

Week 3

A-Level Chemistry

Homework bundle for this week

本周作业合集

exercises.lol

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A-Level Chemistry

Name: _____ Score: _____

1. The weighted mean mass of an element's atoms, compared to carbon-12, is the relative _____ mass.

2. One mole of any substance contains 6.02×10^{23} _____.

3. A balanced equation has the same number of each type of atom on both sides.
☐ True ☐ False
4. The simplest whole-number ratio of atoms in a compound is the _____ formula.

5. Percentage yield is the actual yield divided by the theoretical yield, times 100.
☐ True ☐ False
6. At room temperature and pressure, one mole of any gas occupies about _____ dm^3 .

7. The relative atomic mass (A_r) of an element is:
☐ the weighted average mass of its atoms over all isotopes, compared with 1/12 of carbon-12
☐ the mass of its heaviest isotope
☐ its number of protons
☐ its mass in grams
8. One mole of any substance contains:
☐ 6.02×10^{23} particles
☐ 12 particles
☐ 100 particles
☐ exactly 1 gram of particles
9. A Group 2 element usually forms an ion with charge:
☐ +2
☐ +1
☐ -2

☐ -1

10. Ethane has empirical formula CH_3 and molecular formula C_2H_6 . This shows:

- ☐ the empirical formula is the simplest ratio; the molecular formula is the actual count
- ☐ they are the same thing
- ☐ the molecular formula is simpler
- ☐ ethane has no formula

A-Level Chemistry

1. **atomic**

Ar (relative atomic mass) accounts for the abundance of each isotope.

2. **particles**

This number is the Avogadro constant.

3. **True**

Atoms are neither created nor destroyed, so mass is conserved.

4. **empirical**

The molecular formula is a whole-number multiple of the empirical formula.

5. **True**

It measures how much product you actually obtained compared with the maximum possible.

6. **24**

This is the molar gas volume at rtp (24 dm^3 per mole).

7. **the weighted average mass of its atoms over all isotopes, compared with 1/12 of carbon-12**

Ar is the average over all isotopes (weighted by abundance), measured against 1/12 of a carbon-12 atom.

8. **6.02×10^{23} particles**

A mole always contains the Avogadro number of particles, 6.02×10^{23} .

9. **+2**

Group 2 elements lose two electrons to form $2+$ ions; Group 17 form -1 ions.

10. **the empirical formula is the simplest ratio; the molecular formula is the actual count**

Empirical = simplest whole-number ratio; molecular = the real number of atoms per molecule.

2.1 Relative masses of atoms and molecules

Name: _____ Class: _____ Date: _____

Total: 11 marks

KEY WORDS relative atomic mass 相对原子质量 • unified atomic mass unit 统一原子质量单位 • relative formula mass 相对分子质量 • atom 原子

Objective

Build the skills to answer exam questions on **relative masses of atoms and molecules** — the **unified atomic mass unit** 统一原子质量单位 and the relative masses A_r , M_r and relative formula mass.

You must be able to:

- define the unified atomic mass unit
- define relative atomic, isotopic, molecular and formula mass
- calculate A_r from isotopic abundances and M_r from a formula

1 Worked examples

■ The relative masses

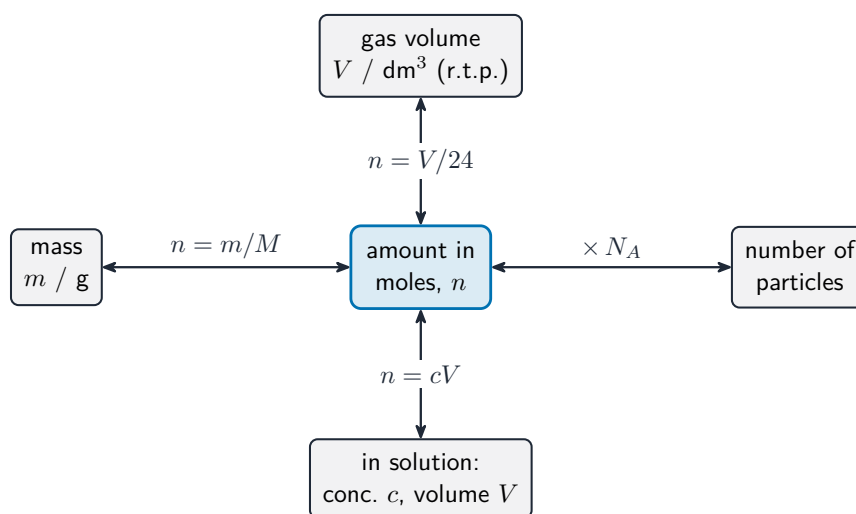
The **unified atomic mass unit** (u) is $\frac{1}{12}$ of the mass of a carbon-12 atom. Masses are then simple numbers relative to it.

- **relative atomic mass** A_r — the weighted average mass of an element's atoms, over all **isotopes** 同位素.
- **relative molecular mass** M_r — the sum of the A_r values of all atoms in a molecule.
- **relative formula mass** — the same, for an ionic compound.



$$A_r = \frac{(75 \times 35) + (25 \times 37)}{100} = 35.5$$

A_r is a weighted average: $75\% \text{ } ^{35}\text{Cl} + 25\% \text{ } ^{37}\text{Cl} \rightarrow A_r = 35.5$



Relative masses connect to amount in moles

■ Calculating M_r

For sulfuric acid, H_2SO_4 (A_r : H 1, S 32, O 16): $M_r = 2(1) + 32 + 4(16) = 98$.

2 Practice

2.1 Define **relative atomic mass**.

[2]

2.2 Calculate the relative molecular mass of calcium carbonate, CaCO_3 (A_r : Ca 40, C 12, O 16).

[1]

3 Exam-style questions

3.1 Why is the relative atomic mass of chlorine 35.5 and not a whole number?

[1]

- A chlorine atoms are damaged
- B it is a weighted average of two isotopes
- C chlorine has half a neutron
- D the value is rounded

3.2 What is the relative formula mass of magnesium hydroxide, $\text{Mg}(\text{OH})_2$ (A_r : Mg 24, O 16, H 1)?

[1]

- A 41
 - B 49
 - C 58
 - D 74
-

3.3 Magnesium has three isotopes: ^{24}Mg (79%), ^{25}Mg (10%) and ^{26}Mg (11%).

(a) Calculate the relative atomic mass of magnesium to 1 decimal place. [3]

(b) Explain why this value is not a whole number. [1]

3.4 Calculate the relative molecular mass of ethanol, $\text{C}_2\text{H}_5\text{OH}$ (A_r : C 12, H 1, O 16). [2]

Solutions

2.1 the average mass of an element's atoms (over its isotopes) compared with $\frac{1}{12}$ of a carbon-12 atom.

2.2 $40 + 12 + 3(16) = 100$.

3.1 B. It is a weighted average of ^{35}Cl and ^{37}Cl .

3.2 C. $24 + 2(16 + 1) = 24 + 34 = 58$.

3.3 (a) $A_r = \frac{(24 \times 79) + (25 \times 10) + (26 \times 11)}{100} = \frac{2432}{100} = 24.3$.

(b) it is a weighted average of isotopes of different mass.

3.4 $2(12) + 6(1) + 16 = 24 + 6 + 16 = 46$.

40 A sample of magnesium contains the isotopes ^{24}Mg , ^{25}Mg and ^{26}Mg only.

The percentage abundance of ^{25}Mg and ^{26}Mg is the same.

The relative atomic mass of magnesium in the sample is 24.3.

What is the percentage abundance of ^{24}Mg ?

- A** 10% **B** 20% **C** 60% **D** 80%

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g $^{-1}$ K $^{-1}$)

40 A sample of gallium contains two isotopes only.

In every 10 atoms in the sample, there are 6 that have 38 neutrons and 4 that have 40 neutrons.

What is the relative atomic mass, A_r , of the gallium in the sample?

A 69.7

B 69.8

C 70.0

D 70.2

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)

1 Chromium, Cr, and its compounds are widely used in many chemical reactions.

(a) Cr exists as four stable isotopes.

(i) The most common isotope of Cr is chromium-52.

Determine the number of protons, neutrons and electrons in an atom of chromium-52.

number of protons neutrons electrons [1]

(ii) Describe how an atom of chromium-54 differs from an atom of chromium-52. Refer to numbers of particles in your answer.

.....
..... [1]

(iii) The relative isotopic masses of the isotopes of Cr can be determined using mass spectrometry.

State what other information is needed to calculate the relative atomic mass, A_r , of Cr.

..... [1]

(iv) Atoms of ^{52}Cr , ^{53}Cr and ^{54}Cr make up more than 95% of naturally occurring chromium atoms. The A_r of naturally occurring Cr is 51.996.

Suggest what these statements imply about the relative isotopic mass of the fourth stable isotope of chromium.

..... [1]

(b) The shorthand electronic configuration of chromium is $[\text{Ar}] 3d^5 4s^1$.

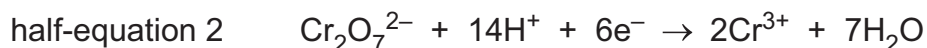
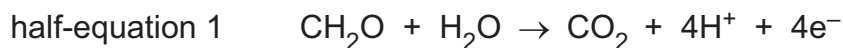
(i) Complete the full electronic configuration of chromium.

..... $3d^5 4s^1$ [1]

(ii) Deduce the total number of unpaired electrons in an atom of chromium.

..... [1]

- (c) Acidified dichromate(VI) ions will convert methanal, CH_2O , to carbon dioxide. The movement of electrons to or from relevant species is shown in the following half-equations.



- (i) Identify the species that is reduced in half-equation 2. Explain your answer.

..... [1]

- (ii) The oxidation state of the carbon atom in methanal is 0.

Calculate the oxidation state of carbon in carbon dioxide.

..... [1]

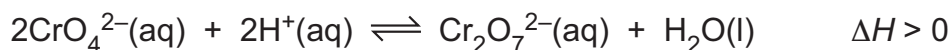
- (iii) Construct the ionic equation for the reaction of dichromate(VI) ions with methanal in acidic conditions.

..... [2]

- (iv) Methanal is a liquid at -30°C but carbon dioxide is a gas at this temperature. Explain why.

.....
.....
.....
..... [2]

- (d) In acidic conditions, a dynamic equilibrium is established between $\text{CrO}_4^{2-}(\text{aq})$ and $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$.



- (i) State what is meant by dynamic equilibrium.

.....
..... [1]

- (ii) Identify the condition necessary to establish dynamic equilibrium.

..... [1]

- (iii) $\text{CrO}_4^{2-}(\text{aq})$ ions are yellow and $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ ions are orange.

State what is observed when the following changes are made to an equilibrium mixture of acidified $\text{CrO}_4^{2-}(\text{aq})$ and $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ ions.

Explain your answers.

- The equilibrium mixture is warmed gently.

observation

explanation

.....

.....

- Dilute $\text{HCl}(\text{aq})$ is added to the equilibrium mixture.

observation

explanation

.....

.....

[4]

- (e) Chromium(IV) fluoride, CrF_4 , is a covalent molecule that shows similar chemical properties to SiCl_4 .

Suggest the type of reaction that occurs when CrF_4 is placed in water.

Construct a relevant equation for this reaction.

type of reaction

equation

[2]

2.2 The mole and the Avogadro constant

Name: _____ Class: _____ Date: _____

Total: 9 marks

KEY WORDS mole 摩尔 • avogadro constant 阿伏伽德罗常量 • solution 溶液 • molar mass 摩尔质量
• atom 原子

Objective

Build the skills to answer exam questions on **the mole** and **the Avogadro constant** — the **mole** 摩尔, the **Avogadro constant** 阿伏伽德罗常量, and the equation $n = m/M$.

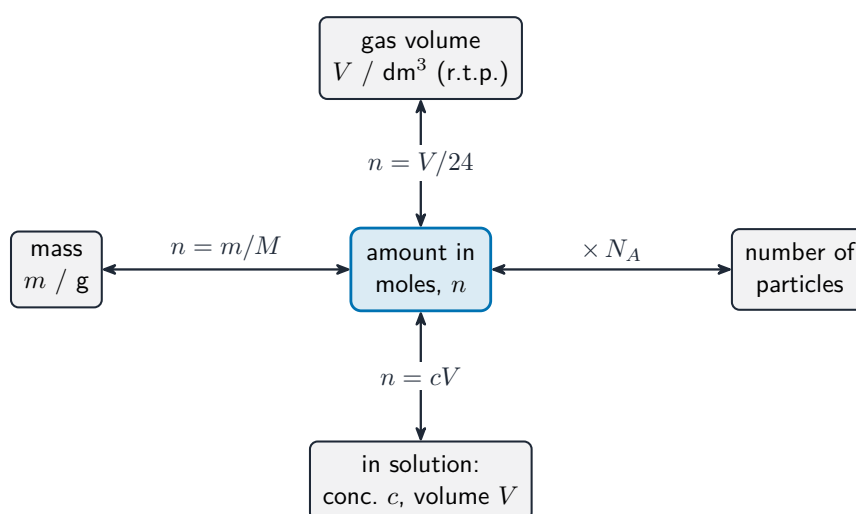
You must be able to:

- define the mole in terms of the Avogadro constant
- convert between mass, moles and number of particles

1 Worked examples

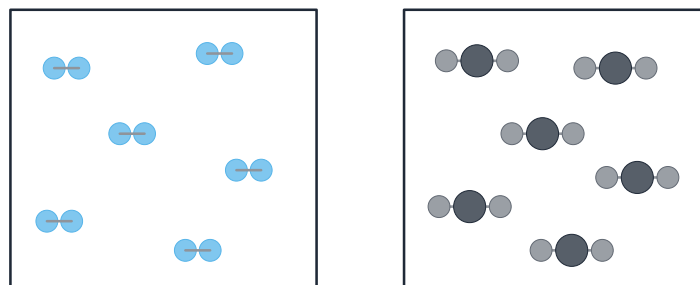
■ The mole

One **mole** is the amount of substance containing $N_A = 6.02 \times 10^{23}$ particles (the **Avogadro constant**). The particles may be atoms, molecules or ions — always say which.



The mole is the hub: convert to mass ($n = m/M$), particles ($\times N_A$), gas volume ($n = V/24$) or solution ($n = cV$)

same volume, same temperature and pressure



hydrogen, H_2

carbon dioxide, CO_2

the same **number** of molecules (6 each), even though CO_2 is bigger

Equal volumes of gas contain equal numbers of molecules

The mass of one mole equals the relative mass — the **molar mass** M (g mol^{-1}):

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

Example. Moles in 8.0 g of CH_4 ($M = 16$): $n = 8.0/16 = 0.50$ mol.

2 Practice

2.1 State the value of the Avogadro constant and what it counts. [2]

2.2 Calculate the number of moles in 36 g of water, H_2O ($M = 18$). [1]

3 Exam-style questions

3.1 How many molecules are in 2.0 mol of carbon dioxide? [1]

- A 3.0×10^{23}
- B 6.02×10^{23}
- C 1.2×10^{24}
- D 2.0×10^{23}

3.2 The mass of 0.25 mol of a compound is 22 g. Its molar mass is: [1]

- A 5.5 g mol^{-1}

- **B** 44 g mol^{-1}
 - **C** 88 g mol^{-1}
 - **D** $5.5 \times 10^{23} \text{ g mol}^{-1}$
-

3.3 Calculate the number of moles in 5.85 g of sodium chloride, NaCl ($M = 58.5$). [2]

3.4 Calculate the number of chloride ions in 5.85 g of NaCl ($N_A = 6.02 \times 10^{23}$). [2]

Solutions

2.1 $6.02 \times 10^{23} \text{ mol}^{-1}$; the number of particles (atoms/molecules/ions) in one mole.

2.2 $n = 36/18 = 2.0 \text{ mol}$.

3.1 C. $2.0 \times 6.02 \times 10^{23} = 1.2 \times 10^{24}$.

3.2 C. $M = m/n = 22/0.25 = 88 \text{ g mol}^{-1}$.

3.3 $n = m/M = 5.85/58.5 = 0.100 \text{ mol}$.

3.4 moles of NaCl = 0.100, so moles of $\text{Cl}^- = 0.100$; number = $0.100 \times 6.02 \times 10^{23} = 6.02 \times 10^{22}$.

2.3 Formulas

Name: _____ Class: _____ Date: _____

Total: 11 marks**KEY WORDS** empirical 实验式 • molecular 分子式 • equations 方程式 • balanced 配平 • ionic equation 离子方程式

Objective

Build the skills to answer exam questions on **formulas** — writing formulas of ionic compounds, balancing **equations** 方程式 (including **ionic equations** 离子方程式), and finding **empirical** 实验式 and **molecular** 分子式 formulas.

You must be able to:

- write formulas of ionic compounds from ionic charges and oxidation numbers
- write and balance equations (including ionic equations) with state symbols
- calculate empirical and molecular formulas from data

1 Worked examples

■ Ionic formulas



$$A_r = \frac{(75 \times 35) + (25 \times 37)}{100} = 35.5$$

Formulae build from relative atomic masses

The total + charge balances the total – charge. Charges from the group: Group 1 +1, 2 +2, 13 +3, 15 –3, 16 –2, 17 –1. Learn: NO_3^- , CO_3^{2-} , SO_4^{2-} , OH^- , NH_4^+ . E.g. iron(III) oxide = Fe_2O_3 (two Fe^{3+} balance three O^{2-}).

■ Equations and ionic equations

A balanced equation has the same atoms on both sides; add **state symbols** (s, l, g, aq). An **ionic equation** shows only what changes (no **spectator ions** 旁观离子): $\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})$.

■ Empirical formula

Divide each element's mass (or %) by its $A_r \rightarrow$ moles; divide by the smallest; round to whole numbers. **Example.** 40.0% C, 6.7% H, 53.3% O: moles $3.33 : 6.7 : 3.33 \rightarrow 1 : 2 : 1 \rightarrow \text{CH}_2\text{O}$. With M_r , scale up to the **molecular formula**.

2 Practice

2.1 Write the formula of (a) calcium nitrate and (b) aluminium sulfate. [2]

2.2 Write the ionic equation for the reaction of silver ions with chloride ions to form silver chloride. [1]

3 Exam-style questions

3.1 What is the formula of iron(III) sulfate? [1]

- A FeSO_4
 - B Fe_2SO_4
 - C $\text{Fe}_2(\text{SO}_4)_3$
 - D $\text{Fe}_3(\text{SO}_4)_2$
-

3.2 A compound has empirical formula CH_2 and $M_r = 42$. Its molecular formula is: [1]

- A CH_2
 - B C_2H_4
 - C C_3H_6
 - D C_4H_8
-

3.3 Balance this equation and add state symbols: $\text{Mg} + \text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$. [2]

3.4 A compound contains 2.4 g of carbon, 0.4 g of hydrogen and 3.2 g of oxygen (A_r : C 12, H 1, O 16).

(a) Calculate its empirical formula. [3]

(b) The M_r of the compound is 60. Deduce its molecular formula. [1]

Solutions

2.1 (a) $\text{Ca}(\text{NO}_3)_2$; (b) $\text{Al}_2(\text{SO}_4)_3$.

2.2 $\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})$.

3.1 C. Two Fe^{3+} balance three $\text{SO}_4^{2-} \rightarrow \text{Fe}_2(\text{SO}_4)_3$.

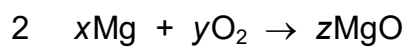
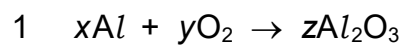
3.2 C. Empirical mass 14; $42/14 = 3 \rightarrow \text{C}_3\text{H}_6$.

3.3 $\text{Mg}(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2(\text{g})$.

3.4 (a) moles: C = $2.4/12 = 0.20$, H = $0.4/1 = 0.40$, O = $3.2/16 = 0.20$; divide by 0.20 $\rightarrow 1 : 2 : 1$; empirical formula CH_2O .

(b) empirical mass 30; $60/30 = 2 \rightarrow \text{C}_2\text{H}_4\text{O}_2$.

17 Three equations are listed. x , y and z are all whole numbers.



Which equations can be balanced if $x = 4$ and $z = 2$?

A 1 and 3

B 1 only

C 2 only

D 3 only

- 3 Cycloalkanes show similar chemical properties to alkanes but have the same empirical formula as alkenes.

(a) Define empirical formula.

.....
..... [1]

- (b) Cyclopentane, C_5H_{10} , has four cyclic structural isomers. One of these isomers is **C**, shown in Fig. 3.1.

Complete Fig. 3.1 to show two other cyclic structural isomers of C_5H_{10} .

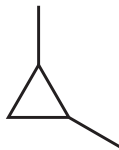
cyclopentane 			C 
--	--	--	---

Fig. 3.1

[2]

- (c) Cyclopentane reacts with Cl_2 in the presence of ultraviolet light to form C_5H_9Cl .

(i) The reaction is initiated by the bond fission of Cl_2 .

State the type of bond fission shown in the initiation step.

..... [1]

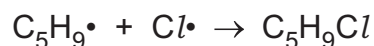
(ii) Complete the equations to show the two propagation steps that follow the initiation step.

propagation 1 $C_5H_{10} + \dots \rightarrow C_5H_9\cdot + \dots$

propagation 2 $C_5H_9\cdot + \dots \rightarrow \dots$

[2]

(iii) The final step is shown.



Give the name for this step in the reaction.

..... [1]

(d) Fig. 3.2 shows a reaction cycle involving cyclopentane, cyclopentene and C_5H_9Cl .

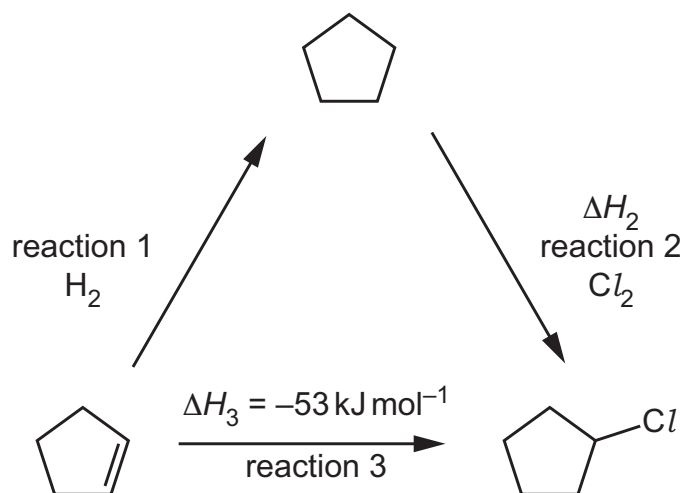


Fig. 3.2

(i) Identify a suitable reagent for reaction 3.

..... [1]

(ii) Use the data in Fig. 3.2 and in Table 3.1 to calculate the enthalpy change of reaction 2, ΔH_2 .

Table 3.1

compound	enthalpy change of combustion, $\Delta H_c / \text{kJ mol}^{-1}$
	-3292
	-3115
H_2	-286

 $\Delta H_2 = \dots\dots\dots \text{ kJ mol}^{-1}$ [2]

(e) Cyclopentene, C_5H_8 , reacts with hot concentrated acidified $KMnO_4$ to form compound **W**, $C_5H_8O_4$.

(i) Draw the structure of **W**.

[1]

(ii) The infrared spectrum of **W** is shown in Fig. 3.3.

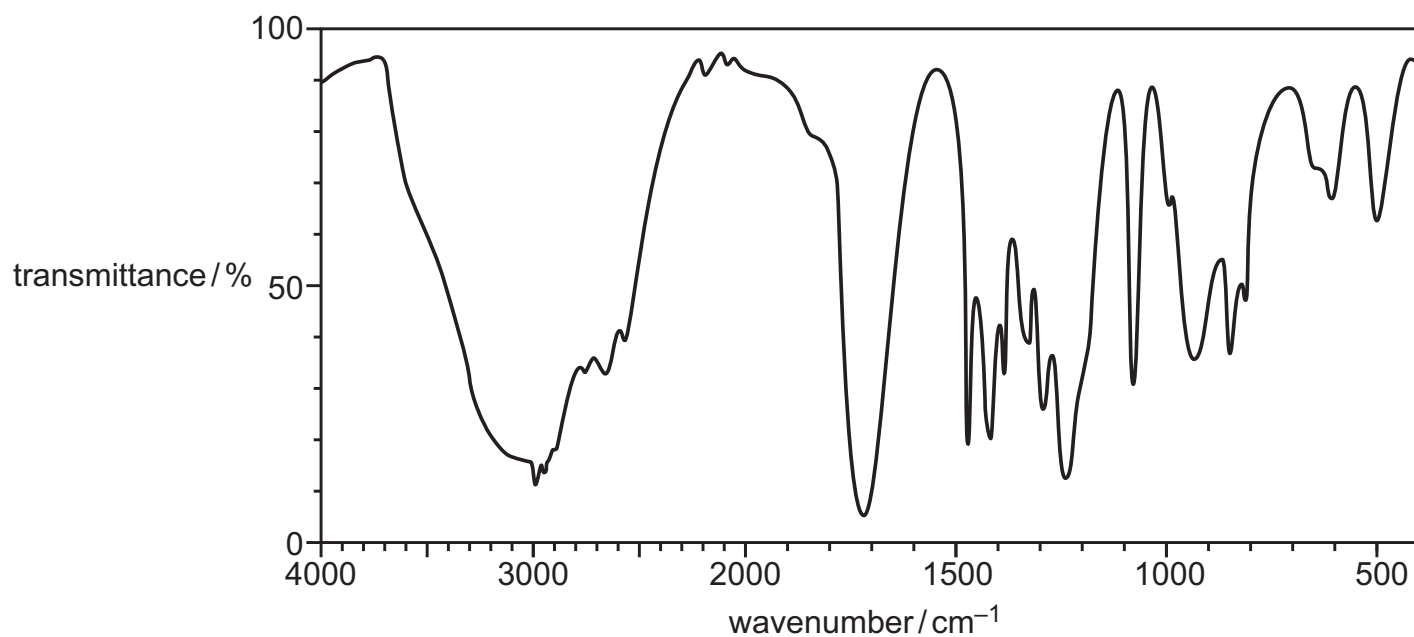


Fig. 3.3

Identify **two** absorptions in the infrared spectrum of **W** that would **not** be present in the infrared spectrum of cyclopentene.

- Write **1** or **2** on Fig. 3.3 against each of these two absorptions.
- Complete Table 3.2 to show which bond is responsible for each absorption that you have identified in Fig. 3.3.

Table 3.2

absorption	1	2
bond responsible		

[2]

Table 3.3

bond	functional groups containing the bond	characteristic infrared absorption range (in wavenumbers)/cm ⁻¹
C–O	hydroxy, ester	1040–1300
C=C	aromatic compound, alkene	1500–1680
C=O	amide carbonyl, carboxyl ester	1640–1690 1670–1740 1710–1750
C≡N	nitrile	2200–2250
C–H	alkane	2850–2950
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3650

[Total: 13]

2.4 Reacting masses and volumes

Name: _____ Class: _____ Date: _____

Total: 11 marks

KEY WORDS limiting reagent 限量试剂 • titration 滴定 • percentage yield 产率 • stoichiometry 化学计量
• ion 离子

Objective

Build the skills to answer exam questions on **reacting masses and volumes** — **stoichiometry** 化学计量, **percentage yield** 产率, **limiting reagent** 限量试剂, gas volumes, and **titration** 滴定 calculations.

You must be able to:

- calculate reacting masses and percentage yield from a balanced equation
- identify the limiting reagent and calculate gas volumes ($n = V/24$)
- calculate solution concentrations from a titration ($n = cV$)

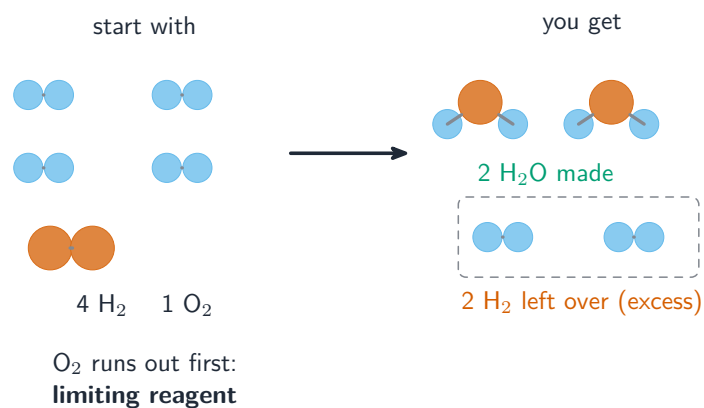
1 Worked examples

■ Reacting masses and percentage yield

Mole ratio comes from the equation. **Example.** Mass of MgO from 4.8 g Mg: $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$. Moles Mg = $4.8/24 = 0.20$; ratio 1:1 $\rightarrow 0.20$ mol MgO; $m = 0.20 \times 40 = 8.0$ g.

$$\text{percentage yield} = \frac{\text{actual product}}{\text{maximum possible}} \times 100\%$$

■ Limiting reagent



Find moles of each reactant, divide by its equation number — the smallest is the **limiting reagent**.

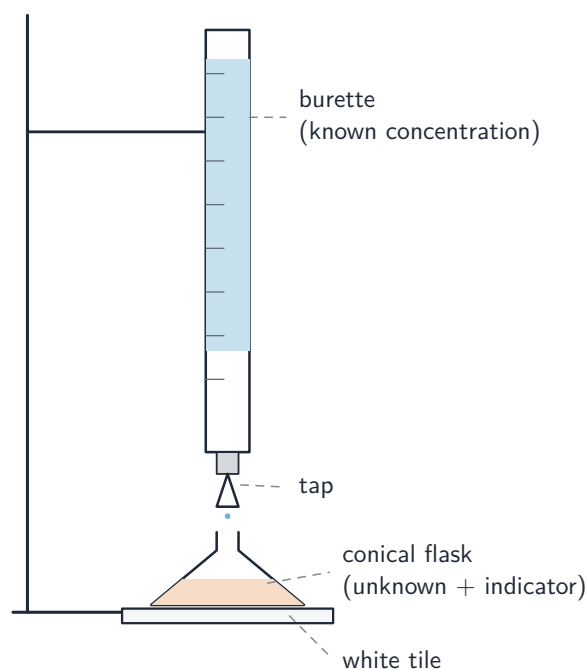
At r.t.p. one mole of any gas = 24.0 dm^3 , so $n = V/24.0$.

hydrogen, H_2

carbon dioxide, CO_2

Equal gas volumes (same T , p) hold equal numbers of molecules

- **Titration** ($n = cV$)



A titration finds an unknown concentration using a solution of known concentration

Example. 20.0 cm^3 of $0.100 \text{ mol dm}^{-3}$ HCl neutralises 25.0 cm^3 NaOH (1:1). Moles HCl = $0.100 \times 0.0200 = 2.00 \times 10^{-3}$; so NaOH conc = $2.00 \times 10^{-3} / 0.0250 = 0.0800 \text{ mol dm}^{-3}$.

2 Practice

2.1 Calculate the mass of carbon dioxide made when 10 g of calcium carbonate decomposes: $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$ (M_r : CaCO_3 100, CO_2 44). [2]

2.2 Calculate the volume of 0.50 mol of gas at r.t.p. [1]

3 Exam-style questions

3.1 24 cm^3 of methane is burned completely in oxygen: $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$. What volume of CO_2 is made (same conditions)? [1]

- A 12 cm^3
- B 24 cm^3

- C 48 cm³
 - D 96 cm³
-

3.2 0.30 mol of H₂ reacts with 0.20 mol of O₂: $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$. The limiting reagent is: [1]

- A hydrogen
 - B oxygen
 - C water
 - D neither — they react exactly
-

3.3 In a titration, 25.0 cm³ of sulfuric acid is exactly neutralised by 20.0 cm³ of 0.100 mol dm⁻³ NaOH: $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$.

(a) Calculate the moles of NaOH used. [1]

(b) Calculate the concentration of the sulfuric acid. [3]

3.4 8.0 g of methanol is made from a reaction whose maximum possible yield is 12.8 g. Calculate the percentage yield. [2]

Solutions

2.1 moles $\text{CaCO}_3 = 10/100 = 0.10$; ratio 1:1 $\rightarrow 0.10$ mol CO_2 ; $m = 0.10 \times 44 = 4.4$ g.

2.2 $V = 0.50 \times 24.0 = 12$ dm³.

3.1 B. Ratio $\text{CH}_4 : \text{CO}_2$ is 1:1, so 24 cm³ of CO_2 .

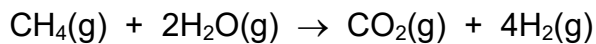
3.2 A. $0.30/2 = 0.15$ for H_2 vs $0.20/1 = 0.20$ for O_2 ; H_2 gives the smaller value, so hydrogen is limiting.

3.3 (a) $n = 0.100 \times 0.0200 = 2.00 \times 10^{-3}$ mol.

(b) ratio $\text{H}_2\text{SO}_4 : \text{NaOH}$ is 1:2, so moles $\text{H}_2\text{SO}_4 = 1.00 \times 10^{-3}$; $c = n/V = 1.00 \times 10^{-3}/0.0250 = 0.0400$ mol dm⁻³.

3.4 $\frac{8.0}{12.8} \times 100 = 62.5\%$.

- 4 Methane and steam react to produce hydrogen.



0.80 g of methane and 1.35 g of steam react. One of the reactants is used up.

Which volume of hydrogen, measured at room conditions, will be produced?

- A** 1.80 dm³ **B** 3.60 dm³ **C** 4.80 dm³ **D** 7.20 dm³

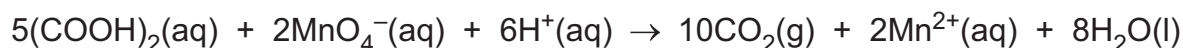
- 4 A solution containing 4.4 g of an organic acid is exactly neutralised by 25.0 cm³ of 2.0 mol dm⁻³ sodium hydroxide. The acid has one COOH group in each molecule.

What is the empirical formula of the acid?

- A** CH₂O **B** C₂H₄O **C** C₃H₆O₃ **D** C₄H₈O₂

1 Hydrated ethanedioic acid is a diprotic acid with the formula $(\text{COOH})_2 \cdot x\text{H}_2\text{O}$ where x is an integer.

Ethanedioic acid reacts with manganate(VII) ions when heated.



You will determine the value of x in $(\text{COOH})_2 \cdot x\text{H}_2\text{O}$ by titrating a solution containing ethanedioic acid with manganate(VII) ions.

- **FA 1** is 6.20 g dm^{-3} aqueous ethanedioic acid, $(\text{COOH})_2 \cdot x\text{H}_2\text{O}$.
- **FA 2** is $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .
- **FA 3** is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4 .

(a) Method

- Fill the burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Use the measuring cylinder to add approximately 20 cm^3 of **FA 3** to the conical flask.
- Place the conical flask on a tripod and gauze and heat carefully until the temperature of the solution is approximately 70°C .
- Remove the flame.
- Carefully lift the hot conical flask and place it on the white tile under the burette.
- Add **FA 2** drop-wise for the first $2\text{--}3 \text{ cm}^3$. Any initial pink colouring may take several seconds to disappear.
- If the reaction mixture turns brown, reheat it to about 70°C . If the brown colour disappears, continue the titration. If the brown colour remains, discard the contents of the flask and begin a new titration.
- The end-point is reached when a permanent pale pink colour is formed.
- Perform a rough titration with **FA 2**. Record your burette readings in the space below.

The rough titre is cm^3 .

- Carry out as many titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record all your burette readings and the volume of **FA 2** added in each accurate titration.

Results

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b)** From your accurate titration results, calculate a suitable mean value to be used in your calculations.

Show clearly how you obtained this value.

25.0 cm³ of **FA 1** required cm³ of **FA 2**. [1]

(c) Calculations

(i) Give your answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to the appropriate number of significant figures. [1]

(ii) Calculate the amount, in mol, of manganate(VII) ions, MnO_4^- , in the volume of **FA 2** calculated in **(b)**.

amount of MnO_4^- = mol [1]

(iii) Calculate the amount, in mol, of ethanedioic acid that reacts with the manganate(VII) ions in **(c)(ii)**.

amount of $(\text{COOH})_2$ = mol

Hence calculate the concentration, in mol dm^{-3} , of ethanedioic acid in **FA 1**.

concentration of $(\text{COOH})_2$ = mol dm^{-3} [2]

(iv) Calculate the relative molecular mass, M_r , of the ethanedioic acid in **FA 1**.

M_r = [1]

(v) Calculate the value of **x** in $(\text{COOH})_2 \cdot x\text{H}_2\text{O}$.

Show your working.

x = [1]

(d) Explain why it is necessary to add **FA 3** in each titration.

.....

..... [1]

[Total: 15]

2 Hydrated zinc sulfate has the formula $\text{ZnSO}_4 \cdot y\text{H}_2\text{O}$ where **y** is an integer.

Hydrated zinc sulfate decomposes when heated, losing only its water of crystallisation and becoming anhydrous.

You will determine the value of **y** in $\text{ZnSO}_4 \cdot y\text{H}_2\text{O}$ by heating the hydrated salt until it becomes anhydrous.

FA 4 is hydrated zinc sulfate, $\text{ZnSO}_4 \cdot y\text{H}_2\text{O}$.

(a) Method

- Weigh the crucible with its lid. Record the mass in the space for Results.
- Add between 3.20g and 3.40g of **FA 4** to the crucible.
- Weigh the crucible with its lid and **FA 4**. Record the mass.
- Place the crucible on the pipeclay triangle. Gently heat the crucible and contents for approximately 2 minutes with the lid on.
- Remove the lid. Heat the crucible and contents strongly for approximately 4 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.

You may wish to begin work on Question 3 while the crucible is cooling.

- Weigh the crucible with its lid and its contents. Record the mass.
- Remove the lid. Heat the crucible strongly for approximately 3 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.
- Weigh the crucible with its lid and its contents. Record the mass.
- Calculate the mass of **FA 4** used and the mass of residue obtained. Record the masses.

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

- (i) Calculate the amount, in mol, of anhydrous zinc sulfate residue formed in the decomposition of **FA 4**.

amount of ZnSO_4 = mol

Calculate the amount, in mol, of water of crystallisation lost.

amount of H_2O = mol
[2]

- (ii) Calculate the value of **y** in the formula $\text{ZnSO}_4 \cdot y\text{H}_2\text{O}$.

Show your working.

y = [2]

- (c) A student suggests using this thermal decomposition method to investigate the number of moles of water of crystallisation in hydrated ethanedioic acid. The teacher says that this method is unsuitable.

Suggest why this method is unsuitable.

.....
..... [1]

[Total: 10]

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed, you should write 'no change'.

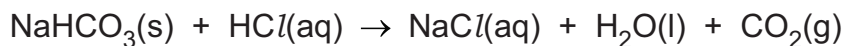
Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used. If a solid is heated, a hard-glass test-tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

- 2** In this experiment you will determine the percentage by mass of a sodium halide impurity present in a sample of sodium hydrogencarbonate by titration.



FB 4 is an aqueous solution made by dissolving 17.20 g of the impure sodium hydrogencarbonate in each dm^3 of solution.

FB 5 is $0.200 \text{ mol dm}^{-3}$ hydrochloric acid, HCl .

FB 6 is methyl orange indicator.

(a) Method

- Fill the burette with **FB 5**.
- Pipette 25.0 cm^3 of **FB 4** into a conical flask.
- Add several drops of **FB 6** to the conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record all your burette readings and the volume of **FB 5** added in each accurate titration.

Keep FB 4 for use in Question 3.

Results

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b)** From your accurate titration results, calculate a suitable mean value to be used in your calculations.
Show clearly how you obtained this value.

25.0 cm^3 of **FB 4** required cm^3 of **FB 5**. [1]

(c) Calculations

(i) Give your answers to **(c)(ii)** and **(c)(iii)** to an appropriate number of significant figures. [1]

(ii) Use your answer to **(b)** to calculate the amount, in mol, of hydrochloric acid in your mean titre.

amount of HCl = mol

Hence determine the amount, in mol, of sodium hydrogencarbonate present in 25.0 cm^3 of **FB 4**.

amount of NaHCO_3 = mol
[1]

(iii) Calculate the mass of sodium hydrogencarbonate present in each dm^3 of solution.

mass of NaHCO_3 = g

Hence calculate the percentage by mass of the sodium halide impurity in **FB 4**.
Show your working.

percentage by mass = %
[2]

(d) A student carries out the experiment in Question 1 using the impure sodium hydrogencarbonate dissolved to make **FB 4**.

State how this affects the value of ΔH_1 determined in **1(b)(iii)** compared to the value the student would get if pure sodium hydrogencarbonate were used.

.....
.....

State what assumption you have made about the sodium halide impurity.

.....
.....

[2]

[Total: 14]

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed, you should write 'no change'.

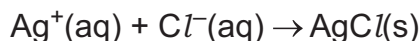
Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used. If any solid is heated a hard-glass test-tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

- 1 The concentration of aqueous chloride ions can be found by titration with aqueous silver nitrate, $\text{AgNO}_3(\text{aq})$.



The indicator used is aqueous potassium chromate(VI), $\text{K}_2\text{CrO}_4(\text{aq})$.

As $\text{AgNO}_3(\text{aq})$ is added to aqueous chloride ions, a white precipitate of $\text{AgCl}(\text{s})$ is formed.

When all the chloride ions have reacted, further addition of $\text{AgNO}_3(\text{aq})$ leads to the formation of a red precipitate of silver chromate(VI), $\text{Ag}_2\text{CrO}_4(\text{s})$. The first appearance of the red precipitate shows the end-point of the titration.

A student carries out an experiment to determine the number of molecules of water of crystallisation, x , in hydrated barium chloride, $\text{BaCl}_2 \cdot x\text{H}_2\text{O}(\text{s})$.

(a) The student makes 250.0 cm^3 of $0.0500 \text{ mol dm}^{-3}$ $\text{AgNO}_3(\text{aq})$ to use for the titration.

- (i) Calculate the mass of solid silver nitrate, $\text{AgNO}_3(\text{s})$, needed to make 250.0 cm^3 of $0.0500 \text{ mol dm}^{-3}$ $\text{AgNO}_3(\text{aq})$.

Give your answer to **two** decimal places.

mass of $\text{AgNO}_3(\text{s}) = \dots\dots\dots \text{g}$ [1]

- (ii) Describe how the student should make 250.0 cm^3 of $0.0500 \text{ mol dm}^{-3}$ $\text{AgNO}_3(\text{aq})$ starting from the mass of $\text{AgNO}_3(\text{s})$ calculated in (a)(i) in a 50 cm^3 beaker.

Give the name and size of any key apparatus used.

Write your answer using a series of numbered steps.

.....

.....

.....

.....

.....

.....

.....

..... [3]

(b) The student uses the following method.

- step 1 Dissolve 1.58 g of $\text{BaCl}_2 \cdot x\text{H}_2\text{O}(\text{s})$ to form 250 cm^3 of aqueous solution. Label this solution **A**.
- step 2 Transfer 20.0 cm^3 of solution **A** into a conical flask.
- step 3 Add aqueous sodium sulfate, $\text{Na}_2\text{SO}_4(\text{aq})$, to the flask and swirl the mixture to remove barium ions from the solution.
- step 4 Add 2–3 drops of $\text{K}_2\text{CrO}_4(\text{aq})$ indicator to the flask.
- step 5 Titrate the contents of the flask against $0.0500\text{ mol dm}^{-3} \text{AgNO}_3(\text{aq})$.
- step 6 Repeat steps 2 to 5 to collect sufficient data for analysis.

(i) Suggest a suitable piece of apparatus for transferring 20.0 cm^3 of solution **A** in step 2.

..... [1]

(ii) Suggest why barium ions are removed in step 3 before performing the titration.

.....
..... [1]

(iii) Suggest why chemically resistant gloves should be worn to carry out step 4.

..... [1]

(c) The student's results are shown in Table 1.1.

Table 1.1

	rough titration	titration 1	titration 2	titration 3
burette reading (final)/ cm^3	20.10	40.55	20.75	20.90
burette reading (initial)/ cm^3	0.00	20.25	0.05	0.30
titre/ cm^3	20.10	20.30	20.70	20.60

The student uses the titres from titrations 2 and 3 shown in Table 1.1 to calculate a mean titre value of 20.65 cm^3 .

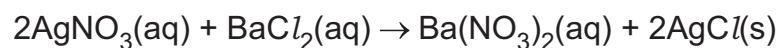
(i) Explain why only these two values are used.

..... [1]

- (ii) Calculate the percentage error in the titre volume for titration 3.
Show your working.

percentage error = [1]

- (d) The equation for the reaction of silver nitrate with barium chloride is shown.



- (i) Calculate the amount, in mol, of $\text{AgNO}_3(\text{aq})$ in the mean titre of 20.65 cm^3 .

amount of AgNO_3 = mol [1]

- (ii) Calculate the amount, in mol, of $\text{BaCl}_2(\text{aq})$ in 250 cm^3 of solution A.

amount of BaCl_2 = mol [1]

- (iii) Calculate the value of x in the formula $\text{BaCl}_2 \cdot x\text{H}_2\text{O}$.

x = [2]

- (e) Another student uses a different experimental method to check the value of x obtained by the method described in (b).

Give a **brief** description of another method, not involving titration, that could be used to determine the value of x in the formula $\text{BaCl}_2 \cdot x\text{H}_2\text{O}(\text{s})$. Write your answer using a series of numbered steps.

Your plan should include details of the following:

- the apparatus and method you would use
- the measurements you would make.

You are provided with standard laboratory apparatus.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [3]

[Total: 16]

- 2 A student carries out an experiment to determine the concentration of aqueous sulfate ions, $\text{SO}_4^{2-}(\text{aq})$, in a sample of lake water.

(a) The student uses the following method.

- step 1** Transfer 25.00 cm^3 of the lake water sample to a beaker and record its conductivity as shown in Fig. 2.1.
- step 2** Add 5.00 cm^3 of 0.100 mol dm^{-3} aqueous barium hydroxide, $\text{Ba}(\text{OH})_2(\text{aq})$, to the beaker.
- step 3** Stir the mixture and record the conductivity of the contents of the beaker as shown in Fig. 2.1.
- step 4** Repeat steps 2 and 3 until a total of 40.00 cm^3 of 0.100 mol dm^{-3} $\text{Ba}(\text{OH})_2(\text{aq})$ has been added to the beaker.

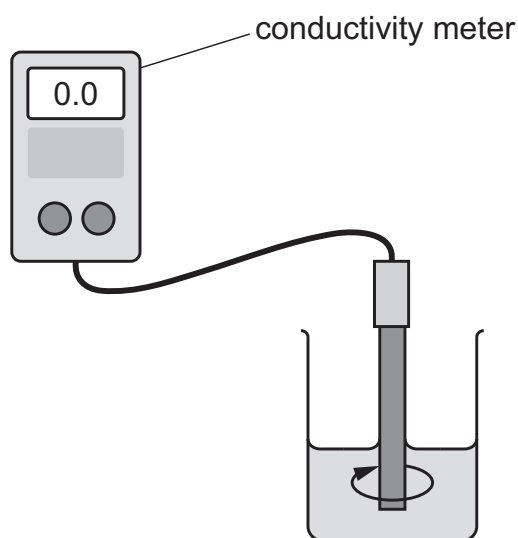


Fig. 2.1

- (i) Suggest a suitable piece of apparatus to transfer 25.00 cm^3 of the lake water sample to the beaker in step 1.

..... [1]

- (ii) 0.100 mol dm^{-3} $\text{Ba}(\text{OH})_2(\text{aq})$ is an irritant to skin and eyes. Other than wearing safety goggles, state **one** safety precaution that the student should take when conducting this experiment.

..... [1]

(b) The student's results are given in Table 2.1.

A correction can be applied to the conductivity values to take into account dilution of the solution as its volume increases using the following equation.

$$\text{corrected conductivity} = \text{measured conductivity} \times \frac{(\text{total volume in beaker})}{25.00}$$

Table 2.1

reading number	volume of $0.100 \text{ mol dm}^{-3}$ $\text{Ba(OH)}_2(\text{aq})$ added to beaker / cm^3	total volume in beaker / cm^3	measured conductivity / $\mu\text{S cm}^{-1}$	corrected conductivity / $\mu\text{S cm}^{-1}$
1	0.00	25.00	37 000	37 000
2	5.00		23 000	27 600
3	10.00		12 000	16 800
4	15.00		2 300	3 680
5	20.00		5 000	
6	25.00		12 000	
7	30.00		18 000	
8	35.00		21 000	
9	40.00		24 500	

(i) Complete Table 2.1.

[2]

(ii) Identify the independent variable in this experiment.

..... [1]

- (c) Plot a graph on the grid in Fig. 2.2 to show the relationship between corrected conductivity and volume of $0.100 \text{ mol dm}^{-3} \text{ Ba(OH)}_2$ added to beaker.

Use a cross (x) to plot each data point.

Draw a line of best fit using readings 1 to 4 and another line of best fit using readings 5 to 9. Extend the lines so that they intersect.

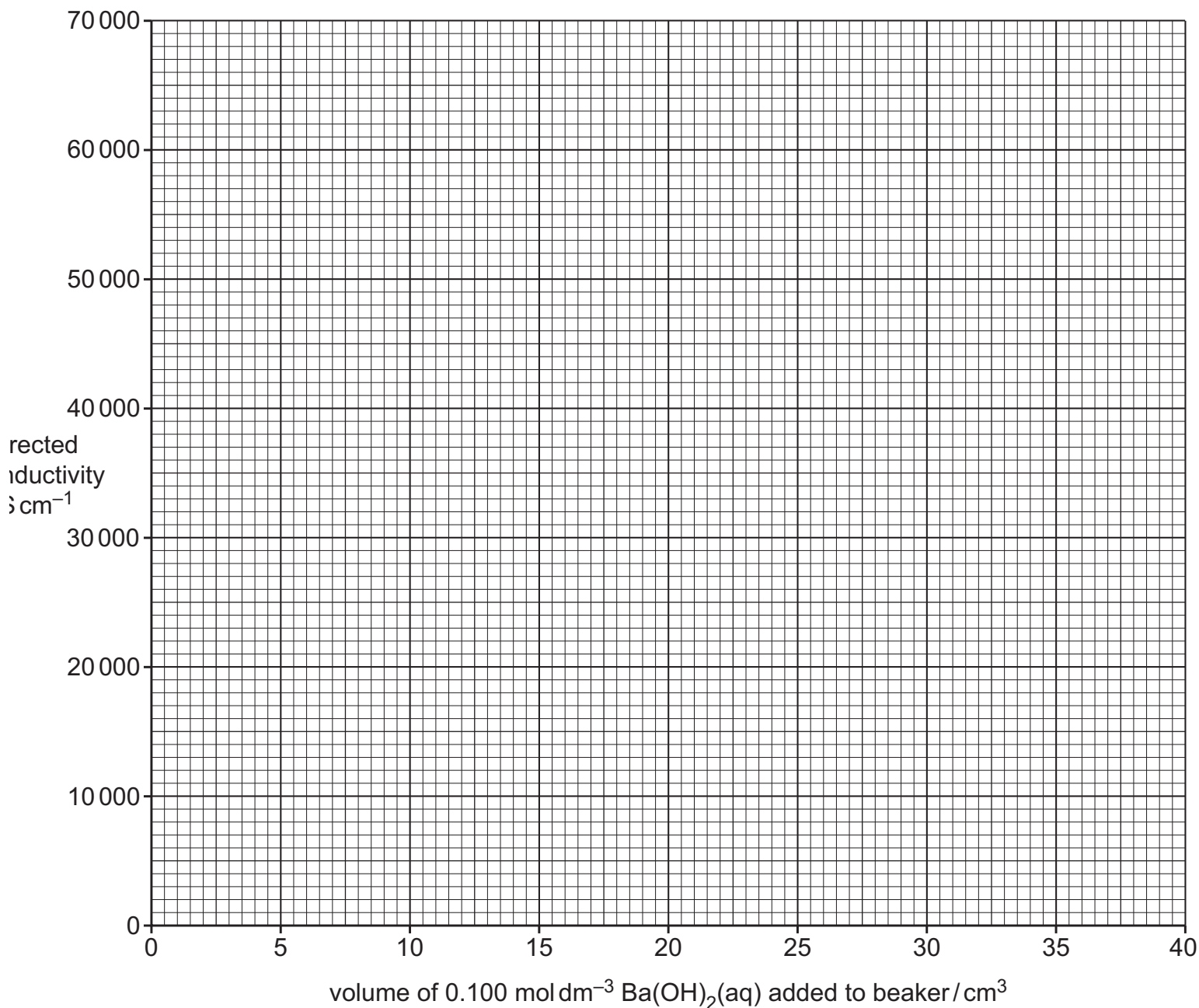


Fig. 2.2

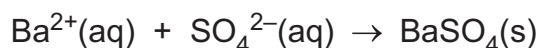
[2]

(d) The point on the graph where the two lines intersect indicates the volume of $0.100 \text{ mol dm}^{-3}$ $\text{Ba(OH)}_2(\text{aq})$ required to react exactly with the $\text{SO}_4^{2-}(\text{aq})$ present in 25.00 cm^3 of lake water being tested.

(i) Use the graph in Fig. 2.2 to determine the volume of $0.100 \text{ mol dm}^{-3}$ $\text{Ba(OH)}_2(\text{aq})$ required to react exactly with $\text{SO}_4^{2-}(\text{aq})$ in the lake water sample.

volume required = cm^3 [1]

(ii) The equation for the reaction taking place in the beaker is shown.



Use your answer in **(d)(i)** to calculate the concentration of $\text{SO}_4^{2-}(\text{aq})$ in the lake water sample.

concentration of $\text{SO}_4^{2-}(\text{aq})$ = mol dm^{-3} [1]

- (e) The concentration of $\text{SO}_4^{2-}(\text{aq})$ in a sample of water can also be determined by measuring the mass of precipitate produced when excess $\text{Ba}(\text{OH})_2(\text{aq})$ is added to the sample.

The student suggests the following method.

step 1 Place 25.0 cm^3 of the water sample in a conical flask.

step 2 Add excess 0.100 mol dm^{-3} $\text{Ba}(\text{OH})_2(\text{aq})$ to the flask.

step 3 Filter the contents of the flask.

step 4 Dry the residue in a warm oven.

step 5 Measure the mass of residue.

- (i) Draw a labelled diagram to describe the arrangement of apparatus that would be needed to complete step 3.

[1]

- (ii) Suggest a step that the student should add between steps 3 and 4 to improve this method.

..... [1]

- (iii) Describe what the student can do to ensure that the residue weighed in step 5 is completely dry.

.....
..... [1]

- (iv) The mass of residue is used to calculate the concentration of $\text{SO}_4^{2-}(\text{aq})$.

Suggest the effect, if any, on the concentration of $\text{SO}_4^{2-}(\text{aq})$ that is calculated if the residue is **not** completely dried in step 4.

Explain your answer.

effect on concentration of $\text{SO}_4^{2-}(\text{aq})$ calculated

explanation

.....
[1]

[Total: 13]

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)

- 1** Iron is an element that is essential in the human diet. Some people need to take iron supplement tablets to ensure an adequate intake of iron.

You will investigate the mass of iron in an iron supplement tablet by titrating a solution with potassium manganate(VII).



FB 1 is an aqueous solution of iron supplement tablets made by dissolving 14 tablets in 1.00 dm^3 of solution. The iron in each tablet is iron(II) sulfate, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$.

FB 2 is $0.0100 \text{ mol dm}^{-3}$ acidified aqueous potassium manganate(VII), KMnO_4 .

FB 3 is dilute sulfuric acid, H_2SO_4 .

(a) Method

- Fill a burette with **FB 2**.
- Pipette 25.0 cm^3 of **FB 1** into a conical flask.
- Use the 25 cm^3 measuring cylinder to add 10.0 cm^3 of **FB 3** to the conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record, in a suitable form in the space below, all your burette readings and the volume of **FB 2** added in each accurate titration.

Rinse the burette with distilled water and leave to drain while you continue Question 1.

Results

I	
II	
III	
IV	
V	
VI	
VII	

[7] -

- (b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

25.0 cm³ of **FB 1** required cm³ of **FB 2**. [1]

(c) Calculations

- (i) Give your answers to (c)(ii), (c)(iii) and (c)(iv) to an appropriate number of significant figures. [1]

- (ii) Calculate the amount, in mol, of manganate(VII) ions in the volume of **FB 2** in (b).

amount of MnO_4^- = mol [1]

- (iii) Use your answer to (c)(ii) and the equations at the start of the question to calculate the concentration, in mol dm⁻³, of iron(II) ions in **FB 1**.

concentration of Fe^{2+} = mol dm⁻³ [1]

- (iv) Use your answer to (c)(iii) to calculate the concentration, in g dm⁻³, of iron(II) ions in **FB 1**.

concentration of Fe^{2+} = g dm⁻³ [1]

- (v) The manufacturer of the iron supplement tablets used to make **FB 1** claims that each tablet contains a minimum of 150 mg of Fe^{2+} .

Use your answer to (c)(iv) and the information given about **FB 1** to determine whether this claim is correct. Show your working.

[1]

- (d) A student used all the **FB 3** and suggests that dilute hydrochloric acid would be a suitable replacement.
Suggest whether the student is correct or not. Explain your answer.

.....
.....
..... [1]