步骤 7、8，直到 20cm³(20g)水全部加完。

10. 把读数列成表，计算在每一个温度下的溶解度（克／100 克）。

11. 把结果点在直角坐标内，连成溶解度曲线。



Titrations

In a titration you react a known volume of one solution (measured in a **pipette**) with a known volume of another solution (measured in a **burette**). You can tell when the reaction is complete because

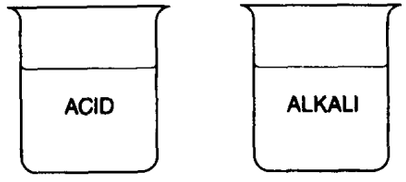
- *either* an indicator which has been added changes colour, *or*
- one of the solutions itself changes colour.

SAFETY!

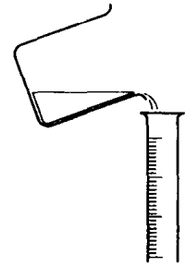
- follow instructions precisely
- wear safety glasses
- acids and alkalis are corrosive: handle them carefully and mop up any spills

PROCEDURE

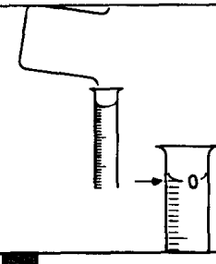
1. Label and fill two beakers with the reacting solutions.



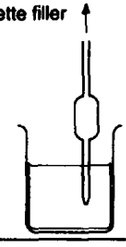
2. Pour a little of one solution into the burette to rinse it. Check the tap works. Pour away all this solution.



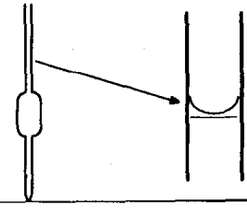
3. Fill the burette. Run liquid through the tap until there are no air bubbles. Zero the burette.



4. Using a pipette filler, rinse out the pipette with the other solution. Then refill the pipette to well above the mark.



5. Carefully let the solution out until the meniscus is on the line.



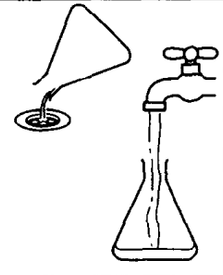
6. Run this solution into a conical flask. Do not force out the last drop, but just touch the pipette tip on the liquid surface.

7. Add just enough indicator to produce a definite colour (about 2–5 drops). Put the conical flask on a white tile. Adjust the height of the burette so that it just sticks into the neck of the conical flask.

8. Run solution from the burette into the conical flask, swirling the flask all the time. Do not shake the flask, or solution will get splashed up the sides where it may not react.

9. Stop when the indicator changes colour and note the volume run in from the burette.

10. Empty and rinse the conical flask. It need not be dried, because any water will dilute both solutions equally.



11. Refill and re-zero the burette.

12. Using the pipette filler, refill the pipette and zero it.

13. Repeat steps 5, 6, and 7.

14. Repeat step 8 but this time stop about 1 cm^3 before the previously recorded volume. Then add the solution drop by drop until the colour just changes.

15. Record the volume added in a table

Final reading			
Initial reading			
Volume added			

16. Do at least two accurate titrations and work out the average volume added.

滴定

滴定时，你用一种已知体积的溶液（用**滴定管**测量）跟另一种已知体积的溶液反应。你可以明确什么时候反应是完成了。因为

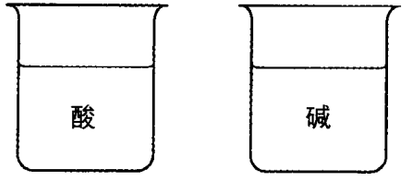
- 要么加入的指示剂改变颜色
- 要么是溶液本身改变颜色

注意安全！

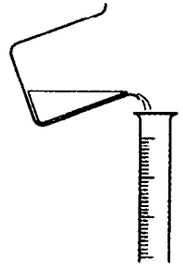
- 严格按照说明要求去做
- 戴防护眼镜
- 酸和碱有腐蚀性，要小心处理，用抹布擦掉滴出来的液滴

操作步骤

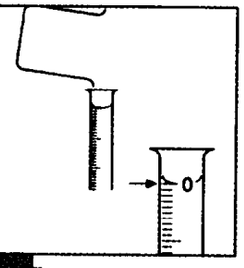
1. 在两个烧杯上做上记号，并各加入反应溶液。



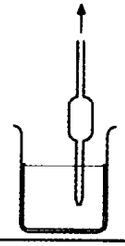
2. 向滴定管里倒入少许一种溶液以清洗滴定管。检查活塞，放掉这种溶液。



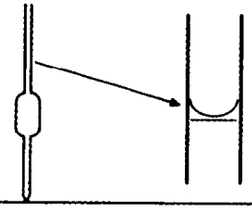
3. 向滴定管里加满溶液，使液体通过活塞流出，直到活塞里没有气泡，且使滴定管里的液面刻度为0。



4. 取一支移液管，用另一种溶液清洗移液管，然后重新注满移液管，直到液面正好高出标记线。

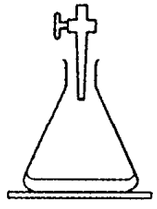


5. 小心放出少许溶液直到凹液面正好在标记线上。

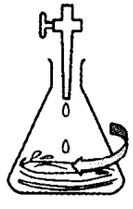


6. 把这种溶液移入锥形瓶中，不要挤出最后一滴液体，只要让移液管的管嘴碰到液面即可。

7. 加入指示剂（约2～5滴）使溶液产生一定的颜色，把锥形瓶放在一块白瓷砖上，调节滴定管高度，使它正好插入锥形瓶的瓶颈。

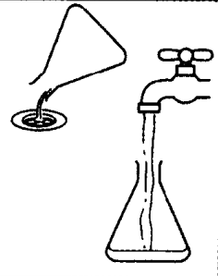


8. 边从滴定管里向锥形瓶里滴入溶液，边摇晃锥形瓶。不能倾倒锥形瓶，否则溶液会溅到瓶子壁上而不起反应。



9. 当指示剂改变颜色时，停止滴定。记下从滴定管里流出的溶液体积。

10. 倒掉锥形瓶里液体并清洗锥形瓶，不必烘干。因为水既会稀释滴定液，也会稀释锥形瓶里的液体。



11. 重新装满滴定管，使液面到零刻度。

12. 取同一支移液管，使液体装满移液管到零刻度。

13. 重复5、6、7步骤。

14. 重复步骤8，但是这次在上一次记录的体积前1立方厘米就停止滴定，然后一滴一滴地滴入溶液，直到指示剂正好变色。

15. 在表里记录所滴溶液的体积。

最终读数			
最初读数			
所加体积			

16. 至少做两次精确的滴定，然后求出所滴体积的平均值。

Testing for cations

SAFETY!
- follow instructions precisely
- wear safety glasses
- acids and alkalis are corrosive: handle them carefully and mop up any spills
- take care with hot objects

UNKNOWN SOLUTION

SODIUM HYDROXIDE

A precipitate forms:

$M^{x+}(aq) + x\,OH^-(aq) \rightarrow M(OH)_x(s)$

ADD MORE SODIUM HYDROXIDE SOLUTION

The precipitate redissolves:

$M(OH)_x(s) + x\,OH^-(aq) \rightarrow M(OH)^-_{x+1}(aq)$

IS THE SOLUTION COLOURED?

Yes it is
Green solution, Cr^{3+}
The cation is [redacted]

No, it is colourless

TAKE THE ORIGINAL SOLUTION, AND ADD AQUEOUS AMMONIA

AQUEOUS AMMONIA

A white precipitate forms
The cation is [redacted]

$Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$

No precipitate remains
The cation is [redacted]

$Zn^{2+}(aq) + 2OH^-(aq) \rightarrow Zn(OH)_2 + 4NH_3(aq) \rightarrow Zn(NH_3)_4^{2+} + 2OH^-(aq)$

The precipitate does not redissolve

IS THE PRECIPITATE COLOURED?

Yes it is
Grey/green — the cation is [redacted]
Red/brown — the cation is [redacted]
Bright blue — the cation is [redacted]

No, it is white
The cation is in [redacted]

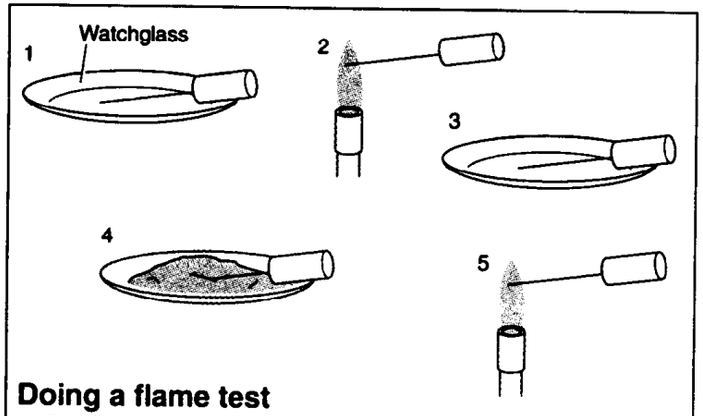
DO A FLAME TEST
Colourless flame [redacted]
Brick red flame [redacted]
Scarlet flame [redacted]
Apple green flame [redacted]

A gas is given off. The gas:
- is colourless
- is pungent
- turns litmus blue
- makes white smoke with the HCl stopper

The gas is ammonia, NH_3
The cation is the [redacted]
Reaction:
$NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$

No precipitate forms
The metal hydroxide is soluble
The cation is in [redacted]

DO A FLAME TEST
Crimson flame [redacted]
Orange flame [redacted]
Lilac flame [redacted]



Doing a flame test

1 Dip the platinum wire in conc. HCl.
2 Heat strongly in the flame to vaporize impurities.
3 Moisten the wire again in conc. HCl.
4 Dip the moistened wire in a small amount of the solid salt.
5 Heat strongly in the flame and note any flame colour.

鉴别阳离子

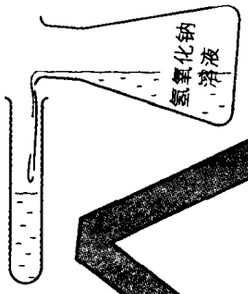
注意安全！

- 严格按要求做
- 戴防护眼镜
- 酸和碱有腐蚀性，要小心处理。用抹布擦掉溅出来的液滴
- 留心热的液体

生成沉淀：

$M^{x+}(aq)+xOH^-(aq) \rightarrow M(OH)_x(s)$

加入更多的氢氧化钠溶液



未知溶液

放出气体，气体是：

- 无色的
- 有刺激性气味的
- 使石蕊变蓝
- 遇盐酸瓶塞产生白色烟雾

气体是氨，NH_3

阳离子是 铵，NH_4^+

反应：

$NH_4^+(aq)+OH^-(aq) \rightarrow NH_3(g)+H_2O(l)$

没有沉淀生成

金属氢氧化物是可溶的

阳离子是 第一族 的。

焰色反应

深红色火焰	Li^+
桔红色火焰	Na^+
淡紫色火焰	K^+

沉淀重新溶解：

$M(OH)_x(s)+xOH^-(aq) \rightarrow M(OH)^-_{x+1}(aq)$

溶液有颜色吗？

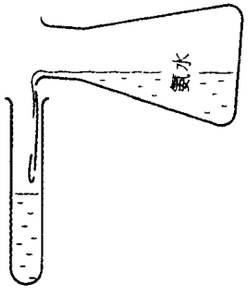
是，有颜色。

绿色溶液 Cr^{3+}

阳离子是 铬，Cr^{3+}

不，没有颜色。

取初始溶液，加入氨水



生成白色沉淀

阳离子是 铝，Al^{3+}

$Al^{3+}(aq)+3OH^-(aq) \rightarrow Al(OH)_3(s)$

沉淀不溶解

溶液有颜色吗？

是的，有颜色。

灰／绿	阳离子是	过渡金属，Fe^{2+}
红／褐	阳离子是	过渡金属，Fe^{3+}
鲜艳的蓝色	阳离子是	过渡金属，Cu^{2+}

是白色的。

阳离子是 第二族 的。

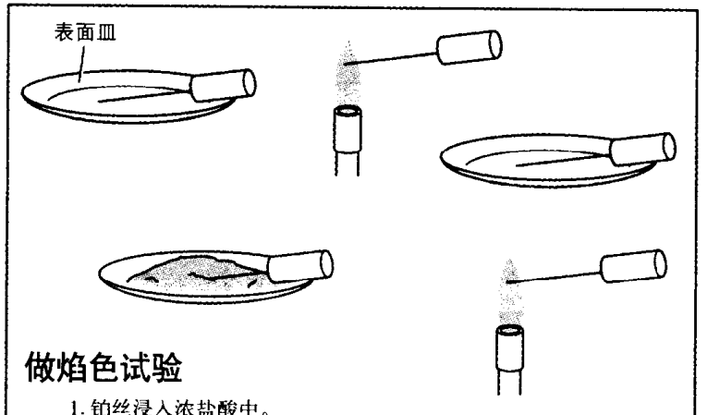
焰色反应

无色火焰	Mg^{2+}
砖红色火焰	Ca^{2+}
深红色火焰	Sr^{2+}
苹果绿色火焰	Ba^{2+}

没有沉淀

阳离子是 锌，Zn^{2+}

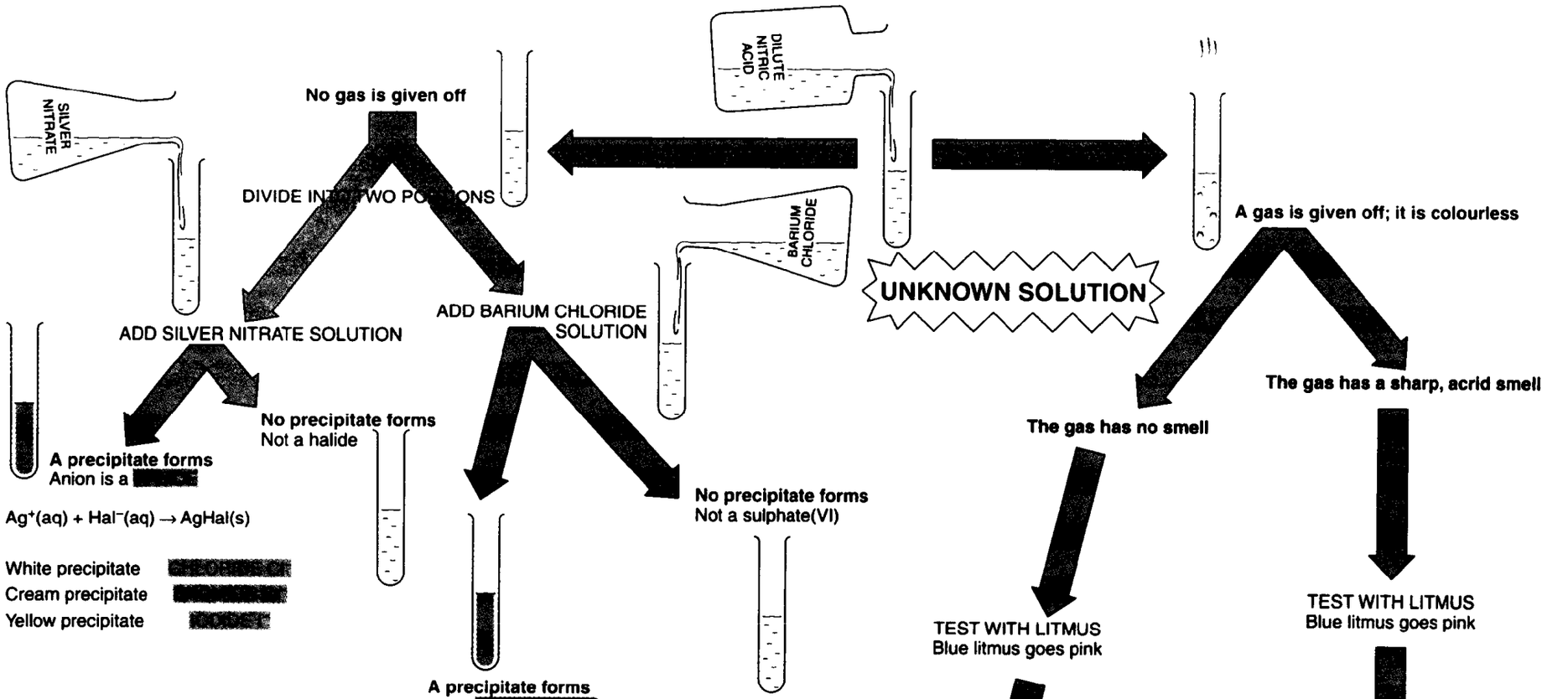
$Zn^{2+}(aq)+2OH^-(aq) \rightarrow Zn(OH)_2+4NH_3(aq) \rightarrow Zn(NH_3)_4^{2+}+2OH^-(aq)$



做焰色试验

1. 铂丝浸入浓盐酸中。
2. 在火焰里对铂丝加强热，使杂质挥发。
3. 再让铂丝浸入浓盐酸。
4. 用这根铂丝蘸取少许固体盐。
5. 在火焰里加强热，观察火焰的颜色。

Testing for anions



TESTING FOR NITRATES

Nitrates are recognized using the **brown ring test**.

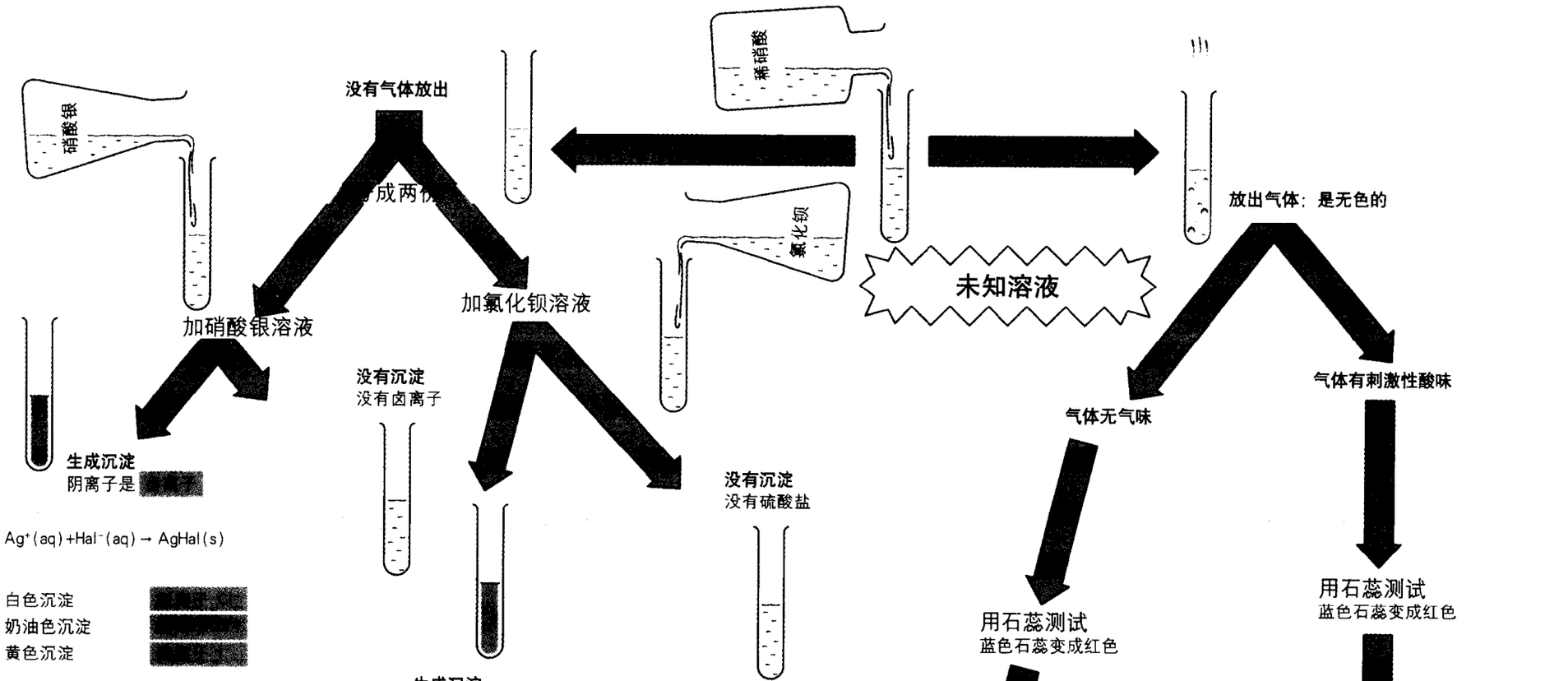
1. Make a fresh solution of iron(II) sulphate.
2. Add this to the unknown solution.
3. Hold the tube at 45°. Add slowly and with great care a little concentrated sulphuric acid.

The dense sulphuric acid settles in the bottom of the tube. If the unknown is a nitrate, a brown ring will form at the top of the sulphuric acid.

SAFETY!

- follow instructions precisely
- wear safety glasses
- acids and alkalis are corrosive: handle them carefully and mop up any spills
- take care with hot objects

鉴别阴离子



鉴别硝酸盐

硝酸盐可以用**棕色圈测试法**。

1. 配制新鲜的硫酸亚铁溶液。
2. 把溶液加入未知的溶液里。
3. 使试管以45°倾斜、慢慢地、非常小心地加入少许浓硫酸。

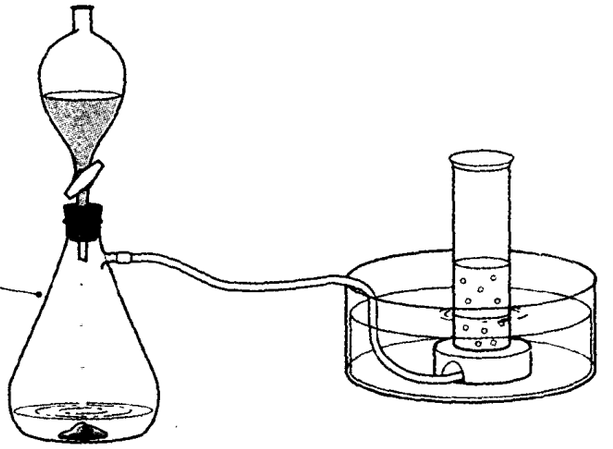
较稠的浓硫酸沉入试管底部，如果未知物是硝酸盐，就会在硫酸的顶部形成一个棕色圈。

注意安全！

- 严格按照操作要求做
- 戴防护眼镜
- 酸和碱有腐蚀性，要小心处理。用抹布擦掉溅出来的液滴
- 小心加热过的物件

Making and testing for gases in the laboratory

MAKING GASES
Gases are always made from the reaction between a solid and a liquid. The volume of gas made is controlled by the amount of liquid run into the flask holding the solid reactant.



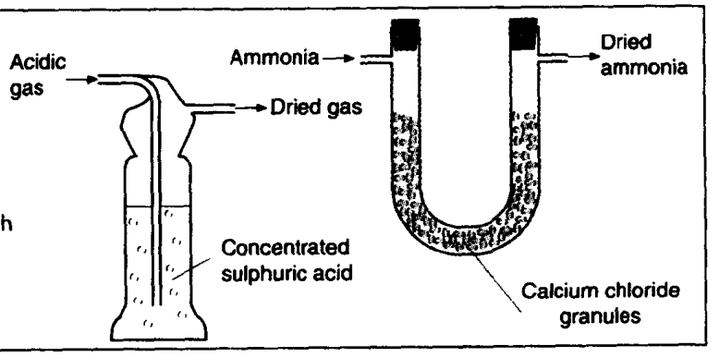
Gas	Liquid	Solid	Reaction
Hydrogen	Dilute sulphuric acid	Magnesium	$H_2SO_4 + Mg \rightarrow H_2 + MgSO_4$
Oxygen	Hydrogen peroxide	Manganese(IV) oxide	$2H_2O_2 \rightarrow O_2 + 2H_2O$
Carbon dioxide	Dilute hydrochloric acid	Calcium carbonate	$2HCl + CaCO_3 \rightarrow CO_2 + CaCl_2 + H_2O$
Hydrogen chloride	Conc. sulphuric acid	Sodium chloride	$H_2SO_4 + 2NaCl \rightarrow 2HCl + Na_2SO_4$
Ammonia	Sodium hydroxide	Ammonium chloride	$NaOH + NH_4Cl \rightarrow NH_3 + NaCl + H_2O$
Sulphur dioxide	Dilute hydrochloric acid	Sodium sulphate(IV)	$2HCl + Na_2SO_3 \rightarrow SO_2 + 2NaCl + H_2O$
Chlorine	Conc. hydrochloric acid	Manganese(IV) oxide	$4HCl + MnO_2 \rightarrow Cl_2 + MnCl_2 + 2H_2O$
Nitrogen dioxide	Dilute nitric acid	Copper metal	$4HNO_3 + Cu \rightarrow Cu(NO_3)_2 + 2NO_2 + H_2O$

Drying gases
Because the liquid involved in the reaction is often an aqueous solution, the gas produced is often wet (contaminated with water).

Gases can be dried by passing them through something which reacts with (and so removes) the water.

Acidic and neutral gases are dried by passing them through concentrated sulphuric acid.

Ammonia is an alkaline gas. It is dried by passing it over calcium chloride granules.

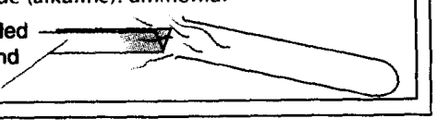


TESTING FOR GASES IN THE LAB

1. Look at its colour
Most gases are colourless but chlorine is green and nitrogen dioxide is brown.

2. Cautiously smell the gas
- Many gases have no smell: oxygen, hydrogen, nitrogen, carbon dioxide.
- Some smell acrid (this means a sharp smell which makes you jerk your head back): sulphur dioxide, hydrogen chloride.
- Others are pungent (they have a very strong smell): ammonia.
- Others have a characteristic or familiar smell: chlorine has a smell we all know from swimming pools.

3. Test with damp litmus paper
Remember that the only positive test is one in which the paper changes colour.
- Litmus goes pink (acidic): hydrogen chloride, sulphur dioxide, carbon dioxide.
- Litmus goes blue (alkaline): ammonia.



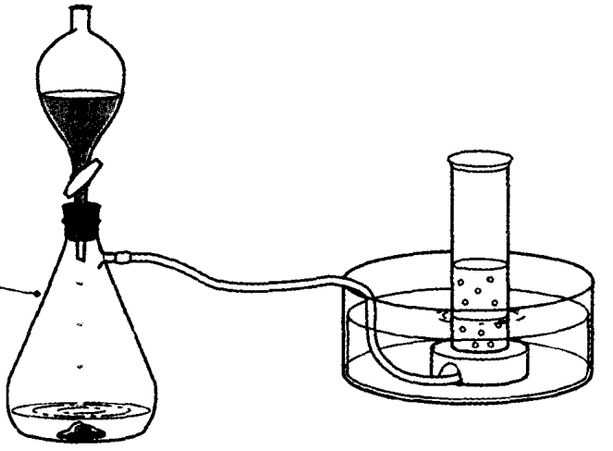
4. Then confirm the identity of the gas with a special test

• hydrogen	ignites with a squeaky pop
• oxygen	relights a glowing splint
• carbon dioxide	turns calcium hydroxide (lime water) cloudy
• hydrogen chloride	white smoke forms with the ammonia bottle stopper
• ammonia	white smoke forms with the concentrated hydrochloric acid bottle stopper
• sulphur dioxide	potassium manganate(VII) on filter paper goes colourless
• chlorine	potassium iodide on filter paper goes brown
• nitrogen dioxide	a piece of copper goes green

实验室制取和鉴别气体

制取气体

气体总是用一种固体跟一种液体反应来制取的。调节注入盛固体反应物的烧瓶里的液体的量，就可以控制产生的气体体积。



气体	液体	固体	反应
氢气	稀硫酸	镁	$H_2SO_4+Mg \rightarrow H_2+MgSO_4$
氧气	过氧化氢	二氧化锰	$2H_2O_2 \rightarrow O_2+2H_2O$
二氧化碳	稀盐酸	硫酸钙	$2HCl+CaCO_3 \rightarrow CO_2+CaCl_2+H_2O$
氯化氢	浓硫酸	氯化钠	$H_2SO_4+2NaCl \rightarrow 2HCl+Na_2SO_4$
氨	氢氧化钠	氯化铵	$NaOH+NH_4Cl \rightarrow NH_3+NaCl+H_2O$
二氧化硫	稀盐酸	亚硫酸钠	$2HCl+Na_2SO_3 \rightarrow SO_2+2NaCl+H_2O$
氯气	浓盐酸	二氧化锰	$4HCl+MnO_2 \rightarrow Cl_2+MnCl_2+2H_2O$
二氧化氮	稀硝酸	金属铜	$4HNO_3+Cu \rightarrow Cu(NO_3)_2+2NO_2+H_2O$

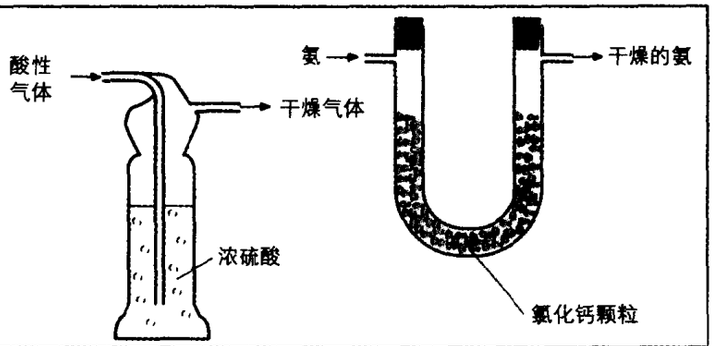
气体干燥

由于反应物涉及的液体往往是一种溶液，所以产生的气体常常是湿的（含有水分）。

让气体通过能跟水反应（从而去掉水分）的物质，就能干燥气体。

让酸性和中性气体通过浓硫酸，能被干燥。

氨是碱性气体，让它通过氯化钙颗粒，能被干燥。



实验室鉴别气体

1. 观测它的颜色

大多数气体是无色的，但是氯气是绿色的，二氧化氮是棕色的。

2. 小心地嗅气味

- 许多气体没有气味：氧气、氢气、氮气、二氧化碳
- 有些闻起来有酸味（这是一种刺激性气味，你会转过头去）：二氧化硫、氯化氢
- 有些有刺鼻的气味（它们有强烈的气味）：氨
- 有些有特征或我们熟悉的气味：氯气的气味我们从游泳池里就都已知道

3. 用湿润的石蕊试纸测试

记住，只有阳性反应，试纸才会变色

- 石蕊变成粉红色（酸性）：氯化氢、二氧化硫、二氧化碳
- 石蕊变成蓝色（碱性）：氨

4. 用特殊的测试来鉴别气体

• 氢气	点燃，有尖利的爆鸣声
• 氧气	带余烬的木条重新点燃
• 二氧化碳	使氢氧化钙（石灰水）溶液变浑浊
• 氯化氢	遇盛氨水的瓶塞生成白色烟雾
• 氨	遇盛浓盐酸的瓶塞生成白色烟雾
• 二氧化硫	使滤纸上的高锰酸钾变成无色
• 氯气	使滤纸上的碘化钾变成褐色
• 二氧化氮	使铜片变成绿色

Sample exam question answers

On the following pages some sample examination questions are answered. As you study them try to notice the following key points:

- what are you told to do and has the answer done it? key words to look for are: ***list; describe; explain; suggest; predict***
- the number of marks offered must be matched by the number of points made
- can you recognise what part of the syllabus is covered by the question because this will guide you to the likely answer
- many of these questions contain hints or even the information you need to answer the question, so study the question very carefully before and while you are answering it

(MEG bear no responsibility for the answers provided.)

1 Complete this table about metals, their uses and the properties which make them suitable for these uses.

The first line has been completed for you.

metal	use	property which makes the metal suitable for this use
aluminium	aeroplane body	low density
copper	saucepan base	conductivity
lead	church roof	malleable
mercury	thermometer	liquid at room temperature
gold	jewellery	shiny appearance
steel	bridges	strong
tin	coating food cans	unreactive
tungsten	lamp filament	high melting point

(7)

(MEG)

Here you must use your general knowledge as well as what you have learnt in chemistry

What do you want a good saucepan to do? It must let the heat from the cooker through easily

What is needed for a roofing material? Something which can spread over the roof matching its shape

This question is easy and obvious

So is this one

You might have to guess here. What other reasons are there for coating a can? You might well get a mark for this too

Make sure here that you give a use which depends on strength

What is the most obvious thing about the filament in a lamp? It is white hot. Why doesn't it melt?

试题解答举例

下面是一些试题解答的范例，在你学习的时候，要知道以下几个关键：

- 明确要你做什么，应该怎么回答？寻找关键词：***列表；讲述；解释；建议；预测***
- 给出的分数必须跟回答的要点相符
- 你能看出来，题目涵盖了教学大纲的哪一部分吗？因为这可以引导你得到预期的答案
- 这些题目大多有一些有用的暗示甚至信息，以便你解题，因此在解题前及解题中要小心地审题

（MEG对提供的答案不承担责任）

1. 填下表，有关金属，它们的用途以及性质。这些性质决定了它们的用途。

表中第一行已做好

金属	用途	性质、由这些性质决定的金属用途
铝	飞机机身	密度小
铜	平底锅底	导电性好
铅	教堂屋顶	延展性好
水银	温度计	室温时是液体
金	首饰	有光泽
钢	桥	坚固
锡	食品罐头镀层	不反应
锑	灯丝	熔点高

这里你要用到你的常识，又要用你在化学里学习到的知识

你要一个好的平底烧杯做什么？它必须很容易地被炉子加热

盖房顶需要什么材料？需要展开并能覆盖整个房顶的东西

这个问题很容易也很明了

这个问题也很容易明了

这儿你必须猜测还有其他理由做罐头的镀层吗？做得好可以得高分

确认，你指出的用途是由强度决定的

明确最明显的特点是什么？它是白热状的，为什么它不熔化？

8 This question is about the use of different materials in the home

The table gives information about the properties of some materials.

material	melting point		density	thermal conductivity	bulk properties	
	below 500°C	above 500°C				
ceramic		yes	medium	low	hard	brittle
glass		yes	medium	low	hard	brittle
iron		yes	high	high	hard	malleable
thermoplastic	yes		low	low	soft	elastic
thermoset plastic		yes	low	low	hard	brittle

Look at the table and find the columns where iron is different from all the others. The conductivity is another perfectly correct answer instead of malleability

Use the information in the table to answer the following questions.

(a) Both ceramics and iron are used to make cooking pots.

(i) Describe one advantage of using iron rather than ceramics for cooking pots.

They are not brittle. They do not break when dropped or banged against something else.

(1)

You are looking for an advantage so you cannot use conductivity. Apart from the two mentioned above, density is the only other property in which iron differs from a ceramic

(ii) Describe one advantage of using ceramics rather than iron for cooking pots.

They are not as heavy. Their density is medium. Iron's is high.

(1)

For two marks, try to say something about both the glass and iron lattices.

(b) Glass and iron have different properties caused by their different arrangement of atoms.

(i) Describe a difference in the arrangement of atoms in glass and iron

The atoms in glass are randomly arranged, those in iron are in a regular lattice.

(2)

Malleability is a key metallic property and is caused by layers of atoms sliding past each other. If glass is not malleable, then the atoms in it cannot slide past each other.

(ii) How does the arrangement of atoms help to explain why glass is brittle but iron is malleable?

In glass there are no layers of atoms which can slide over each other as they do in iron, so in glass moving the atoms makes it break.

(2)

(c) The properties of iron can be altered by adding another metal to make an alloy

Make sure you choose a property you can explain in part (ii).

(i) Suggest a property of iron that could be changed by adding another metal.

Hardness

(1)

(ii) Explain in terms of atoms, how the addition of another metal to iron causes this change.

Atoms of a different size stop the layers of iron atoms sliding over each other.

(2)

(MEG)

8. 这个题目是关于家庭里不同材料的用途

表格里给出关于一些材料性质的信息。

材料	熔点		密度	导热性	重要性质	
	< 500℃	> 500℃				
陶器		是	中等	差	硬	脆
玻璃		是	中等	差	硬	脆
铁		是	大	好	硬	有延展性
热塑性塑料	是		小	差	软	塑性
热固性塑料		是	小	差	硬	脆

现测表格，从纵列里发现，铁跟其他所有物质不一样，导热性可以替代延展性，作为另一个正确的答案。

利用表格里信息回答问题。

(a) 用陶瓷和铁来制烧锅。

(i) 讲述铁的一种优点，说明为什么用铁比用陶瓷好。

铁不脆，当铁锅掉到地上过跟其他东西撞击时，不会破碎。

(1)

你正在寻找一种优点，所以你不能利用导（热、电）性。除了上述提到的两项，密度是唯一另一个铁跟陶瓷不同的性质。

(ii) 讲述陶瓷的一种优点，说明为什么用陶瓷比用铁好。

陶瓷不重，它们的密度居中，铁较重。

(1)

为 2 分，设法讲出有关玻璃和铁的晶格的一些事。

(b) 玻璃和铁由于它们不同的原子排布，所以有不同的性质。

(i) 讲述玻璃和铁里原子排布的一个不同点。

玻璃里原子排布是杂乱无章的，而在铁里原子是有规则地分布在晶格上的。

(2)

延展性是重要的金属特性，是由原子层之间互相滑动造成的。如果玻璃没有延展性，那么它的原子就不可能互相滑动。

(ii) 怎样利用原子排布来解释：为什么玻璃是脆的而铁有延展性。

在玻璃里没有原子层可以互相滑动，而在铁里就有原子层可以互相滑动，因此在玻璃里原子移动，玻璃破碎。

(2)

(c) 如果加入另一种金属制成合金，铁的性质可以改变。

(i) 通过加入另一种金属，建议改变铁的一种性质。

硬度

(1)

确保你选择的性质可以解释第 (ii) 部分。

(ii) 按照原子的思路解释，为什么加入另一种金属会引起这一改变。

不同大小的原子可以阻止铁原子层互相之间滑动。

(2)

(MEG)

(d) Thermoset plastics are often used to make the bodies of electric kettles.

(i) What advantage does this use of thermoset plastics have over the use of iron?

They are poor conductors of heat. They will not feel so hot.

(1)

(ii) What advantage does this use of thermoset plastics have over the use of thermoplastics?

They do not soften when they are heated.

(1)

(iii) Explain the difference in properties of thermoplastics and thermosets in terms of their structures.

Thermoplastics soften when heated because they have weak (Van der Waals) forces between the chains of atoms. Thermosets have strong covalent cross-links between the chains. Heat energy breaks the weak forces but not the strong ones.

(3)

(MEG)

(d) 热固性塑料常用来做电热水壶的壶身。

(i) 用热固性塑料比用铁做有什么优点?

它们是热的不良导体，摸上去不会觉得很烫。

(1)

(ii) 用热固性塑料比用热塑性塑料有什么优点?

受热时不会软化。

(1)

(iii) 按照它们的结构，解释热塑性塑料和热固性塑料的性质不同点。

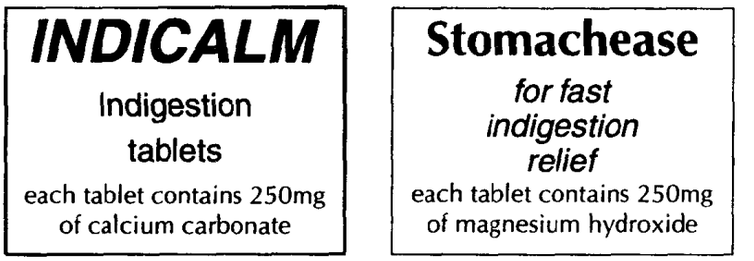
当受热时，热塑性塑料会软化，因为在它们的原子链之间只有很弱的力（范德华力）。而热固性塑料在原子链之间有很强的共价交联键。热能可以打破弱力，但不能打破强力。

(3)

(MEG)

10 Indigestion tablets contain substances which neutralise excess hydrochloric acid in the stomach.

The labels from two makes of tablets are shown



(a) (i) Balance this equation for the reaction between calcium carbonate and hydrochloric acid.

$$CaCO_3 + HCl = CaCl_2 + CO_2 + H_2O$$

$CaCO_3 + 2\,HCl = CaCl_2 + CO_2 + H_2O$ (2)

On the right-hand side there are two chlorines and two hydrogens, so there must be two HCls on the left-handside

(ii) Write a balanced equation for the reaction between magnesium hydroxide, $Mg(OH)_2$ and hydrochloric acid, HCl.

$Mg(OH)_2 + 2\,HCl = MgCl_2 + 2H_2O$ (2)

Magnesium is in the same group as calcium, so the formula of magnesium chloride will be similar to that of calcium chloride. The other product from acid + base must be water. Now balance the atoms systematically

(b) The stomach contains hydrochloric acid of concentration 1.0 mol/dm^3.

Find by calculation which indigestion tablet will neutralise the larger volume of this acid.

You must show your working.

Relative Atomic Masses: Ca = 40; Mg = 24; O = 16; C = 12.

$$\text{amount of substance (mol)} = \frac{\text{mass of substance (g)}}{\text{molar mass (g/mol)}}$$

$$\text{amount of substance in solution (mol)} = \text{volume of solution (litres)} \times \text{concentration (mol/litre)}$$

Use the formulas given to you and work out the amount of each base in the mass given on the labels. As in both equations, one mole of each base reacts with two moles of acid, the greater amount of base will need the greater amount of acid

Molar mass of calcium carbonate = 40 + 12 + 48 = 100

Amount of calcium carbonate $= \frac{0.250}{100} = 2.5 \times 10^{-3}$ **mol**

Molar mass of magnesium hydroxide = 24 + 32 + 2 = 58

Amount of magnesium hydroxide $= \frac{0.250}{58} = 4.31 \times 10^{-3}$ **mol**

From the equations, each base reacts with twice the amount of acid .

There is a greater amount of magnesium hyrdoxide so it will neutralise the larger amount of acid which is $2 \times 4.31 \times 10^{-3}$
$= 8.62 \times 10^{-3}$ **moles**

There is 1 mol in $1000cm^3$
so there will be 8.62×10^{-3} **mol in** $8.62\ cm^3$ **of acid**

(MEG)

10. 消化药片所含的物质能中和胃里过量的盐酸。

两种药品的标记如下:

在右边有 2 个氯原子和 2 个氢原子，所以在左边必定有 2 个氯化氢分子。

(a) (i) 配平硫酸钙跟盐酸反应的方程式。

$$CaCO_3 + HCl = CaCl_2 + CO_2 + H_2O$$

$$CaCO_3 + 2HCl = CaCl_2 + CO_2 + H_2O$$ ..... (2)

镁跟钙是相同的原子团。因此氯化镁跟氯化钙的分子式相似。

酸 + 碱反应的其他产物必定是水，现在系统地平衡原子数。

(ii) 写出氢氧化镁跟盐酸反应的方程式并配平。

$$Mg(OH)_2 + 2HCl = MgCl_2 + 2H_2O$$ ..... (2)

(b) 胃里有盐酸，浓度是 1.0 摩尔 / 分米^3。

通过计算，比较哪一种消化药片能中和较多体积的胃酸。

要写出计算步骤。

相对原子量: Ca = 40; Mg = 24; O = 16; C = 12.

$$\text{物质的量 (mol)} = \frac{\text{物质的质量 (g)}}{\text{摩尔质量 (g/mol)}}$$

$$\underset{\text{(mol)}}{\text{溶液里物质的量}} = \underset{\text{(l)}}{\text{溶液体积}} \times \underset{\text{(mol/l)}}{\text{浓度}}$$

应用已知的分子式，再根据药片里每种碱的含量，算出这种碱的物质的量。

因为在两个方程式里，一摩尔每种碱都跟 2 摩尔酸反应，碱的物质的量越大，所需的酸的物质的量就越大。

碳酸钙的摩尔质量 = 40+12+48 = 100

碳酸钙的量 $= \frac{0.250}{100} = 2.5 \times 10^{-3}$mol

氢氧化镁的摩尔质量 = 24+32+2 = 58

氢氧化镁的量 $= \frac{0.250}{58} = 4.31 \times 10^{-3}$mol

从方程式可见每一种碱跟它两倍的酸的量反应

氢氧化镁物质的量较大，因此它中和的酸的物质的量也较大是 $2 \times 4.13 \times 10^{-3}$
$= 8.62 \times 10^{-3}$ 摩尔

在 1000cm^3 里有 1mol

因此在 8.63cm^3 酸里有 8.62×10^{-3}mol

(MEG)

11 The table gives information about some substances.

	boiling point °C	electrical conductivity (molten)	density g/cm^3
carbon dioxide	−78	poor	0.002
diamond	4800	poor	3.500
silicon dioxide	2230	poor	2.650
sodium chloride	1413	good	2.170
sulphur dioxide	−10	poor	0.003

Look at the boiling points. Two substances have low boiling points compared to the other three.

(a) (i) Which **two** substances in the table are made of simple molecules?

1. *Carbon dioxide*
2. *Sulphur dioxide*

(2)

(ii) Use your knowledge of the forces between atoms and molecules to explain the difference in density of carbon dioxide and diamond.

In diamond all the atoms are covalently bonded closely together so diamond has high density. Carbon dioxide is made of separate molecules weakly bonded to each other so the density is low.

(4)

To gain four marks, try to say something about the bonding and density in each substance

(b) Explain why:

(i) Solid sodium chloride will not conduct electricity, but molten sodium chloride will.

In solid sodium chloride the ions are held fixed in the lattice. When sodium chloride melts the ions become free to move and carry charge through the liquid.

(3)

Remember that for a substance to conduct, there must be charged particles free to move. In metals, the charged particles are the outer, delocalised electrons, but here they are ions which can only move in the liquid state

(ii) Molten silicon dioxide will not conduct electricity, but molten sodium chloride will.

Silicon dioxide is a covalent substance and contains no ions so there is nothing to carry the charge.

(1)

Only one point to make here. Without any ions conduction will not happen

(MEG)

11. 下表给出一些物质的信息。

	沸点 ℃	导电性 (熔融态)	密度 g/cm³
二氧化碳	-78	差	0.002
金刚石	4800	差	3.500
二氧化硅	2230	差	2.650
氯化钠	1413	好	2.170
二氧化硫	-10	差	0.003

请看沸点。跟其他三种物质相比，两种物质的沸点较低。

(a) (i) 表中哪(两种)物质由单分子组成?

1. 二氧化碳
2. 二氧化硫

(2)

(ii) 运用你学到的原子和分子间力的知识，解释二氧化碳和钻石的密度为什么不同。

在钻石里所有的原子都以共价键紧密结合，因此钻石密度大。二氧化碳由分散的分子组成，它们以很弱的键互相吸引，所以密度低。

(4)

为了得到4分，要设法说出每一种物质有关成键和密度的情况。

(b) 解释原因

(i) 固体氯化钠不导电，但熔融的氯化钠能导电。

在固体氯化钠里离子被固定在晶格上，当氯化钠熔化时，离子可以自由地运动，带着电荷在液体里移动。

(3)

记住一种物质能导电，那种物质必定有可以自由移动的带电粒子。在金属里，带电粒子就是外层的离域电子。但是这儿它们都是离子，只能在液态状况下移动。

(ii) 熔融的二氧化硅不导电，但熔融的氯化钠却能导电。

二氧化硅是一种共价物质，它没有离子，因此它没有能携带电荷的粒子。

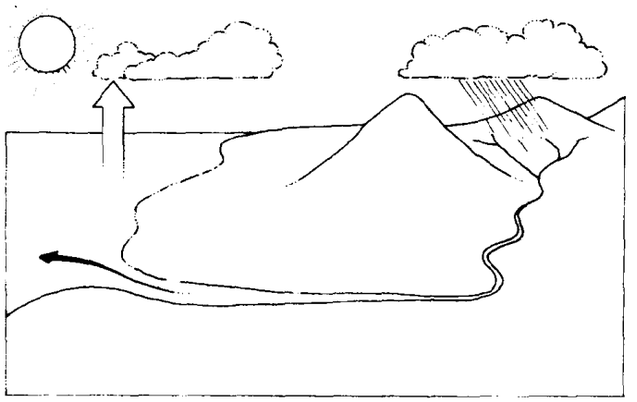
(1)

(MEG)

这儿只需指出一点，没有任何离子，就不会导电。

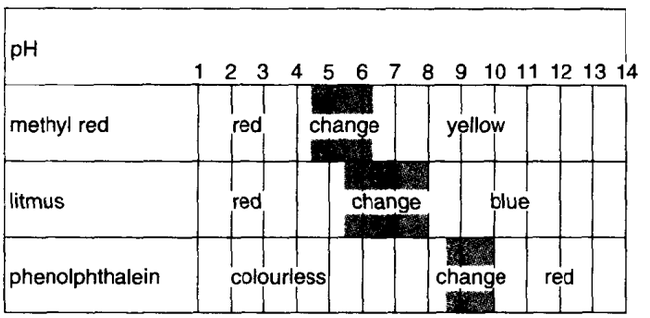
Self-assessment questions

1 This picture combines the water cycle with the weathering of rocks.



Add the words evaporation, condensation, erosion, transportation and deposition in suitable places. (5)

2 Here are the colours of three indicators between pH 1 and 13:



Give the colours of the following mixtures. (4)

a pure water + litmus
b sulphuric acid + methyl red
c sodium hydroxide (pH13) + methyl red + phenolphthalein
d alkali + phenolphthalein

3 Lumps of calcium carbonate react with dilute nitric acid to give carbon dioxide gas and a solution of calcium nitrate. (Relative atomic masses are: Ca = 40; C = 12; O = 16; H = 14)

a Write a balanced chemical equation for this reaction (2)
b What mass of carbon dioxide will result from the reaction of 10g of calcium carbonate with excess nitric acid? (2)

4 Combustion is the process that happens when a fuel burns.

a What is the fuel in a candle? (1)
b What is the main type of energy that results from combustion? (1)
c Name the two main waste gases produced by the combustion of petrol. (2)
d Name the gas that reacts with the fuel during combustion. (1)

5 The following boxes contain information about the layers that make up the Earth.

a Label each box with the correct letter:
C = crust M = mantle
OC = outer core IC = inner core. (4)

liquid; mainly iron; up to 4000 °C	
solid; rock; 250°C (average)	
plastic solid; rock; up to 3700°C	
solid; mainly iron; up to 4500°C	

b Iron usually melts at 1535 °C. Explain why iron inside the Earth is solid at 4500 °C. (1)
c Explain why scientists believe that rocks in the mantle have a higher density than rocks in the crust. (2)

6 A salt is made when an acid reacts with a metal or a metal compound. Fill in the gaps in the following table. (5)

Salt	Metal/metal compound	Acid
zinc sulphate		sulphuric acid
	lead carbonate	nitric acid
sodium chloride		
copper sulphate		sulphuric acid

7 **a** Using circles to represent water molecules, draw diagrams to show the arrangement of molecules in ice (solid), water (liquid), and steam (gas). (3)
b Why do ice cubes have a fixed shape? (1)

8 Refer to the metal reactivity series to explain why a blast furnace cannot be used to extract aluminium from its ore. (2)

9 Sodium is a metallic element; sodium chloride is a compound containing sodium; sodium chloride dissolves in water.

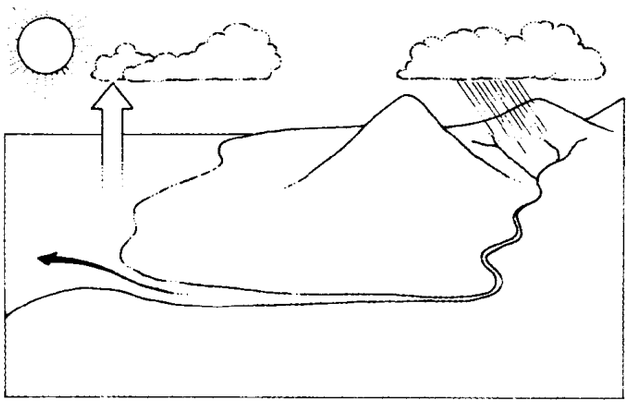
a Choose from the words ions, atoms, molecules, to describe the main particles present in:
(i) sodium
(ii) sodium chloride
(iii) water. (2)

b Explain why sodium chloride (m.p. 801°C) has a much higher melting point than water.

c Explain why sodium chloride solution conducts electricity, whereas solid sodium chloride does not. (3)

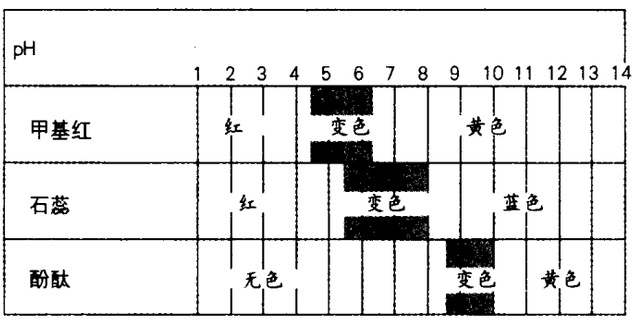
自我评估题

1. 这是一幅水循环结合岩石风化的图。



在图上合适的地方加注蒸发、冷凝、腐蚀、运动和沉淀。(5)

2. 这是三种指示剂在 pH1 ~ pH13 的颜色。



给出下列混合物的颜色。 (4)

a 纯水 + 石蕊

b 硫酸 + 甲基红

c 氢氧化钠 (pH13) + 甲基红 + 酚酞

d 碱 + 酚酞

3. 块状硫酸钙跟稀硝酸反应放出二氧化碳气体，生成硝酸钙溶液。(相对原子量是: Ca=40; C=12; O=16; H=14)

a 写出这一反应的化学方程式并配平 (2)

b 10克硫酸钙跟过量硝酸反应，可以生成多少质量的二氧化碳? (2)

4. 当燃料燃烧时，发生燃烧反应。

a 蜡烛里是什么燃料? (1)

b 燃烧反应主要产生什么形式的能? (1)

c 指出石油燃烧产生的两种主要的废气。 (2)

d 在燃烧时，跟燃料反应的气体是什么? (1)

5. 下列图框给出地球圈层组成的有关信息。

a 用正确的字母填入每一框内:
C= 地壳 M= 地幔
OC= 外核 IC= 内核

液态; 主要是铁; 4000℃以上	
固态; 岩石; 250℃(平均)	
塑胶固体; 岩石; 3700℃以上	
固体; 主要是铁; 4500℃以上	

b 铁通常在1535℃熔化，解释为什么在地球内部在4500℃时，铁仍是固体。 (1)

c 解释为什么科学家相信在地幔里的岩石比地壳里的岩石密度大。 (2)

6. 当一种酸跟一种金属或一种金属化合物反应时生成一种盐，请在下表内填空。 (5)

盐	金属 / 金属化合物	酸
硫酸锌		硫酸
	碳酸铅	硝酸
氯化钠		
硫酸铜		硫酸

7. a 用圆圈代表水分子，画出方块图表示冰 (固体)，水 (液体) 和水蒸气 (气体) 里水分子的排布。 (3)

b 为什么冰立方体有固定的形状? (1)

8. 参考金属活动性顺序，解释为什么不能用高炉从铝矿里提炼铝。 (2)

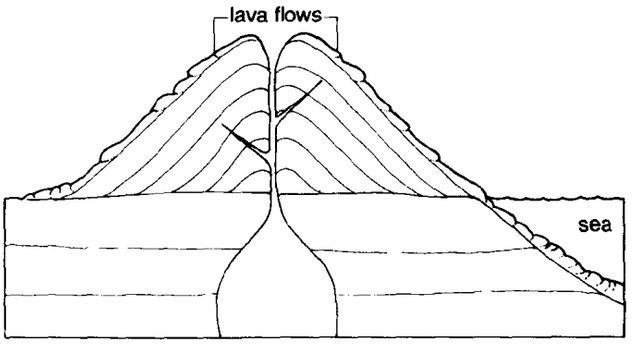
9. 钠是一种金属元素，氯化钠是一种含钠的化合物，氯化钠溶解于水。

a 选择离子、原子、分子来表示存在的主要粒子:
(i) 钠
(ii) 氯化钠
(iii) 水 (2)

b 解释为什么氯化钠 (熔点801℃) 比水的熔点高得多。

c 解释为什么氯化钠溶液导电，而固体氯化钠不导电。 (3)

10 This diagram shows an active volcano.



Shade and label (with letters **a b c d**) the regions where you would most likely find:

a metamorphic rock
b igneous rock with small crystals
c igneous rock with large crystals
d sedimentary rock. (4)

11 Jack adds samples of four metals A, B, C, and D to water and to acid. He notes down the following results:

Metal	Reaction with water	Reaction with acid
A	none	slow
B	none	none
C	rapid	violent
D	very slow	rapid

a Arrange the metals in order of increasing reactivity. (2)

b Jack dissolves the chloride salt of metal B in water and then adds metal A. Does he expect anything to happen? Explain your answer. (2)

12 Changes happen at the electrodes during electrolysis. Fill in the chart to show what you expect to happen. (4)

Electrolysis system	At the anode(+)	At the cathode (–)
copper sulphate between copper electrodes		
dilute sulphuric acid between carbon electrodes		

13 Rusting is the corrosion of iron and many of its alloys.

a What two substances must be present for rusting to happen? (2)

b Roman swords made of iron have been found in peat bogs. Why have these swords not completely rusted away? (1)

c What do rusting and combustion have in common? (1)

14 Seranjit has four different powders in bottles whose labels have fallen off. She tests each powder by adding a little to some dilute hydrochloric acid. These are the results she wrote down:

Bottle 1
All dissolved: hydrogen given off

Bottle 2
Nothing happened

Bottle 3
All dissolved: CO_2 given off

Bottle 4
Some dissolved, but not all

On which bottle should Seranjit stick each of the following labels? (4)

MAGNESIUM

SILICON

MAGNESIUM/SILICON MIXTURE

MAGNESIUM CARBONATE

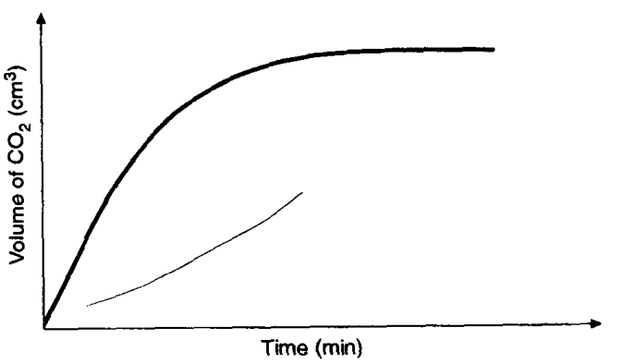
15 The table contains information about the five elements A–E (not their actual symbols).

Element	Group number	Proton number	Nucleon number
A	I	11	23
B	II	20	40
C	VI	16	32
D	0	18	39

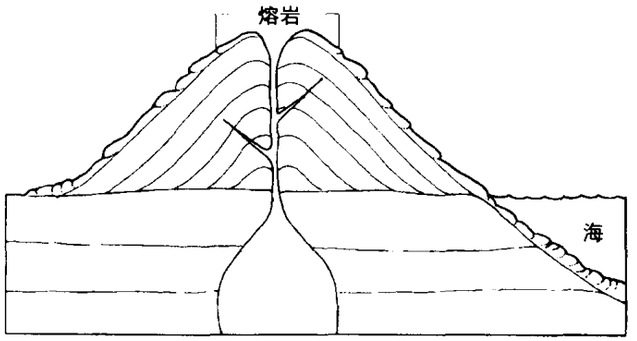
a Which elements will form:
(i) a basic oxide?
(ii) covalent compounds?
(iii) a chloride which is a liquid at room temperature? (3)

b Which element has:
(i) 12 neutrons in it nucleus?
(ii) an ion with electronic structure 2, 8, 8?
(iii) an isotope $^{34}_{16}X$? (3)

16 The graph below follows the amount of CO_2 evolved when 1g of marble chips dissolves in an excess amount of 2 M nitric acid.



10. 下图表示一座活火山。



在你认为最可能找到的区域涂色，并加上标记（用a b c d字母）

a 变质岩
b 带小晶粒的火成岩
c 带大晶粒的火成岩
d 沉积岩 (4)

11. 杰克向水里和酸里加入A，B，C，D四种金属试样，观察到下列结果：

金属	跟水反应	跟酸反应
A	无反应	慢
B	无反应	无反应
C	迅速	激烈
D	很慢	迅速

a 按活动性递增的顺序，排列这些金属。 (2)

b 杰克把金属B的氯化物溶入水中。然后加入金属A，他能预测反应发生吗？解释你的回答。 (2)

12. 在电解时，电极上有变化发生。填下表，表明你预测的反应。 (4)

电解系统	在阳极(+)	在阴极(−)
在铜电极之间的硫酸铜		
在碳电极之间的稀硫酸		

13. 铁和它的许多合金的腐蚀就是生锈。

a 要使锈蚀发生，哪两种物质必须存在？ (2)

b 在泥煤里发现有铁做的古罗马剑，为什么这些剑没有全部锈蚀？ (1)

c 锈蚀跟燃烧反应有什么相同点？ (1)

14. 塞雷吉有四个装有不同粉末的瓶子，它们的标签都掉了。她加入少量稀盐酸来测试每种粉末，这些是她记录的结果。

第一瓶
全部溶解，放出氢气

第二瓶
没有反应

第三瓶
全部溶解，放出CO_2

第四瓶
部分而不是全部溶解

塞雷吉应该怎样选用下列各个标签，分别贴在各个瓶上？ (4)

镁
硅
镁／硅混合物
碳酸镁

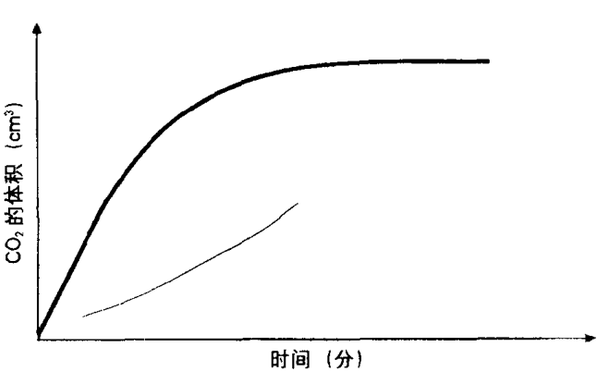
15. 表格含有关于从A-E（不是它们的实际元素符号）5种元素的信息。

元素	族	中子数	质子数
A	I	11	23
B	II	20	40
C	VI	16	32
D	0	18	39

a 哪些元素会变成：
(i) 一种碱性化合物？
(ii) 共价化合物？
(iii) 一种氯化物，它在室温时是液体？ (3)

b 哪种元素：
(i) 的原子核里有12个质子？
(ii) 的离子的电子层结构是2，8，8？
(iii) 有同位素 $^{34}_{16}X$？ (3)

16. 1克块状大理石溶解在过量的2M硝酸里，下图表示，随着反应的进行，产生的CO_2的量。



a Sketch the graph that would result if the marble were powdered. (2)

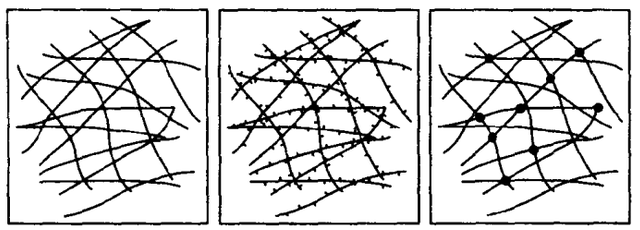
b Sketch the graph that would result if excess 1 M nitric acid were reacted with 1g of marble chips. (2)

17 Four elements A, D, E, and G have the following atomic numbers:
A = 10; D = 11; E = 17; G = 19.

a Which one of A, E, and G will have similar properties to D? (1)

b Which of these four elements will be in the same group of the periodic table as argon (electronic structure 2, 8, 8)? (1)

18 The diagrams show the arrangement of the hydrocarbon chains in three synthetic polymer materials.



a Which polymer is a thermoset? (1)

b Which polymer softens at the lowest temperature? (1)

c Explain why Polymer A has the lowest density. (2)

19 Label each of the following rocks either sedimentary, igneous or metamorphic. (3)

a hard with large crystals

b no crystals, no fossils

c soft with fossils

20 This table gives the properties of some materials.

Properties	Use
flammable volatile liquid	
flexible ductile conductor	
rigid mouldable insulator	
non-flammable and inert gas	
cheap dense solid with high compressive strength	
light solid with high tensile strength	

Complete the 'Use' column in the table by choosing letters from the following: (6)

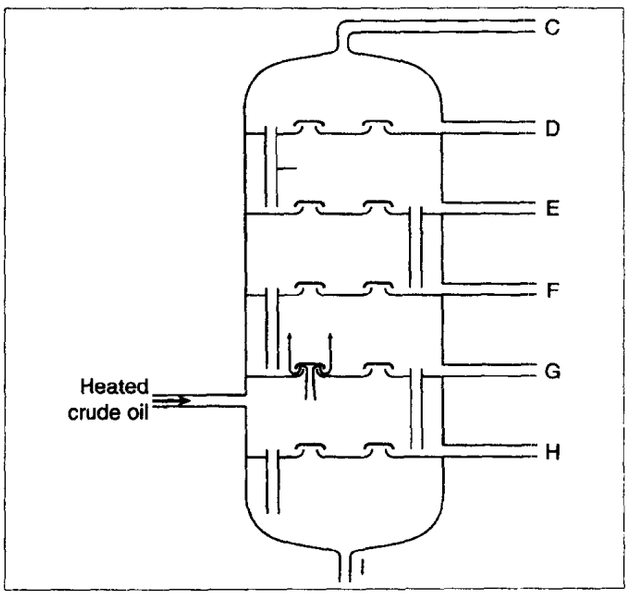
A the body of an electric plug
B the wings of an aircraft
C the fuel for a car
D the supports of a motorway bridge
E the filling of an electric light bulb
F the wire inside an electric cable

21 Lucien is trying to make pure sugar crystals from sugar-beet. Help him by listing these practical steps in the correct order. (3)

A crystallize
B chop/mince
C evaporate
D boil in water
E filter
F redissolve/recrystallize

22 *Magma* cools to make *igneous rocks* which are then weathered to form *sedimentary rocks.* These rocks can also change into metamorphic rocks which can then weather or be incorporated again into molten magma. This series of changes makes up the rock cycle. Draw a labelled diagram of the rock cycle. Include the words *erosion/transport, deposition* and *heat/pressure.* (4)

23 This is a diagram of a fractional distillation column used in an oil refinery.



a label the coolest part inside the fractionating column with a star (*). (1)

b What happens to vapour as it rises through a bubble cap (e.g. B)? (2)

c What happens to a liquid that passes down through the tubes labelled A? (1)

d From which of the pipes C–I will flow the hydrocarbon C_3H_6? (1)

e The hydrocarbon $C_{10}H_{22}$ passes into a catalytic cracker. One product of cracking is propene C_3H_6. Give the formula of the other product. (2)

f Propene is used to make a polymer called a polypropene. Give the structures of propene and a section of polypropene. Explain how propene polymerizes to make polypropene molecules. (4)

24 Methane, carbon dioxide, and oxides of nitrogen are greenhouse gases. Give the major source of each gas. Describe how scientists believe greenhouse gases contribute to global warming. (4)

a 如果大理石是粉末状的，结果会怎样，画出草图。

(2)

b 如果1M过量的硝酸跟1克大理石块反应，结果怎样，画出曲线。

(2)

17. A、D、E、G四种元素有以下的原子序数：
A=10；D=11；E=17；G=19。

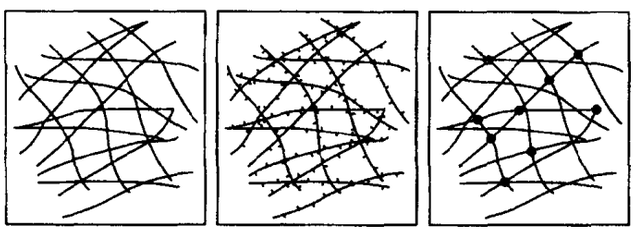
a A，E，G中哪一种跟D的性质相似？

(1)

b 四种元素里的哪一种跟氩（电子结构是2，8，8）在周期表里处于同一族？

(1)

18. 下图显示三种合成聚合物材料里的碳氢链的排布。



A B C

a 哪种聚合物是热固性的？ (1)

b 哪种聚合物在最低温时软化？ (1)

c 解释为什么聚合物A的密度最小？ (2)

19. 指出下列哪种岩石是沉积岩、火成岩还是变质岩？

a 硬，有大晶粒 (3)

b 没有晶粒，没有化石

c 软，有化石

20. 下表列出一些物质的性质。

性质	用途
易燃易挥发液体	
能弯曲有延性导体	
坚硬可塑的绝缘体	
不能燃烧的惰性气体	
密度小、抗压强度高的固体	
抗张强度高的轻质固体	

选择下列字母填入“用途”一栏里： (6)

A 电源插座

B 飞机机翼

C 汽车燃料

D 筑高速公路桥

E 充填电灯泡

F 电缆内芯

21. 路西想用甜菜做纯净的糖晶体，请帮他把这些操作步骤按正确顺序排列。

(3)

A 结晶

B 切碎

C 蒸发

D 在水里煮沸

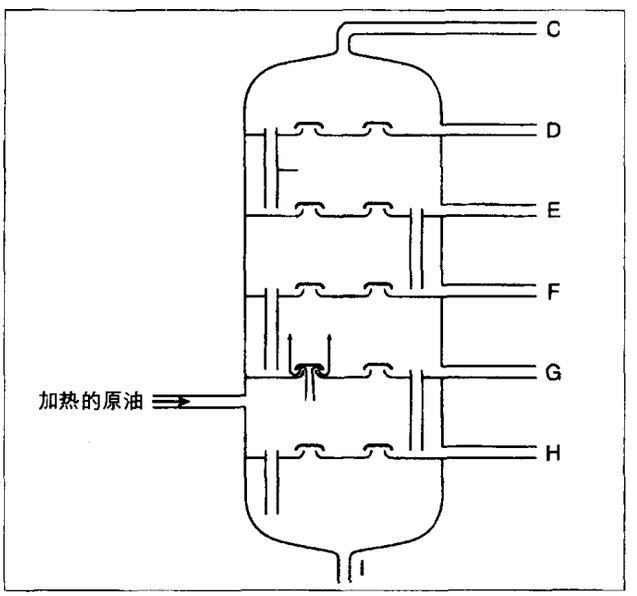
E 过滤

F 再溶解／再结晶

22. 岩浆冷却变成火成岩。火成岩风化形成沉积岩。这些岩石也能变成变质岩，然后又风化或者被重新变成岩浆。这一系列的变化形成岩石的循环，画一幅带标记的岩石循环图，要用到这些词：*腐蚀／运动，沉降和热／压力*。

(4)

23. 这是一幅用来精炼油的分馏塔的图。



a 用星号*标出 分馏塔里温度最低的部位。

(1)

b 当蒸汽上升通过泡罩时，有什么发生？（比如B）

(2)

c 当一种液体向下流过管子时（用A标记）有什么发生？

(1)

d 在C—I的管道里哪一个流过烃 C_3H_6？

(1)

e 烃 $C_{10}H_{22}$ 通过一种催化裂解设备。一种裂解产品是丙烯 C_3H_6，给出另一个产品的分子式。

(2)

f 丙烯用来制一种叫聚丙烯的聚合物。写出丙烯的结构式和聚丙烯的部分结构式。解释丙烯是怎样聚合生成聚丙烯分子的。

(4)

24. 甲烷、二氧化碳和氮的氧化物是造成温室效应的气体。讲出每种气体的主要来源，讲述科学家是怎样认为温室气体使全球变暖的。

(4)

25 Mary pours $50cm^3$ of water into a measuring cylinder and then adds a piece of rock. The water level goes up to $85cm^3$ and then slowly falls to $83cm^3$.

a Why does the water level slowly fall? (1)

b What will Mary see as the water level falls? (1)

c Which sort of rock is it *least* likely to be; sedimentary, igneous or metamorphic? (1)

26 Sandy's teacher asks her to make pure salt from a lump of mineral rock salt. Label these steps (1–2–3–4–5–6–7) in the right order so that Sandy will end up with pure dry crystals of salt. (3)

Order	Step
	Filter
	Press between dry filter papers
	Stir with hot water
	Wash quickly with cold water
	Evaporate
	Crush
	Cool and crystallise

Large amounts of ammonia are needed to make fertilizers. Ammonia is made by the Haber process that uses an iron catalyst to combine hydrogen and nitrogen and nitrogen gases at 450°C and 150 atmospheres pressure.

$$3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g)$$

The yield of ammonia increases as temperature decreases and as pressure increases.

a What is the relationship between temperature and the rate of the reaction? (1)

b Highest yields are obtained at temperatures below 350°C. Why is the Haber process usually run at 450°C? (2)

c Why does increasing the pressure increase the rate of the reaction? (1)

d Suppose a Haber process reactor vessel bursts open. What would be the volume of $1m^3$ of reactants (at 450°C/150 atmos.) under external conditions (27°C and 1 atmos.)? (3)

25. 玛利把50立方厘米水倒入量筒，然后加入一块岩石，水线上升到85立方厘米，然后又慢慢下降到83立方厘米。

a 为什么水线会缓慢下降？

(1)

b 当水线下降时，玛利看到了什么？

(1)

c 岩石最可能是什么种类的，沉积岩，火成岩还是变质岩？

(1)

26. 桑迪的老师要他用块状的岩盐矿制取纯盐，把这些步骤按正确的顺序，标上记号（1-2-3-4-5-6-7），这样桑迪最后能得到纯净的盐晶体。 (3)

次序	操作步骤
	过滤
	挤压干的滤纸
	搅拌热水
	用冷水迅速冲洗
	蒸发
	压碎
	冷却、结晶

制造肥料需要大量的氨，氨是用哈伯法生产的，它是用铁做催化剂，让氢跟氮在450℃，150大气压下结合。

$3H_2(g)+N_2(g) \rightleftharpoons 2NH_3(g)$

氨产量随温度降低、压力升高而增加。

a 温度和反应速度之间是什么关系？

(1)

b 在温度低于350℃时，可以获得最高的产量，为什么哈伯法通常把温度定在450℃？

(2)

c 为什么增加压力可以提高反应速度？

(1)

d 假如一个用哈伯法生产的反应容器突然炸开，1立方米体积的反应物（在450℃/150大气压下）会变成多大体积？这时外部环境是（27℃和1个大气压）。

(3)

Answers

(Short answers only)

2 **a** purple
b red
c orange
d pale red

3 **a** $CaCO_{3(s)} + 2HNO_{3\,(aq)} \rightarrow CO_{2(g)} + Ca(NO_3)_{2\,(aq)} + H_2O_{(l)}$
b RMM of $CaCO_3$ = 100g ⇒ 10g = 0.1 mol $CaCO_3$
from the equation this gives 0.1 mol CO_2
RMM of CO_2 = 44g therefore 4.4g CO_2 evolved

4 **a** paraffin wax
b heat energy
c carbon dioxide and steam
d oxygen

5 **a** OC, C, M, IC
b It is under enormous pressure which raises its melting point.

6

Salt	Metal/metal compound	Acid
zinc sulphate	*zinc; zinc oxide/ hydroxide/carbonate*	sulphuric acid
lead nitrate	lead carbonate	nitric acid
sodium chloride	*sodium carbonate/ hydroxide/oxide*	*hydrochloric acid*
copper sulphate	*copper oxide/ carbonate/hydroxide*	sulphuric acid

9 **a** atoms, ions, molecules
b The ionic bonds that exist between the sodium and chloride ions are much stronger than the bonds which hold the water molecules together. Therefore less energy is required to split the water molecules into liquid form than is required to melt the sodium chloride.
c In a liquid the ions can move, carrying a charge through the solution, while in a solid state the sodium and chloride ions are held fixed in the lattice so no charge is carried across.

11 **a** B, A, D, C
b Yes, because A is more reactive than B a reaction will take place. The more reactive metal, A, will go into solution displacing either hydrogen from the solution or metal B if it is below hydrogen in the reactivity list.

12

Electrolysis system	At the anode (+)	At the cathode (-)
Copper sulphate between copper electrodes	anode dissolves	copper deposits
Dilute sulphuric acid between carbon electrodes	oxygen collects	hydrogen collects

13 **a** oxygen and water
b The water in bogs is very still and there is little mixing between the surface water which contains oxygen from the air, and the deep water which has little oxygen dissolved in it. The swords buried deep in the bog are in contact with water, but not oxygen. Without oxygen rusting will not take place.
c Both rusting and combustion require oxygen.

14 1, 2, 4, 3

15 **a** **(i)** A or B
(ii) C
(iii) C

b **(i)** A
(ii) B or C
(iii) C

17 **a** G
b A

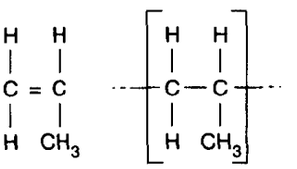
18 **a** C
b A

19 **a** igneous
b metamorphic
c sedimentary

20 C, F, A, E, D, B

21 B, D, E, C, A, F

23 **b** As the vapour passes through the bubble cap, it comes into contact with liquid in the collecting tray. This cools the vapour to the temperature of the liquid, and fractions which boil at or above this temperature will condense.
c The liquid will fall into the hotter liquid in the collecting tray below where it will vapourise and pass back up through the bubble cap.
d C
e C_7H_{16}
f



propene poly-propene

During polymerisation one of the bonds making the double bond in propene molecules breaks. The electrons from the broken bonds form two new single bonds with neighbouring propene molecules. Gradually long chains form.

25 **a** The water level falls as the rock is porous and water seeps into the holes producing a fall in volume.
b Air bubbles will rise as the water falls.
c Metamorphic.

答案
（只有简答）

2 a 紫色
b 红色
c 橙色
d 淡红色

3 a $CaCO_3(s)+2HNO_3(aq) \rightarrow CO_2(g)+Ca(NO_3)_2(aq)+H_2O(l)$
b $CaCO_3$的摩尔质量 = 100g ⇒ 10g = 0.1mol$CaCO_3$
从方程式可知放出0.1molCO_2
CO_2的摩尔质量 = 44 克，因此生成 4.4 克 CO_2

4 a 石蜡
b 热能
c 二氧化碳和水蒸气
d 氧气

5 a OC, C, M, IC
b 在巨大的压力下，它的熔点升高

6

盐	金属／金属化合物	酸
硫酸锌	锌；氧化锌／氢氧化锌／硫酸锌	硫酸
硝酸铅	碳酸铅	硝酸
氯化钠	碳酸钠／氢氧化钠／氧化钠	盐酸
硫酸铜	氧化铜／碳酸铜／氢氧化铜	硫酸

9 a 原子、离子、分子

b 钠离子跟氯离子之间的离子键要比水分子之间的键强得多，因此使（固态）水分子变成液态水分子所需的能量要比熔化氯化钠所需的能量少。

c 在液体里，离子可以携带电荷在溶液里移动，而在固态时氯离子和钠里离子是固定在晶格上的，所以不能携带电荷运动。

11 a B, A, D, C

b 是。因为A比B活泼，反应就会发生。A金属越活泼，它进入溶液要么把氢从溶液里置换出来，要未把金属B从溶液里置换出来，如果在活动顺序表里B在氢的后面的话。

12

电解系统	在阳极（+）	在阴极（-）
铜电极之间的硫酸铜	阳极溶解	铜沉淀
碳电极之间的稀硫酸	收集氧气	收集氢气

13 a 氧气和水
b 沼泽里的水不会流动，是静止的，在它的表面几乎没有来自空气的氧气，而在深水里，几乎没有溶解的氧气。剑深埋在沼泽里跟 水接触，但不跟氧气接触，没有氧，锈蚀就不会发生
c 生锈和燃烧都需要氧气

14 a 1, 2, 3, 4

15 a (i)A 或者 B
(ii)C
(iii)C
b (i)A
(ii)B 或者 C
(iii)C

17 a G
b A

18 a C
b A

19 a 火成岩
b 变质岩
c 沉积岩

20 C, F, A, E, D, B

21 B, D, E, C, A, F

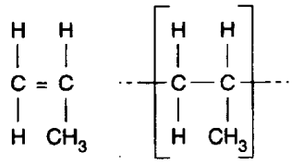
23 b 当蒸气通过泡罩时，蒸气跟 集液盘里的液体接触，这使蒸气冷却到液体的温度。在这个温度或高于这个温度会沸腾的馏分就会冷凝。

c 液体会下降到下面的集液盘较热的液体里，在这里，液体会蒸发，再通过泡罩。

d C

e C_7H_{16}

f



丙烯　　聚丙烯

在聚合时，丙稀分子里双键中的一个键破裂。破裂的键上的电子跟相邻的丙稀分子形成两个新的单键，渐渐地形成长键。

25 a 当岩石穿孔，水渗进孔内时，造成体积减少，水线下降。

b 当水线下降时，空气泡就会上升。

c 变质岩。

26 3, 7, 2, 6, 4, 1, 5

27 **a** Rate is proportional to temperature.

b The reaction slows down as the temperature falls, so even though there is a high yield this is obtained too slowly to be viable.

c The increase in pressure pushes the reacting molecules closer together. This means they have a greater chance of colliding and therefore reacting.

d $62.2m^3$

26 3, 7, 2, 6, 4, 1, 5

27 **a** 反应速度和温度成比例

b 当温度下降时，反应变慢，所以即使产率高，但因为反应太慢，所以实际上是行不通的。

c 升高压力，使反应分子靠紧，这表示它们有更多的机会互相碰撞，从而发生反应。

d 62.2 立方米。

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Entries in **bold** type indicate main topic entries. 用黑体印刷的词条是主题词条

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23 Na 11	24 Mg 12											27 Al 13	28 Si 14	31 P 15	32 S 16	35 Cl 17	40 Ar 18
39 K 19	40 Ca 20	45 Sc 21	48 Ti 22	51 V 23	52 Cr 24	55 Mn 25	56 Fe 26	59 Co 27	59 Ni 28	64 Cu 29	65 Zn 30	70 Ga 31	73 Ge 32	75 As 33	79 Se 34	80 Br 35	84 Kr 36
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