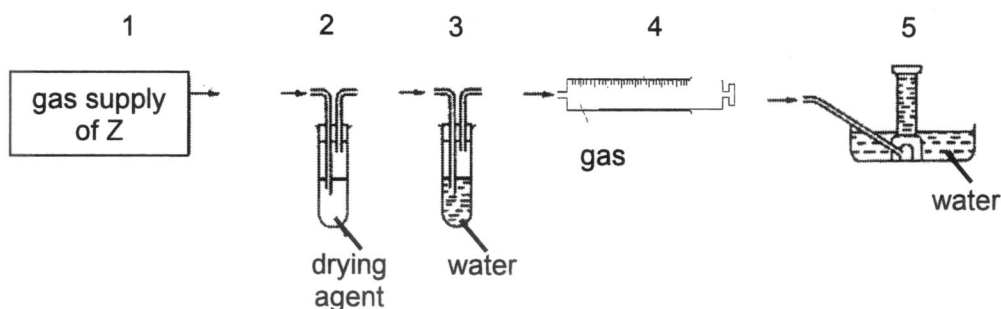
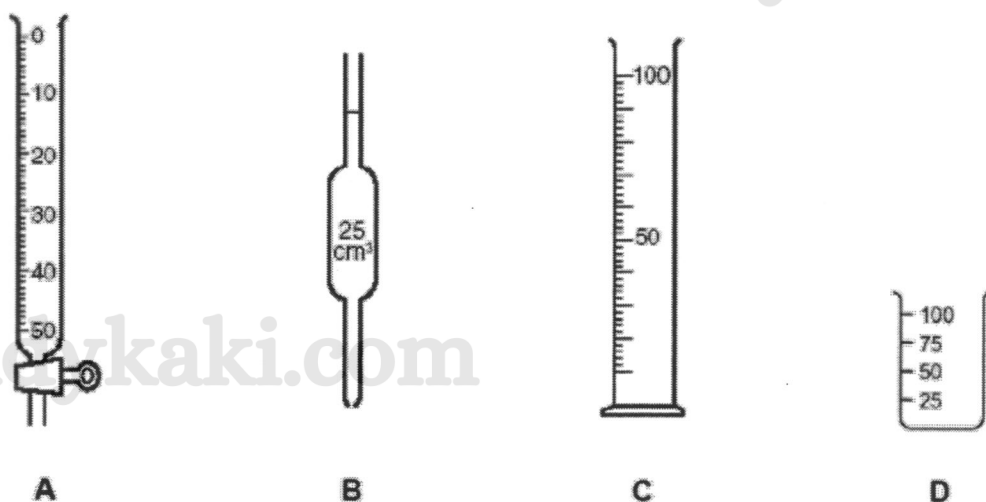


- 1 Gas Z is insoluble in water and denser than air.  
An impure supply of Z contains water vapour and a water soluble impurity.



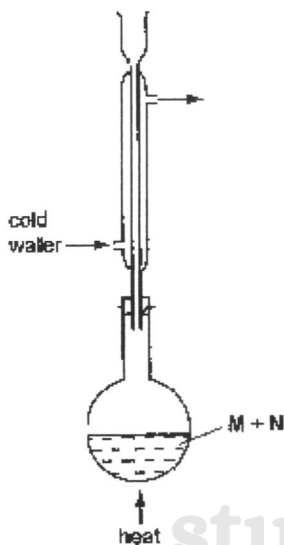
In which order should the pieces of apparatus be applied to collect a pure, dry sample of Z?

- A 1, 2, 3, 4
  - B 1, 2, 3, 5
  - C 1, 3, 2, 4
  - D 1, 3, 2, 5
- 2 A student wishes to measure the volume of dilute hydrochloric acid needed to neutralize 25.0 cm<sup>3</sup> of dilute potassium hydroxide. What apparatus should he use to measure that volume most accurately?



- 3 A student accidentally mixed 50 cm<sup>3</sup> of water with 50 cm<sup>3</sup> of cooking oil. Which method would allow him to obtain 25 cm<sup>3</sup> of the oil most easily?
- A chromatography
  - B evaporation
  - C filtration
  - D use of a separating funnel

- 4 Petrol and paraffin are accidentally mixed in an oil refinery. What is the best method of separating and collecting them?
- A condensation  
 B evaporation  
 C filtration  
 D fractional distillation
- 5 The diagram shows the apparatus used to prepare a liquid compound, L.



Compound L (boiling point 57 °C) is made by heating together two liquids, M (boiling point 78 °C) and N (boiling point 95 °C). The reaction is slow.

What is the purpose of the condenser?

- A To allow liquid L to escape as fast as it is formed.  
 B To enable M and N to mix more efficiently.  
 C To keep air away from the reacting liquids.  
 D To prevent M and N from escaping before the reaction is completed.

- 6 The rate of diffusion of carbon dioxide gas and sulfur dioxide gas was compared at 30 °C and 60 °C.

Which would have the fastest rate of diffusion?

- A carbon dioxide gas at 30 °C  
 B carbon dioxide gas at 60 °C  
 C sulfur dioxide gas at 30 °C  
 D sulfur dioxide gas at 60 °C

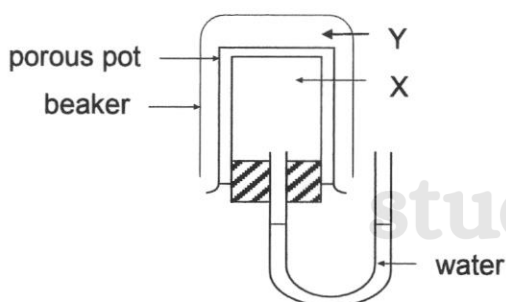
- 7 The table shows the boiling points of some elements.

element	boiling point / °C
nitrogen	-196
oxygen	-183
xenon	-108

A mixture of oxygen, nitrogen and xenon at  $-200\text{ }^{\circ}\text{C}$  is allowed to warm up gradually by  $20\text{ }^{\circ}\text{C}$ .

Which substance(s) will still be in the liquid state at the higher temperature?

- A nitrogen only  
 B oxygen only  
 C xenon only  
 D a mixture of oxygen and xenon
- 8 The apparatus is used to show the diffusion of gases.



Which pair of gases, X and Y, would cause a drop in the level of water on the right side of the U-shaped tube?

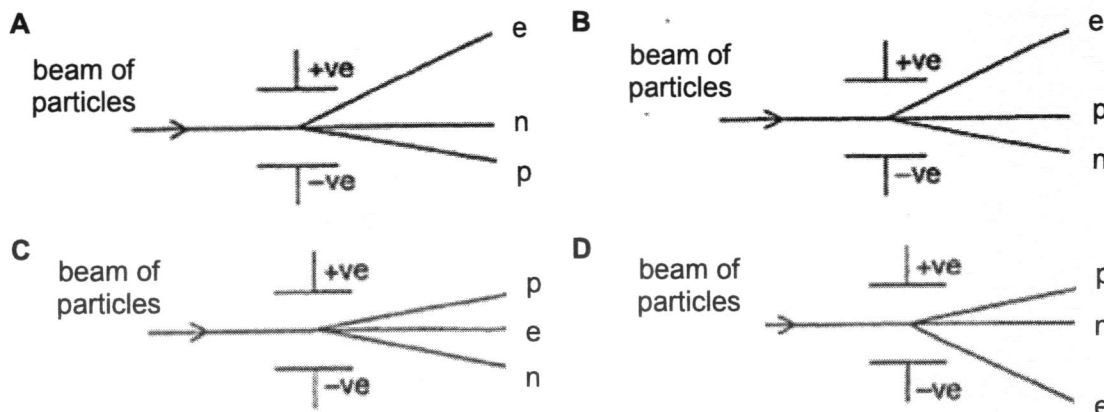
	X	Y
A	$\text{CO}_2$	$\text{C}_2\text{H}_6$
B	$\text{C}_2\text{H}_4$	$\text{N}_2$
C	$\text{SO}_2$	$\text{NO}_2$
D	$\text{CO}$	$\text{NO}_2$

- 9 An atom of argon has 18 electrons surrounding its nucleus.

Which particle does **not** have 18 electrons surrounding its nucleus?

- A  $\text{Ca}^{2+}$   
 B  $\text{Cl}^-$   
 C  $\text{K}^+$   
 D  $\text{O}^{2-}$

- 10 A beam of particles contains neutrons, n, protons, p, and electrons, e. The beam is passed between charged plates. Which diagram shows how the particles are affected by the plates?



- 11 An atom of element W is represented by  ${}^7_3\text{W}$ . Which statement about an atom of W is correct?

- A It is in Group 17 of the Periodic Table.  
 B It is in Group 13 of the Periodic Table.  
 C The total number of protons and neutrons is 10.  
 D The total number of protons and electrons is 6.

- 12 Element X has an electronic configuration of 2,8,8,1. Element Y has an electronic configuration of 2,8,6. Which of the following shows the type of bonding and the chemical formula of the compound formed between X and Y?

	type of bonding	chemical formula
A	covalent	$\text{X}_2\text{Y}$
B	covalent	$\text{XY}_2$
C	ionic	$\text{X}_2\text{Y}$
D	ionic	$\text{XY}_2$

- 13 Element Q has 12 protons. Element R has 17 protons.

The compound formed between Q and R will

- A conduct electricity when molten.  
 B have a low boiling point.  
 C have a macromolecular structure.  
 D not conduct electricity when dissolved in water.

- 14 Which substance could be copper?

	melting point / °C	conduction of electricity when	
		in liquid state	in aqueous solution
A	-114	none	none
B	-114	none	good
C	550	none	insoluble
D	1085	good	insoluble

- 15 Which list contains all elements that exist as diatomic molecules at room temperature?
- A hydrogen, fluorine, neon  
 B nitrogen, chlorine, neon  
 C nitrogen, oxygen, fluorine  
 D oxygen, chlorine, helium
- 16 Which statement explains why magnesium oxide has a very high melting point?
- A Magnesium atoms and oxygen atoms are joined by strong double bonds.  
 B The crystal lattice of magnesium oxide resembles that of diamond.  
 C The magnesium ions are strongly attracted to the oxide ions.  
 D The reaction between magnesium and oxygen is very vigorous.
- 17 Which property is common to both diamond and graphite?
- A Each atom in the structure forms four covalent bonds.  
 B They act as a lubricant when finely divided.  
 C They are electrical insulators.  
 D They react with oxygen to produce carbon dioxide.
- 18 How many covalent bonds are there in the molecule with the formula  $\text{CH}_3\text{CH}_2\text{CH}_3$ ?
- A 9  
 B 10  
 C 11  
 D 12
- 19 Four statements comparing compounds and mixtures are given.
- 1 Compounds have fixed compositions.
  - 2 Compounds have variable melting points.
  - 3 Mixtures have fixed compositions.
  - 4 Mixtures have variable melting points.

Which statements are correct?

- A 1 and 2  
 B 1 and 4  
 C 2 and 3  
 D 3 and 4
- 20 Barium sulfate can be formed by the precipitation reaction of aqueous barium nitrate and aqueous sodium sulfate.

What is the ionic equation for the reaction?

- A  $\text{Ba}^{2+}(\text{aq}) + \text{NO}_3^-(\text{aq}) + \text{Na}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + \text{NaNO}_3(\text{aq})$   
 B  $\text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$   
 C  $\text{Ba}(\text{aq}) + \text{SO}_4(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$   
 D  $\text{Ba}(\text{NO}_3)_2(\text{aq}) + \text{Na}_2\text{SO}_4(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + 2\text{NaNO}_3(\text{aq})$

- 21 The equation for the reaction between magnesium hydroxide and nitric acid is shown below.



What values of  $x$ ,  $y$  and  $z$  would balance the equation?

	$x$	$y$	$z$
<b>A</b>	1	1	2
<b>B</b>	1	2	2
<b>C</b>	2	1	2
<b>D</b>	2	2	1

- 22 Which is the molecular formula of a hydrocarbon containing 85.7 % of carbon by mass?

- A**  $\text{C}_2\text{H}_2$   
**B**  $\text{C}_2\text{H}_4$   
**C**  $\text{C}_3\text{H}_8$   
**D**  $\text{C}_4\text{H}_{10}$

- 23 How many moles of iron can be extracted from 58 g of  $\text{Fe}_3\text{O}_4$ ?

- A** 0.50 mol  
**B** 0.75 mol  
**C** 1.00 mol  
**D** 1.50 mol

- 24 8 g of  $\text{X}_2\text{O}_3$ , an oxide of element X, contains 5.6 g of X.

How many moles of X does 5.6 g of the element contain?

**A**  $\frac{2.4}{16} \times \frac{2}{3}$

**B**  $\frac{2.4}{16} \times \frac{3}{2}$

**C**  $\frac{8}{16} \times \frac{2}{3}$

**D**  $\frac{8}{16} \times \frac{3}{2}$

- 25 Which substance contains the same number of molecules as 9 g of water?

- A** 1 g of hydrogen gas  
**B** 28 g of nitrogen gas  
**C** 32 g of oxygen gas  
**D** 44 g of carbon dioxide gas

- 26 What is the concentration of hydrogen ions in 0.05 mol/dm<sup>3</sup> hydrochloric acid?

- A** 0.010 mol/dm<sup>3</sup>  
**B** 0.025 mol/dm<sup>3</sup>  
**C** 0.050 mol/dm<sup>3</sup>  
**D** 0.100 mol/dm<sup>3</sup>

- 27 A new indicator, TUV, has just been produced in the laboratory. It changes colour according to the pH range below:

pH range	colour
0 - 2	yellow
3 - 6	blue
7 - 14	colourless

Which pair of substances can be distinguished by adding indicator TUV to each sample separately?

- A aqueous ammonia and sodium chloride solution  
 B dilute carbonic acid and potassium chloride solution  
 C dilute ethanoic acid and rainwater  
 D dilute hydrochloric acid and dilute sulfuric acid
- 28 Which reaction does **not** produce a soluble salt?
- A copper metal with dilute hydrochloric acid  
 B copper(II) sulfate solution with excess aqueous ammonia  
 C zinc metal with dilute hydrochloric acid  
 D zinc sulfate solution with excess aqueous sodium hydroxide
- 29 A white solid is often seen around the stoppers of bottles containing sodium hydroxide solution.

Which substance has reacted with sodium hydroxide to form the solid?

- A carbon dioxide in the air  
 B glass  
 C oxygen in the air  
 D water in the solution
- 30 The table shows properties of four chlorides.

Which row shows the properties of magnesium chloride?

	colour	solubility in water	method of preparation
A	blue	soluble	insoluble base and acid
B	green	soluble	metal and acid
C	white	soluble	metal and acid
D	white	insoluble	titration

- 31 Barium sulfate is insoluble in water. Which method could be used to prepare a pure sample of the salt from dilute sulfuric acid?
- A add an excess of barium carbonate, filter, crystallise the filtrate  
 B add an excess of barium carbonate, filter, wash and dry the residue  
 C add aqueous barium chloride, filter, crystallise the filtrate  
 D add aqueous barium chloride, filter, wash and dry the residue
- 32 Which salt can be prepared by titration?
- A calcium carbonate  
 B potassium nitrate  
 C silver chloride  
 D zinc carbonate

33 Which ion reacts with aqueous ammonia to give a precipitate that dissolves in an excess of aqueous ammonia?

- A aluminium ion
- B iron(II) ion
- C iron(III) ion
- D zinc ion

34 Aqueous sodium hydroxide reacts with a metal ion producing a coloured precipitate. This precipitate changes colour on standing.

What is the ion present?

- A calcium ion
- B copper(II) ion
- C iron(II) ion
- D iron(III) ion

35 Two bottles in the laboratory are unlabelled. One bottle is known to contain aqueous sodium iodide and the other aqueous sodium chloride.

Which test would identify the solutions?

- A addition of aqueous silver nitrate
- B addition of dilute sulfuric acid
- C addition of blue litmus paper
- D addition of aqueous sodium hydroxide

36 The results of some tests on fertiliser X are:

- i warming X with aqueous sodium hydroxide gave a gas which turned moist red litmus paper blue
- ii mixing aqueous X with acidified barium chloride did **not** give a white precipitate
- iii mixing aqueous X with acidified silver nitrate gave a white precipitate

What ions does fertiliser X contain?

- A ammonium and chloride
- B ammonium and sulfate
- C chloride and sulfate
- D potassium and chloride

37 Which reaction is **not** an example of a redox reaction?

- A  $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$
- B  $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$
- C  $\text{Ba}(\text{NO}_3)_2 + \text{H}_2\text{SO}_4 \rightarrow \text{BaSO}_4 + 2\text{HNO}_3$
- D  $2\text{SO}_2 + \text{O}_2 \rightarrow 2\text{SO}_3$

38 A gaseous reducing agent is passed through an aqueous solution of X. The solution changes from purple to colourless. What could X be?

- A acidified potassium manganate(VII)
- B bromine
- C chlorine
- D potassium iodide

- 39 What happens when a magnesium atom becomes a magnesium ion?
- A It is oxidised by losing two electrons.
  - B It is oxidised by gaining two electrons.
  - C It is reduced by losing two electrons.
  - D It is reduced by gaining two electrons.
- 40 The equation below shows the oxidation of ethanol to ethanoic acid by acidified potassium dichromate(VI).



From the equation, the oxidation state of chromium changes from +6 to

- A +2.
- B +3.
- C -2.
- D -2.

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### The Periodic Table of Elements

Group																	
1	2											13	14	15	16	17	18
											1 H hydrogen 1						2 He helium 4
<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: auto;"> <p><b>Key</b></p> <p>proton (atomic) number</p> <p>atomic symbol</p> <p>name</p> <p>relative atomic mass</p> </div>																	
3 Li lithium 7	4 Be beryllium 9											5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganeson –

	lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
	actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

The volume of one mole of any gas is 24 dm<sup>3</sup> at room temperature and pressure (r.t.p.).

The Avogadro constant,  $L = 6.02 \times 10^{23} \text{ mol}^{-1}$

**Section A [70 marks]**Answer **all** the questions.

Write your answers in the spaces provided.

- 1 (a) Write down the name of the piece of apparatus that is most suitable for the procedures:

(i) measuring the volume of 80 cm<sup>3</sup> of sulfuric acid;

..... [1]

(ii) delivering exactly 23.6 cm<sup>3</sup> of aqueous calcium hydroxide into a flask;

..... [1]

(iii) holding 6.7 g of copper(II) sulfate crystals for weighing;

..... [1]

(iv) separating a mixture of calcium carbonate and aqueous zinc sulfate.

..... [1]

- (b) Hydrogen gas is produced when zinc metal reacts with hydrochloric acid. Complete the diagram in Fig. 1.1 to show how the gas is collected and measured. Label the apparatus clearly.

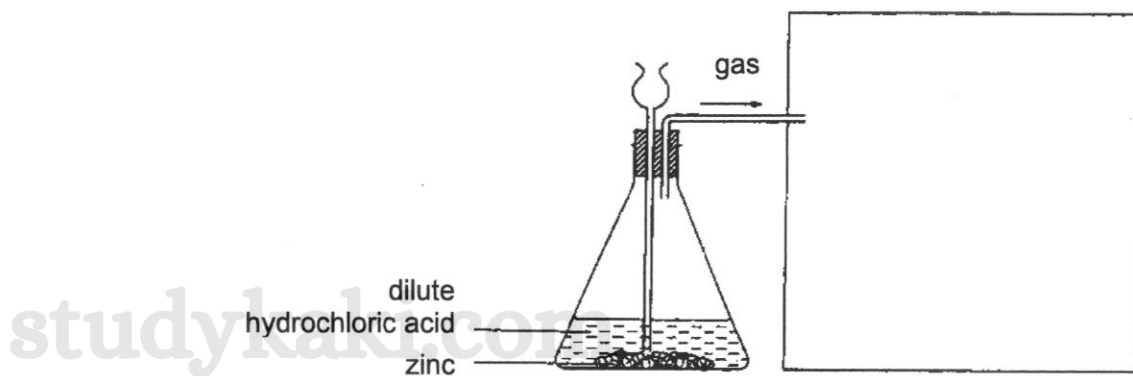


Fig. 1.1

[1]

2 A student carried out two experiments.

(a) In experiment 1, two gas jars were set up as shown in Fig. 2.1.

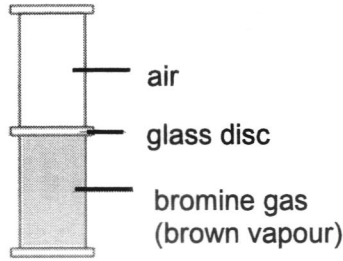


Fig. 2.1

(i) What was observed when the glass disc was removed for a period of time?

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

(ii) Explain the observation in (a)(i).

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

(b) The experiment was repeated, using green chlorine gas,  $Cl_2$ .

How would the rate of change be different from that observed in experiment 1? Explain your answer.

.....  
.....  
.....  
.....  
..... [3]

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- (d) Calculate the mass of zinc sulfate crystals obtained if 0.36 mole of zinc sulfate was formed.

[2]

- (e) Given that 8.64 dm<sup>3</sup> of carbon dioxide was evolved during the reaction,

- (i) calculate the number of carbon dioxide molecules present.

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[2]

- (ii) How many oxygen atoms are there in 8.64 dm<sup>3</sup> of carbon dioxide?

[1]

- 7 Fig. 7.1 shows some properties and reactions involving substances A, B, C, D and E.

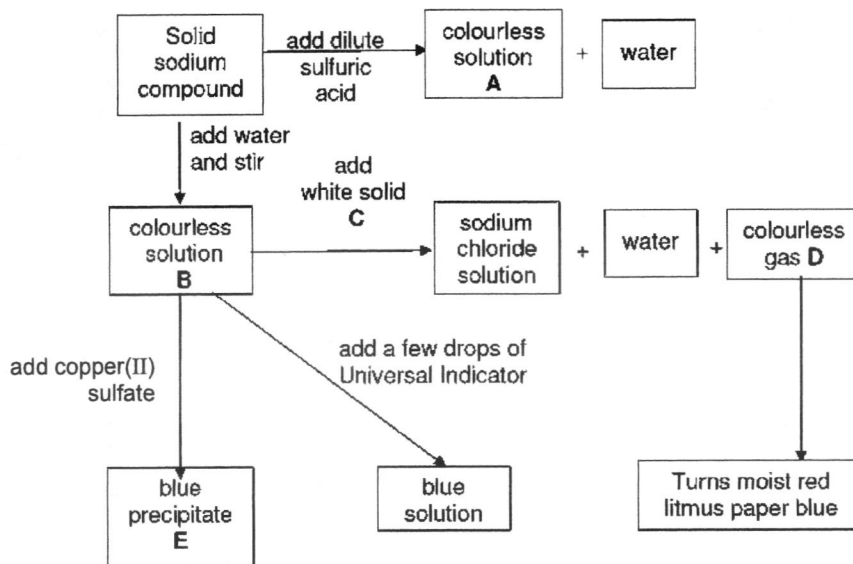


Fig. 7.1

- (a) Identify substances A, B, C, D and E.

A: .....

B: .....

C: .....

D: .....

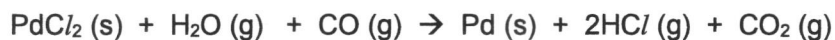
E: .....

[5]

- (b) Write a chemical equation for the reaction between B and C.

..... [1]

- 8 Palladium(II) chloride is used in carbon monoxide detectors at home. The reaction between palladium(II) chloride and carbon monoxide is shown below.



- (a) Identify the oxidising agent in the reaction.

..... [1]

- (b) In terms of oxidation states, explain why this is a redox reaction.

.....  
 .....  
 .....

[2]

- 9 Phosphine,  $\text{PH}_3$ , which has a structure similar to ammonia, is a gas which smells of garlic and is used as a fumigant to ward off pests in farms. It can be produced when phosphorus,  $\text{P}_4$ , is warmed with a solution of aqueous sodium hydroxide.

(a) An **unbalanced** chemical equation for the reaction is shown.



Balance the equation above.

[1]

(b) Draw a 'dot-and-cross' diagram to show the bonding in a molecule of phosphine. Show only the valence electrons.

[2]

(c) State two physical properties of phosphine.

.....  
 .....

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[2]

(d) Phosphine can also be prepared through the reaction between aqueous phosphonium chloride,  $\text{PH}_4\text{Cl}$ , and warm aqueous sodium hydroxide. During the reaction, it is found that phosphonium compounds undergo similar reactions with warm aqueous sodium hydroxide as ammonium compounds.

(i) State the type of bonding and physical property which allows phosphonium chloride to exist as a solid and for phosphine to exist as a gas at room temperature and pressure.

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.....  
 .....  
 .....

[2]

(ii) Hence, explain why phosphonium chloride exists as a solid, while phosphine exists as a gas at room temperature and pressure.

.....  
 .....  
 .....  
 .....  
 .....  
 .....  
 .....

[2]

- 10 (a) A mixture of amino acids is separated and analysed by two-way paper chromatography. After the chromatogram is removed from the solvents and dried, a locating agent containing ninhydrin is sprayed on it.

The positions of five amino acids, V, W, X, Y and Z are shown in the final chromatogram, Fig. 10.1, below.

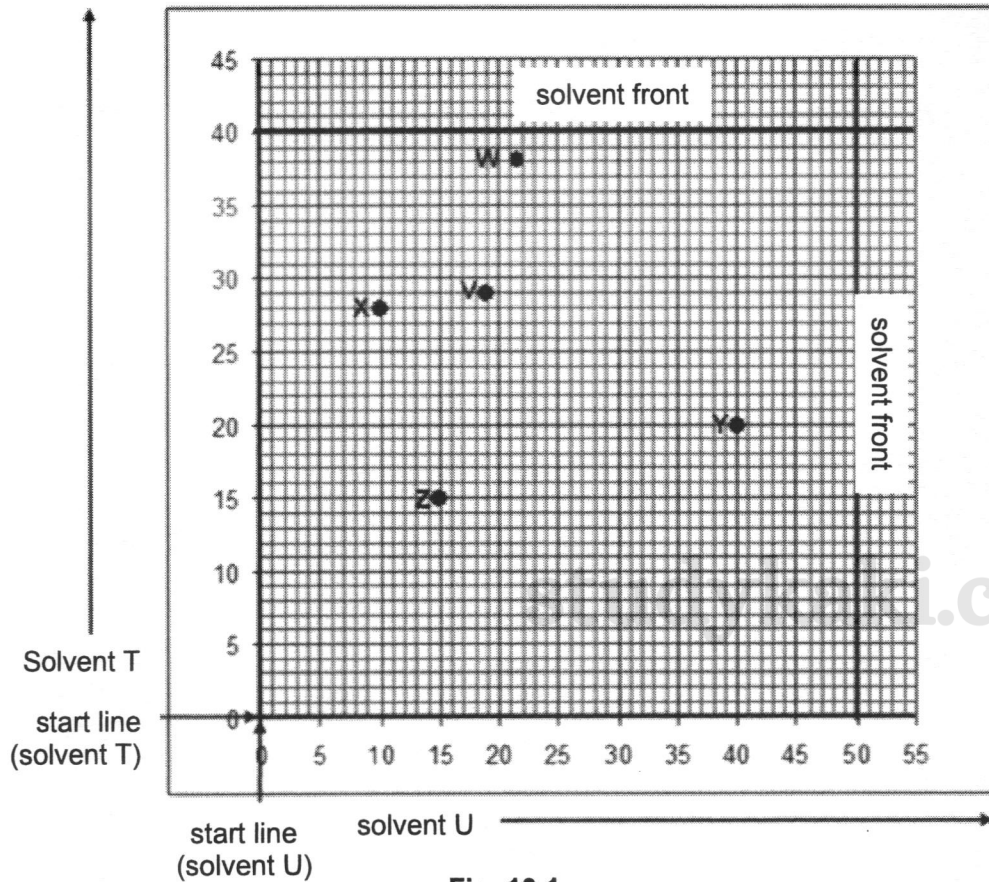


Fig. 10.1

Data of some amino acids can be found in Table 10.2 below.

Table 10.2

amino acid	$R_f$ value in	
	solvent T	solvent U
glutamic acid	0.38	0.30
tyrosine	0.66	0.45
glycine	0.50	0.26
arginine	0.70	0.20
proline	0.95	0.43
leucine	0.91	0.73
alanine	0.72	0.38

(i) Calculate the  $R_f$  value of amino acid V in Solvent U.

[1]

(ii) Calculate the  $R_f$  value of amino acid X and identify the amino acid from Table 10.2.

[2]

(iii) Given that an amino acid, aspartic acid, has  $R_f$  values of 0.25 and 0.60 in Solvent T and Solvent U respectively, calculate the distance moved by the amino acid in each of the two solvents.

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[2]

(iv) Using your answers from (a)(iii), indicate the position of aspartic acid on the chromatogram in Fig. 10.1 with a "x". Label the spot as A.

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[1]

(v) Why is it necessary to spray the chromatogram with a locating agent?

.....

.....

[1]

- (b) Desalination is the process of converting seawater into drinking water. Older processes used a distillation method to desalinate water, as shown in Fig. 10.3.

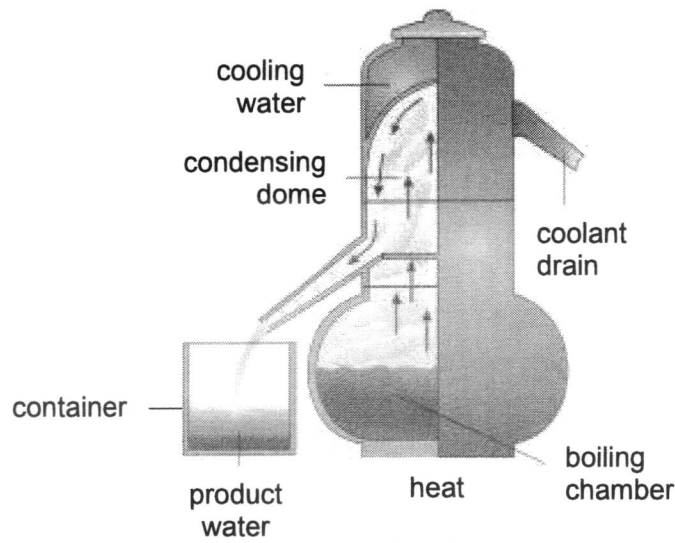


Fig. 10.3

Explain how this process produces salt-free water.

.....

.....

.....

.....

.....

.....

[3]

11 A toilet cleaner contains the acid salt, sodium dihydrogen phosphate,  $\text{NaH}_2\text{PO}_4$ .

(a) Explain why sodium dihydrogen phosphate is both an 'acid' and a 'salt'.

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

(b) Sodium dihydrogen phosphate can be made by reacting sodium hydroxide with phosphoric acid,  $\text{H}_3\text{PO}_4$ .

(i) Write an equation for the formation of sodium dihydrogen phosphate.


..... [1]

(ii) Suggest the formula of **two** other salts formed from sodium hydroxide and phosphoric acid.

..... [2]

(c) Table 11.1 shows information about other acids.

**Table 11.1**

name	pH of a $0.5 \text{ mol/dm}^3$ solution	 increasing acid strength
sodium dihydrogen phosphate	4.5	
ethanoic acid	3.8	
sulfuric acid	1.0	

(i) Explain why sulfuric acid behaves as a *strong acid* but ethanoic acid behaves as a *weak acid*.

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

- (ii) Describe an experiment, other than measuring pH, that you could carry out to show that sulfuric acid is a strong acid but ethanoic acid is a weak acid.

State what measurements you would take and what results you would expect.

.....

.....

.....

.....

.....

.....

.....

.....

.....

[4]

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**Section B [10 marks]**

Answer **one** questions in this section.  
Write your answers in the spaces provided.

- 12 (a) Under certain conditions, steam reacts with methane gas,  $\text{CH}_4$ , to produce carbon monoxide and hydrogen only.

(i) Write a balanced equation for the reaction.

..... [1]

(ii) What is meant by 'molar gas volume'? State its value for methane gas at room temperature and pressure.

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

(iii) Calculate the total volume of gas that can be obtained when  $500 \text{ cm}^3$  of methane reacts completely with steam.

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[2]

(b) CFCs are compounds that contain only carbon, chlorine and fluorine. They are atmospheric pollutants and destroy ozone in the upper atmosphere.

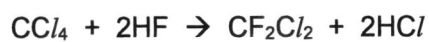
(i) 'CFC-11' has the following composition by mass:

C: 8.7 %, F: 13.8 %, Cl: 77.5 %

Calculate the empirical formula of CFC-11.

[3]

- (ii) 'CFC-12' has the molecular formula  $\text{CF}_2\text{Cl}_2$ . It can be made by the reaction of hydrogen fluoride, HF, with tetrachloromethane,  $\text{CCl}_4$ .



What is the maximum mass of CFC-12 that can be made from 200 g of hydrogen fluoride?

[2]

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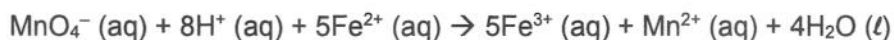
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- 13** Steel is an alloy. In an experiment to determine the mass of iron in steel, a 4.5 g sample of steel was reacted with excess dilute sulfuric acid. The iron in the steel was converted to iron(II) sulfate.

**(a)** Write the balanced chemical equation for the reaction of iron and dilute sulfuric acid. Include state symbols.

..... [2]

**(b)** The aqueous iron(II) sulfate solution produced was titrated with aqueous potassium manganate(VII),  $\text{KMnO}_4$ . The ionic equation is as shown:



Given that  $50.0 \text{ cm}^3$  of  $0.30 \text{ mol/dm}^3$  potassium manganate(VII) was used,

**(i)** calculate the number of moles of manganate ions ( $\text{MnO}_4^-$ ) that reacted,

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**(ii)** calculate the number of moles of iron(II) ions that reacted,

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[1]

**(iii)** calculate the percentage of iron present in the sample.

[2]

- (c) Sodium azide is a compound with the formula,  $\text{NaN}_3$ . It is usually used in air-bags, fitted in cars, which inflate in an accident.
- (i) Find the concentration, in  $\text{mol/dm}^3$ , of a solution containing 6.5 g of sodium azide dissolved in  $500 \text{ cm}^3$  of water.

[1]

- (ii) Sodium azide reacts with dilute sulfuric acid to give sodium sulfate and a compound X which contains 2.33 % hydrogen and 97.7 % nitrogen by mass. What is the empirical formula for compound X?

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[3]

### The Periodic Table of Elements

Group																												
1	2											13	14	15	16	17	18											
<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <b>Key</b>                      proton (atomic) number                      atomic symbol                      name                      relative atomic mass                 </div>												1																2
												H hydrogen 1																He helium 4
3	4											5	6	7	8	9	10											
Li lithium 7	Be beryllium 9											B boron 11	C carbon 12	N nitrogen 14	O oxygen 16	F fluorine 19	Ne neon 20											
11	12	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18											
Na sodium 23	Mg magnesium 24											Al aluminium 27	Si silicon 28	P phosphorus 31	S sulfur 32	Cl chlorine 35.5	Ar argon 40											
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36											
K potassium 39	Ca calcium 40	Sc scandium 45	Ti titanium 48	V vanadium 51	Cr chromium 52	Mn manganese 55	Fe iron 56	Co cobalt 59	Ni nickel 59	Cu copper 64	Zn zinc 65	Ga gallium 70	Ge germanium 73	As arsenic 75	Se selenium 79	Br bromine 80	Kr krypton 84											
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54											
Rb rubidium 85	Sr strontium 88	Y yttrium 89	Zr zirconium 91	Nb niobium 93	Mo molybdenum 96	Tc technetium —	Ru ruthenium 101	Rh rhodium 103	Pd palladium 106	Ag silver 108	Cd cadmium 112	In indium 115	Sn tin 119	Sb antimony 122	Te tellurium 128	I iodine 127	Xe xenon 131											
55	56	57–71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86											
Cs caesium 133	Ba barium 137	lanthanoids	Hf hafnium 178	Ta tantalum 181	W tungsten 184	Re rhenium 186	Os osmium 190	Ir iridium 192	Pt platinum 195	Au gold 197	Hg mercury 201	Tl thallium 204	Pb lead 207	Bi bismuth 209	Po polonium —	At astatine —	Rn radon —											
87	88	89–103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118											
Fr francium —	Ra radium —	actinoids	Rf rutherfordium —	Db dubnium —	Sg seaborgium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —	Rg roentgenium —	Cn copernicium —	Nh nihonium —	Fl flerovium —	Mc moscovium —	Lv livermorium —	Ts tennessine —	Og oganesson —											

lanthanoids	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
	La lanthanum 139	Ce cerium 140	Pr praseodymium 141	Nd neodymium 144	Pm promethium —	Sm samarium 150	Eu europium 152	Gd gadolinium 157	Tb terbium 159	Dy dysprosium 163	Ho holmium 165	Er erbium 167	Tm thulium 169	Yb ytterbium 173	Lu lutetium 175
actinoids	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
	Ac actinium —	Th thorium 232	Pa protactinium 231	U uranium 238	Np neptunium —	Pu plutonium —	Am americium —	Cm curium —	Bk berkelium —	Cf californium —	Es einsteinium —	Fm fermium —	Md mendelevium —	No nobelium —	Lr lawrencium —

The volume of one mole of any gas is  $24 \text{ dm}^3$  at room temperature and pressure (r.t.p.).

The Avogadro constant,  $L = 6.02 \times 10^{23} \text{ mol}^{-1}$

**3E Chemistry End-of-Year Examination 2023 Paper 1 Answers**

1	2	3	4	5	6	7	8	9	10
C	A	D	D	D	B	C	D	D	A
11	12	13	14	15	16	17	18	19	20
D	C	A	D	C	C	D	B	B	B
21	22	23	24	25	26	27	28	29	30
C	B	B	A	A	C	B	A	A	C
31	32	33	34	35	36	37	38	39	40
D	B	D	C	A	A	C	A	A	B

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**3E Chemistry End-of-Year Examination 2023 Paper 1 Explanation**

Qn	Answer	Explanation																														
1	C	The water soluble impurity should be removed using water first → 3 Any water vapour in the water should be removed → 2 Collection should be in a gas syringe to prevent more water from contaminating the gas → 4																														
2	A	In order to determine the volume of acid needed to neutralise the alkali using titration, a burette is needed for accurate measurements.																														
3	D	Oil and water are IMMISCIBLE liquids. Hence they can only be separated using a separating funnel.																														
4	D	Petrol and paraffin are MISCIBLE liquids. Hence they can only be separated by fractional distillation.																														
5	D	Due to the low boiling points of M and N, the condenser prevents the evaporating M and N from escaping before the reaction is complete. The cool temperature of the condenser will condense the vapours of M and N, making them flow back into the reaction flask.																														
6	B	The lower the Mr, the faster the rate of diffusion. Hence carbon dioxide gas will diffuse faster than sulfur dioxide gas. The higher the temperature, the faster the rate of diffusion. Hence gases will diffuse faster at 60 °C than at 30 °C.																														
7	C	When warmed from -200 °C to -180 °C, only nitrogen and oxygen will boil and become a gas. Xenon will still remain as a liquid at -180 °C.																														
8	D	Diffusion of gases depends on the Mr of the gas. For there to be a drop in the level of water on the right side of the U-shaped tube, gas X must have a lower Mr than gas Y for it to diffuse out of the porous pot.																														
<table border="1"> <thead> <tr> <th></th> <th>X</th> <th>Mr of X</th> <th>Y</th> <th>Mr of Y</th> <th>Remarks</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>CO<sub>2</sub></td> <td>44</td> <td>C<sub>2</sub>H<sub>6</sub></td> <td>30</td> <td>Gas Y will diffuse in, causing a drop on the left side of the tube.</td> </tr> <tr> <td>B</td> <td>C<sub>2</sub>H<sub>4</sub></td> <td>28</td> <td>N<sub>2</sub></td> <td>28</td> <td>No change in the level of water in the tube.</td> </tr> <tr> <td>C</td> <td>SO<sub>2</sub></td> <td>64</td> <td>NO<sub>2</sub></td> <td>46</td> <td>Gas Y will diffuse in, causing a drop on the left side of the tube.</td> </tr> <tr> <td>D</td> <td>CO</td> <td>28</td> <td>NO<sub>2</sub></td> <td>46</td> <td>Gas X will diffuse out, causing a drop on the right side of the tube.</td> </tr> </tbody> </table>				X	Mr of X	Y	Mr of Y	Remarks	A	CO <sub>2</sub>	44	C <sub>2</sub> H <sub>6</sub>	30	Gas Y will diffuse in, causing a drop on the left side of the tube.	B	C <sub>2</sub> H <sub>4</sub>	28	N <sub>2</sub>	28	No change in the level of water in the tube.	C	SO <sub>2</sub>	64	NO <sub>2</sub>	46	Gas Y will diffuse in, causing a drop on the left side of the tube.	D	CO	28	NO <sub>2</sub>	46	Gas X will diffuse out, causing a drop on the right side of the tube.
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9	D	Electronic configuration of Ca <sup>2+</sup> is 2, 8, 8 = 18 electrons Cl <sup>-</sup> is 2, 8, 8 = 18 electrons K <sup>+</sup> is 2, 8, 8 = 18 electrons O <sup>2-</sup> is 2, 8 = 10 electrons																														

10	A	e (charge -1) attracted to +ve plate. n (0 charge) no attraction. p (charge +1) attracted to -ve plate.
11	D	For all atoms, number of protons = number of electrons. Element X has 3 protons and 3 electrons. Hence it has a total of 6 protons and electrons.
12	C	Since X is a metal and Y is a non-metal. The 2 elements would react to form an ionic compound. X will form an ion with a +1 charge while Y will form an ion with a -2 charge. Hence the compound formed would be X <sub>2</sub> Y.
13	A	Electronic configuration of Q is 2, 8, 2. Electronic configuration of R is 2, 8, 7. Since Q is a metal and R is a non-metal, Q and R will form an ionic compound with the following properties: <ul style="list-style-type: none"> <li>• high melting and boiling point,</li> <li>• soluble in water but not in organic solvents,</li> <li>• conducts electricity in the molten and aqueous states but not in the solid state.</li> </ul>
14	D	Copper is a metal. Hence it should have a high melting point. Metals conduct electricity in the solid and liquid state and are insoluble in water (except Group 1 metals).
15	C	Hydrogen, oxygen, nitrogen and all group 17 elements exist as diatomic molecules.
16	C	The magnesium ions and oxide ions are held together by very strong electrostatic forces of attraction. Hence a large amount of heat energy is needed to overcome the strong forces of attraction. Thus magnesium oxide has a very high melting point.
17	D	Both diamond and graphite are allotropes of carbon. Hence they can react with oxygen to produce carbon dioxide.
18	B	$  \begin{array}{ccccccc}  & \text{H} & \text{H} & \text{H} & & & \\  &   &   &   & & & \\  \text{H} & - \text{C} & - \text{C} & - \text{C} & - \text{H} & & \\  &   &   &   & & & \\  & \text{H} & \text{H} & \text{H} & & &   \end{array}  $ <p>There are single carbon-carbon bonds between the carbon atoms. Hence there is a total of 10 covalent bonds.</p>
19	B	B: Statement 1 (correct) Statement 2 – compounds melt at an exact and sharp melting point (wrong) Statement 3 – mixtures do not have a fixed composition (wrong) Statement 4 – mixture melt and boil over a range of temperatures (correct)
20	B	B: $\text{Ba}(\text{NO}_3)_2 (\text{aq}) + \text{Na}_2\text{SO}_4 (\text{aq}) \rightarrow \text{BaSO}_4 (\text{s}) + 2\text{NaNO}_3 (\text{aq})$  Splitting the aqueous substances: $  \text{Ba}^{2+}(\text{aq}) + 2\text{NO}_3^-(\text{aq}) + 2\text{Na}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + 2\text{Na}^+(\text{aq}) + 2\text{NO}_3^-(\text{aq})  $ Cancelling spectator ions to obtain the final ionic equation: $  \text{Ba}^{2+} (\text{aq}) + \text{SO}_4^{2-} (\text{aq}) \rightarrow \text{BaSO}_4 (\text{s})  $

21	C	Coefficients of x, y and z can be obtained by balancing the atoms of each element on the left side and right side of the equation.										
22	B	<table border="1"> <thead> <tr> <th>Formula</th> <th>Percentage of carbon</th> </tr> </thead> <tbody> <tr> <td>C<sub>2</sub>H<sub>2</sub></td> <td><math>\frac{2(12)}{2(12) + 2(1)} \times 100\% = 92.3\%</math></td> </tr> <tr> <td>C<sub>2</sub>H<sub>4</sub></td> <td><math>\frac{2(12)}{2(12) + 4(1)} \times 100\% = 85.7\%</math></td> </tr> <tr> <td>C<sub>3</sub>H<sub>8</sub></td> <td><math>\frac{3(12)}{3(12) + 8(1)} \times 100\% = 81.8\%</math></td> </tr> <tr> <td>C<sub>4</sub>H<sub>10</sub></td> <td><math>\frac{4(12)}{4(12) + 10(1)} \times 100\% = 82.8\%</math></td> </tr> </tbody> </table>	Formula	Percentage of carbon	C <sub>2</sub> H <sub>2</sub>	$\frac{2(12)}{2(12) + 2(1)} \times 100\% = 92.3\%$	C <sub>2</sub> H <sub>4</sub>	$\frac{2(12)}{2(12) + 4(1)} \times 100\% = 85.7\%$	C <sub>3</sub> H <sub>8</sub>	$\frac{3(12)}{3(12) + 8(1)} \times 100\% = 81.8\%$	C <sub>4</sub> H <sub>10</sub>	$\frac{4(12)}{4(12) + 10(1)} \times 100\% = 82.8\%$
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23	B	<p>Mr of Fe<sub>3</sub>O<sub>4</sub> = 3(56) + 4(16) = 232</p> <p>Mole of Fe<sub>3</sub>O<sub>4</sub> = mass ÷ Mr = 58 ÷ 232 = 0.25 mol.</p> <p>For 1 mole of Fe<sub>3</sub>O<sub>4</sub>, Fe : O = 3 : 4</p> <p>Mole of iron = molar ratio of iron x mole = 3 x 0.25 = 0.75 mol.</p>										
24	A	<p>Mass of oxygen = 8 – 5.6 = 2.4 g</p> <p>Mole of oxygen = <math>\frac{2.4}{16 \times 3}</math> mol</p> <p>Mole of X = <math>\frac{2.4}{16 \times 3} \times 2 = \frac{2.4}{16} \times \frac{2}{3}</math> mol</p>										
25	A	<p>For gases, the same number of moles = the same number of molecules.</p> <p>Mole of water = mass ÷ Mr = 9 ÷ [2(1) + 16] = 0.5 mol.</p> <p>A: mole of H<sub>2</sub> = mass ÷ Mr = 1 ÷ 2(1) = 0.5 mol. (correct)</p> <p>B: mole of N<sub>2</sub> = mass ÷ Mr = 28 ÷ 2(14) = 1 mol. (wrong)</p> <p>C: mole of O<sub>2</sub> = mass ÷ Mr = 32 ÷ 2(16) = 1 mol. (wrong)</p> <p>D: mole of CO<sub>2</sub> = mass ÷ Mr = 44 ÷ [12 + 2(16)] = 1 mol. (wrong)</p>										
26	C	<p>HCl(aq) → H<sup>+</sup>(aq) + Cl<sup>-</sup>(aq)</p> <p>Since HCl : H<sup>+</sup> = 1 : 1, the concentration of hydrogen ions would be the same as the concentration of hydrochloric acid.</p>										
27	B	<p>A: aqueous ammonia (weak alkali = colourless); sodium chloride (neutral = colourless) (cannot differentiate)</p> <p>B: dilute carbonic acid (weak acid = blue); potassium chloride (neutral = colourless) (can differentiate)</p> <p>C: ethanoic acid (weak acid = blue); rain water (weak acid = blue) (cannot differentiate)</p> <p>D: hydrochloric acid (strong acid = yellow); sulfuric acid (strong acid = yellow) (cannot differentiate)</p>										
28	A	<p>A: unreactive metal, copper, will not react with acids</p> <p>B: blue ppt, copper(II) hydroxide, is soluble in excess aqueous ammonia</p> <p>C: soluble zinc chloride is formed</p> <p>D: white ppt, zinc hydroxide, is soluble in excess aqueous sodium hydroxide</p>										

29	A	As sodium hydroxide is alkaline, with will react with the acidic carbon dioxide in the air to form sodium carbonate which is a white solid. NaOH will not react with glass and water. (B & D wrong) NaOH will not react with neutral oxygen in the air. (C wrong)
30	C	Magnesium chloride is a white salt → C and D It is soluble in water and prepared using the acid with insoluble metal / metal carbonate / base method.
31	D	Barium sulfate is an insoluble salt and so it is prepared using the precipitation method.
32	B	Only soluble salts can be crystallised from their aqueous solutions. All carbonates (except SPA) and silver chloride are insoluble salts.
33	D	The white ppt, zinc hydroxide, is soluble in excess aqueous ammonia and aqueous sodium hydroxide.
34	C	Copper(II), iron(II) and iron(III) ions produce coloured ppts with aqueous sodium hydroxide. On standing, only iron(II) hydroxide would turn from green to brown.
35	A	Sodium iodide would react with aqueous silver nitrate to produce a yellow ppt of silver iodide while sodium chloride would react with aqueous silver nitrate to produce a white ppt of silver chloride.
36	A	Test (i): positive test for ammonium ion Test (ii): negative test for sulfate ion Test (iii): positive test for chloride ion
37	C	Precipitation and neutralisation reactions are not redox reactions. The reaction in C is a precipitation reaction.
38	A	Since X reacts with a reducing agent, it means that X is an oxidising agent. The purple colour of X indicates that it is acidified potassium manganate(VII).
39	A	The loss of electrons is oxidation. Magnesium atom has two valence electrons and hence will lose 2 electrons to form its ion.
40	B	Calculation for oxidation state of Cr in $\text{Cr}_2(\text{SO}_4)_3$ $2(\text{Cr}) + 3(\text{SO}_4^{2-}) = 0$ $2(\text{Cr}) + 3(-2) = 0$ $\text{Cr} = +3$

**Section A [70 marks]**Answer **all** the questions.

Write your answers in the spaces provided.

- 1 (a) Write down the name of the piece of apparatus that is most suitable for the procedures:

- (i) measuring the volume of 80 cm<sup>3</sup> of sulfuric acid;

Measuring cylinder

[1]

- (ii) delivering exactly 23.6 cm<sup>3</sup> of aqueous calcium hydroxide into a flask;

Burette

[1]

- (iii) holding 6.7 g of copper(II) sulfate crystals for weighing;

Evaporating dish / watch glass

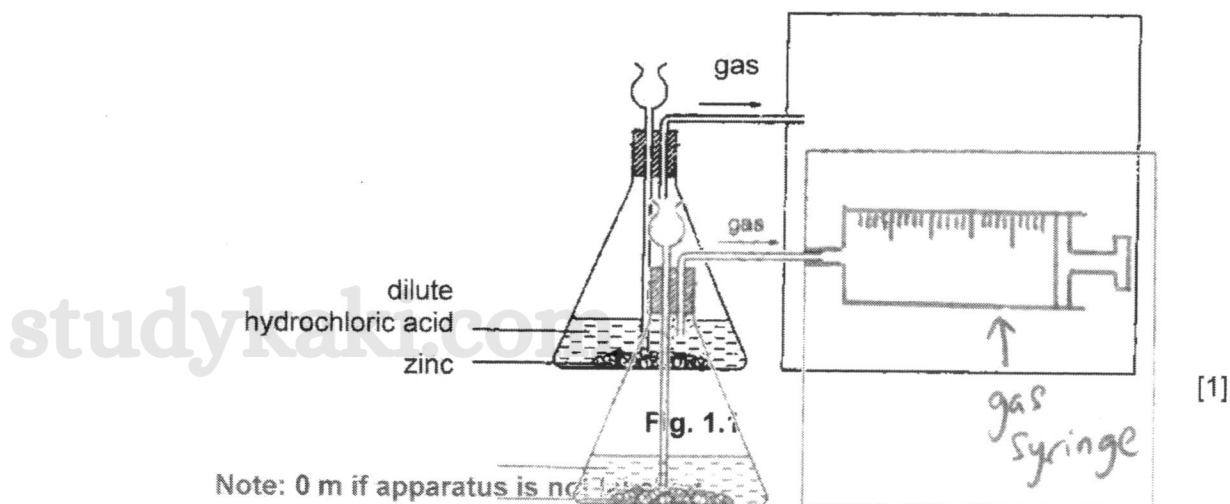
[1]

- (iv) separating a mixture of calcium carbonate and aqueous zinc sulfate.

Filter funnel with filter paper

[1]

- (b) Hydrogen gas is produced when zinc metal reacts with hydrochloric acid. Complete the diagram in Fig. 1.1 to show how the gas is collected and measured. Label the apparatus clearly.



[1]

2 A student carried out two experiments.

(a) In experiment 1, two gas jars were set up as shown in Fig. 2.1.

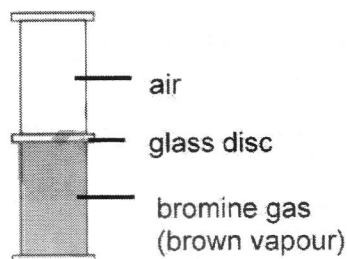


Fig. 2.1

(i) What was observed when the glass disc was removed for a period of time?

**Brown vapour of bromine spreads upward until both gases are completely mixed up/homogenous eventually.** [1]

(ii) Explain the observation in (a)(i).

**Diffusion has taken place for both bromine and air particles.** [1]

(b) The experiment was repeated, using green chlorine gas,  $\text{Cl}_2$ .

How would the rate of change be different from that observed in experiment 1? Explain your answer.

**Rate of change will be faster.** [1]

**Chlorine has a relative molecular mass of 71.**

**Bromine has a relative molecular mass of 160.** [1]

[Note: 1m for both  $M_r$  stated.]

**Chlorine has a lower relative molecular mass and diffuse faster.** [1] [3]

- 3 Water freezes at 0 °C.

Describe, in terms of particles, the arrangement and movement of water molecules when its temperature increases from -1 °C to 1 °C.

At -1 °C, water is in the solid state. The molecules are very closely packed in an orderly manner and vibrating about their fixed positions. [1]

As the temperature increases, the water molecules will gain heat energy and vibrate faster until at 0 °C, the water molecules would gain enough energy to overcome the strong forces of attraction holding them together and break away from their fixed position. [1]

At 1 °C, the water molecules are now quite closely packed but in a disorderly manner and sliding freely over one another. [1] [3]

- 4 Uranium-235 and uranium-238 are two isotopes of uranium.

- (a) Define the term 'isotopes'.

Isotopes are atoms of the same element with the same number of protons but different number of neutrons. [1]

- (b) Complete Table 4.1 to show the number of protons, electrons and neutrons each uranium isotope has.

Table 4.1

isotope	number of		
	protons	electrons	neutrons
uranium-235	92	92	143
uranium-238	92	92	146

[2]

Note: All 3 particles for each isotope must be correct to be awarded 1m.

- (c) Although uranium exists as two isotopes with different relative atomic masses, the relative atomic mass of uranium is shown as 238 in the Periodic Table. Explain.

The relative atomic mass of an element is the average mass of its isotopes based on relative abundance. [1]

Since the relative atomic mass of uranium is shown as 238 in the Periodic Table, it means that almost all uranium exists in the form uranium-238. Only a small percentage of uranium exists as the uranium-235 isotope. [1]

[2]

Note: Uranium actually exists as 3 isotopes. Their respective abundance are  $^{238}\text{U}$  99.2739 to 99.2752%,  $^{235}\text{U}$  0.7198 to 0.7202% and  $^{234}\text{U}$  0.0050 to 0.0059%.

- 5 Substances can be classified as solids, liquids or gases. Also, substances can be classified as either elements, compounds or mixtures.

Complete Table 5.1. Part of the table has been completed for you as an example.

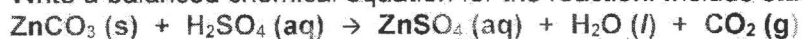
**Table 5.1**

classification	example at room temperature	name the atoms joined together in one of the molecules in the example, if any
solid element	copper	no molecules present
liquid compound	Water	Hydrogen and oxygen
gaseous mixture	Air	Oxygen (for O <sub>2</sub> ) Or Carbon and oxygen (for CO <sub>2</sub> ) Or nitrogen (for N <sub>2</sub> )

[2]

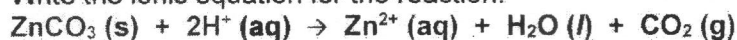
- 6 A student prepared a sample of zinc sulfate crystals by reacting excess zinc carbonate powder with sulfuric acid. An aqueous solution of zinc sulfate, carbon dioxide and water was formed.

(a) Write a balanced chemical equation for the reaction. Include state symbols.



[2]

(b) Write the ionic equation for the reaction.



[1]

(c) Describe how the student can obtain pure zinc sulfate crystals from the reaction above.

1. Filter the mixture. Residue: Excess zinc carbonate powder, filtrate: aqueous zinc sulfate. [1]
2. Heat the aqueous zinc sulfate to obtain a hot saturated solution. [1]
3. Allow the hot saturated zinc sulfate solution to cool slowly for crystallisation to occur / crystals to form. [1]
4. Once crystallisation is complete, filter, wash and then dry the pure zinc sulfate crystals between pieces of filter paper. [1]

[4]

- (d) Calculate the mass of zinc sulfate crystals obtained if 0.36 mole of zinc sulfate was formed.

$$\text{Mr of ZnSO}_4 = 65 + 32 + 4(16) = 161$$

$$\text{mass of ZnSO}_4 = \text{mole} \times \text{Mr} = 0.36 \times 161 = 57.96 \text{ g} \quad [2]$$

- (e) Given that 8.64 dm<sup>3</sup> of carbon dioxide was evolved during the reaction,

- (i) calculate the number of carbon dioxide molecules present.

$$\text{Mole of CO}_2 = \frac{\text{vol. in dm}^3}{24 \text{ dm}^3} = \frac{8.64}{24} = 0.36 \text{ mol.} \quad [1]$$

Number of CO<sub>2</sub> molecules

$$= \text{mole} \times 6.02 \times 10^{23}$$

$$= 0.36 \times 6.02 \times 10^{23}$$

$$= 2.1672 \times 10^{23}$$

$$\approx 2.17 \times 10^{23} \text{ molecules} \quad [1] \quad [2]$$

- (ii) How many oxygen atoms are there in 8.64 dm<sup>3</sup> of carbon dioxide?

CO<sub>2</sub> molecule : oxygen atom = 1 : 2

Number of oxygen atoms

$$= 2.1672 \times 10^{23} \times 2$$

$$= 4.3344 \times 10^{23} \text{ atoms} \quad [1]$$

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- 7 Fig. 7.1 shows some properties and reactions involving substances A, B, C, D and E.

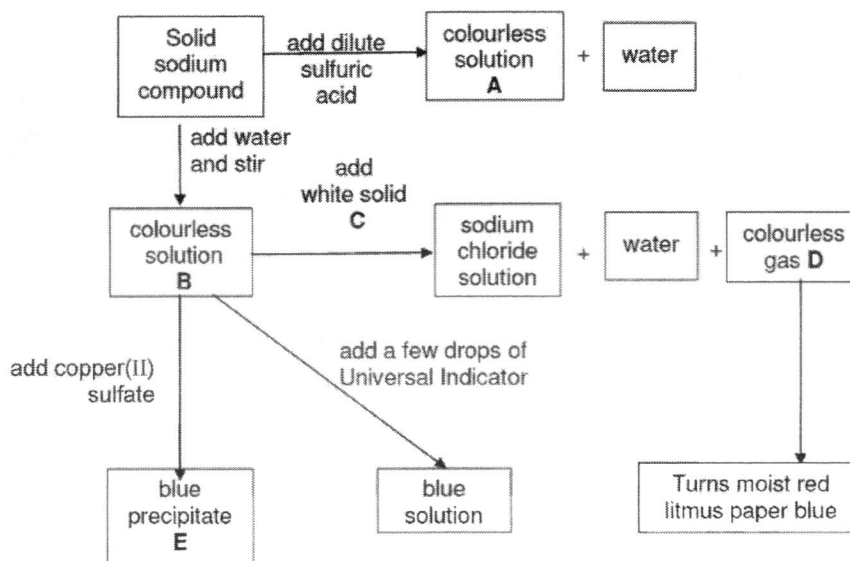


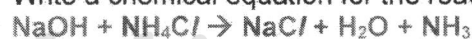
Fig. 7.1

- (a) Identify substances A, B, C, D and E.

- A: sodium sulfate  
 B: sodium hydroxide  
 C: ammonium chloride  
 D: ammonia  
 E: copper(II) hydroxide

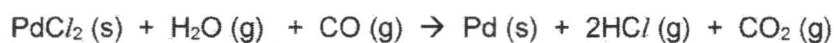
[5]

- (b) Write a chemical equation for the reaction between B and C.



[1]

- 8 Palladium(II) chloride is used in carbon monoxide detectors at home. The reaction between palladium(II) chloride and carbon monoxide is shown below.



- (a) Identify the oxidising agent in the reaction.

Palladium(II) chloride

[1]

- (b) In terms of oxidation states, explain why this is a redox reaction.

The oxidation state of palladium in  $\text{PdCl}_2$  decreased from +2 to 0 in Pd. Hence  $\text{PdCl}_2$  is reduced. [1]

The oxidation state of carbon in CO increased from +2 to +4 in  $\text{CO}_2$ . Hence CO is oxidised. [1]

Since both oxidation and reduction took place together, it is a redox reaction.

[2]

- 9 Phosphine,  $\text{PH}_3$ , which has a structure similar to ammonia, is a gas which smells of garlic and is used as a fumigant to ward off pests in farms. It can be produced when phosphorus,  $\text{P}_4$ , is warmed with a solution of aqueous sodium hydroxide.

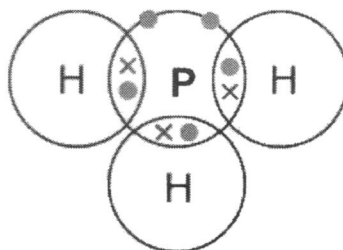
(a) An **unbalanced** chemical equation for the reaction is shown.



Balance the equation above.

[1]

(b) Draw a 'dot-and-cross' diagram to show the bonding in a molecule of phosphine. Show only the valence electrons.



[2]

(c) State two physical properties of phosphine.

Phosphine has a low melting and boiling point. [1]

Phosphine does not conduct electricity in any state. [1]

[2]

(d) Phosphine can also be prepared through the reaction between aqueous phosphonium chloride,  $\text{PH}_4\text{Cl}$ , and warm aqueous sodium hydroxide. During the reaction, it is found that phosphonium compounds undergo similar reactions with warm aqueous sodium hydroxide as ammonium compounds.

(i) State the type of bonding and physical property which allows phosphonium chloride to exist as a solid and for phosphine to exist as a gas at room temperature and pressure.

Phosphonium chloride is an ionic compound which has a high melting and boiling point. [1]

Phosphine is a covalent compound with a low melting and boiling point. [1]

[2]

(ii) Hence, explain why phosphonium chloride exists as a solid, while phosphine exists as a gas at room temperature and pressure.

The phosphonium ions and chloride ions are held together by strong electrostatic forces of attraction. Hence a large amount of heat energy is needed to overcome the strong forces of attraction. [1]

Thus phosphonium chloride has a high melting and boiling point and so it exists as a solid.

Phosphine exists as small discrete molecules held together by weak intermolecular forces of attraction. Hence a small amount of heat energy is needed to overcome the weak forces of attraction. [1]

Thus phosphine has a low melting and boiling point and so it exists as a gas at room temperature and pressure.

[2]

- 10 (a) A mixture of amino acids is separated and analysed by two-way paper chromatography. After the chromatogram is removed from the solvents and dried, a locating agent containing ninhydrin is sprayed on it.

The positions of five amino acids, V, W, X, Y and Z are shown in the final chromatogram, Fig. 10.1, below.

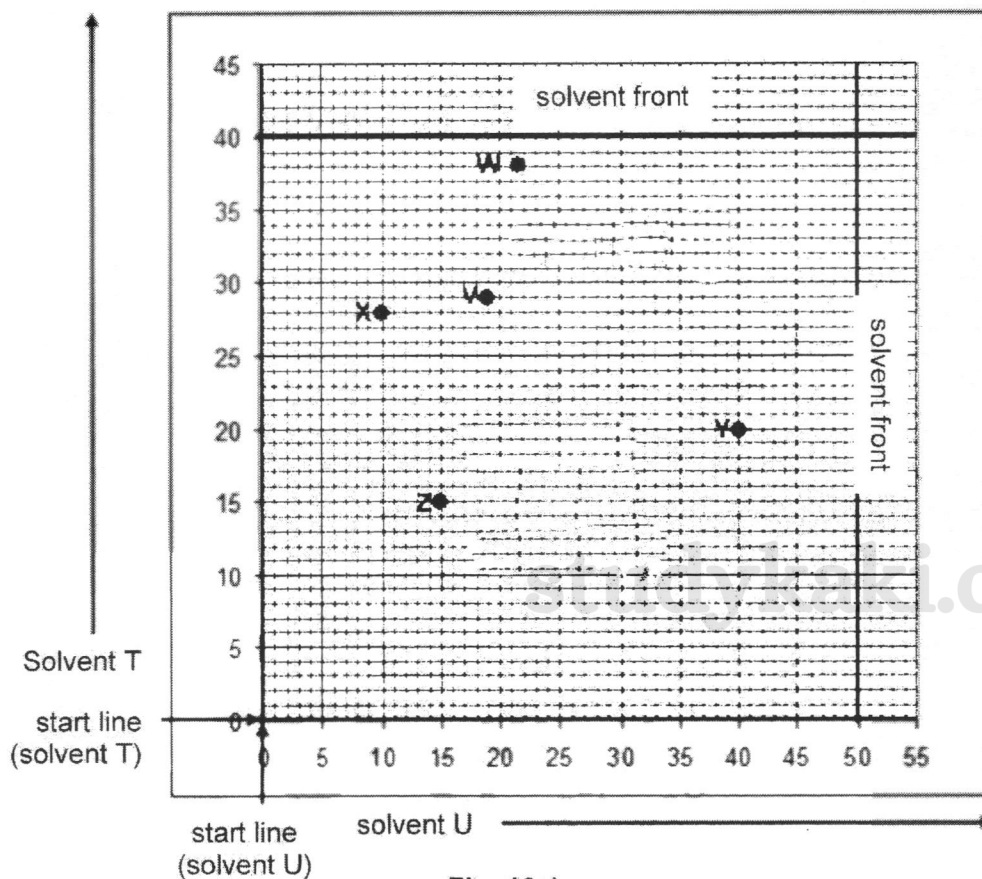


Fig. 10.1

Data of some amino acids can be found in Table 10.2 below.

Table 10.2

amino acid	$R_f$ value in	
	solvent T	solvent U
glutamic acid	0.38	0.30
tyrosine	0.66	0.45
glycine	0.50	0.26
arginine	0.70	0.20
proline	0.95	0.43
leucine	0.91	0.73
alanine	0.72	0.38

- (i) Calculate the  $R_f$  value of amino acid V in Solvent U.

$$R_f \text{ value} = 19 / 50 = 0.38 \quad [1]$$

- (ii) Calculate the  $R_f$  value of amino acid X and identify the amino acid from Table 10.2.

$$\text{Amino acid X: } R_f \text{ value in solvent T} = 28 / 40 = 0.7$$

$$R_f \text{ value in solvent U} = 10 / 50 = 0.2 \quad [1]$$

Amino acid X is Arginine. [1] [2]

- (iii) Given that an amino acid, aspartic acid, has  $R_f$  values of 0.25 and 0.60 in Solvent T and Solvent U respectively, calculate the distance moved by the amino acid in each of the two solvents.

$$\text{Distance moved in solvent T} = 0.25 \times 40 = 10 \quad [1]$$

$$\text{Distance moved in solvent U} = 0.6 \times 50 = 30 \quad [1] \quad [2]$$

- (iv) Using your answers from (a)(iii), indicate the position of aspartic acid on the chromatogram in Fig. 10.1 with a "x". Label the spot as A. [1]

See Fig. 10.1

- (v) Why is it necessary to spray the chromatogram with a locating agent?

Amino acids are colourless substances, hence, a locating agent is sprayed to react and to show the position of the substances on the chromatogram. [1]

- (b) Desalination is the process of converting seawater into drinking water. Older processes used a distillation method to desalinate water, as shown in Fig. 10.3.

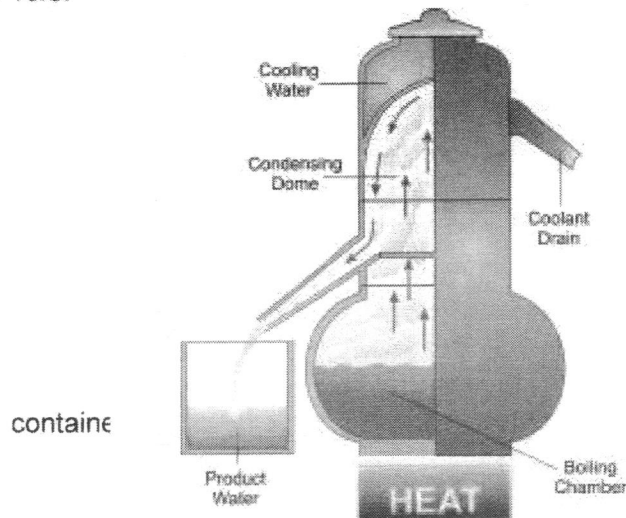


Fig. 10.3

Explain how this process produces salt-free water.

**Seawater is heated and water evaporates. [1]**

**It condenses on the cooler side of the condensing dome and collects in the container. [1]**

**The salt which has a higher boiling point is left in the boiling chamber, thus producing salt-free water. [1]**

[3]

11 A toilet cleaner contains the acid salt, sodium dihydrogen phosphate.

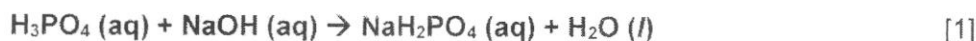
(a) Explain why sodium dihydrogen phosphate is both an 'acid' and a 'salt'.

$\text{NaH}_2\text{PO}_4$  is an acid because it dissociates in water to produce  $\text{H}^+$  ions. [1]

It is also a salt as it is formed by  $\text{Na}^+$  ions and  $(\text{H}_2\text{PO}_4)^-$  ions. [1]

(b) Sodium dihydrogen phosphate can be made by reacting sodium hydroxide with phosphoric acid,  $\text{H}_3\text{PO}_4$ .

(i) Write an equation for the formation of sodium dihydrogen phosphate.




(ii) Suggest the formula of **two** other salts formed from sodium hydroxide and phosphoric acid.



(c) Table 11.1 shows information about other acids.

Table 11.1

name	pH of a 0.5 mol/dm <sup>3</sup> solution	 increasing acid strength
sodium dihydrogen phosphate	4.5	
ethanoic acid	3.8	
sulfuric acid	1.0	

(i) Explain why sulfuric acid behaves as a *strong acid* but ethanoic acid behaves as a *weak acid*.

**Sulfuric acid dissociates completely to produce  $\text{H}^+$  ions in water while ethanoic acid dissociates partially to produce  $\text{H}^+$  ions in water.** [1]

**Note: Strength of acid depends on the concentration of  $\text{H}^+$  ions present.**

- (ii) Describe an experiment, other than measuring pH, that you could carry out to show that sulfuric acid is a strong acid but ethanoic acid is a weak acid.

State what measurements you would take and what results you would expect.

Add one 4 cm strip of magnesium ribbon into each of two clean and dry test-tubes. [1]

Add 10 cm<sup>3</sup> of sulfuric acid and ethanoic acid of the same concentration respectively into each test tube. [1]

Observe the effervescence and record the time taken for the for magnesium ribbon to completely disappear, indicating the complete reaction of the magnesium ribbon. [1]

[4]

The one that takes a longer time to completely react and has a slower rate of effervescence is ethanoic acid.

The one that takes a shorter time to completely react and has a faster rate of effervescence is sulfuric acid. [1]

**Section B [10 marks]**

Answer **one** questions in this section.  
Write your answers in the spaces provided.

- 12 (a) Under certain conditions, steam reacts with methane gas, CH<sub>4</sub>, to produce carbon monoxide and hydrogen only.

- (i) Write a balanced equation for the reaction.

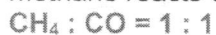


*Note: 0m for not balanced equation.*

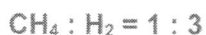
- (ii) What is meant by 'molar gas volume'? State its value for methane gas at room temperature and pressure.

'Molar gas volume' is the volume occupied by 1 mole of gas.  
At r.t.p., molar volume of methane = 24 dm<sup>3</sup> [2]

- (iii) Calculate the total volume of gas that can be obtained when 500 cm<sup>3</sup> of methane reacts completely with steam.



$$\text{Volume of CO} = 500 \text{ cm}^3$$



$$\text{Volume of H}_2 = 500 \times 3 = 1500 \text{ cm}^3$$

$$\text{Total volume of gases} = 500 + 1500 = 2000 \text{ cm}^3 \quad [2]$$

*Note: 1m for correct volume of both CO and H<sub>2</sub> gases.*

- (b) CFCs are compounds that contain only carbon, chlorine and fluorine. They are atmospheric pollutants and destroy ozone in the upper atmosphere.

- (i) 'CFC-11' has the following composition by mass:

C: 8.7 %, F: 13.8 %, Cl: 77.5 %

Calculate the empirical formula of CFC-11.

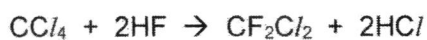
Element	C	F	Cl
Percentage	8.7	13.8	77.5
÷ Ar	$8.7 \div 12$ = 0.725	$13.8 \div 19$ = 0.726316	$77.5 \div 35.5$ = 2.1831
÷ smallest	$0.725 \div 0.725$ = 1	$0.72632 \div 0.725$ = 1	$2.1831 \div 0.725$ = 3
Empirical formula: CFCl <sub>3</sub>			

[3]

**Note:**

**2m for correct working for 3 elements;**  
**1m for correct working for 1-2 elements;**  
**1m for correct empirical formula.**

- (ii) 'CFC-12' has the molecular formula  $\text{CF}_2\text{Cl}_2$ . It can be made by the reaction of hydrogen fluoride, HF, with tetrachloromethane,  $\text{CCl}_4$ .



What is the maximum mass of CFC-12 that can be made from 200 g of hydrogen fluoride?

$$\text{Mole of HF} = \text{mass} \div \text{Mr} = 200 \div (1 + 19) = 10 \text{ mol.}$$

$$\text{HF} : \text{CF}_2\text{Cl}_2 = 2 : 1$$

$$\text{Mole of CF}_2\text{Cl}_2 = 10 \div 2 = 5 \text{ mol.}$$

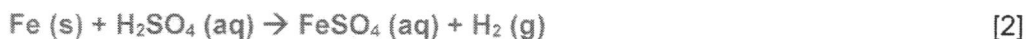
$$\text{Mass of CF}_2\text{Cl}_2 = \text{mole} \times \text{Mr} = 5 \times [12 + 2(19) + 2(35.5)] = 605 \text{ g} \quad [2]$$

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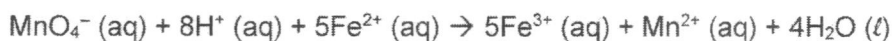
- 13** Steel is an alloy. In an experiment to determine the mass of iron in steel, a 4.5 g sample of steel was reacted with excess dilute sulfuric acid. The iron in the steel was converted to iron(II) sulfate.

- (a) Write the balanced chemical equation for the reaction of iron and dilute sulfuric acid. Include state symbols.



*Note: 1m for correct formulae; 1m for correct state symbols.*

- (b) The aqueous iron(II) sulfate solution produced was titrated with aqueous potassium manganate(VII),  $\text{KMnO}_4$ . The ionic equation is as shown:



Given that  $50.0 \text{ cm}^3$  of  $0.30 \text{ mol/dm}^3$  potassium manganate(VII) was used,

- (i) calculate the number of moles of manganate ions ( $\text{MnO}_4^-$ ) that reacted,

$$\begin{aligned} \text{Number of moles of KMnO}_4 & \\ &= \text{conc.} \times \text{vol. in dm}^3 \\ &= 0.3 \times 0.05 \\ &= 0.015 \text{ mol} \end{aligned}$$

$$\begin{aligned} \text{KMnO}_4 : \text{MnO}_4^- &= 1 : 1 \\ \text{Moles of MnO}_4^- &= 0.015 \text{ mol.} \end{aligned}$$

studykaki.com [1]

- (ii) calculate the number of moles of iron(II) ions that reacted,

$$\begin{aligned} \text{MnO}_4^- : \text{Fe}^{2+} &= 1 : 5 = 0.015 \text{ mol} : 0.075 \text{ mol} \\ \text{Moles of Fe}^{2+} &= 0.075 \text{ mol.} \end{aligned} \quad [1]$$

- (iii) calculate the percentage of iron present in the sample.

$$\text{Mass of iron present} = \text{mole} \times \text{Ar} = 0.075 \times 56 = 4.2 \text{ g} \quad [1]$$

$$\begin{aligned} \text{Percentage of iron} & \\ &= \left( \frac{\text{mass of Fe}}{\text{mass of steel}} \right) \times 100 \% \\ &= \left( \frac{4.2}{4.5} \right) \times 100 \% \\ &= 93.333 \% \\ &\approx 93.3 \% \text{ (3 sf)} \quad [1] \end{aligned}$$

[2]

- (c) Sodium azide is a compound with the formula,  $\text{NaN}_3$ . It is usually used in air-bags, fitted in cars, which inflate in an accident.
- (i) Find the concentration, in  $\text{mol/dm}^3$ , of a solution containing 6.5 g of sodium azide dissolved in  $500 \text{ cm}^3$  of water.

Number of moles of  $\text{NaN}_3$

$$= \text{mass} \div \text{Mr}$$

$$= 6.5 \div [23 + 3(14)]$$

$$= 0.1 \text{ mol}$$

$$500 \text{ cm}^3 = 0.5 \text{ dm}^3$$

Concentration of  $\text{NaN}_3$  solution

$$= \text{mole} \div \text{vol. in dm}^3$$

$$= 0.1 \div 0.5$$

$$= 0.2 \text{ mol/dm}^3$$

[1]

- (ii) Sodium azide reacts with dilute sulfuric acid to give sodium sulfate and a compound X which contains 2.33 % hydrogen and 97.7 % nitrogen by mass. What is the empirical formula for compound X?

Element	H	N
Percentage	2.33	97.7
$\div \text{Ar}$	$2.33 \div 1 = 2.33$	$97.7 \div 14 = 6.97857$
$\div \text{smallest}$	$2.33 \div 2.33 = 1$	$6.97857 \div 2.33 = 2.995 \approx 3$
Empirical formula: $\text{HN}_3$		

[3]

Note:

1m for correct working for H;

1m for correct working for N;

1m for correct empirical formula.

Accept  $\text{N}_3\text{H}$  as the empirical formula.

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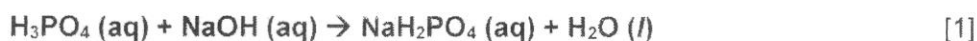
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