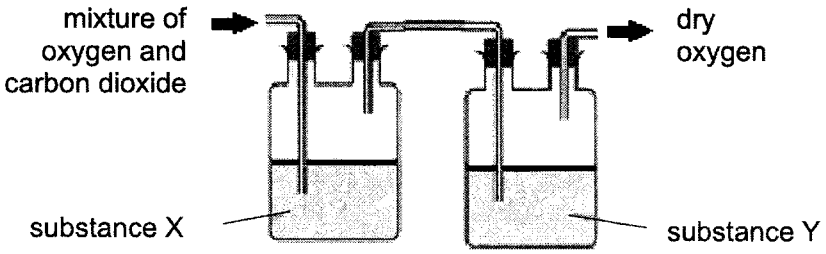
1 A gaseous mixture of oxygen and carbon dioxide was passed through substance X and substance Y. Dry oxygen was obtained at the end of the setup.



Which of the following shows the correct identities of substances X and Y?

	substance X	substance Y
A	water	concentrated sulfuric acid
B	limewater	aqueous sodium hydroxide
C	water	aqueous sodium hydroxide
D	limewater	concentrated sulfuric acid

2 The table shows some information about the solubilities of three solids.

solid	solubility in water	solubility in ethanol
K	soluble	insoluble
L	insoluble	soluble
M	insoluble	insoluble

The following steps could be carried out to obtain pure K from a mixture K, L and M.

1 filter
2 evaporate filtrate to dryness
3 add water
4 add ethanol

What is the correct order of steps to be carried out?

A 4, 1, 2

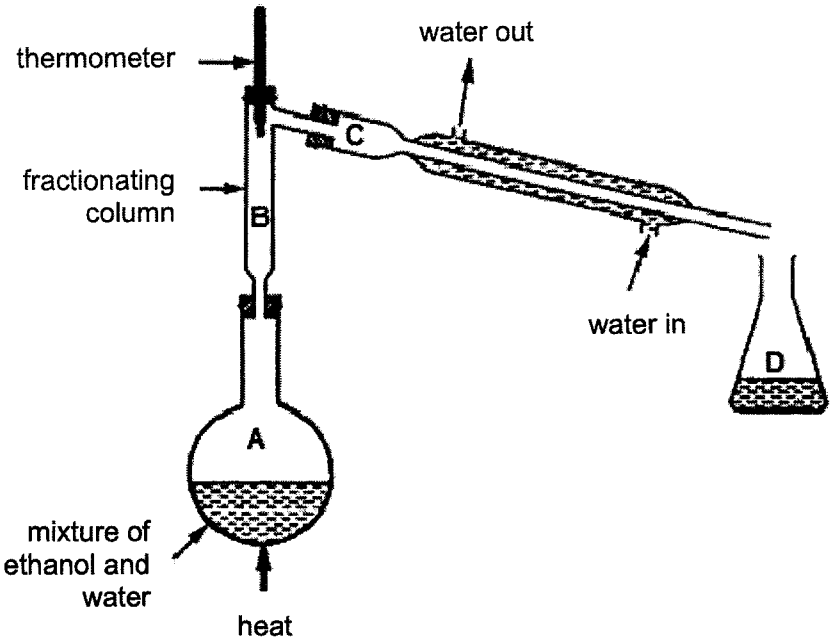
B 3, 1, 2

C 3, 2, 4, 1

D 4, 1, 3, 2

3 A mixture containing equal volumes of two miscible liquids is placed in the apparatus shown in the diagram and heated until the thermometer first shows a steady reading.

At which point, **A**, **B**, **C** or **D** will there be the highest proportion of the liquid with the higher boiling point?



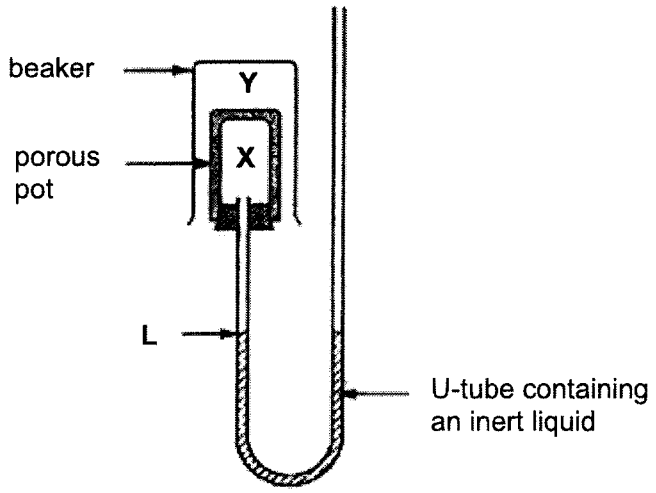
4 When pink cobalt(II) chloride crystals are heated, they form steam and a blue solid.

When water is added to the blue solid, it turns pink and becomes hot.

Which terms describe the pink cobalt(II) chloride crystals and the reactions?

	pink cobalt(II) chloride	reactions
A	anhydrous	reversible
B	anhydrous	irreversible
C	hydrated	irreversible
D	hydrated	reversible

5 The apparatus consists of a porous pot containing a gas X which is then surrounded by a gas Y in a beaker.



Which of the following pairs of gases would cause an upward movement of the liquid in the U-tube at the point labelled L?

	gas X	gas Y
A	H_2	NH_3
B	CO_2	N_2
C	O_2	H_2
D	NH_3	Ne

6 The atmosphere of Venus contains mainly oxygen, argon and nitrogen. The melting and boiling points of these gases are shown in the table.

gas	melting point / °C	boiling point/ °C
oxygen	-219	-183
argon	-189	-186
nitrogen	-210	-196

What temperature should the sample of air be in order to obtain two of the gases as liquids?

A -180 °C

B -184 °C

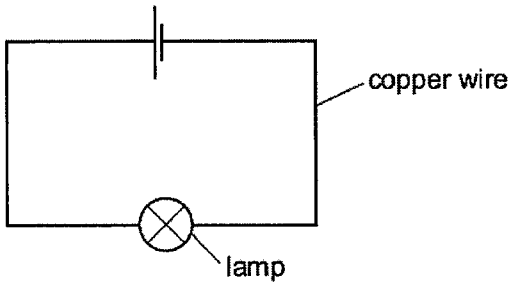
C -190 °C

D -198 °C

7 Which row gives a possible correct number of neutrons and electrons in an ion of chlorine-35?

	neutrons	electrons
A	18	17
B	17	17
C	18	18
D	17	18

8 An electrical circuit is set up using copper wire.



Which process takes place in the copper wire?

A Cations stay in position and electrons move to the positive terminal of the battery.

B Cations and electrons move to the negative terminal of the battery.

C Anions move to the positive terminal and cations move to the negative terminal of the battery.

D Cations stay in position and anions move to the positive terminal of the battery.

9 How many covalent bonds are there in the molecule with the formula CH_2CHCH_3?

A 7

B 8

C 9

D 10

10 Which of the following aqueous solutions contains the highest number of ions?

A 1 dm^3 of 0.1 mol/dm^3 $Al(NO_3)_3$

B 1 dm^3 of 0.2 mol/dm^3 H_2SO_4

C 1 dm^3 of 0.3 mol/dm^3 $MgCl_2$

D 1 dm^3 of 0.4 mol/dm^3 HNO_3

11 The formula of an oxide of element Y is Y_2O. 9.4 g of Y_2O contains 7.8 g of Y.

How many moles of Y does 7.8 g of the element contain?

A $\frac{1.6}{16} \times 2$

B $\frac{1.6}{16} \times \frac{1}{2}$

C $\frac{9.4}{16} \times 2$

D $\frac{9.4}{16} \times \frac{1}{2}$

12 Hydrogen reacts with oxygen according to the following equation.

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

What is the total volume of gas left in the mixture when 30 cm^3 of hydrogen reacts with 30 cm^3 of oxygen? (All volumes measured at room temperature and pressure)

A 15 cm^3

B 30 cm^3

C 45 cm^3

D 60 cm^3

13 Tin is extracted from its ore, SnO_2, by reducing it with coal in a blast furnace.

$$SnO_2 + 2C \rightarrow Sn + 2CO$$

What is the percentage purity of the tin ore if 900 g of SnO_2 produces 102 g of tin?

A $\frac{119}{102} \times \frac{900}{151} \times 100\%$

B $\frac{119}{102} \times \frac{900}{151} \times 100\%$

C $\frac{102}{119} \times \frac{151}{900} \times 100\%$

D $\frac{102}{119} \times \frac{900}{151} \times 100\%$

14 50.0 cm^3 of 0.10 mol/dm^3 of silver nitrate, $AgNO_3$, is added to 150.0 cm^3 of 0.05 mol/dm^3 sodium iodide, NaI, in a beaker. After the reaction, solid silver iodide settles to the bottom of the beaker.

What are the ions are present in solution?

A sodium ions and iodide ions

B sodium ions and nitrate ions

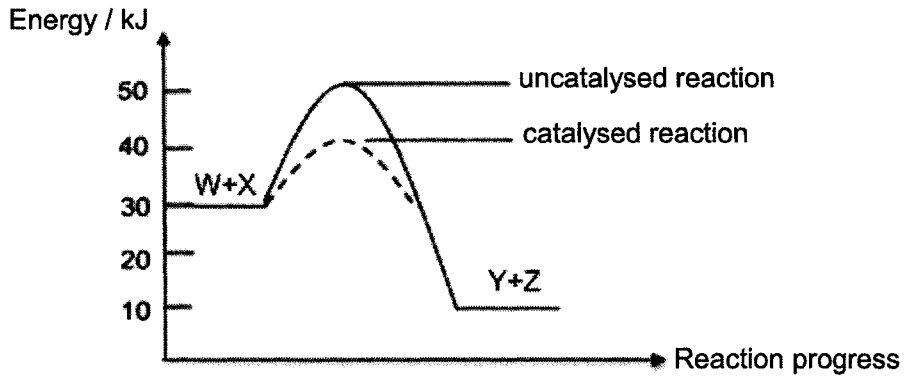
C sodium ions, nitrate ions and iodide ions

D sodium ions, silver ions and nitrate ions

15 A reversible reaction is represented by the equation shown.

$$W + X \leftrightarrow Y + Z$$

The energy profiles for the reversible reaction under catalysed and uncatalysed conditions are shown.



What is the activation energy of the reverse catalysed reaction?

A -40 kJ

B -10 kJ

C +30 kJ

D +40 kJ

16 The table shows the chemical formula of some carbon-containing compounds.

chemical name	chemical formula
sodium carbide	Na_2C_2
carbon dioxide	CO_2
iron(II) carbide	Fe_2C
carbonate ion	CO_3^{2-}

Which two compounds contain carbon with the same oxidation state?

A carbon dioxide and carbonate ion

B sodium carbide and carbonate ion

C carbon dioxide and iron(II) carbide

D sodium carbide and iron(II) carbide

17 Which reaction does **not** involve oxidation or reduction?

A $Fe^{2+} \rightarrow Fe^{3+} + e^-$

B $2H_2 + O_2 \rightarrow 2H_2O$

C $CuO + H_2 \rightarrow Cu + H_2O$

D $2H^+ + CO_3^{2-} \rightarrow H_2O + CO_2$

18 Solid calcium carbonate reacts with dilute hydrochloric acid to produce calcium chloride salt, carbon dioxide gas and water.

Which row shows the correct effect on the rate of the reaction when a factor is changed?

	factor changed	effect on rate of reaction
A	particle size of calcium carbonate increased	decrease
B	concentration of hydrochloric acid increased	decrease
C	pressure of surrounding increased	increase
D	temperature increased	decrease

19 A white solid reacted with both hydrochloric acid and aqueous sodium hydroxide solution separately.

What could be the identity of the solid?

A lithium oxide

B calcium oxide

C phosphorus oxide

D zinc oxide

20 Which method(s) is/are suitable to distinguish between 1.00 mol/dm^3 of hydrochloric acid and 1.00 mol/dm^3 of ethanoic acid?

1 using a pH meter
2 determining the volume of 1.00 mol/dm^3 of sodium hydroxide solution used to neutralise 25.0 cm^3 of the acids separately
3 measuring the total volume of hydrogen gas formed when excess magnesium is added to the acids separately

A 1 only

B 1 and 3 only

C 2 and 3 only

D 1, 2 and 3

21 A salt is prepared by titrating a carbonate with an acid.

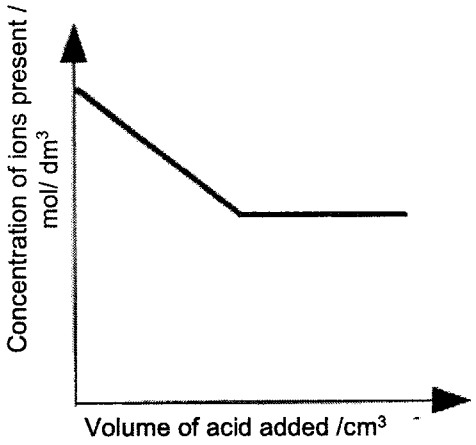
What are the solubilities of the carbonate and the salt?

	carbonate	salt
A	soluble	insoluble
B	insoluble	soluble
C	soluble	soluble
D	insoluble	insoluble

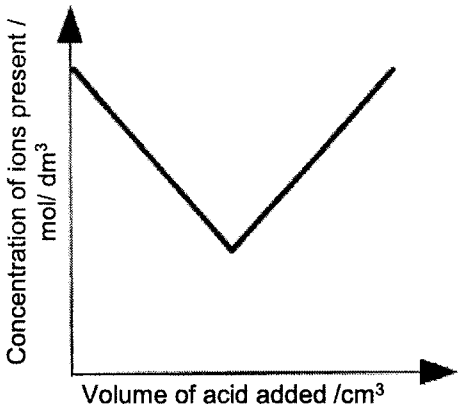
22 Dilute sulfuric acid was added to aqueous barium hydroxide until the acid was in excess.

Which graph best represents the variation in the concentration of ions in the solution?

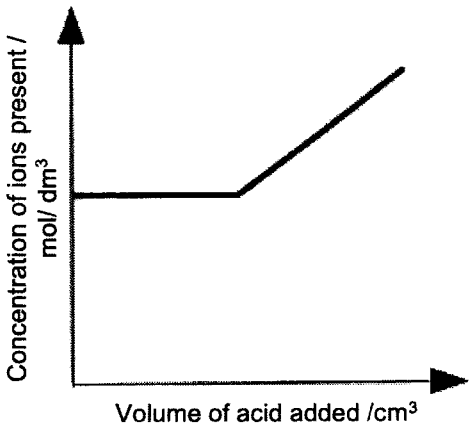
A



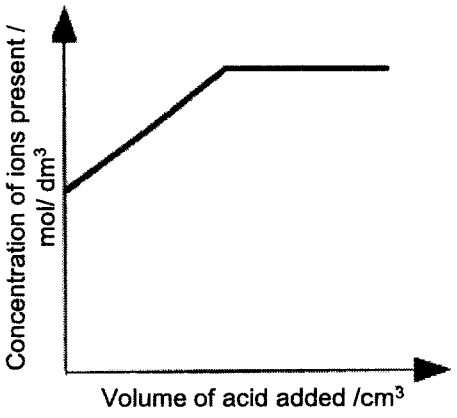
B



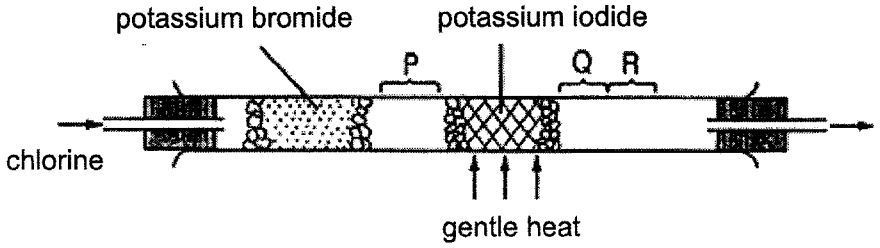
C



D



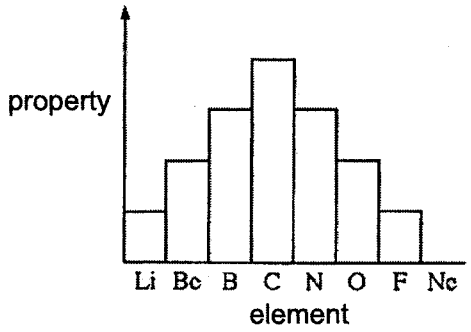
23 Using the apparatus shown, chlorine was passed through the tube. After a short time, coloured substances were at P, Q and R.



Identify the colours expected at P, Q and R.

	P	Q	R
A	yellow-green gas	reddish brown vapour	violet vapour
B	reddish brown vapour	violet vapour	black solid
C	yellow-green gas	violet vapour	black solid
D	reddish brown vapour	black vapour	violet vapour

24 The chart shows a property of elements from lithium to neon.



Which property of these elements is shown on the chart?

A number of electrons used in bonding

B relative atomic mass of the element

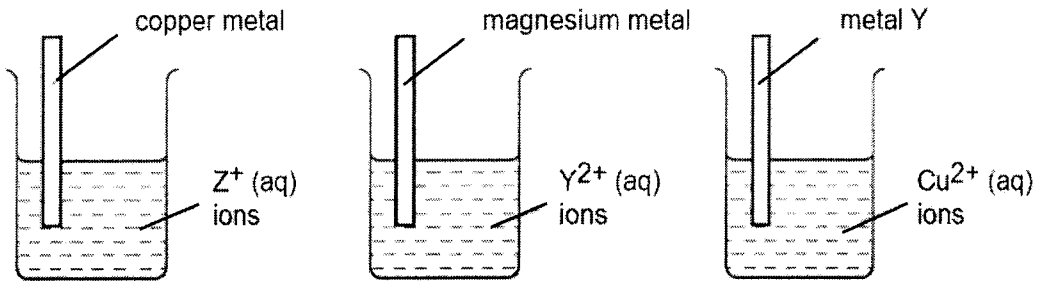
C number of electrons shells in an atom

D number of valence electrons

Refer to the information below for questions **25** and **26**.

Three experiments were conducted to compare the reactivities of four different metals - copper, magnesium, metal Y and metal Z.

A deposit was observed on the metal strip for each experiment.



25 How many metals that were investigated will be able to react with aqueous hydrochloric acid?

A 1

B 2

C 3

D 4

26 If a simple cell was set up between two of the metals above, which pair of electrodes will give the largest voltmeter reading?

A magnesium and Z

B copper and Y

C magnesium and copper

D Z and Y

27 A large volume of copper(II) sulfate solution is left in an iron container overnight.

Which statement describes the effect observed in the morning?

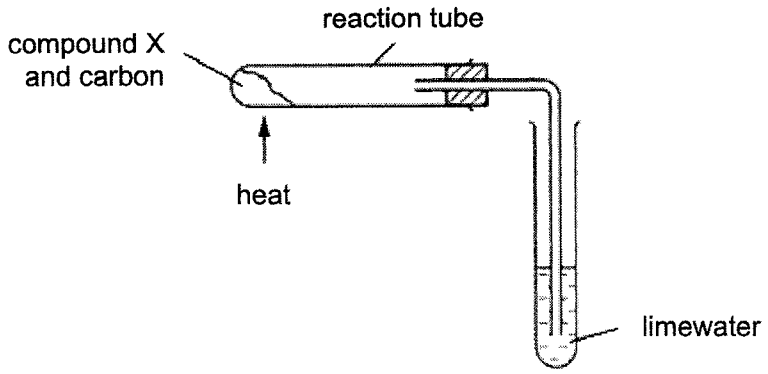
A Atmospheric oxygen reacts with the copper(II) sulfate and crystals are left behind.

B The part of the container in contact with the solution is coated with copper.

C The solution evaporates completely and some copper(II) sulfate crystals are left behind.

D Some fine iron particles are formed in the solution.

28 Compound X is heated with carbon using the apparatus shown.



A brown solid is formed in the reaction tube and a white precipitate forms in limewater.

What is compound X?

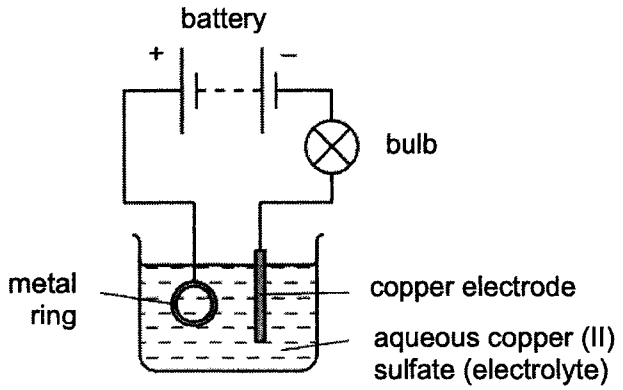
A calcium oxide

B copper(II) oxide

C magnesium oxide

D sodium oxide

29 The diagram shows apparatus used in an attempt to electroplate a metal ring with copper.



The experiment did not work.

Which change is needed to make the experiment work?

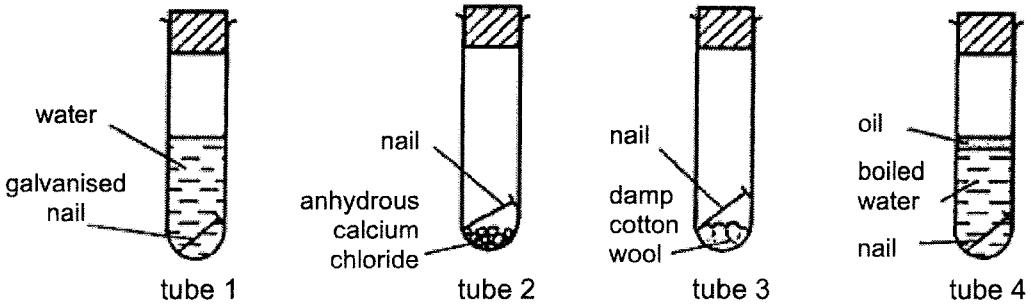
A add solid copper(II) sulfate to the electrolyte

B increase the temperature of the electrolyte

C replace the copper electrode with a carbon electrode.

D reverse the connections to the battery

30 A student set up four test tubes to investigate rusting in iron nails.



After leaving the tubes for a week, which tube(s) would show evidence of rusting?

A 2 only

B 3 only

C 1 and 2 only

D 3 and 4 only

31 Which molecule present in car exhaust fumes is **not** a pollutant?

A nitrogen monoxide

B sulfur dioxide

C carbon dioxide

D carbon monoxide

32 A catalytic converter is a device used to reduce the emissions from an internal combustion engine used in most modern day vehicles. However, they may also have negative impacts on the environment.

Which of the following describes the negative impact that catalytic convertors cause?

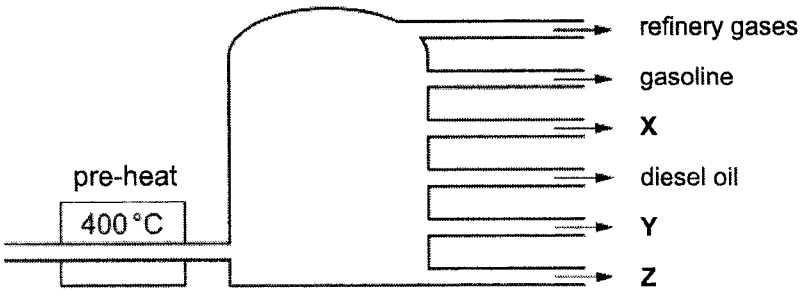
A They contribute to poisonous gases in air that cause breathing difficulties.

B They emit by-products which lead to the depletion of the ozone.

C They increase the amount of carbon particles in the air which leads to smog.

D They contribute the greenhouse gases which leads to global warming.

33 The diagram shows a fractionating column used in the separation of petroleum.



Which row about X, Y and Z are correct?

A Y has higher viscosity than X.

B Y has higher density compared to Z.

C Y has higher average molecular mass compared Z.

D Z has higher flammability compared to X.

34 Which of the following mixtures could **not** be produced when heptane, C_7H_{16} is cracked?

A propene + butane

B propane + butene

C propane + butane + hydrogen

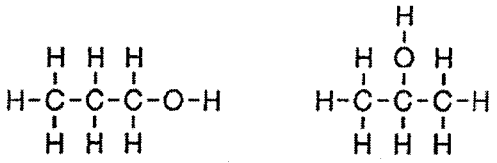
D butene + propene + hydrogen

35 Which pair of compounds are isomers of each other?

A

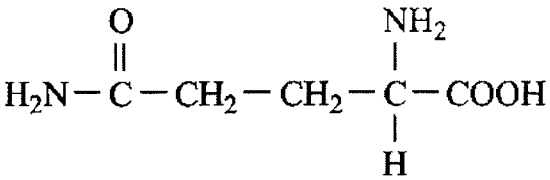
B

C



D

36 The structural formula of the amino acid, glutamine, is shown.



Which of the following statements about the amino acid are correct?

1 It undergoes addition polymerisation.
2 It reacts with magnesium to produce hydrogen gas.
3 It forms a polymer with the same linkage as nylon.
4 It decolourises acidified potassium manganate(VII) solution readily.

A 1 and 3

B 1 and 4

C 2 and 3

D 3 and 4

37 The number of C=C bonds in a vegetable oil can be found by reacting the oil with aqueous bromine.

0.02 moles of vegetable oil was found to react completely with 19.2 g of aqueous bromine.

How many C=C bonds are there in one molecule of vegetable oil?

A 2

B 6

C 8

D 12

38 An organic compound M is known to have the following properties.

1 It does not decolourise bromine solution.
2 It does not react with aqueous sodium hydroxide.
3 It does not produce a sweet-smelling substance when warmed with a mixture of ethanoic acid and concentrated sulfuric acid.

What could be the chemical formula of compound M?

A $CH{=}CHCOOH$

B $CH_3CH_2CH_2OH$

C $CH_2{=}CHCOOCH_3$

D $CH_3CH_2CH_2Cl$

39 Which property does **not** change when ethene undergoes polymerisation to form poly(ethene)?

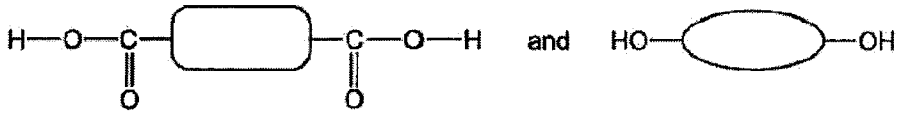
A boiling point

B empirical formula

C molecular mass

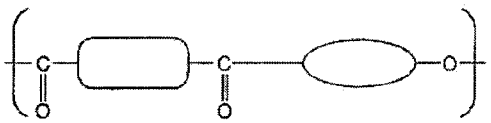
D molecular formula

40 A condensation polymer is made from the two monomers shown.

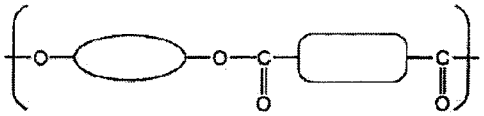


What is the repeat unit of the polymer?

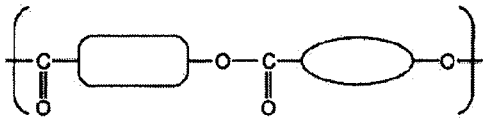
A



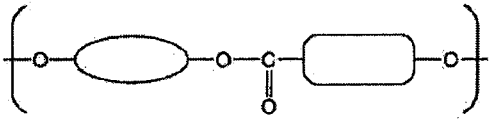
B



C



D



END OF PAPER 1

The Periodic Table of Elements

Group																	
I	II											III	IV	V	VI	VII	0
							1 H hydrogen 1										2 He helium 4
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											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 –		114 Fl flerovium –		116 Lv livermorium –		

Key

proton (atomic) number
atomic symbol
name
relative atomic mass

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^3 at room temperature and pressure (r.t.p.).

Section A

Answer **all** questions in this section in the spaces provided.
The total mark for this section is 50.

A1 Fig. 1.1 shows how the outer shell electrons are arranged in a compound.

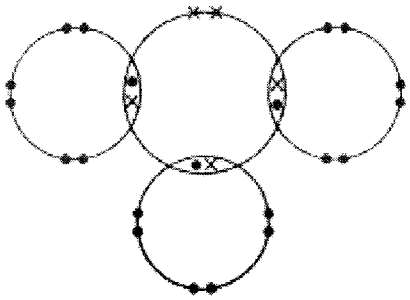


Fig. 1.1

(a) Put a tick (√) in **one** box in each row to show which statement(s) about the compound is/are **true** and which is/are **false**.

	true	**false**
It is a saturated hydrocarbon.		
It could be ammonia.		
It is a halogen compound.		
It is an ionic compound.		

[2]

(b) Draw a similar diagram to show the arrangement of electrons in a molecule of carbon dioxide, CO_2.

You only need to show outer shell electrons.

[2]

[Total: 4]

A2 A small piece of sodium metal is heated until it melts. It is then placed into chlorine gas where sodium burns quickly with a bright intense flame to form solid sodium chloride.

$$2\,Na + Cl_2 \rightarrow 2\,NaCl$$

(a) Explain, in terms of electron transfer, why the reaction is a redox reaction.

.....

.....

.....

.....

..... [3]

(b) Predict how sodium would react with fluorine. State all the observations and explain your answer.

.....

.....

.....

..... [2]

(c) Calculate the percentage yield of sodium chloride, if 40 g of sodium produces 65 g of sodium chloride.

percentage yield = ... % [2]

[Total: 7]

A3 Ammonia is produced in the Haber process. The volume of gases in the reaction chamber is monitored throughout the reaction and the results are plotted in the graph shown in Fig. 3.1.

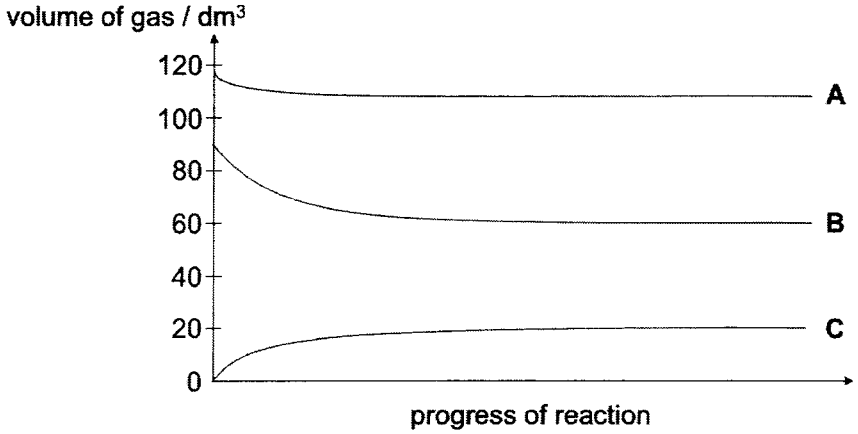


Fig. 3.1

(a) Complete the table below to show the source and method used to obtain hydrogen and nitrogen for Haber process.

	source	method
hydrogen gas		
nitrogen gas		

[2]

(b) Identify the graph (**A**, **B** or **C**) in Fig. 3.1 that represents the following gases in the Haber process.

nitrogen : .....

hydrogen : .....

ammonia: ..... [1]

(c) Suggest a reason why Fig. 3.1 shows that the production of ammonia in the Haber process is a reversible reaction.

.....

..... [1]

[Total: 4]

A4 Graphene is a 2-dimensional single sheet of carbon atoms arranged in a hexagonal network. Due to graphene's physical and chemical properties, it is a promising new advanced material that has been used in several key applications such as batteries, energy storage, and as catalyst.

Fig. 4.1 shows the structure of a single sheet of graphene.

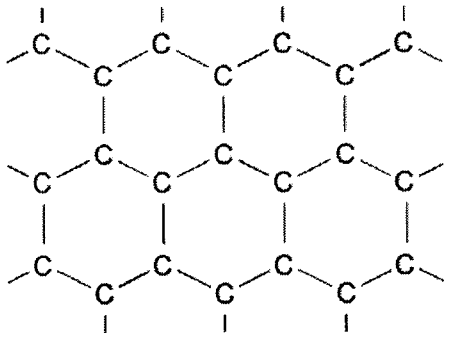


Fig 4.1

(a) Graphene and graphite have similar physical properties.

Give **two** physical properties of graphene that are similar to graphite. Explain, in terms of bonding and structure, why these physical properties are similar.

Property 1 .....

.....

.....

Property 2 .....

.....

..... [3]

(b) Diamond and graphite have very different physical properties.

State **one** such physical property and explain why.

.....

.....

..... [2]

(c) A recent development in graphene chemistry is the creation of graphene sponges. Graphene sponges (shown in Fig. 4.2) are three dimensional foam-like structures that has high surface area at extremely low density.

A piece of graphene sponge placed on a flower.

Microscopic view of the graphene sponge

Fig. 4.2

Because of its foam-like structure, graphene foam is able to capture gases. One possible use of graphene sponges is in flue gas desulfurisation in fossil fuel powerplants. Traditionally, calcium carbonate is used in the process of flue gas desulfurisation.

(i) Explain why calcium carbonate can be used in flue gas desulfurisation.

.....

..... [1]

(ii) Describe the environmental impact if flue gas is not desulfurised.

.....

..... [1]

[Total: 7]

A5 Group I and Group VII elements show trends in their melting points and boiling points.

	element	melting point / °C	boiling point / °C
Group I	lithium	180	1330
	sodium	97.8	890
	potassium	64	774
Group VII	chlorine	–101	–35
	bromine	–7	59
	iodine	114	184

(a) **(i)** The trends in melting points and boiling points for elements in Group I differ from those of Group VII.

Describe the trends down each group.

....

....

.... [2]

(ii) The melting point and boiling point of sodium is higher than that of chlorine. Use ideas about bonding to explain why.

....

....

....

....

....

.... [3]

(b) The table shows the densities of chlorine and bromine at room temperature and pressure.

element	density / g/cm^3
chlorine	0.03
bromine	3.12

A student makes a comment about the densities.
"The difference in molecular mass of chlorine and bromine is not enough to account for the difference in densities."

(i) Explain why the student is correct.

.....

.....

..... [2]

(ii) What is the main reason that the densities of chlorine and bromine are so different?

.....

..... [1]

(c) All the elements in Group VII are diatomic.

Explain the meaning of the term *diatomic*.

.....

..... [1]

[Total: 9]

A6 Some information about four elements, **P**, **Q**, **R** and **S** are shown in Table 6.1.

Table 6.1

Element	**P**	**Q**	**R**	**S**
Density in g/dm^3	2.22	8.9	0.9	7.9
Melting point /°C	3720	1083	64	1538
Atomic radius /pm	77	135	203	126
Charge on the ion(s)	Usually 4– and 4+	Usually 1+ and 2+	1+	Usually 2+ and 3+
Colour of the element	Black	Reddish Brown	Silvery	Silver Grey
Formulae and appearance of the chlorides at room temperature	PCl_4 is a colourless liquid	QCl is a white solid QCl_2 is a blue-green solid	RCl is a white solid	SCl_2 is a greenish white solid SCl_3 is an orange solid

The four elements can be arranged in decreasing order in the reactivity series as such:

R > **P** > **S** > hydrogen > **Q**

(a) Which of the following, **P**, **Q**, **R** and **S** are transition elements?

Using information from Table 6.1, give **two** pieces of evidence to support your answer.

1. ....

....

2. ....

.... [2]

[Turn Over

(b) A small piece of element **R** is placed in cold water that had a few drops of Universal Indicator added.

Describe what would be observed and write the balanced chemical equation for the reaction that occurred.

.....

.....

.....

.....

..... [3]

(c) Which of the following, **P**, **Q**, **R** or **S** is **not** a metal?

Use evidence from Table 6.1 to support your answer.

.....

.....

..... [2]

(d) In the construction industry, elements **P** and **S** are found in alloys that are used to make the support pillars for buildings.

(i) Give the meaning of the term *alloy*.

..... [1]

(ii) Draw a labelled diagram showing the arrangement of atoms in an alloy containing **P** and **S**.

[1]

(iii) With reference to the arrangement of atoms drawn in **(d)(ii)**, explain why alloys are used in the construction industry rather than the elements.

.....

.....

..... [1]

[Total: 10]

A7 Ethanoic acid is a colourless liquid and organic compound. The global demand for ethanoic acid is about 6.5 million tons per year. While the common use of ethanoic acid at home is as the main component of vinegar, 90% of ethanoic acid produced globally is used as a chemical feedstock to produce ethanoate esters and metal ethanoate salts.

(a) Describe why ethanoic acid is considered a weak acid.

.....

..... [1]

All metal ethanoate salts are soluble in water. Copper(II) ethanoate is a dark green crystalline solid and has been used as fungicides and coloured pigments. Fig. 7.1 shows the chemical formula of copper(II) ethanoate.

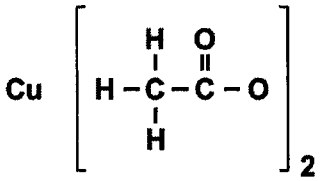


Fig. 7.1

Copper(II) ethanoate is commonly prepared industrially using the steps below.

Step 1 – Add an excess of **substance X** to ethanoic acid in a reaction chamber. Heat reaction gently. Open the cover of the reaction chamber to ensure that the pressure within the reaction chamber does not increase due to gas production during the reaction.

Step 2 – When effervescence stops, the reaction mixture is filtered and the filtrate is collected in another container.

(b) Draw a 'dot-and-cross' diagram for the **ethanoate ion** found in copper(II) ethanoate.

Show outer electrons only.

[2]

(c) **(i)** Identify substance X.

..... [1]

(ii) Either evaporation to dryness or crystallisation will produce pure and dry copper(II) ethanoate from the solution obtained in Step 2.

Describe an advantage and a disadvantage evaporation to dryness have over crystallisation.

advantage .....

.....

disadvantage .....

..... [2]

Methyl ethanoate is a ethanoate ester with a pleasant smell that is similar to nail polish remover. Commonly used as a solvent, it is highly volatile and flammable.

(d) **(i)** Deduce and draw the structural formula for methyl ethanoate.

[1]

(ii) Explain, in terms of bonding, why copper(II) ethanoate exists as crystals while methyl ethanoate exists as a volatile liquid at room temperature.

.....

.....

.....

..... [2]

[Total: 9]

Section B

Answer all **three** questions in this section.

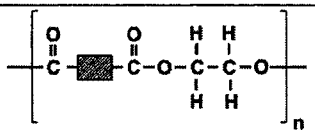
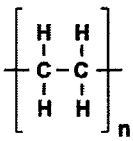
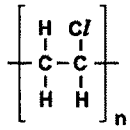
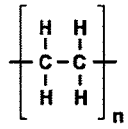
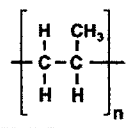
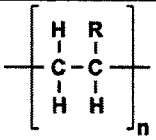
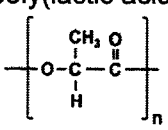
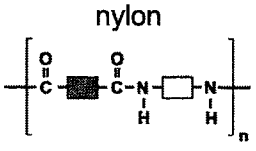
The last question is in the form of an either/or and only one of the alternatives should be attempted.

B8 Plastic Recycling

Plastic recycling is the processing of plastic waste into new and useful products. Although plastic recycling is essential to prevent further harm on our environment, Singapore's recycling rate of plastics in 2021 was only 6%. Each plastic polymer has its own unique chemical structure and properties. In order to ensure the quality and value of the recycled plastic, plastics of different polymer types have to be sorted out before they can be recycled. The Resin Identification Code (RIC) was introduced so that plastic item can be labelled for easier sorting.

Table 8.1 shows the names of the polymers that fall under the 7 different RIC as well as their proportion in global plastic waste. Plastics usually consist of polymer chains of varying lengths. Table 8.1 shows the general range of molar masses of the different plastics.

Table 8.1

RIC	polymer name	chemical structure	molar mass / g/mol	% of all plastic waste
1 PETE	poly(ethylene terephthalate)		8 000 – 31 000	18.8
2 HDPE	high density poly(ethene)		100 000 – 250 000	19.8
3 V	poly(vinyl chloride)		50 000 – 120 000	5.3
4 LDPE	low density poly(ethene)		100 000 – 250 000	13.9
5 PP	poly(propene)		75 000 – 700 000	19.1
6 PS	poly(styrene)	 where **R** represents a hydrocarbon branch	100 000 – 400 000	5.9
7 OTHER	Other plastics (such as polycarbonates, polyamides.	poly(lactic acid)  nylon 	–	17.2

(a) **(i)** Deduce and draw the structural formula of the monomer(s) of poly(propene).

monomer(s) of poly(propene) [1]

(ii) Explain, in terms of bonding and structure, why the melting point of a polymer is always higher than its monomer(s).

.....

.....

.....

..... [2]

(b) The shortest chain of poly(styrene) consists of 962 repeating units. Elemental analysis of poly(styrene) found that the polymer contains 92.3% of carbon and 7.7% of hydrogen by mass.

Calculate and deduce the formula of **R** in poly(styrene).

formula of **R**= ..... [3]

Mechanical recycling and depolymerisation

There are two methods that are commonly used to recycle plastics. Mechanical recycling is a physical method that melts plastics of the same polymer before making them into small pellets to be used again. Depolymerisation is a chemical method that uses either heat or chemical reactions to convert the polymers back into its monomers. Since each polymer has its own unique chemical properties, machinery and methods are specific to one particular plastic.

Fig. 8.1 shows the journey of plastic trash from recycling bin to becoming a new plastic product.

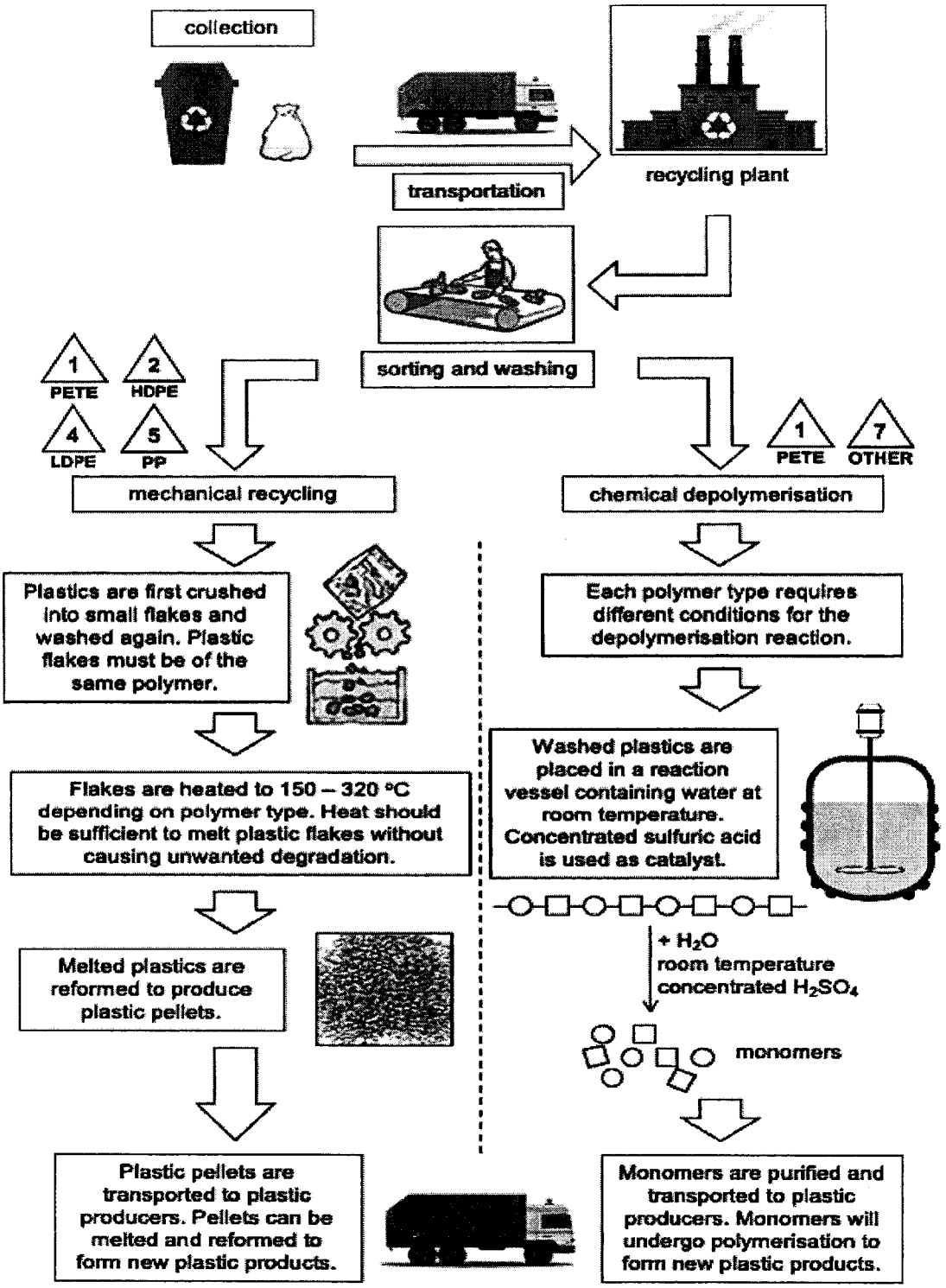


Fig. 8.1

(c) A student looks at the data in Table 8.1 and Fig. 8.1 and suggests that mechanical recycling can only recycle addition polymers while depolymerisation only recycles condensation polymers.

Do you agree with the student? Use the data to support your answer.

.....

..... [1]

(d) Most recycling companies find that it is more cost-effective to develop mechanical recycling methods as compared to depolymerisation recycling methods.

By referring to Table 8.1 and/or Fig. 8.1, suggest a reason why this is so.

.....

..... [1]

(e) Based on Fig. 8.1, give **two** reasons why recycling plastic is **not** entirely environmentally friendly.

1. .....

.....

2. .....

..... [2]

(f) Fig. 8.2 shows how poly(lactic acid) is depolymerised to form its monomer.

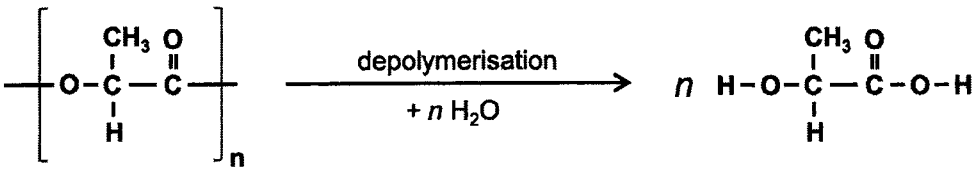


Fig. 8.2

Is poly(lactic acid) a condensation polymer or addition polymer? Give **two** evidence from Fig. 8.2 that supports your answer.

.....

.....

..... [2]

[Total: 12]

B9 An experiment is carried out to electrolyse dilute aqueous sodium chloride.

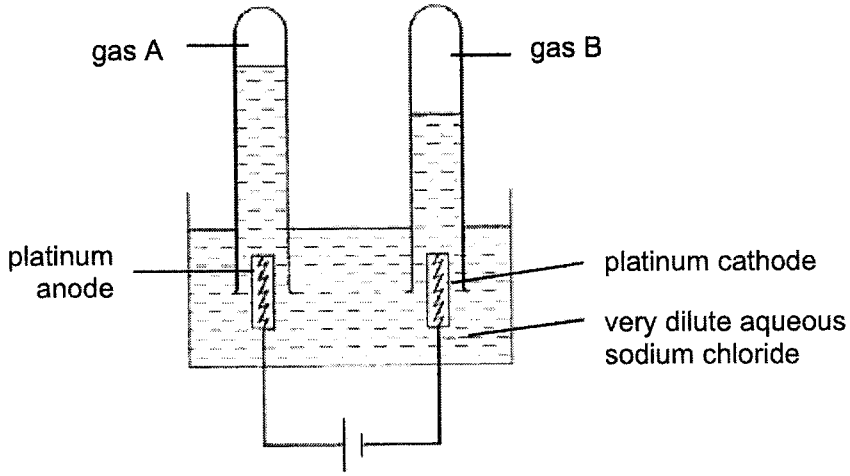


Fig. 9.1

(a) **(i)** Identify all the ions present in the solution.

..... [1]

(ii) Write an ionic equation for each reaction that happens at the anode and cathode.

anode: .....

cathode: ..... [2]

(iii) Describe a simple test and its result that would identify the gas given off at the anode.

.....

.....

..... [2]

(b) After the electrolysis has been running for some time, the solution becomes more concentrated.

What are the products of the electrolysis when the solution becomes concentrated? Give your reasoning.

.....

.....

.....

.....

..... [3]

[Total: 8]

EITHER

B10 Fig. 10.1 shows the volume of gas produced with time for four experiments **1 to 4** where a metal carbonate, **M**CO_3 is reacted with different concentrations and volumes of hydrochloric acid.

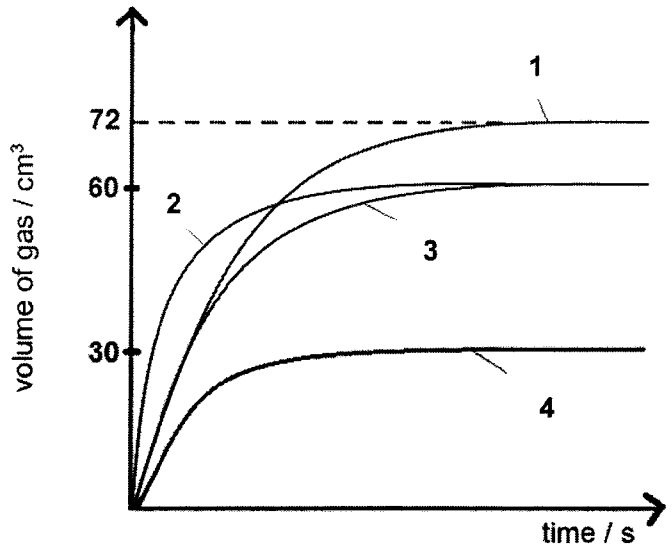


Fig. 10.1

(a) Give the identity of the gas produced in the experiments.

..... [1]

(b) With reference to Fig. 10.1, complete the table below.

experiment number	concentration of acid in mol/dm³	volume of acid /cm³
	0.125	20
	0.200	30
	0.250	
3	0.200	

[3]

(c) **M** forms an ion with a 2+ charge in the reaction between the metal carbonate and hydrochloric acid. The mass of MCO_3 used in each experiment is 0.375 g.
The chemical equation of the reaction is as shown below.

$$MCO_3 + 2\,HCl \rightarrow MCl_2 + CO_2 + H_2O$$

(i) Only experiment **1** has no excess of either reactants at the end of the reaction, while the rest of the experiments (**2**, **3**, **4**) have an excess of metal carbonate MCO_3.

Calculate the number of moles of hydrochloric acid used in experiment **1**.

number of moles = ... mol [1]

(ii) Hence or otherwise, calculate the relative molecular mass of **M** and identify metal **M**.

identity of metal **M** is ..... [3]

(d) Using ideas on collisions between particles, explain why the speed of reaction in experiment **2** is faster than experiment **3**.

.....

.....

..... [2]

[Total: 10]

OR

B10 Displacement reactions can be used for the extraction of metals.

In the 19th century, Frederich Wohler obtained aluminium metal by reacting potassium with aluminium chloride at a high temperature to form potassium chloride and aluminium. Wohler also observed that the temperature increased during the reaction.

$$AlCl_3 + 3\,K \rightarrow Al + 3\,KCl$$

(a) **(i)** Write an ionic equation for the reaction.

..... [1]

(ii) Explain, using oxidation states, which substance is reduced.

.....

.....

.....

..... [2]

(iii) Determine the mass of aluminium chloride needed to produce 0.81 kg of aluminium metal.

mass of aluminium chloride ..... g [2]

(b) **(i)** Is the reaction between potassium and aluminium chloride exothermic or endothermic? Give a reason to support your answer.

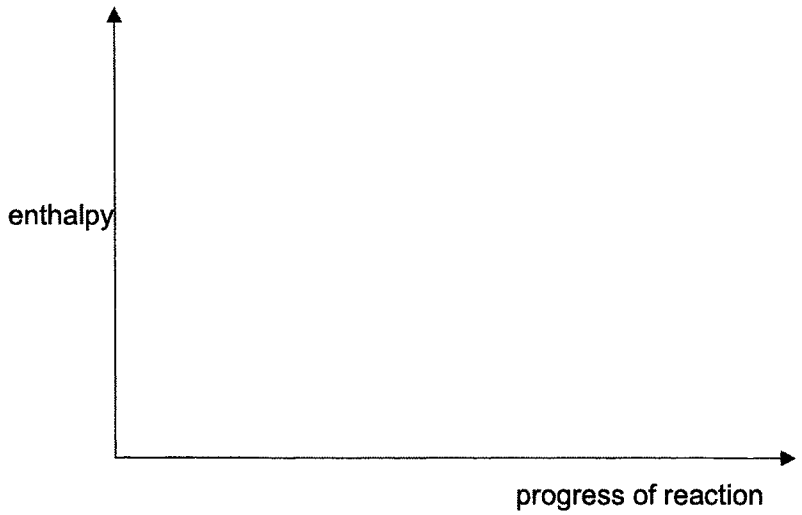
.....

..... [1]

(ii) Draw the energy profile diagram for this reaction.

Your diagram should include

- labels for the reaction enthalpy change,
- activation energy, and
- formulae of reactants and products.



[3]

(c) Beryllium is less reactive than potassium and more reactive than aluminium.

Deduce whether Wohler's technique can be used to obtain beryllium from beryllium chloride. Suggest one reason why.

.....

..... [1]

[Total: 10]

END OF PAPER 2

The Periodic Table of Elements

Group I	Group II											Group III	Group IV	Group V	Group VI	Group VII	Group 0
							1 H hydrogen 1										2 He helium 4
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											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 –		114 Fl flerovium –		116 Lv livermorium –		

Key

proton (atomic) number
atomic symbol
name
relative atomic mass

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^3 at room temperature and pressure (r.t.p.).

Secondary 4E
Chemistry
Preliminary Examination 2022

Mark Scheme

Paper 1 (40 marks)

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

A – 11, B – 10, C – 11, D – 8

Paper 2
Section A (50 marks)

A1(a)

	true	false
It is a saturated hydrocarbon.		✓
It could be ammonia.		✓
It is a halogen compound.	✓	
It is an ionic compound.		✓

4 pt → 2m, 3 - 2 pt → 1 m, 1 – 0 → 0m **2**

(b)

carbon dioxide, CO_2

correct number of sharing electrons in carbon;
correct number of sharing electrons in oxygen; **2**

[Total: 4]

A2(a)

Sodium is oxidized as it loses an electron to form sodium ion, Na^+ **1**
Chlorine is reduced as it gains an electron to form chloride ion, Cl^- **1**
Since oxidation and reduction occurs concurrently/simultaneously/at the same time, **1**
Hence it is a redox reaction

(b)

Sodium will explode into flames/When placed into fluorine gas to form a white solid of sodium fluoride (observation should be more vigorous than what is given in question stem, reject: bubble form) **1**
Fluorine is above chlorine in Group VII and hence more reactive; **1**

(c)	Mole of sodium = 40/23 = 1.7391 mol Mole ratio of Na: NaCl = 1: 1 Mass of sodium chloride produced = 1.7391 X 58.5 = 101.74 g %yield = 65/101.74 x 100 = <u>63.9%</u>	1 1
		[Total: 7]

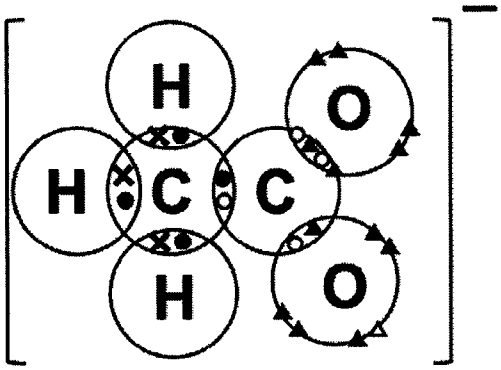
A3(a)	<table><tr><th></th><th>source</th><th>method</th></tr><tr><td>hydrogen gas</td><td>Crude oil</td><td>cracking</td></tr><tr><td>nitrogen gas</td><td>liquid air</td><td>Fractional distillation</td></tr></table>	2
(b)	nitrogen: A hydrogen: B ammonia: C	1
(c)	<u>reactants are not fully reacted</u> even when reaction has stopped. (reject: reaction does not complete)	1
		[Total: 4]

A4(a)	high melting point or strong (reject: hard, strength and hardness is different) - 1 <u>strong covalent bonds between</u> carbon atoms -2 require a lot of <u>energy</u> to <u>break -3</u> electrical conductor -4 one carbon atom bonded to three other carbon atoms/ 3 valence electrons in carbon used in bonding <u>1 valence electron</u> in each carbon <u>not involved in bonding/delocalised -5</u> <u>mobile electron</u> present -6 6 – 5 points → 3 m, 4 – 3 pt → 2m, 2 pt → 1 m, 1 – 0 pt → 0m (reject: soft / slippery, there is only one layer in graphene)	3
(b)	<table><tr><td>hard</td><td>cannot conduct electricity</td></tr><tr><td><u>strong covalent bonds</u> between carbon atoms require a lot of <u>energy</u> to <u>break</u></td><td><u>all valence electrons</u> used in bonding <u>no mobile electrons/charged particles</u> present (if part (a) did not mention)</td></tr></table>	1

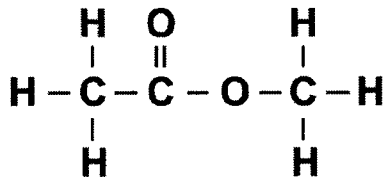
	as compared to the weak intermolecular forces of attraction between graphite layers.	1 valence electron in each carbon not involved in bonding/delocalised mobile electron present	1
(c) (i)	sulfur dioxide is an acidic oxide and will react with the calcium carbonate. (not a marking point but students are reminded that this is not a neutralisation reaction and calcium carbonate is not a base)		1
(c) (ii)	sulfur dioxide causes • respiratory problems OR • lead to the formation of 'acid rain' which harms aquatic life and corrodes metal and stone structures ecf if (c)(i) mentions a different pollutant		**1**
			[Total: 7]
A5 (a)(i)	In group I, melting point and boiling point decreases down the group. In group VII, melting point and boiling point increases down the group.		**1** **1**
(a)(ii)	Students need to be clearer with the different bonding present in different substances. Common mistakes include 1) not knowing the particles found in each structures (e.g. mistaking atoms with molecules, atoms with ions). 2) Students must also remember that forces are overcome and bonds are broken. Sodium is a metal with strong electrostatic force of attraction/metallic bond between the cations and the sea of electrons. Whereas, chlorine exists as diatomic molecules with weak intermolecular forces of attraction between the molecules. Hence, lots of energy required to overcome the strong electrostatic forces of attraction in sodium. Hence higher melting point. Little energy needed to overcome weak intermolecular forces of attraction in chlorine gas. Hence low melting point.		 **1** **1** **1**
(b)(i)	Students answered this question badly. Many students did not answer the question which should involve students explaining why the difference in molecular mass does not account for the difference in density. Many students instead explain what should account for density without accounting for the molecular mass. The molecular mass of chlorine is 71 and the molecular mass of bromine is 160. Even though bromine is slightly more than twice the mass of chlorine, but the density of bromine is at least a 100 times that of chlorine. (show the difference in density is much larger than the difference in molecular mass)		 **1** **1**

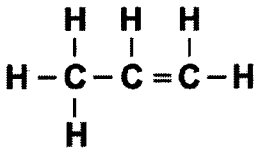
	Accept: volume needs to be considered as well (1 m)	
(ii)	Chlorine is a gas and bromine is a liquid at room temperature. Reject: students mention states without specifying	**1**
(c)	Question is badly done. While we accepted a range of answers, the definition of diatomic should be as follows. Diatomic means molecules with two atoms covalently bonded together. Accept: students answer must include both concept of two atoms and being bonded.	**1**
		[Total: 9]
A6(a)	Students must remember that evidence from the data provided should be given clearly. Transition elements are Q (1) and S(2) - variable oxidation states (3) - formed coloured compounds (4) 4 pt → 2m, 3 - 2 pt → 1 m	**2**
(b)	Bubbles of gas produced/gas extinguishes burning splint with pop sound Colour of water changes from green to dark blue/purple. Remind students that Group I alkali should turn universal indicator purple $2R + 2H_2O \longrightarrow 2ROH + H_2$	**1** **1** **1**
(c)	P because it forms a chloride that is a liquid at room temperature/low melting point The chloride is a covalent compound/simple molecule hence P is a non-metal **OR** **P** is from Group IV Q,R,S are from Group I and II which are all metals Reject: if students explain that P is a non-metal because the rest are metals. **OR** **P** is black in colour Metals are usually grey/shiny	**1** **1**
(d)	This question was surprisingly badly done. disappointing Alloy is a mixture of a metal with another element.	**1**
(ii)	 must be labelled, P must be smaller than S,	**1**

	Can only have two sizes of particles Quantity does not matter.	
(iii)	disruption of the regular arrangement of layers of atoms makes it hard for the layers to slide hence making alloys harder and stronger	1
		[TOTAL:10]

A7(a)	dissociates/ionises (reject: dissolves) partially in water forming hydrogen ions and ethanoate ions	1
(b)	Students either forget that atoms form bonds to form a complete valence shell of electrons or they forget that they are drawing an ion and forget to include the charge  1m for charge, 1m for dot and cross (accept even if symbols for electrons are the same)	2
(c)(i)	copper carbonate/copper(II) carbonate (reject: copper oxide as gas is produced) Students did not read the passage carefully to realise that substance X has to react with an acid to produce a gas. There are also many students who wrote names of salts showing their lack of understanding of acid reactions.	1
(ii)	Many students are unfamiliar with the evaporation to dryness procedure. Many students think that evaporation to dryness does not need heat. Some students did not understand the phrasing of the question and described the advantages of crystallisation over evaporation to dryness.	2

advantage	disadvantage
- higher yield of solute / crystallisation does not crystallise all solute - faster - with heat, will be dryer	- heat sensitive compounds will decompose/solute might decompose - impurities in the solution will also be obtained - solute obtained is less pure

(d)(i)	 Students need to learn the condensation reaction to form esters better.	1
(ii)	copper(II) ethanoate has <u>strong electrostatic forces</u> of attraction (a) methyl ethanoate has <u>weak intermolecular forces</u> of attraction (b) more <u>energy</u> required to <u>overcome</u> All – 2m, (a) or (b) – 1m	2
		[Total: 9]

Section B (30 marks)		
B8(a)		**1**
(ii)	Macromolecule (polymer) has a <u>higher molar mass/relative molecular mass</u> than the monomer <u>stronger intermolecular forces</u> between polymer molecules more energy required to overcome the forces between polymer molecules	**1** **1**
(b)	Mr of repeating unit - 100 000 / 962 = <u>103.95</u> Empirical formula <u>CH</u> Molecular formula of repeating unit 103.95 / 13 = 8 (C_8H_8) R – C_6H_5	**1** **1** **1** **1**
(c)	Disagree, PETE is a <u>condensation polymer</u> so mechanical recycling can recycle condensation polymers. OR	**1**

element	C	H
%composition	92.3	7.7
Ar	12	1
mole	92.3/12 = 7.691	7.7 / 1 = 7.7
ratio	1	1

	Agree, PETE and polymers under others are condensation polymers can be recycled using chemical depolymerisation	
(d)	mechanical recycling recycles more types of plastics as compared to chemical depolymerisation OR mechanical recycling recycles a higher percentage of plastic waste as compared to chemical depolymerisation	1
(e)	- transportation requires fossil fuels to be burnt - mechanical recycling requires plastic to be heated and that requires fossil fuels to be burnt to provide the energy - Chemical depolymerisation requires concentrated sulfuric acid which will harm the environment when released. - Washing of the plastic requires water to be used which will deplete the world's water supply	2
(f)	condensation polymerisation - Monomer has a higher molar mass than the repeating unit - monomers are joined together by an ester linkage - when monomers combine to form the polymer, a small molecule of water is released. - when polymer is broken down to the monomer, a small molecule of water is added. ANY TWO	2
		[Total: 12]
B9 (a)(i)	Hydrogen, hydroxide, sodium and chloride ion OR H^+, OH^- , Na^+, Cl^-	1
(ii)	Anode: $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$ Cathode: $2H^+ + 2e^- \rightarrow H_2$	1 1
(iii)	Place a glowing splint at the gas; Splint relights	1 1
(b)	At cathode, hydrogen gas is produced, as sodium ion (reject: sodium) cannot be discharged. At anode, chlorine gas is produced. When solution is concentrated sodium chloride, chloride ions are preferentially discharged over hydroxide ions.	1 1 1
		[Total: 8]
Either		
B10 (a)	carbon dioxide	1

(b)

experiment	concentration of acid in mol/dm^3	volume of acid /cm^3
4	0.125	20
1	0.200	30
2	0.250	**20**
3	0.200	**25**

5 points → 3 m, 4 pt → 2m, 3 - 2 pt → 1 m, 1 pt → 0 m — **3**

(c)

(i) No. of moles of HCl = 0.200 x 0.03 = 0.006 mol — **1**

(ii)
Mole ratio HCl:MCO_3 is 2:1
No. of moles of MCO_3 = 0.003 — **1**
Molar mass of MCO_3 = 0.375/0.003 = 125 g/mol — **1**
Atomic mass of M = 125 – M_r CO_3 = 125 – 60 = 65 — **1**

OR
Mole ratio CO_2:MCO_3 is 1:1
No. of moles of MCO_3 = 0.003
Molar mass of MCO_3 = 0.375/0.003 = 125 g/mol
Atomic mass of M = 125 – M_r CO_3 = 125 – 60 = 65

Hence M is Zinc

(d)

When there is an increase of concentration of acid,
There is <u>greater number of reacting particles per unit volume.</u> — **1**
<u>Hence higher frequency of effective collisions</u> and higher speed of reaction. — **1**

[Total: 10]

Or

B10 (a)(i) 3K(s) + $A\ell^{3+}(l)$ → $3K^+(l)$ + $A\ell$(s) — **1**

(ii) Aluminium is reduced as its oxidation state of +3 in $A\ell^{3+}$ ions decreased to 0 in $A\ell$ atoms — **2**

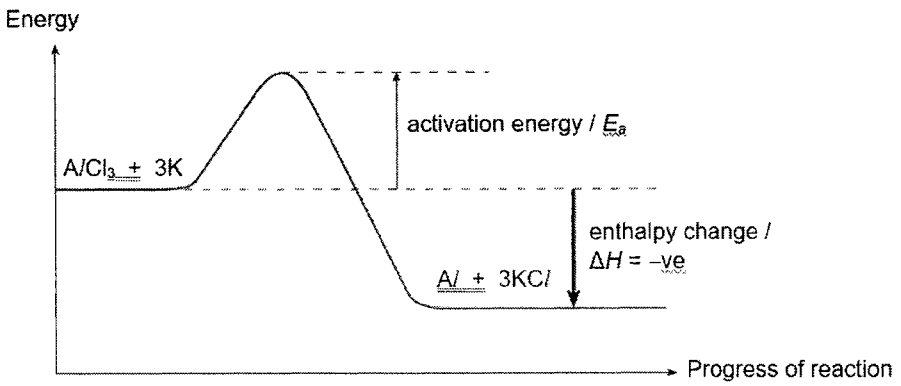
1m – decrease
1m – oxidation states

(iii) M_r of $A\ell Cl_3$ = 27 + 3(35.5) = 133.5
From equation, no of moles of $A\ell Cl_3$ = no. of moles of $A\ell$
= 810/27 = <u>30 mol</u> — **1**

Mass of aluminium chloride = 30 x 133.5 = <u>4000 g</u> — **1**

Award 1 m if never convert kg to grams.

(b)(i) (i) reaction is exothermic as temperature increased during the reaction. — **1**

(b)(ii)	 ecf from (c)(i) 1 m – correct labels for Ea and enthalpy change 1 m – exothermic graph 1 m – correct labels from reactant and products	**3**
(c)	Yes. Since beryllium is less reactive than potassium, potassium can displace beryllium out beryllium chloride. Reject: 'IT' can displace beryllium	**1**
		[Total: 10]