HOLIDAY HOMEWORK 假期作业

AP Chemistry

Exercise sheets, topic by topic.

每个单元：练习卷。

For class or self-study • no answer keys included.

Contents 目录

1 Moles and formulas – Part 1

Name: ____________ Class: ________ Date: __________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	**中文**	**Write it 3 times** (English)		
moles	摩尔			
Avogadro's number	阿伏伽德罗常数			
molar mass	摩尔质量			
Isotopes	同位素			
relative abundance	相对丰度			
empirical formula	实验式			

Recall

You have already met the building blocks of chemistry:

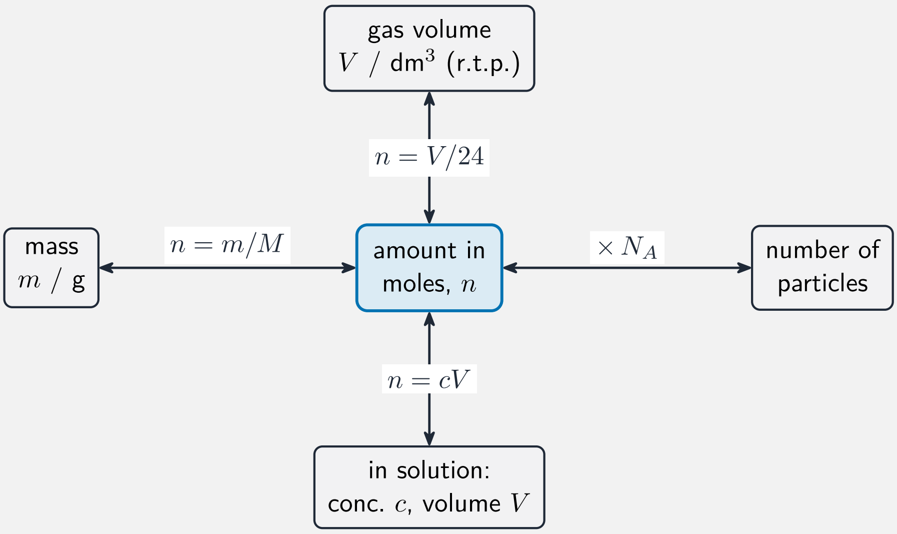
- Atoms are far too small to count one by one.
- Every element has a **relative atomic mass** written on the periodic table.
- You have written formulas like H_2O and CO_2.

This sheet lines up the "counting" tool chemists use –the mole. Each idea has a worked example.

New ideas

■ 1 The mole

Because atoms are so tiny, chemists count them in **moles** 摩尔. One mole is **Avogadro's number** 阿伏伽德罗常数 of particles, $N_A = 6.022 \times 10^{23}$.



■ 2 Molar mass

The **molar mass** 摩尔质量 M (grams per mole) comes straight from the periodic table. It converts between mass and moles:

$$n = \frac{m}{M}.$$

Worked example. 36.0 g of water (M = 18.0 g/mol) is $n = \dfrac{m}{M} = \dfrac{36.0}{18.0} = 2.0$ mol, which is $2.0 \times 6.022 \times 10^{23} = 1.2 \times 10^{24}$ molecules.

■ 3 Isotopes and relative atomic mass

Isotopes 同位素 are atoms of the same element with different numbers of neutrons. The relative atomic mass is the **weighted average** of the isotope masses, using their **relative abundance** 相对丰度.

Worked example. Chlorine is 75.8% chlorine-35 and 24.2% chlorine-37: $A_r = (35)(0.758) + (37)(0.242) = 35.5$ –closer to 35 because it is more abundant.

■ 4 Empirical formula

The **empirical formula** 实验式 is the simplest whole-number ratio of atoms. Find it by turning each element's mass into moles and dividing by the smallest.

Worked example. A compound of 40.0% C, 6.7% H, 53.3% O: C $= \frac{40.0}{12} = 3.33$, H $= \frac{6.7}{1} = 6.7$, O $= \frac{53.3}{16} = 3.33$; dividing by 3.33 gives 1 : 2 : 1, so CH_2O.

Watch out: the relative atomic mass is a **weighted** average –it sits closer to the more abundant isotope, not exactly halfway between the two.

Practice

Try these in order. The methods are all above.

2.1 How many moles are in 22.0 g of carbon dioxide ($M = 44.0$ g/mol)? [2]

2.2 How many molecules are in 0.50 mol of a gas? ($N_A = 6.022 \times 10^{23}$) [2]

2.3 An element is 60% of an isotope of mass 20 and 40% of an isotope of mass 22. Find its relative atomic mass. [3]

2.4 Find the mass of 3.0 mol of water ($M = 18.0$ g/mol). [2]

2.5 A compound is 50% sulfur and 50% oxygen by mass ($S = 32$, $O = 16$). Find its empirical formula. [3]

1 Atomic structure and periodic trends – Part 2

Name: ______________ Class: __________ Date: ____________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
nucleus	原子核			
electron configuration	电子排布			
valence electrons	价电子			
atomic radius	原子半径			
ionization energy	电离能			
electronegativity	电负性			
cations	阳离子			
anions	阴离子			
ionic compound	离子化合物			

Recall

You already know a lot about atoms and the periodic table:

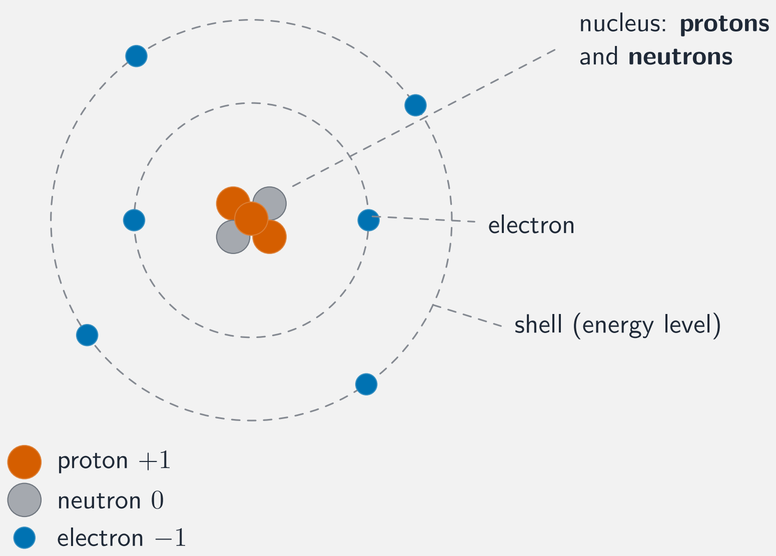
- An atom has a tiny central **nucleus** with electrons around it.
- Electrons sit in **shells**; the outer ones decide how the atom reacts.
- The periodic table groups elements with similar behaviour.

This sheet lines these ideas up for AP. Each idea has a worked example.

New ideas

1 Inside the atom

An atom has a tiny **nucleus** 原子核 (protons and neutrons) surrounded by electrons in shells and subshells (s, p, d).



The **electron configuration** 电子排布 lists how the electrons fill up, lowest energy first, e.g. $1s^2\,2s^2\,2p^6$.

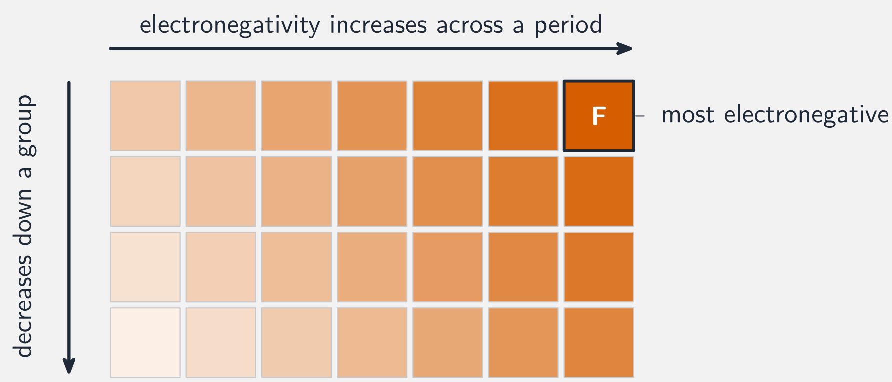
Worked example. Sulfur ($Z = 16$) fills to $1s^2\,2s^2\,2p^6\,3s^2\,3p^4$ –its 16 electrons placed in order.

2 Valence electrons

The outer **valence electrons** 价电子 control an atom's chemistry: they are the ones gained, lost, or shared in reactions.

3 Periodic trends

Across and down the table, three trends follow from nuclear pull and shielding:



- **atomic radius** 原子半径: smaller across a period, larger down a group.

- **ionization energy** 电离能 (energy to remove an electron): larger across, smaller down.
- **electronegativity** 电负性 (pull on shared electrons): larger across and up, toward fluorine.

■ 4 Ions and ionic compounds

Metals lose electrons to form positive **cations** 阳离子; nonmetals gain electrons to form negative **anions** 阴离子. Opposite charges attract into an **ionic compound** 离子化合物, whose formula balances the charges.

Worked example. Aluminium (3+) and oxide (2−) combine as Al_2O_3, so the +6 and −6 cancel.

Watch out: atomic radius and ionization energy go in **opposite** directions –a small atom holds its electrons tightly (high ionization energy), a large atom holds them loosely (low ionization energy).

Practice

Try these in order. The methods are all above.

2.1 Write the electron configuration of oxygen ($Z = 8$). [2]

2.2 State what "valence electrons" are and why they matter. [2]

2.3 State how atomic radius changes (a) across a period, (b) down a group. [2]

2.4 Sodium loses one electron and chlorine gains one. Write the formula of the compound they form, and state the charges. [2]

2.5 Magnesium (2+) combines with chloride (1−). Write the formula of the compound.[2]

2 Types of chemical bonding – Part 1

Name: ____________ Class: ________ Date: __________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
chemical bond	化学键			
ionic bond	离子键			
covalent bond	共价键			
metallic bond	金属键			
polar covalent	极性共价			
ionic solid	离子固体			
lattice	晶格			
delocalized	离域			
alloy	合金			

Recall

You already know that atoms join together in different ways:

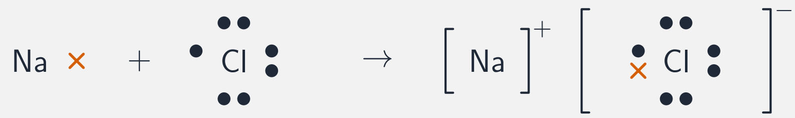
- A metal and a non-metal form an **ionic** compound by transferring electrons.
- Two non-metals form a **covalent** bond by sharing electrons.
- Metals are shiny and conduct electricity.

This sheet lines up the three kinds of bonding and what they explain. Each idea has a worked example.

New ideas

1 The three types of bond

A **chemical bond** 化学键 holds atoms together. Which type forms depends on the atoms:



sodium gives its outer electron (×) to chlorine

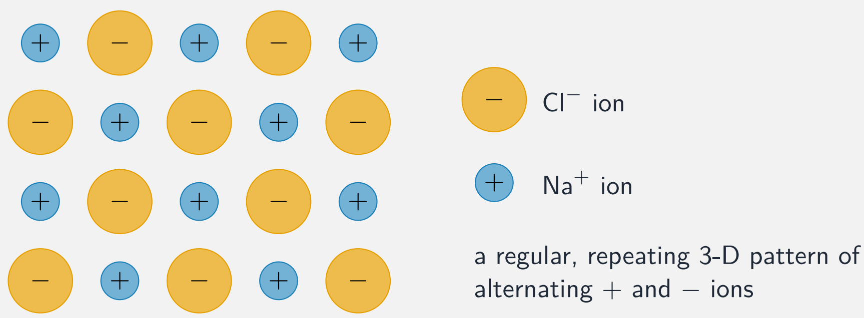
- **ionic bond** 离子键: a metal gives electrons to a non-metal (opposite charges attract).
- **covalent bond** 共价键: two non-metals **share** electrons.
- **metallic bond** 金属键: metal atoms share a "sea" of loose electrons.

2 Polar covalent bonds

When two atoms share electrons **unequally** (one pulls harder), the bond is a **polar covalent** 极性共价 bond –one end is slightly negative, the other slightly positive.

3 Ionic solids

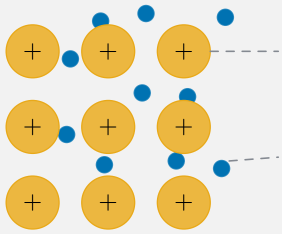
An **ionic solid** 离子固体 is a giant repeating **lattice** 晶格 of alternating positive and negative ions.



The strong attraction gives high melting points and brittleness.

4 Metals and alloys

In a metal, positive ions sit in a sea of **delocalized** 离域 (free-moving) electrons – which is why metals conduct and bend. An **alloy** 合金 mixes in different-sized atoms, which stops the layers sliding and makes it harder (like steel).



Watch out: an ionic solid does **not** conduct electricity when solid –its ions are locked in place. It conducts only when **molten or dissolved**, where the ions are free to move.

Practice

Try these in order. The methods are all above.

2.1 State the type of bond formed between (a) a metal and a non-metal, (b) two non-metals. [2]

2.2 Explain, in terms of electrons, how a metal conducts electricity. [2]

2.3 State why an ionic solid conducts electricity when molten but not when solid. [2]

2.4 Explain why an alloy is usually harder than the pure metal. [2]

2.5 Sodium and chlorine form sodium chloride. State the type of bond and describe what happens to the electrons. [2]

2 Lewis diagrams and molecular shapes – Part 2

Name: ____________ Class: ________ Date: __________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
Lewis diagram	路易斯结构			
lone pairs	孤对电子			
octet	八隅体			
VSEPR	价层电子对互斥			

Recall

In Part A you met covalent bonds, where atoms share electrons. Now draw molecules and predict their shapes:

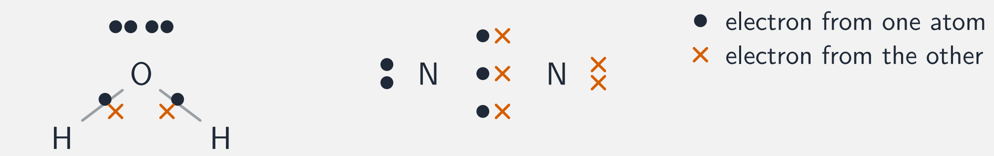
- You have drawn simple dot-and-cross diagrams before.
- Molecules are not flat blobs –they have definite 3-D shapes.

Each idea has a worked example before the Practice.

New ideas

■ 1 Lewis diagrams

A **Lewis diagram** 路易斯结构 shows an atom's outer electrons as shared **bonding pairs** and unshared **lone pairs** 孤对电子. Most atoms want a full **octet** 八隅体– eight outer electrons (hydrogen wants just two).



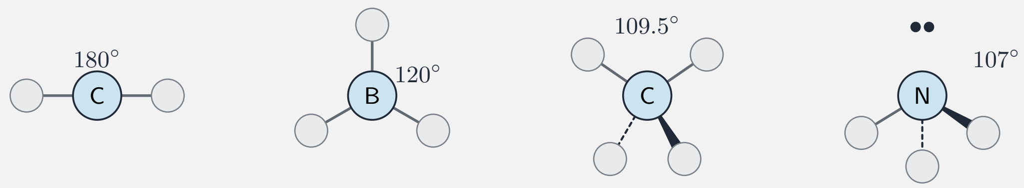
H_2O: 2 bonding pairs + 2 lone pairs

N_2: triple bond (3 shared pairs)

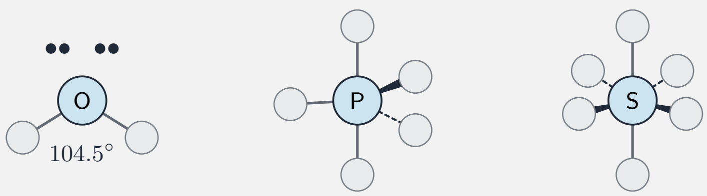
Worked example. In carbon dioxide CO_2, carbon shares **two** pairs with each oxygen (two double bonds, $O = C = O$), so every atom reaches an octet.

2 Molecule shapes

VSEPR 价层电子对互斥 theory predicts shape with one simple rule: the electron pairs around a central atom spread out **as far apart as possible**.



linear CO_2 | **trigonal planar** BF_3 | **tetrahedral** CH_4 | **pyramidal** NH_3



bent H_2O | **trig. bipyramidal** PF_5, $120°$ & $90°$ | **octahedral** SF_6, $90°$

- 2 pairs → linear; 3 pairs → flat triangle; 4 pairs → tetrahedral.

Worked example. Methane CH_4 has four bonding pairs around carbon, so they point to the corners of a **tetrahedron** (angles 109.5°).

3 Lone pairs bend the shape

Lone pairs take up space too, and they push the bonds a little closer together, bending the shape.

Worked example. Water H_2O has two bonding pairs and two lone pairs; the lone pairs push the two O–H bonds down to a **bent** shape (about 104.5°).

4 Polar molecules

If a molecule's shape leaves its bond dipoles unbalanced, the whole molecule is **polar** (like water). If they cancel by symmetry, it is non-polar (like CO_2).

> **Watch out:** a molecule can have polar bonds but still be non-polar overall –if its symmetric shape makes the dipoles cancel. CO_2 is the classic example.

Practice

Try these in order. The methods are all above.

2.1 State how many outer electrons most atoms want (the octet rule), and the exception for hydrogen. [2]

2.2 State the shape and bond angle of methane CH_4 (four bonding pairs). [2]

2.3 Explain why water is a bent shape rather than straight. [2]

2.4 A molecule of CO_2 has polar bonds but is non-polar overall. Explain why. [2]

2.5 State the VSEPR rule that decides the shape of a molecule. [1]

3 Forces between molecules and states of matter – Part 1

Name: ____________ Class: ________ Date: __________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
Intermolecular forces	分子间作用力			
London dispersion forces	伦敦色散力			
dipole–dipole	偶极偶极			
hydrogen bonding	氢键			

Recall

You already know about the three states of matter:

- Solids are packed tight, liquids flow, gases spread out to fill any space.
- Heating a solid melts it; heating a liquid boils it.
- Water boils at 100 °C, but many gases boil far below room temperature.

This sheet explains why, using the weak forces **between** molecules. Each idea has a worked example.

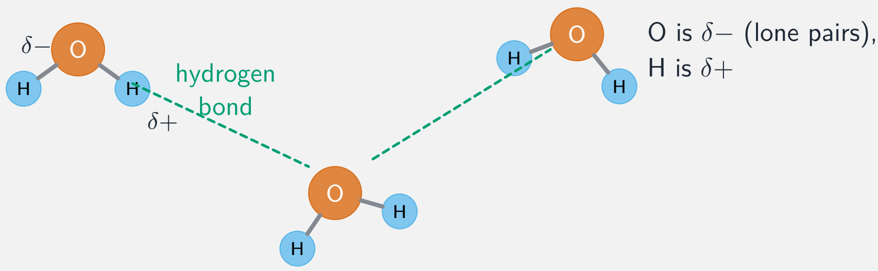
New ideas

■ 1 Forces between molecules

Intermolecular forces 分子间作用力 are attractions **between** whole molecules – much weaker than the bonds inside a molecule, but they decide melting and boiling points.

■ 2 The three kinds

From weakest to strongest:



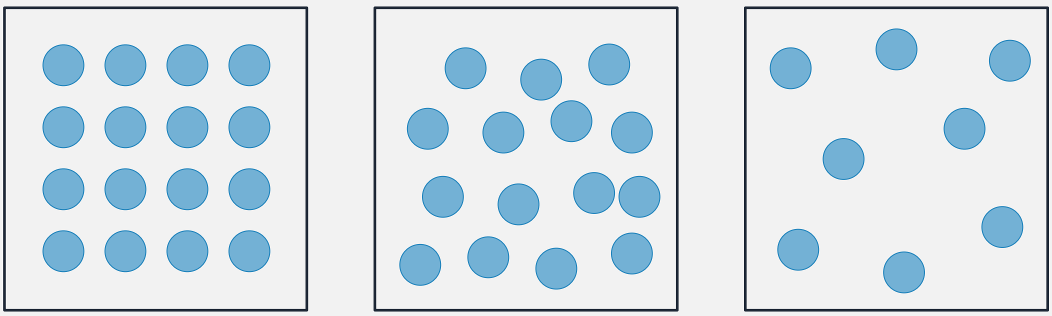
- **London dispersion forces** 伦敦色散力–present in all molecules; stronger for bigger ones.
- **dipole–dipole** 偶极偶极–between polar molecules.
- **hydrogen bonding** 氢键–a strong force when H is joined to N, O, or F.

3 Stronger forces, higher boiling point

The stronger the intermolecular forces, the more energy is needed to pull the molecules apart, so the higher the boiling point.

Worked example. Water (18 g/mol, hydrogen-bonded) boils at 100 °C, but methane (16 g/mol, only weak dispersion forces) boils at −162 °C –almost the same size, hugely different boiling points, because of the forces between molecules.

4 The states of matter



solid
regular, touching
vibrate in place

liquid
close, random
slide past each other

gas
far apart, random
move fast

Heating raises the particles' energy; when it beats the attractions, the substance melts or boils.

Watch out: boiling breaks the weak forces **between** molecules, not the strong bonds **inside** them. When water boils, the H–O bonds stay intact –the molecules just separate from each other.

Practice

Try these in order. The methods are all above.

2.1 State whether intermolecular forces are stronger or weaker than the bonds inside a molecule. [1]

2.2 Name the three types of intermolecular force, from weakest to strongest. [2]

2.3 Explain why water has a much higher boiling point than methane, even though they are a similar size. [2]

2.4 State what type of intermolecular force is present in all molecules. [1]

2.5 When water boils, state what is broken –the bonds inside the molecules, or the forces between them. [1]

3 Solutions, concentration, and separation – Part 2

Name: ______________ Class: _________ Date: ____________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
solution	溶液			
solute	溶质			
solvent	溶剂			
molarity	摩尔浓度			
chromatography	色谱法			
Solubility	溶解度			

Recall

You have made and used solutions many times:

- Salt dissolves in water to make salt water.
- You have separated mixtures by filtering.
- Some things dissolve in water and some do not.

This sheet makes ”how much is dissolved” exact, and lines up the ways to separate mixtures. Each idea has a worked example.

New ideas

■

A **solution** 溶液 is a **solute** 溶质 dissolved in a **solvent** 溶剂. Its concentration is measured as **molarity** 摩尔浓度:

$$M = \frac{\text{moles of solute}}{\text{litres of solution}}.$$

Worked example. Dissolving 0.50 mol of salt in 2.0 L of water gives $M = \frac{0.50}{2.0} =$ 0.25 M.

■ 2 Dilution

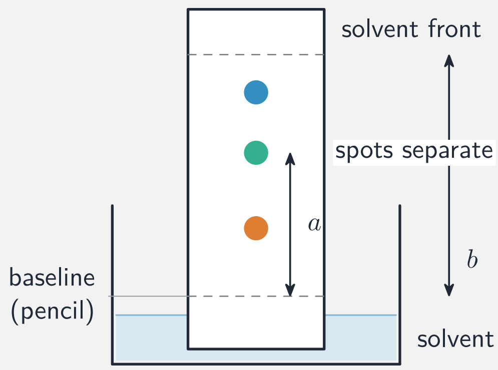
Adding solvent spreads the same moles through more volume, so the concentration drops. Because the moles do not change,

$$M_1V_1 = M_2V_2.$$

Worked example. To dilute 50 mL of 6.0 M acid to 2.0 M: $V_2 = \frac{M_1V_1}{M_2} = \frac{6.0 \times 50}{2.0} =$ 150 mL, so you add $150 - 50 = 100$ mL of water.

■ 3 Separating mixtures

Because a mixture's parts keep their own properties, physical methods separate them:



$$R_f = \frac{a}{b} = \frac{\text{spot}}{\text{solvent}}$$

- **filtration** –by particle size,
- **distillation** –by boiling point,
- **chromatography** 色谱法–by how strongly each part sticks versus moves with a solvent.

■ 4 What dissolves in what

Solubility 溶解度 follows the rule "**like dissolves like**": polar and ionic solutes dissolve in polar solvents (like water); non-polar solutes dissolve in non-polar solvents (like oil).

> **Watch out:** in a dilution the number of **moles of solute stays the same** –only the volume (and so the concentration) changes. That is exactly why $M_1V_1 = M_2V_2$ works.

Practice

Try these in order. The methods are all above.

2.1 Find the molarity of a solution with 0.20 mol of solute in 0.50 L of solution. [2]

2.2 You dilute 100 mL of 3.0 M solution to 1.0 M. Find the final volume. [3]

2.3 Name the separation method best suited to separating (a) sand from water, (b) two liquids with different boiling points. [2]

2.4 Explain, using "like dissolves like", why oil does not dissolve in water. [2]

2.5 State what stays constant during a dilution. [1]

4 Reactions, equations, and stoichiometry – Part 1

Name: ______________ Class: __________ Date: ____________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
chemical reaction	化学反应			
precipitate	沉淀			
physical change	物理变化			
chemical change	化学变化			
Stoichiometry	化学计量			
limiting reactant	限量反应物			

Recall

You have already worked with chemical reactions:

- A reaction makes **new substances** –you might see a colour change, bubbles, or a solid form.
- You have balanced equations so both sides have the same atoms.
- You have used moles to work out amounts.

This sheet lines up how to calculate amounts from an equation. Each idea has a worked example.

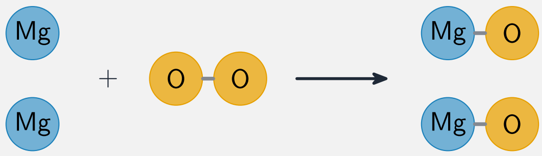
New ideas

■

A **chemical reaction** 化学反应 rearranges atoms into new substances. You can tell one happened by a colour change, a gas or a **precipitate** 沉淀 (solid) forming, or a temperature change.

■ 2 Balanced equations

Atoms are never created or destroyed, so an equation must be **balanced** –the same number of each atom on both sides.



$2Mg + O_2 \rightarrow 2MgO$

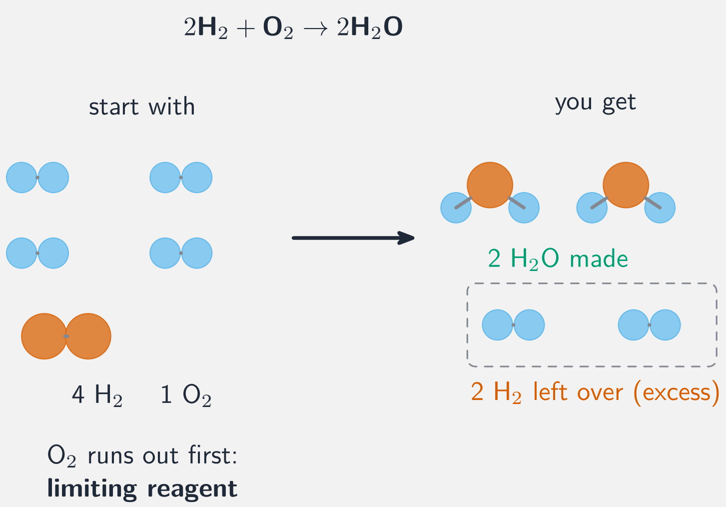
2 Mg and 2 O on each side: balanced

■ 3 Physical or chemical change

A **physical change** 物理变化 changes form but not identity (melting, dissolving); a **chemical change** 化学变化 makes new substances. Dissolving salt is physical –the salt is unchanged.

■ 4 Stoichiometry

Stoichiometry 化学计量 uses the balanced equation's mole ratio to link amounts. The path is always grams → moles → (mole ratio) → moles → grams. The **limiting reactant** 限量反应物 runs out first and sets how much product forms.



Worked example. How much water forms when 4.0 g of hydrogen burns? $2H_2 + O_2 \rightarrow 2H_2O$. Moles of $H_2 = \frac{4.0}{2.0} = 2.0$; the ratio is $2 : 2 = 1 : 1$, so 2.0 mol of water forms, mass $= 2.0 \times 18 = 36$ g.

Watch out: always use the **mole ratio** from the balanced equation, not the mass ratio. Convert grams to moles first, cross the ratio, then convert back.

Practice

Try these in order. The methods are all above.

2.1 List three signs that a chemical reaction has taken place. [2]

2.2 State whether each is a physical or a chemical change: (a) ice melting, (b) wood burning. [2]

2.3 Balance this equation: $H_2 + O_2 \rightarrow H_2O$. [2]

2.4 For $2Mg + O_2 \rightarrow 2MgO$, how many moles of MgO form from 3.0 mol of Mg? [2]

2.5 How many grams of MgO form from 0.20 mol of Mg in the reaction above? (M(MgO) = 40 g/mol) [3]

4 Titration, acids and bases, and redox – Part 2

Name: ______________ Class: __________ Date: ____________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
titration	滴定			
equivalence point	等当点			
acid	酸			
base	碱			
redox	氧化还原			
oxidation	氧化			
reduction	还原			

Recall

You have met acids and bases before, and maybe done a titration:

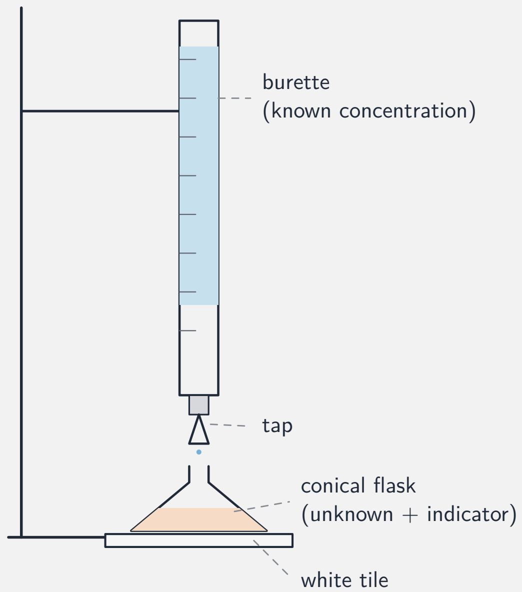
- Acids taste sour and turn litmus red; bases (alkalis) feel soapy and turn it blue.
- An acid and a base react to make a salt and water.
- Some reactions transfer electrons –like a metal reacting with oxygen.

This sheet lines up three important reaction types. Each idea has a worked example.

New ideas

■

A **titration** 滴定 finds an unknown concentration by reacting it with a solution of known concentration until they exactly match –the **equivalence point** 等当点.

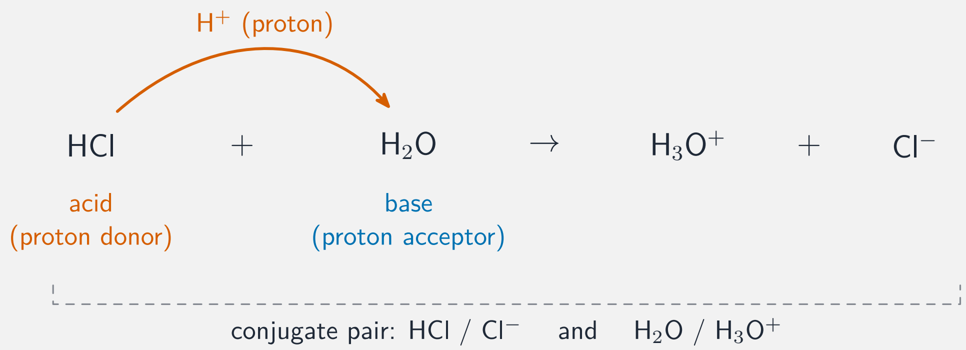


Worked example. 25.0 mL of acid is neutralized by 30.0 mL of 0.100 M NaOH (a 1 : 1 reaction). Moles of NaOH = 0.0300 × 0.100 = 3.00×10^{-3}, so moles of acid are the same, giving $[\text{acid}] = \dfrac{3.00 \times 10^{-3}}{0.0250} = 0.120$ M.

■ 2 Acid–base reactions

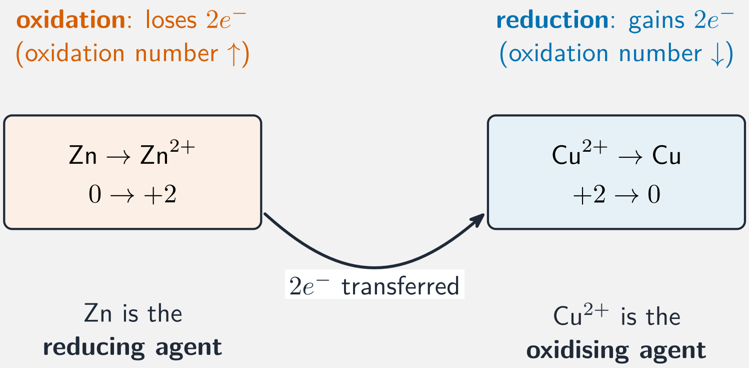
An **acid** 酸 gives away a proton (H^+); a **base** 碱 accepts one. They react to make water and a salt:

$$H^+ + OH^- \rightarrow H_2O.$$



■ 3 Redox reactions

In a **redox** 氧化还原 reaction, electrons transfer between substances:



- **oxidation** 氧化 is **loss** of electrons,
- **reduction** 还原 is **gain** of electrons.

Remember "OIL RIG": Oxidation Is Loss, Reduction Is Gain.

Worked example. When magnesium burns, $Mg \rightarrow Mg^{2+} + 2e^-$: it **loses** electrons, so magnesium is oxidized.

Watch out: every oxidation is paired with a reduction –the electrons one substance loses are exactly the electrons another gains. You cannot have one without the other.

Practice

Try these in order. The methods are all above.

2.1 State what happens at the equivalence point of a titration. [1]

2.2 20.0 mL of acid is neutralized by 25.0 mL of 0.100 M NaOH (a 1 : 1 reaction). Find the acid's concentration. [3]

2.3 Write the ionic equation for an acid reacting with a base to form water. [1]

2.4 State whether oxidation is the loss or gain of electrons, and do the same for reduction. [2]

2.5 In the reaction $Zn \rightarrow Zn^{2+} + 2e^-$, state whether zinc is oxidized or reduced, and why. [2]

5 Reaction rate and collision theory – Part 1

Name: ______________ Class: __________ Date: ____________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
Kinetics	动力学			
reaction rate	反应速率			
Collision theory	碰撞理论			
activation energy	活化能			

Recall

You already know how to make a reaction go faster:

- Use a higher concentration, or a higher temperature.
- Break a solid into smaller pieces (more surface area).
- Add a catalyst.

This sheet explains **why** these work, using the idea of colliding particles. Each idea has a worked example.

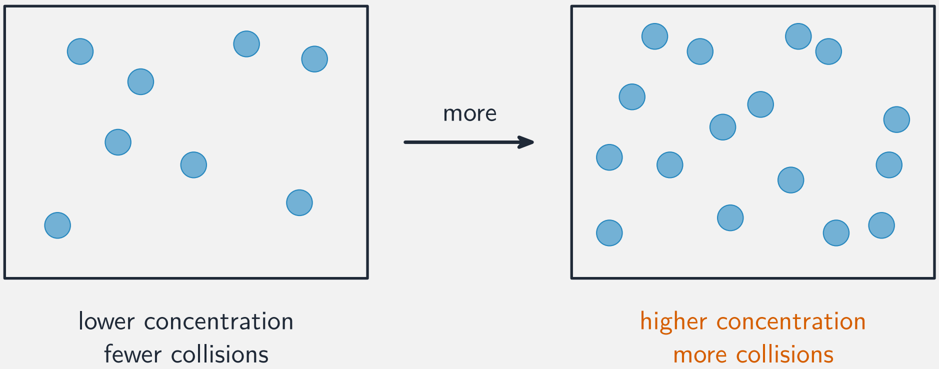
New ideas

■ 1 Reaction rate

Kinetics 动力学 is the study of **reaction rate** 反应速率–how fast reactants turn into products. The rate usually **slows down** as the reaction goes, because the reactants get used up.

■ 2 What speeds a reaction up

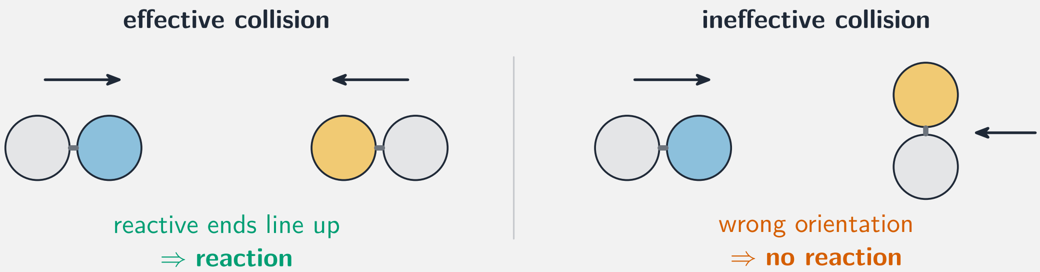
The rate rises with:



- higher **concentration** (more particles, more collisions),
- higher **temperature** (faster, more energetic particles),
- larger **surface area** (more contact),
- a **catalyst**.

3 Collision theory

Collision theory 碰撞理论 explains it: for a reaction, particles must collide with **enough energy** and in the **right orientation**.



4 Activation energy

The minimum energy a collision needs to react is the **activation energy** 活化能 E_a. Only collisions above this energy succeed.

Worked example. Raising the temperature works mainly because more particles now have energy above E_a –so a far larger fraction of collisions succeed, and the rate rises sharply.

Watch out: heating speeds a reaction up mostly because **more particles exceed the activation energy**, not just because they collide a bit more often. The energy of the collisions matters more than the number.

Practice

Try these in order. The methods are all above.

2.1 List four things that make a reaction go faster. [2]

2.2 State the two conditions a collision must meet to lead to a reaction. [2]

2.3 Explain, using collision theory, why increasing the concentration speeds up a reaction. [2]

2.4 State what the activation energy of a reaction is. [1]

2.5 Explain why powdered chalk reacts with acid faster than a single lump of the same mass. [2]

5 Rate laws and energy profiles – Part 2

Name: ______________ Class: __________ Date: ____________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
rate law	速率方程			
rate constant	速率常数			
orders	级数			
energy profile	能量图			
transition state	过渡态			
catalyst	催化剂			

Recall

In Part A you saw that reactions need collisions with enough energy. Now put that on a graph and in a formula:

- An **energy profile** shows the energy hill a reaction must climb.
- A catalyst lowers that hill.
- The rate depends on how much reactant is present.

Each idea has a worked example before the Practice.

New ideas

■ 1 The rate law

The **rate law** 速率方程 links the rate to the reactant concentrations:

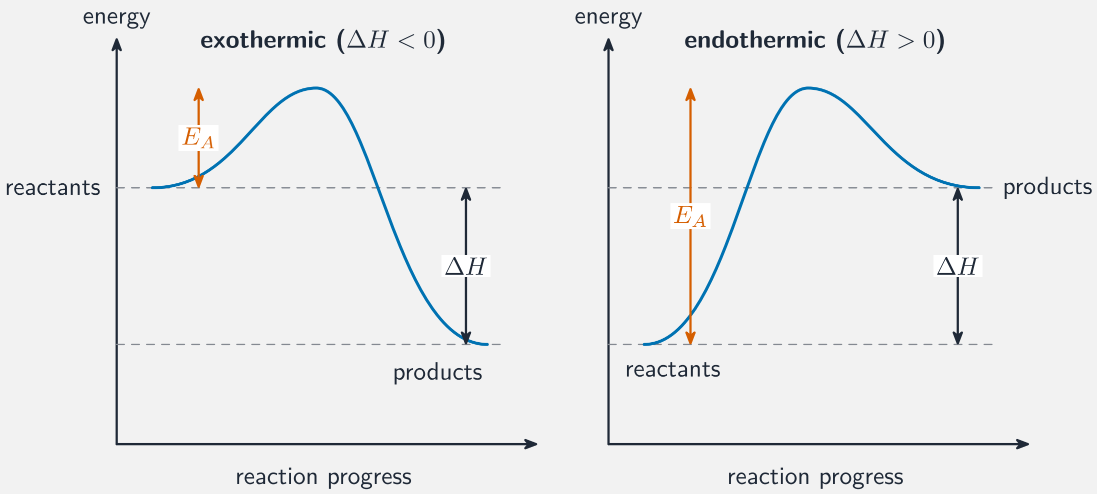
$$\text{rate} = k[\mathrm{A}]^m[\mathrm{B}]^n,$$

where k is the **rate constant** 速率常数 and m, n are the **orders** 级数. The orders are found by **experiment**, not from the equation.

Worked example. If doubling [A] makes the rate four times bigger, the reaction is **second order** in A ($2^2 = 4$), so rate $= k[\mathrm{A}]^2$.

2 Energy profiles

An **energy profile** 能量图 plots energy along the reaction path.



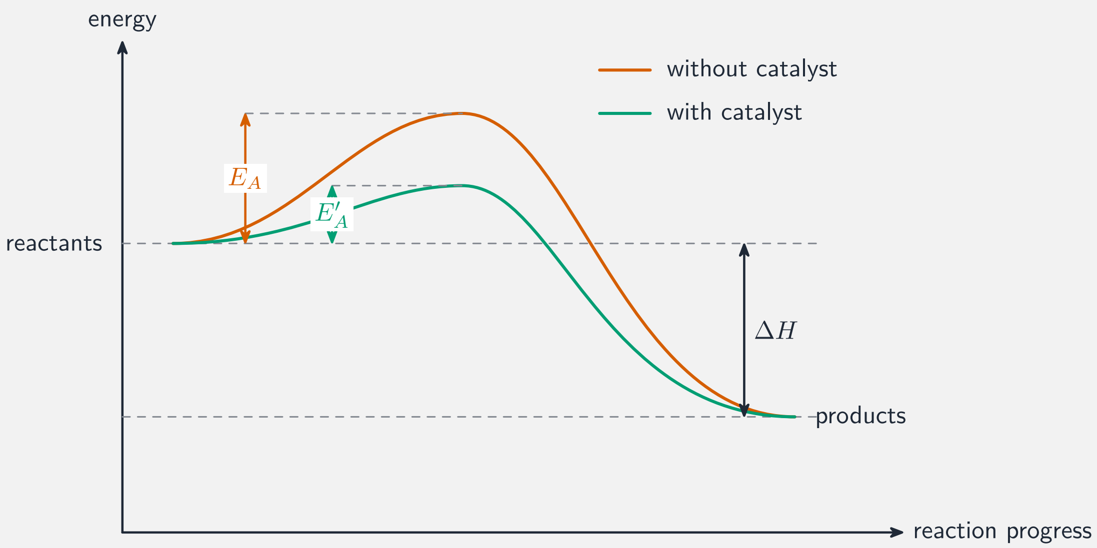
- the height of the hill is the **activation energy** E_a,
- the peak is the **transition state** 过渡态,
- the gap between reactants and products is ΔH.

3 Exothermic and endothermic

If the products end **lower** than the reactants, energy is released (**exothermic**); if **higher**, energy is absorbed (**endothermic**).

4 Catalysts

A **catalyst** 催化剂 gives the reaction a new path with a **lower activation energy**, so it goes faster –but it is not used up and does not change ΔH.



Watch out: the reaction orders come from **experiment**, not from the balanced equation's coefficients. You cannot read them off the equation.

Practice

Try these in order. The methods are all above.

2.1 In a rate law, state what k and the "order" mean. [2]

2.2 Doubling [A] doubles the rate. State the order of the reaction in A. [1]

2.3 On an energy profile, state what the height of the hill represents. [1]

2.4 A reaction's products are lower in energy than the reactants. State whether it is exothermic or endothermic. [1]

2.5 Explain how a catalyst speeds up a reaction, and state what it does **not** change. [2]

6 Heat, enthalpy, and calorimetry – Part 1

Name: ______________ Class: __________ Date: ____________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	**中文**	**Write it 3 times** (English)		
Thermochemistry	热化学			
exothermic	放热			
endothermic	吸热			
specific heat	比热容			
Calorimetry	量热法			
phase change	相变			

Recall

You have already noticed that reactions involve energy:

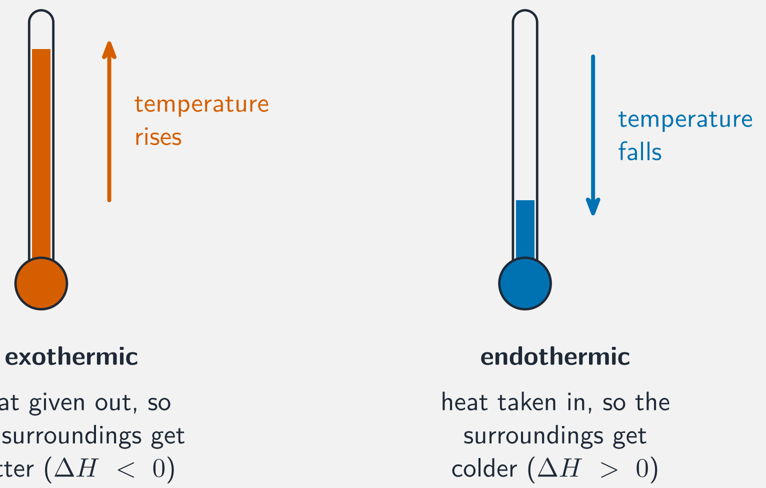
- Some reactions release heat and feel hot (like burning fuel).
- Some absorb heat and feel cold (like a cold pack).
- You have used $q = mc\Delta T$ to work out heat.

This sheet lines up how chemists measure reaction energy. Each idea has a worked example.

New ideas

■ 1 Exothermic and endothermic

Thermochemistry 热化学 tracks the energy of reactions. A reaction is **exothermic** 放热 if it releases energy (feels hot, $\Delta H < 0$) and **endothermic** 吸热 if it absorbs energy (feels cold, $\Delta H > 0$).



■ 2 Heat and specific heat

The heat to change a substance's temperature is

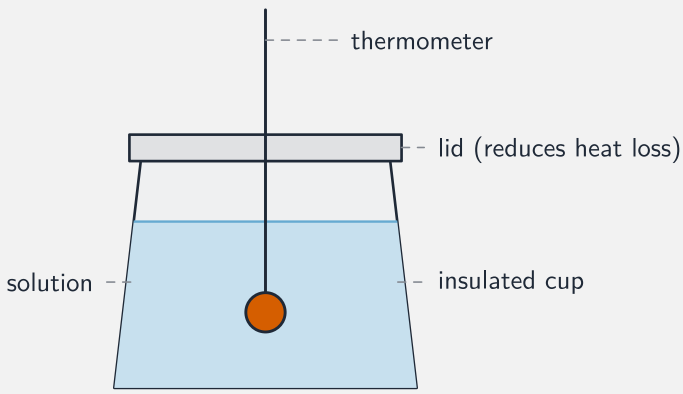
$$q = mc\,\Delta T,$$

where c is the **specific heat** 比热容 (energy per gram per degree).

Worked example. Warming 50 g of water ($c = 4.18$) by 10 °C takes $q = mc\,\Delta T = 50 \times 4.18 \times 10 = 2.1 \times 10^3$ J.

■ 3 Calorimetry

Calorimetry 量热法 measures a reaction's heat by tracking the temperature change of the surrounding water: the heat the water gains equals the heat the reaction releases.



Worked example. A reaction warms 100 g of water by 8.0 °C: the water gains $q = 100 \times 4.18 \times 8.0 = 3.3 \times 10^3$ J, so the reaction **released** 3.3 kJ (exothermic).

■ 4 Phase changes

During a **phase change** 相变 (melting or boiling) the temperature stays **constant** –the heat goes into pulling the particles apart, not into raising their temperature.

> **Watch out:** an exothermic reaction has a **negative** ΔH (it loses energy to the surroundings); an endothermic one has a **positive** ΔH. Getting the sign right is essential.

Practice

Try these in order. The methods are all above.

2.1 State whether an exothermic reaction has a positive or negative ΔH, and whether it feels hot or cold. [2]

2.2 Find the heat needed to warm 200 g of water by 5.0 °C ($c = 4.18$). [2]

2.3 A reaction warms 150 g of water by 6.0 °C. Find the heat released ($c = 4.18$). [3]

2.4 State what happens to the temperature of a substance while it is melting, and why. [2]

2.5 A cold pack gets cold when activated. State whether the reaction inside is exothermic or endothermic. [1]

6 Finding enthalpy changes – Part 2

Name: ____________ Class: ________ Date: __________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
enthalpy of reaction	反应焓			
enthalpy of formation	生成焓			
Hess's law	盖斯定律			

Recall

In Part A you measured reaction heat. Now **calculate** it from data:

- Breaking bonds takes in energy; making bonds gives energy out.
- You have used bond energies before to estimate a reaction's energy change.

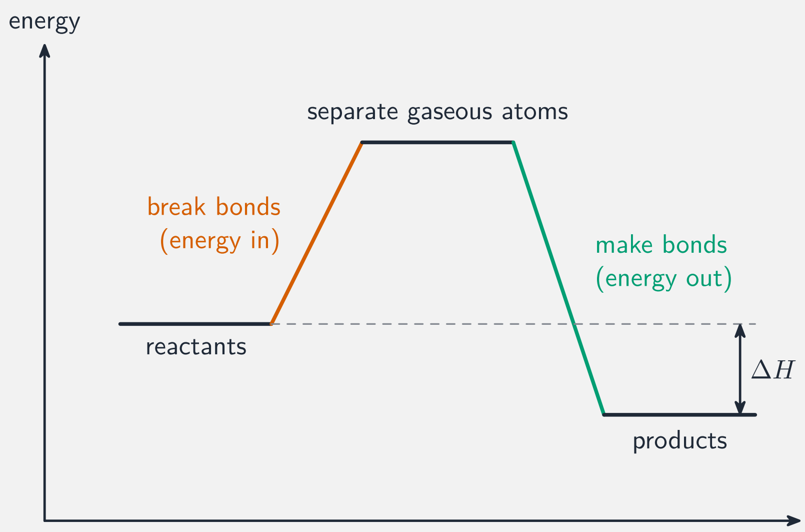
Each idea has a worked example before the Practice.

New ideas

■ 1 Bond enthalpies

The **enthalpy of reaction** 反应焓 ΔH can be estimated from bond energies: add the energy to **break** all reactant bonds, then subtract the energy **released** forming the product bonds:

$$\Delta H \approx \sum(\text{bonds broken}) - \sum(\text{bonds formed}).$$



Worked example. For $H_2 + Cl_2 \rightarrow 2HCl$ (H–H = 436, Cl–Cl = 242, H–Cl = 431 kJ/mol): broken = 436 + 242 = 678; formed = 2 × 431 = 862; $\Delta H \approx 678 - 862 = -184$ kJ (exothermic).

■ 2 Enthalpy of formation

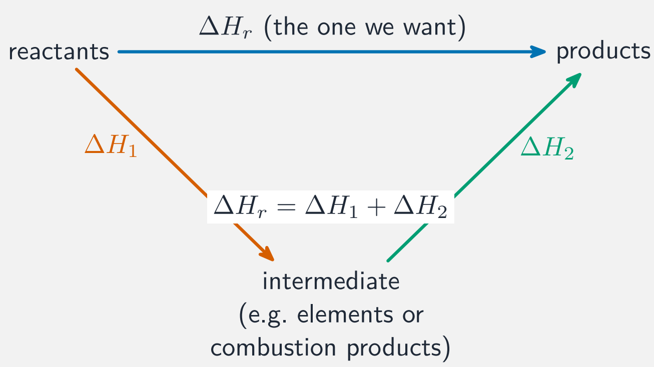
The **enthalpy of formation** 生成焓 ΔH_f is the energy to make one mole of a compound from its elements. A reaction's enthalpy is

$$\Delta H = \sum \Delta H_f(\text{products}) - \sum \Delta H_f(\text{reactants}).$$

Worked example. For $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ (ΔH_f: $CH_4 = -75$, $CO_2 = -394$, $H_2O = -286$, $O_2 = 0$): $\Delta H = [-394 + 2(-286)] - [-75] = -966 + 75 = -891$ kJ.

■ 3 Hess's law

Hess's law 盖斯定律 says that if a reaction is the sum of several steps, its ΔH is the sum of the steps' ΔH values –no matter what route is taken.



Watch out: breaking a bond **takes in** energy (positive) and forming a bond **releases** energy (negative). If the bonds formed are stronger than the bonds broken, the reaction is exothermic overall.

Practice

Try these in order. The methods are all above.

2.1 State whether breaking a bond takes in or gives out energy, and do the same for forming a bond. [2]

2.2 A reaction breaks bonds worth 500 kJ and forms bonds worth 650 kJ. Find ΔH and state whether it is exothermic. [3]

2.3 For $H_2 + Br_2 \rightarrow 2HBr$ (H–H = 436, Br–Br = 193, H–Br = 366 kJ/mol), estimate ΔH. [3]

2.4 State what Hess's law tells you about the enthalpy change of a reaction that goes in several steps. [1]

7 Dynamic equilibrium and the equilibrium constant – Part 1

Name: ______________ Class: __________ Date: ____________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
reversible reaction	可逆反应			
Chemical equilibrium	化学平衡			
equilibrium constant	平衡常数			

Recall

You have met reversible reactions before:

- Some reactions can go both forwards and backwards (shown with $\rightleftharpoons$).
- At **equilibrium**, the amounts stop changing even though the reaction has not stopped.
- The Haber process for ammonia is a famous reversible reaction.

This sheet makes equilibrium exact. Each idea has a worked example.

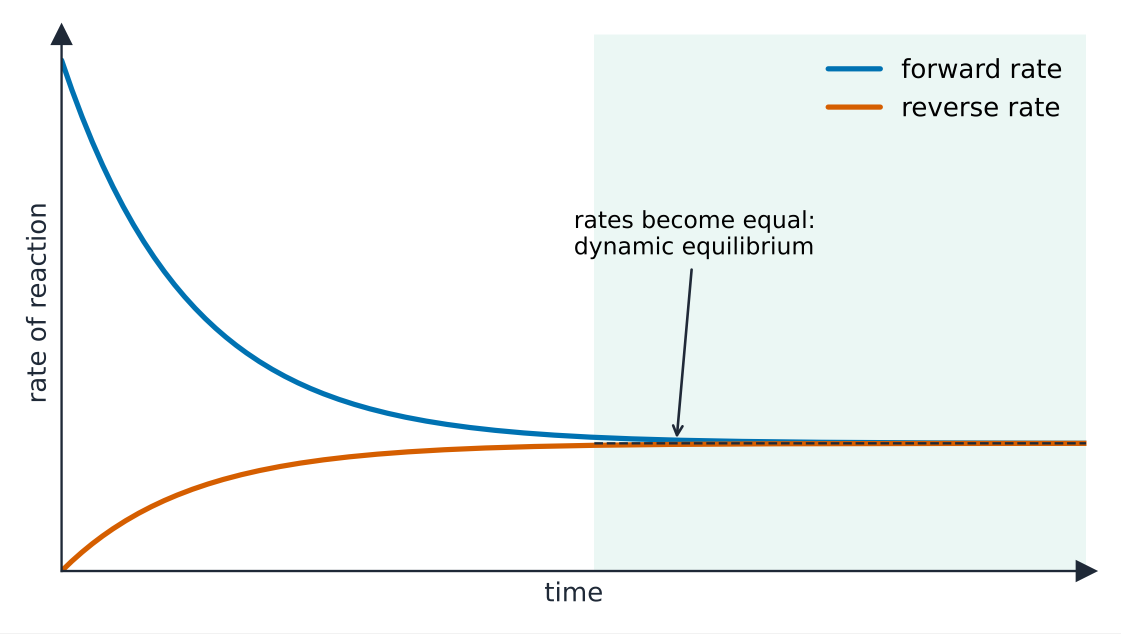
New ideas

■ 1 Reversible reactions

A **reversible reaction** 可逆反应 can run both ways at once. Reactants make products, and products remake reactants.

■ 2 Dynamic equilibrium

Chemical equilibrium 化学平衡 is reached when the forward and reverse reactions go at the **same rate**, so the concentrations stop changing. It is **dynamic** –both reactions keep going, they just balance out.



3 The equilibrium constant

The **equilibrium constant** 平衡常数 K compares products to reactants at equilibrium:

$$K = \frac{[\text{products}]}{[\text{reactants}]},$$

each concentration raised to its coefficient.

Worked example. For $N_2O_4 \rightleftharpoons 2NO_2$ with $[N_2O_4] = 0.20$ M and $[NO_2] = 0.10$ M: $K = \frac{[NO_2]^2}{[N_2O_4]} = \frac{(0.10)^2}{0.20} = 0.050.$

4 What K tells you

- K much greater than 1: products are favoured (reaction nearly complete).
- K much less than 1: reactants are favoured (little reaction).

Watch out: at equilibrium the forward and reverse **rates** are equal, but the **amounts** of reactant and product are usually **not** equal –they are just no longer changing.

Practice

Try these in order. The methods are all above.

2.1 State what ”dynamic equilibrium” means. [2]

2.2 For $A \rightleftharpoons B$ with $[A] = 0.40$ M and $[B] = 0.80$ M, find $K = \dfrac{[B]}{[A]}$. [2]

2.3 A reaction has $K = 1 \times 10^6$. State whether products or reactants are favoured. [1]

2.4 For $H_2 + I_2 \rightleftharpoons 2HI$ with $[H_2] = [I_2] = 0.10$ M and $[HI] = 0.50$ M, find $K = \dfrac{[HI]^2}{[H_2][I_2]}$. [3]

2.5 State whether the amounts of reactant and product must be equal at equilibrium. [1]

7 Le Chatelier's principle – Part 2

Name: ______________ Class: __________ Date: ____________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)
Le Chatelier's principle	勒沙特列原理	____________ ____________ ____________

Recall

In Part A you met equilibrium. Now see what happens when you **disturb** it:

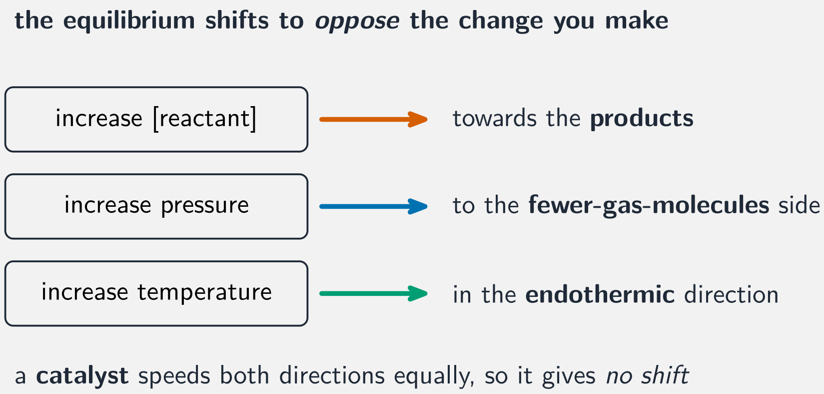
- Squeeze a gas equilibrium and it shifts one way.
- Heat it and it shifts another way.
- Factories use these tricks to get more product (like ammonia).

Each idea has a worked example before the Practice.

New ideas

■ 1 Le Chatelier's principle

Le Chatelier's principle 勒沙特列原理 says: if you disturb a system at equilibrium, it shifts to **partly cancel** the change.



■ 2 Changing concentration

- Add more **reactant** → the equilibrium shifts **forward** (toward products).
- Remove **product** → it also shifts **forward** to replace it.

Worked example. In $N_2 + 3H_2 \rightleftharpoons 2NH_3$, adding more N_2 shifts the equilibrium toward the right, making more ammonia.

■ 3 Changing pressure

For gases, raising the pressure (by squeezing) shifts the equilibrium toward the side with **fewer** gas molecules.

Worked example. In $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (4 gas molecules → 2), higher pressure shifts it toward the ammonia side, which has fewer molecules.

■ 4 Changing temperature

Raising the temperature shifts the equilibrium in the **endothermic** direction (the one that absorbs heat); lowering it shifts the other way.

Watch out: a catalyst speeds a reaction reaching equilibrium, but it does **not** shift the position of the equilibrium –it changes the forward and reverse rates equally.

Practice

Try these in order. The methods are all above.

2.1 State what Le Chatelier's principle says a system does when disturbed. [1]

2.2 For $A + B \rightleftharpoons C$, state which way the equilibrium shifts if you (a) add more A, (b) remove C. [2]

2.3 For a gas reaction where the left side has more gas molecules than the right, state which way higher pressure shifts the equilibrium. [2]

2.4 State the effect of adding a catalyst on the **position** of an equilibrium. [1]

2.5 In the Haber process, explain why a high pressure gives a better yield of ammonia ($N_2 + 3H_2 \rightleftharpoons 2NH_3$). [2]

8 Acids, bases, and pH – Part 1

Name: ____________ Class: ________ Date: __________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
acid	酸			
base	碱			
conjugate base	共轭碱			
strong acid	强酸			
strong base	强碱			

Recall

You already know a lot about acids and bases:

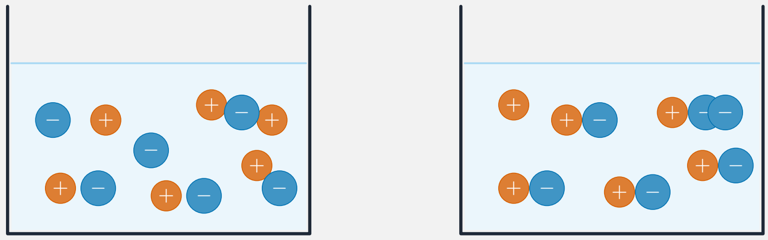
- Acids turn litmus red; bases (alkalis) turn it blue.
- The **pH scale** runs from 0 (very acidic) to 14 (very alkaline), with 7 neutral.
- Some acids are strong and some are weak.

This sheet makes pH exact. Each idea has a worked example.

New ideas

■ 1 Acids and bases

By the **Brønsted–Lowry** idea, an **acid** 酸 gives away a proton (H^+) and a **base** 碱 accepts one. When an acid loses its proton it becomes its **conjugate base** 共轭碱.



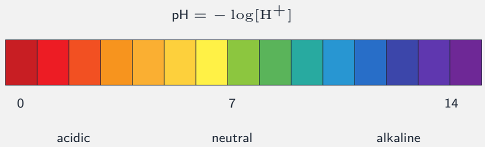
strong acid
fully dissociated: many ions

weak acid
mostly molecules: few ions

■ 2 The pH scale

The **pH** measures acidity:

$$pH = -\log[H^+].$$



A lower pH means a higher $[H^+]$ and a more acidic solution.

■ 3 Strong acids and bases

A **strong acid** 强酸 or **strong base** 强碱 dissociates **completely** in water, so all of it splits into ions. Then $[H^+]$ equals the acid's concentration, and you can find the pH directly.

Worked example. For 0.010 M HCl (a strong acid, fully dissociated), $[H^+] = 0.010$ M, so $pH = -\log(0.010) = 2.0$.

Watch out: pH is a **logarithmic** scale, so each step of 1 pH unit means a **ten-fold** change in $[H^+]$. A solution of pH 2 is ten times more acidic than pH 3, not just a little more.

Practice

Try these in order. The methods are all above.

2.1 State the Brønsted–Lowry definitions of an acid and a base. [2]

2.2 State what happens to a strong acid when it dissolves in water. [1]

2.3 Find the pH of 0.10 M HCl (a strong acid). [2]

2.4 Find the pH of a solution with $[H^+] = 1 \times 10^{-5}$ M. [2]

2.5 A solution of pH 3 is compared with one of pH 5. State how many times more acidic the pH-3 solution is. [2]

8 Weak acids and buffers – Part 2

Name: ______________ Class: _________ Date: ____________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
weak acid	弱酸			
titration curve	滴定曲线			
equivalence point	等当点			
buffer	缓冲溶液			

Recall

In Part A you met acids, bases, and pH. Now the difference between strong and weak, and a special mixture that resists pH change:

- A strong acid splits fully into ions; a weak acid only partly.
- Blood and many chemicals keep a steady pH –thanks to buffers.

Each idea has a worked example before the Practice.

New ideas

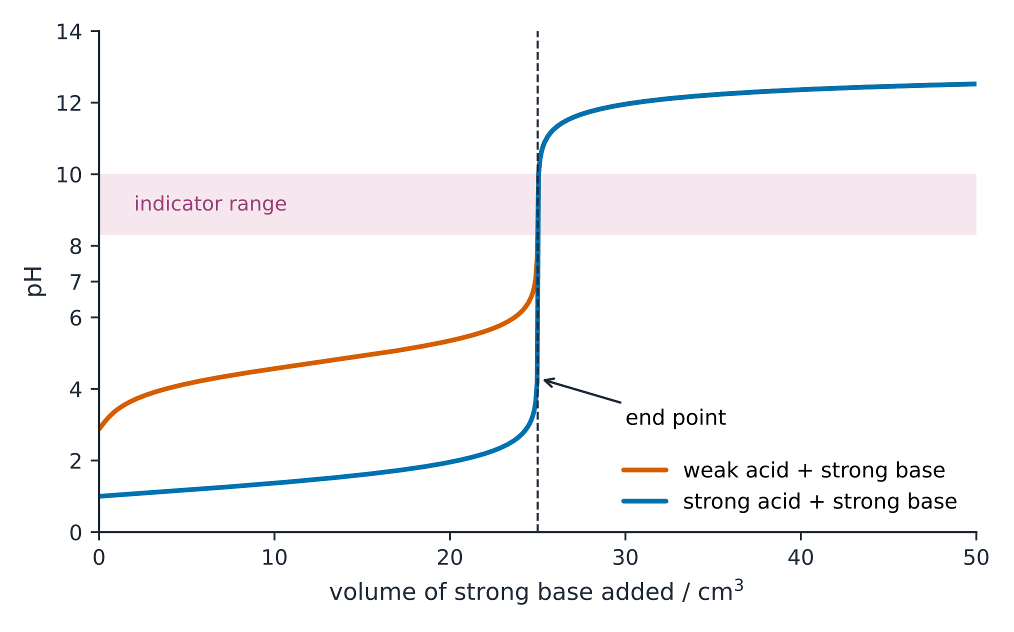
1 Weak acids

A **weak acid** 弱酸 only **partly** dissociates in water –most of it stays as whole molecules. So at the same concentration a weak acid has a **lower** $[H^+]$, and a **higher** pH, than a strong one.

Worked example. 0.10 M HCl (strong) has pH 1.0, but 0.10 M acetic acid (weak) has pH about 2.9 –less acidic, because only a little of it dissociates.

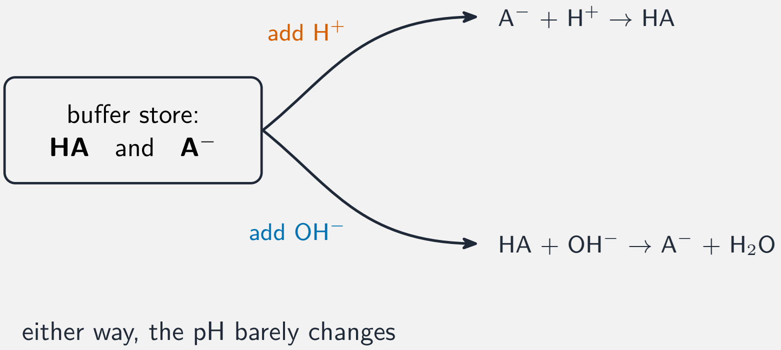
2 Titration curves

A **titration curve** 滴定曲线 plots pH as base is added to acid. It rises gently, then jumps steeply at the **equivalence point** 等当点 (where the moles of acid and base are equal).



■ 3 Buffers

A **buffer** 缓冲溶液 resists changes in pH. It contains a weak acid **and** its conjugate base together.



■ 4 How a buffer works

Add acid, and the conjugate base mops up the extra H^+; add base, and the weak acid supplies H^+ to replace what is removed. Either way, the pH barely moves.

Watch out: a buffer needs **both** a weak acid **and** its conjugate base present at once. A strong acid alone is not a buffer –it cannot soak up added acid.

Practice

Try these in order. The methods are all above.

2.1 State the difference between a strong acid and a weak acid. [2]

2.2 Explain why 0.10 M acetic acid has a higher pH than 0.10 M hydrochloric acid. [2]

2.3 On a titration curve, state what happens to the pH at the equivalence point. [1]

2.4 State the two things a buffer solution must contain. [2]

2.5 Explain how a buffer keeps the pH steady when a small amount of acid is added. [2]

9 Entropy and free energy – Part 1

Name: ______________ Class: __________ Date: ____________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	**中文**	**Write it 3 times** (English)		
Entropy	熵			
Gibbs free energy	吉布斯自由能			
thermodynamically favorable	热力学有利			

Recall

You already have a feel for these ideas:

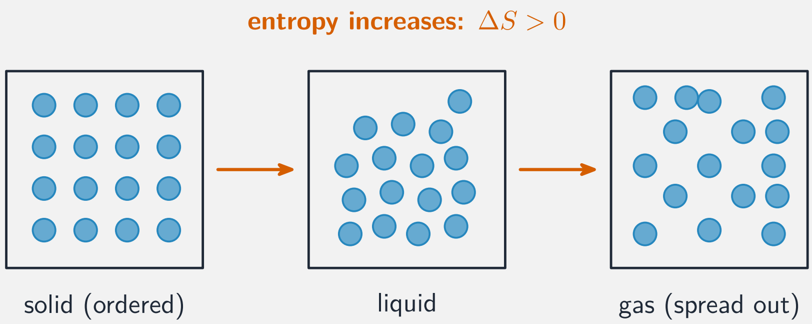
- Gases are more ”spread out” and disordered than solids.
- Some reactions happen on their own; others need pushing.
- You have met exothermic (heat out) and endothermic (heat in) reactions.

This sheet explains what decides whether a reaction happens by itself. Each idea has a worked example.

New ideas

1 Entropy

Entropy 熵 S measures how spread-out and disordered a system is. It **increases** going solid → liquid → gas, when a solid dissolves, or when more gas is made.



2 Gibbs free energy

Whether a reaction happens on its own depends on **Gibbs free energy** 吉布斯自由能:

$$\Delta G = \Delta H - T\Delta S.$$

A reaction is **thermodynamically favorable** 热力学有利 (it can happen by itself) when $\Delta G < 0$.

	ΔS **positive**	ΔS **negative**
ΔH **neg.**	feasible at **all** temperatures	feasible only at **low** temperature
ΔH **pos.**	feasible only at **high** temperature	**never** feasible

$\Delta G = \Delta H - T\Delta S$; **feasible when** $\Delta G \leq 0$

3 Enthalpy and entropy together

- Exothermic ($\Delta H < 0$) **and** entropy-increasing ($\Delta S > 0$) $\rightarrow$ always favorable.
- If they oppose each other, the **temperature** decides.

Worked example. A reaction with $\Delta H = +40$ kJ and $\Delta S = +0.120$ kJ/K becomes favorable only above $T = \dfrac{\Delta H}{\Delta S} = \dfrac{40}{0.120} = 333$ K (about 60 °C).

4 Favorable is not the same as fast

$\Delta G < 0$ means a reaction **can** happen, not that it happens **fast**. A favorable reaction can still be very slow if it has a high activation energy (diamond turning to graphite takes ages).

Watch out: match your units before using $\Delta G = \Delta H - T\Delta S$ –ΔH is usually in kJ but ΔS in J, so convert one of them first.

Practice

Try these in order. The methods are all above.

2.1 State whether entropy increases or decreases when a gas condenses into a liquid. [1]

2.2 State the condition on ΔG for a reaction to be thermodynamically favorable. [1]

2.3 A reaction has $\Delta H = -50$ kJ and $\Delta S = +0.10$ kJ/K. State whether it is favorable, and why. [2]

2.4 A reaction has $\Delta H = +30$ kJ and $\Delta S = +0.10$ kJ/K. Find the temperature above which it becomes favorable. [3]

2.5 Explain why a reaction can be thermodynamically favorable but still not happen at a noticeable rate. [2]

9 Electrochemistry - cells and electrolysis – Part 2

Name: ______________ Class: __________ Date: ____________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
galvanic cell	原电池			
electrolytic cell	电解池			
anode	阳极			
cathode	阴极			
cell potential	电池电势			
electrolysis	电解			
Faraday's law	法拉第定律			

Recall

You have seen electricity and chemistry meet before:

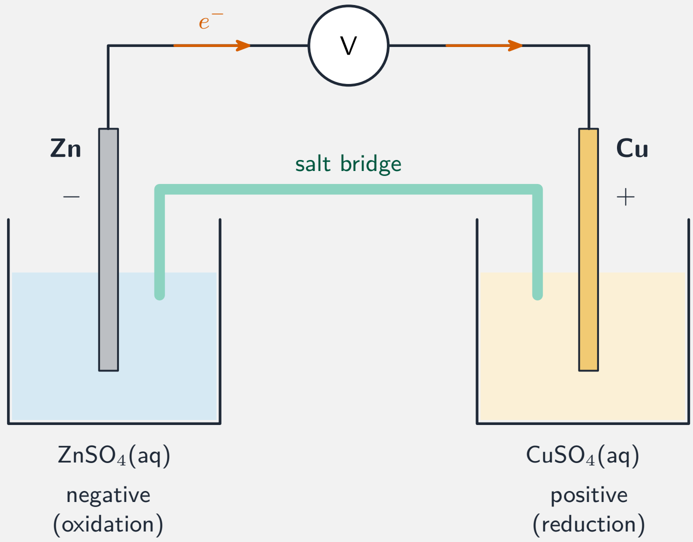
- A battery uses a chemical reaction to push a current.
- Electrolysis uses a current to split compounds (like water or molten salts).
- Redox reactions move electrons.

This sheet lines up how chemical reactions and electricity connect. Each idea has a worked example.

New ideas

1 Two kinds of cell

A redox reaction can push electrons through a wire:



- A **galvanic cell** 原电池 uses a favorable reaction to **produce** electricity (a battery).
- An **electrolytic cell** 电解池 uses electricity to **force** an unfavorable reaction.

2 Anode and cathode

In both, **oxidation** happens at the **anode** 阳极 and **reduction** at the **cathode** 阴极.

3 Cell potential

The **cell potential** 电池电势 E°_{cell} measures the driving force in volts:

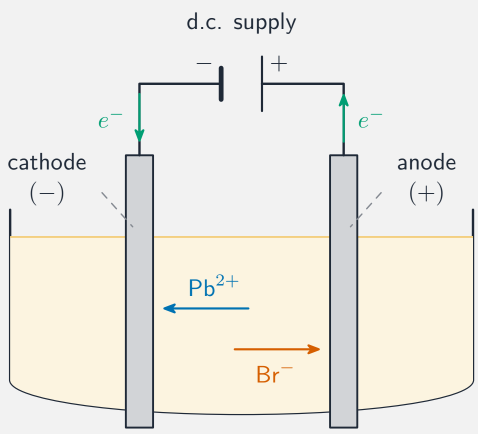
$$E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}.$$

A **positive** value means the reaction runs on its own (a working battery).

Worked example. A copper–zinc cell has $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}} = 0.34 - (-0.76) = 1.10$ V –positive, so it works as a battery.

4 Electrolysis and charge

In **electrolysis** 电解, the amount of product depends on the charge passed (**Faraday's law** 法拉第定律). Charge = current × time.



molten lead(II) bromide, $PbBr_2$

cathode: $Pb^{2+} + 2e^- \rightarrow Pb$ (silvery lead)

anode: $2Br^- \rightarrow Br_2 + 2e^-$ (red-brown bromine)

Worked example. A current of 2.0 A for 30 min passes charge $Q = It = 2.0 \times 1800 = 3600$ C, which is $\frac{3600}{96485} = 0.037$ mol of electrons.

Watch out: oxidation is always at the **anode** and reduction at the **cathode** –in both galvanic and electrolytic cells. A handy memory: "an ox" (anode = oxidation), "red cat" (cathode = reduction).

Practice

Try these in order. The methods are all above.

2.1 State the difference between a galvanic cell and an electrolytic cell. [2]

2.2 State which electrode (anode or cathode) is where oxidation happens. [1]

2.3 A cell has $E^\circ_{\text{cathode}} = +0.80$ V and $E^\circ_{\text{anode}} = -0.44$ V. Find the cell potential. [2]

2.4 State what a positive cell potential tells you about the reaction. [1]

2.5 A current of 1.5 A flows for 20 minutes. Find the charge passed. [2]