PEARSON EDEXCEL IGCSE CHEMISTRY · 4CH1

# CHEMISTRY



EXAM QUESTION PACK

## SECTION 1: PRINCIPLES OF CHEMISTRY (PACK 3)

| SCORE | PERCENTAGE |
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STEMUP

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Q1.

This question is about elements in Group 7 and their compounds.

The table gives information about some of these elements.

| Element | Symbol | Melting point in °C | Boiling point in °C | Colour at room temperature (20 °C) |
|---|---|---|---|---|
| fluorine | F | –220 | –188 | |
| chlorine | Cl | –101 | –35 | pale green |
| bromine | Br | –7 | 59 | red-brown |
| iodine | I | 114 | 184 | grey |

(a) (i) Predict the colour of fluorine at room temperature.

**(1)**

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(ii) How many of the elements in the table are liquids at room temperature (20°C)?

**(1)**

☒ **A** 0

☒ **B** 1

☒ **C** 2

☒ **D** 3

(iii) The element astatine is below iodine in Group 7.

Predict the formula of a molecule of astatine.

**(1)**

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(b) Sea water contains bromide ions.

Bromine can be obtained by bubbling chlorine through a sample of sea water.

The ionic equation for the reaction is

$$Cl_2(g) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$$

(i) Explain which species acts as an oxidising agent in this reaction.

**(2)**

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(ii) The reaction occurs because chlorine is more reactive than bromine.

Bromine is below chlorine in Group 7.

Explain the decrease in reactivity from chlorine to bromine.

**(3)**

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(c) Elements in Group 7 react with elements in Group 1 to form ionic compounds.

Which pair of ions both have the electronic configuration 2.8.8?

**(1)**

☒ **A** $Li^+$ and $Cl^-$

☒ **B** $K^+$ and $F^-$

☒ **C** $Li^+$ and $F^-$

☒ **D** $K^+$ and $Cl^-$

**(Total for question = 9 marks)**

Q2.

This question is about Group 7, the halogens.

(a) Which halogen has the palest colour?

**(1)**

☒ **A** astatine

☒ **B** bromine

☒ **C** fluorine

☒ **D** iodine

(b) Which halogen is a solid at room temperature?

**(1)**

☒ **A** astatine

☒ **B** bromine

☒ **C** chlorine

☒ **D** fluorine

(c) The table shows the electronic configurations of a fluorine atom and a chlorine atom.

| | **Electronic configuration** |
|---|---|
| fluorine | 2.7 |
| chlorine | 2.8.7 |

Explain the relative reactivities of fluorine and chlorine using the information in the table.

**(4)**

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(d) Lithium reacts with chlorine to form lithium chloride.

(i) Write a chemical equation for the reaction of lithium with chlorine.

**(1)**

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(ii) Describe tests to show that the product of the reaction is lithium chloride.

**(5)**

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**(Total for question = 12 marks)**

Q3.

Astatine, bromine, chlorine, fluorine and iodine are all halogens.
They are found in Group 7 of the Periodic Table.

(a) Predict which halogen has the lightest colour.

**(1)**

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(b) Name a halogen that is a solid at room temperature.

**(1)**

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(c) Bromine can be obtained from the bromide ions in sea water.

Chlorine is bubbled into sea water.
The chlorine oxidises the bromide ions to bromine atoms.

The bromine atoms then form bromine molecules.

(i) Complete the equation to show how bromine **atoms** are formed from bromide ions.

**(1)**

$$Cl_2 + \ldots\ldots\ldots\ldots Br^- \rightarrow 2Cl^- + \ldots\ldots\ldots\ldots Br$$

(ii) State why this reaction is described as the oxidation of bromide ions.

**(1)**

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(iii) Write an equation to show how bromine atoms form bromine molecules.

**(1)**

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(d) Boron and fluorine form a covalent compound that has the molecular formula $BF_3$

Draw a dot-and-cross diagram to show the arrangement of the outer electrons in a molecule of $BF_3$

Use crosses (✕) to represent the outer electrons of boron. Use dots (•) to represent the outer electrons of fluorine.

**(2)**

**(Total for question = 7 marks)**

Q4.

This question is about the insoluble salt silver chloride (AgCl).

Silver chloride can be made by the reaction between copper(II) chloride and silver nitrate.

(a) Describe how a student could prepare a pure, dry sample of silver chloride starting with copper(II) chloride solution and
silver nitrate solution.

**(4)**

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(b) A student investigates the quantity of silver chloride produced when different volumes of silver nitrate solution are added to copper(II) chloride solution.

This is the student's method.

- pour 5.0 $cm^3$ of copper(II) chloride solution into a test tube
- add 1.0 $cm^3$ of silver nitrate solution to the test tube
- allow the silver chloride precipitate to settle
- measure the height of the precipitate

The student repeats the method using different volumes of silver nitrate solution.

The table shows the student's results.

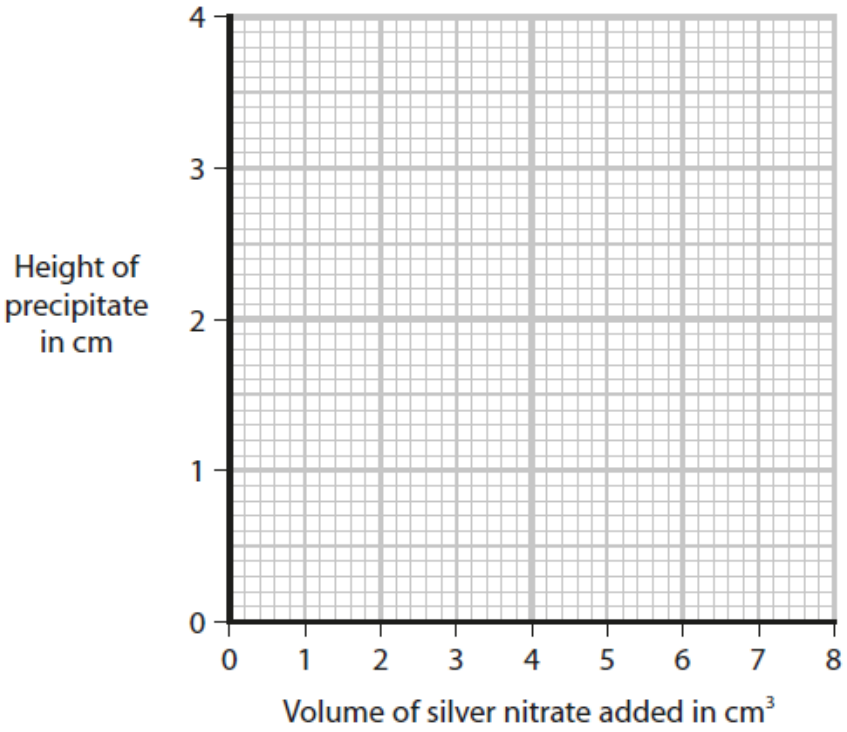
| Volume of silver nitrate added in $cm^3$ | Height of precipitate in cm |
|---|---|
| 0.0 | 0.0 |
| 1.0 | 0.5 |
| 2.0 | 1.0 |
| 3.0 | 1.2 |
| 4.0 | 2.0 |
| 5.0 | 2.5 |
| 6.0 | 3.0 |
| 7.0 | 3.0 |
| 8.0 | 3.0 |

(i) Plot the student's results.

**(2)**

(ii) Draw two straight lines of best fit, ignoring the anomalous result.

**(1)**




(iii) Suggest a mistake the student made to cause the anomalous result.

**(1)**

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(iv) Give a reason why the last three heights are the same.

**(1)**

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(c) The equation for the reaction between copper(II) chloride and silver nitrate is

$$CuCl_2(aq) + 2AgNO_3(aq) \rightarrow 2AgCl(s) + Cu(NO_3)_2(aq)$$

A student measures 25.0 $cm^3$ of 0.500 $mol/dm^3$ copper(II) chloride solution and reacts it with silver nitrate solution.

(i) Name a piece of apparatus suitable for measuring 25.0 $cm^3$ of copper(II) chloride solution.

**(1)**

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(ii) Calculate the maximum mass, in grams, of silver chloride that could be produced.

[$M_r$ of AgCl = 143.5]

**(3)**

maximum mass = ..... g

(iii) In an experiment using different solutions, the mass of silver chloride produced is 0.744 g.

The maximum mass of silver chloride that could be produced is 0.850 g.

Calculate the percentage yield.

**(2)**

percentage yield = ..... %

**(Total for question = 15 marks)**

Q5.

A student investigates the solubility of potassium nitrate in water.
She measures the masses of potassium nitrate that dissolve in 25 $cm^3$ of water at different temperatures.

The table shows the student's results. One of the results is anomalous.

| Temperature in °C | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
|---|---|---|---|---|---|---|---|
| Mass of potassium nitrate in g | 8.0 | 10.0 | 12.5 | 16.0 | 17.5 | 26.5 | 34.0 |

(a) (i) Plot the results on the grid.

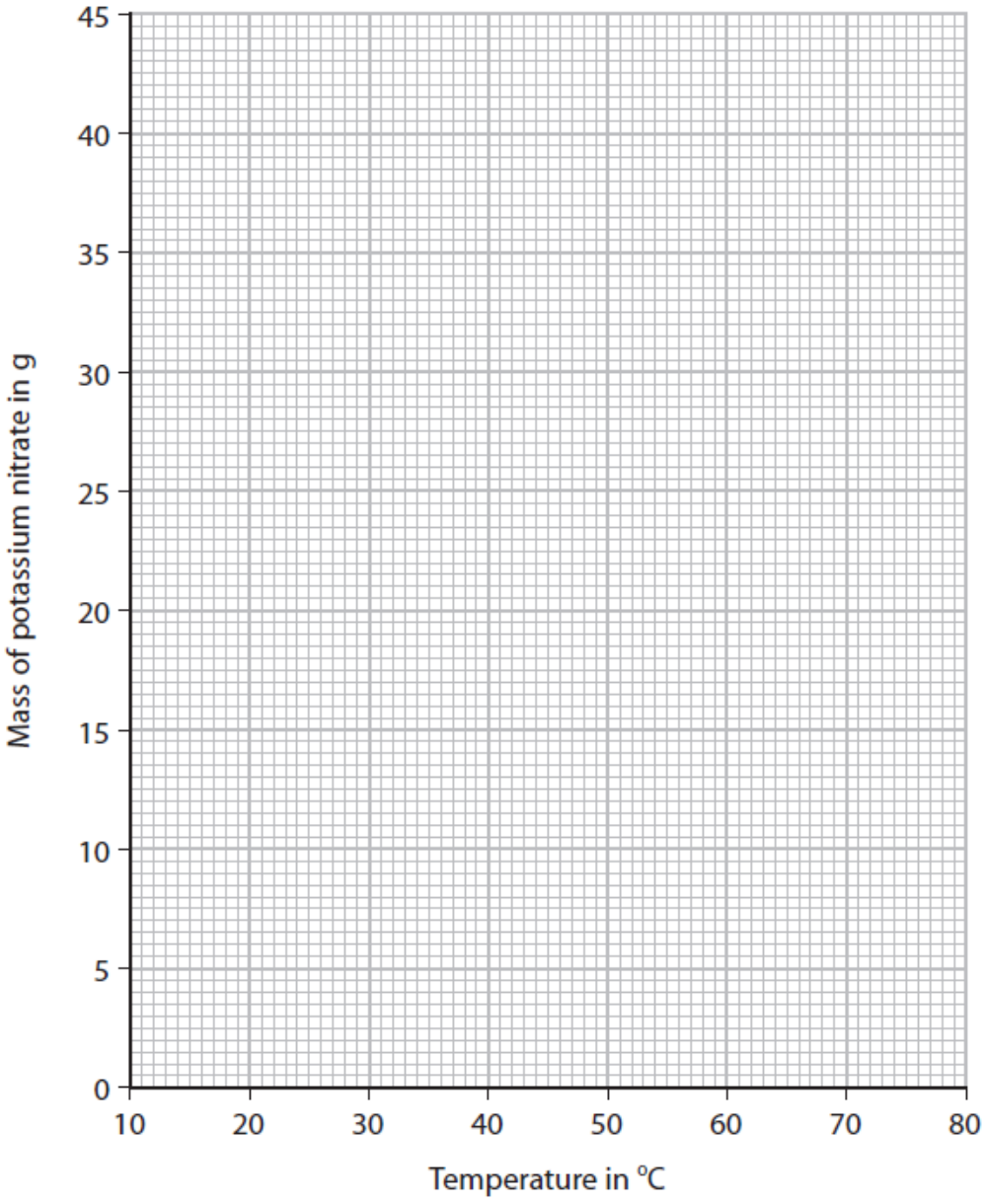
**(1)**

(ii) Draw a circle around the anomalous result.

**(1)**

(iii) Ignoring the anomalous result, draw a curve of best fit.

**(1)**




(b) Suggest **two** possible mistakes that could have caused the anomalous result.

**(2)**

1 .....

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2 .....

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(c) Use your graph to find the maximum mass of potassium nitrate that dissolves in 25 $cm^3$ of water at 75 °C.

Show on your graph how you obtained your answer.

**(2)**

mass = ..... g

(d) Use your graph to calculate the solubility of potassium nitrate in g per 100 g of water at 25 °C.

[1.0 $cm^3$ of water has a mass of 1.0 g]

**(2)**

solubility = ..... g per 100 g of water

**(Total for question = 9 marks)**

Q6.

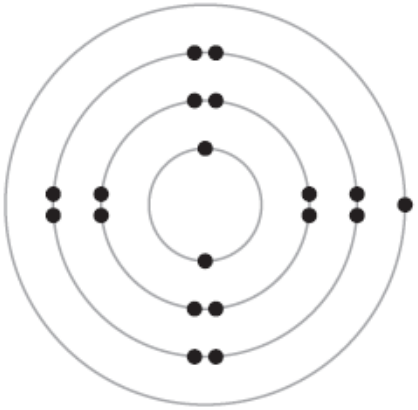
This question is about ionic compounds.

(a) State the formula of the cation and the anion in magnesium sulfate.

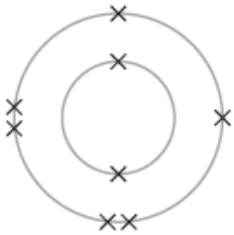
**(2)**

cation . . . . . anion . . . . . .

(b) The diagram shows the electronic configuration of a potassium atom and an oxygen atom.



potassium



oxygen

Potassium oxide ($K_2O$) is an ionic compound.

Draw the electronic configuration of a potassium ion and an oxide ion.

Show the charge on each ion.

**(3)**

potassium ion

oxide ion

(c) A sample of solid potassium oxide is added to water.

A reaction occurs and a colourless solution forms.

When a few drops of phenolphthalein indicator are added to the solution it turns pink.

(i) Identify the ion responsible for the colour change.

**(1)**

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(ii) Give a chemical equation for the reaction between potassium oxide and water.

**(1)**

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(d) Explain why ionic compounds conduct electricity when molten or in aqueous solution, but not when in the solid state.

**(2)**

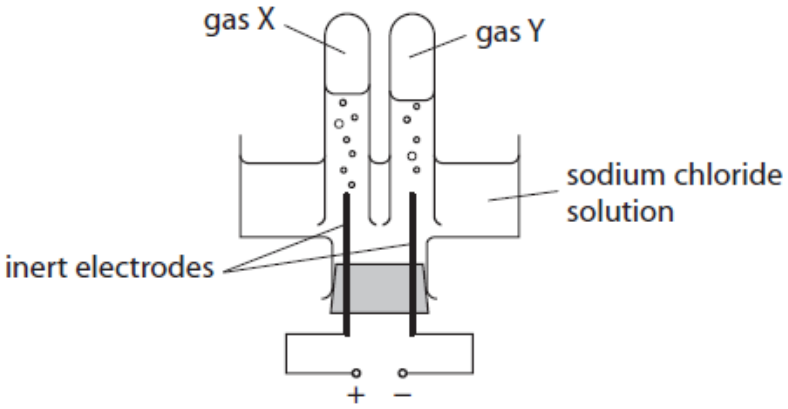
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(e) The diagram shows the apparatus a teacher uses to demonstrate the electrolysis of a concentrated aqueous solution of sodium chloride.




During the electrolysis two gases, X and Y, are formed. One of the gases produces a squeaky pop when tested with a lighted splint.

Use ionic half-equations to identify X and Y.

**(4)**

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**(Total for question = 13 marks)**

Q7.

This question is about magnesium and magnesium compounds.

(a) Magnesium burns in oxygen to form magnesium oxide.

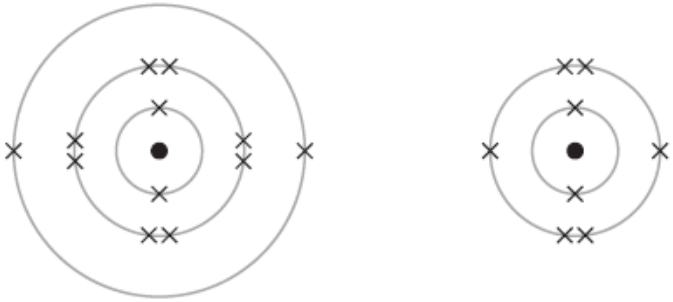
State two observations that would be seen during the reaction.

**(2)**

1 .....

2 .....

(b) The diagram shows the electron configurations of a magnesium atom and an oxygen atom.



magnesium atom oxygen atom

Describe the changes in the electronic configurations when magnesium reacts with oxygen to form the ionic compound magnesium oxide, MgO

**(2)**

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(c) Magnesium can be produced by the electrolysis of molten magnesium chloride.

(i) State why magnesium cannot be produced by heating magnesium oxide with carbon.

**(1)**

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(ii) Explain the different ways that magnesium and magnesium chloride conduct electricity.

**(4)**

magnesium

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magnesium chloride

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(d) During the electrolysis of molten magnesium chloride, magnesium is formed at the negative electrode.

The ionic half-equation for the reaction is

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

(i) State why this is a reduction reaction.

**(1)**

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(ii) Write an ionic half-equation for the formation of chlorine at the positive electrode.

**(1)**

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**(Total for question = 11 marks)**

Q8.

This question is about three stages in the manufacture of sulfuric acid.

(a) In stage 1, sulfur is burned in oxygen to form sulfur dioxide gas.

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

(i) State one environmental problem caused by the release of sulfur dioxide into the atmosphere.

**(1)**

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(ii) A mass of 6.4 tonnes of sulfur is burned to produce sulfur dioxide gas.

Calculate the maximum volume, in $dm^3$, of sulfur dioxide gas that can be produced at rtp.

[molar volume of sulfur dioxide gas at rtp = 24 $dm^3$]

Give your answer in standard form.

**(3)**

maximum volume = ..... $dm^3$

(b) In stage 2, sulfur dioxide is reacted with oxygen to form sulfur trioxide gas.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The yield of sulfur trioxide is approximately 98%.

(i) A catalyst is used in this reaction.

Explain how a catalyst increases the rate of a reaction.

**(2)**

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(ii) The temperature is kept constant.

Give a reason why increasing the pressure would increase the yield of sulfur trioxide.

**(1)**

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(iii) Suggest why it is not necessary to increase the pressure in stage 2.

**(1)**

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(c) In stage 3, the sulfur trioxide is reacted with concentrated sulfuric acid to form a liquid called oleum, $H_2S_2O_7$

The oleum is then added to water to form concentrated sulfuric acid.

Complete the chemical equations for these two reactions.

**(2)**

..... + ..... → $H_2S_2O_7$

$H_2S_2O_7$ + ..... → .....

(d) Sulfuric acid reacts with ammonia to form ammonium sulfate, $(NH_4)2SO_4$

Calculate the percentage by mass of nitrogen in ammonium sulfate.

[$M_r$ of $(NH_4)2SO_4$ = 132]

**(2)**

percentage = ..... %

**(Total for question = 12 marks)**

Q9.

This is a method used to measure the solubility of a solid in water:

- add an excess of solid to some water in a boiling tube and stir
- measure the temperature of the saturated solution formed
- weigh an empty evaporating basin
- pour some of the saturated solution into the evaporating basin
- weigh the basin and contents
- heat the evaporating basin to remove all of the water
- weigh the evaporating basin and remaining solid.

(a) The table shows the results of an experiment using this method.

| | |
|---|---|
| mass of evaporating basin / g | 89.6 |
| mass of evaporating basin + saturated solution / g | 115.8 |
| mass of evaporating basin + solid / g | 94.9 |

Calculate the mass of solid obtained and the mass of water removed.

**(2)**

mass of solid = ..... g

mass of water = ..... g

(b) In another experiment, at a different temperature, the mass of solid obtained is 10.5 g and the mass of water removed is 16.8 g.

Calculate the solubility of the solid, in g per 100 g of water, at this temperature.

**(2)**

solubility = ..... g per 100 g of water

(c) If the evaporating basin is heated too strongly some of the solid decomposes to form a gas.

Explain how this strong heating would affect the value of the calculated solubility of the solid.

**(3)**

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**(Total for question = 7 marks)**

Q10.

This question is about metals.

(a) Which statement describes metallic bonding?

**(1)**

☒ **A** electrostatic attraction between oppositely charged ions

☒ **B** electrostatic attraction between the nuclei of two atoms and a pair of electrons shared between them

☒ **C** electrostatic attraction between positively charged particles and delocalised electrons

☒ **D** electrostatic attraction between atoms

(b) Aluminium is malleable and can be easily shaped to make saucepans used for cooking food.

State two other properties of aluminium that make it suitable for saucepans used for cooking food.

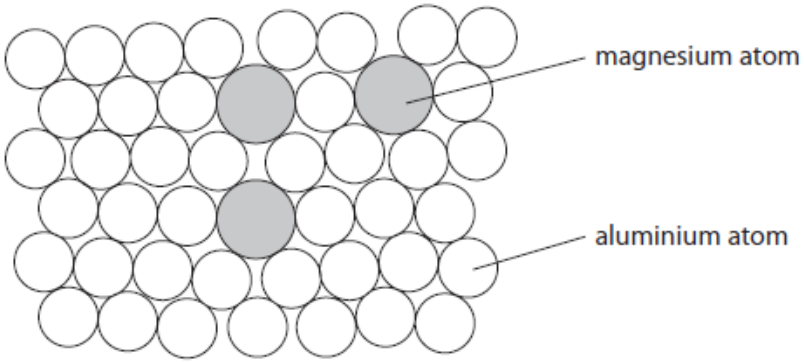
**(2)**

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2 .....

(c) Magnalium is an alloy of aluminium and magnesium.

The diagram shows how the atoms are arranged in this alloy.




(i) State what is meant by the term **alloy**.

**(1)**

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(ii) Explain why magnalium is harder than aluminium.

**(3)**

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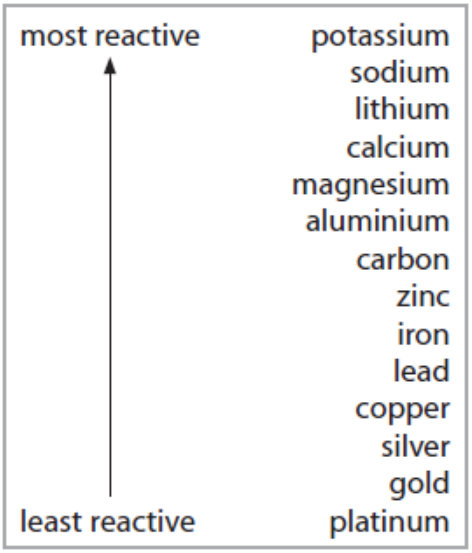
**(Total for question = 7 marks)**

Q11.

Metals are found in the Earth's crust either as uncombined elements or in metal compounds in rocks.

The method of extraction of a metal is related to its position in the reactivity series.

The table shows the positions of some metals and carbon in the reactivity series.




(a) (i) State the name given to rocks that contain metal compounds used in the extraction of metals.

**(1)**

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(ii) Name a metal that is found as an uncombined element in the Earth's crust.

**(1)**

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(b) Carbon extraction and electrolysis are two methods of obtaining a metal from a compound.

(i) Explain, without giving practical details, which method is most suitable to obtain calcium from calcium chloride.

**(2)**

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(ii) Explain, without giving practical details, which method is most suitable to obtain lead from lead oxide.

**(2)**

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(c) Explain, using a labelled diagram, why lead metal is malleable.

**(3)**

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(d) Aluminium is extracted from aluminium oxide.

The overall equation for the process is

$$2Al_2O_3 \rightarrow 4Al + 3O_2$$

Calculate the maximum mass, in grams, of aluminium that could be obtained from 1.275 kg of aluminium oxide.

**(3)**

mass = ..... g

**(Total for question = 12 marks)**

Q12.

A student is given a mixture of salt solution and sand.

She wants to obtain pure water from the mixture.

(a) She separates the sand from the salt solution.

Which method of separation should she use?

**(1)**

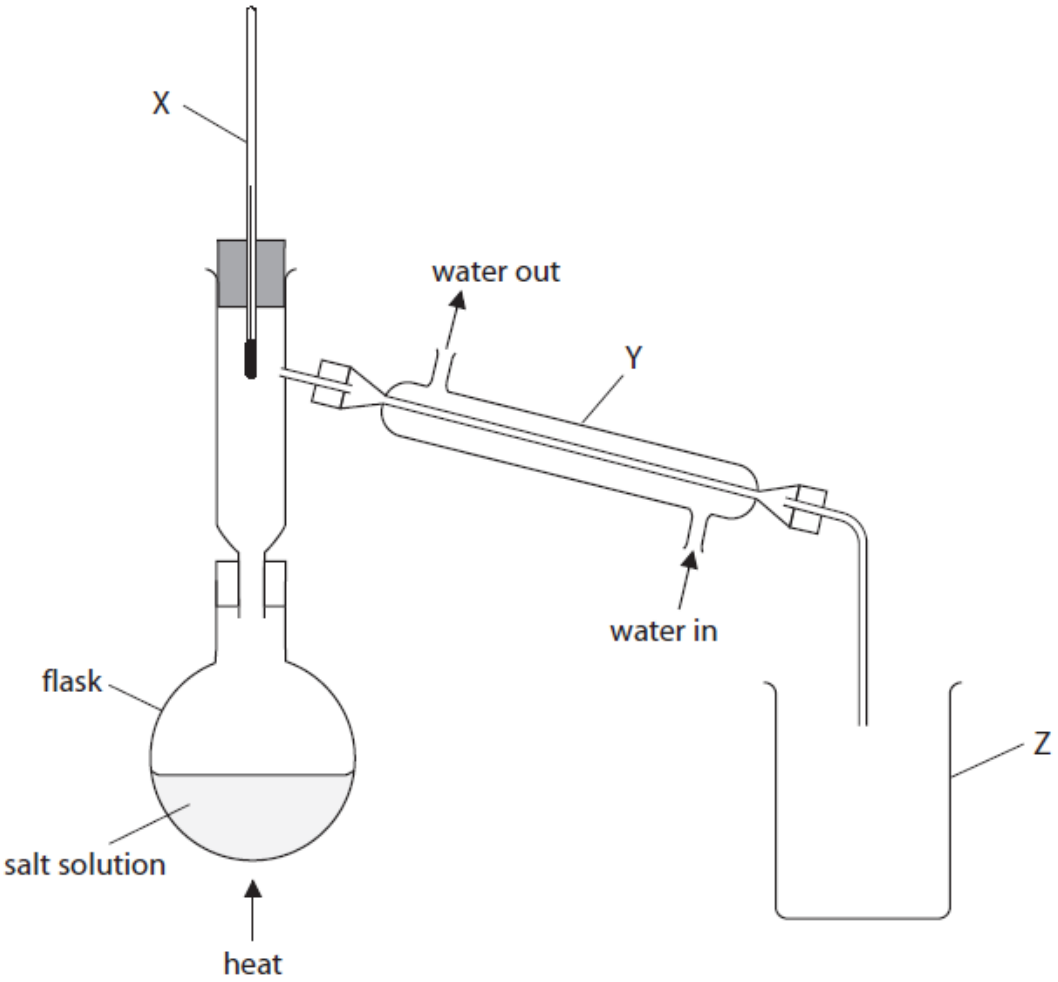
☒ **A** crystallisation

☒ **B** filtration

☒ **C** fractional distillation

☒ **D** simple distillation

(b) The student then uses this apparatus to obtain pure water from the salt solution.




(i) Name the pieces of apparatus labelled X, Y and Z.

**(3)**

X .....

Y .....

Z .....

(ii) State what remains in the flask when the separation is complete.

**(1)**

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**(Total for question = 5 marks)**

Q13.

A teacher prepares the insoluble salt lead(II) bromide ($PbBr_2$) by mixing solutions of lead(II)

nitrate and sodium bromide.

(a) Describe what the teacher should do next to obtain a pure, dry sample of lead(II) bromide.

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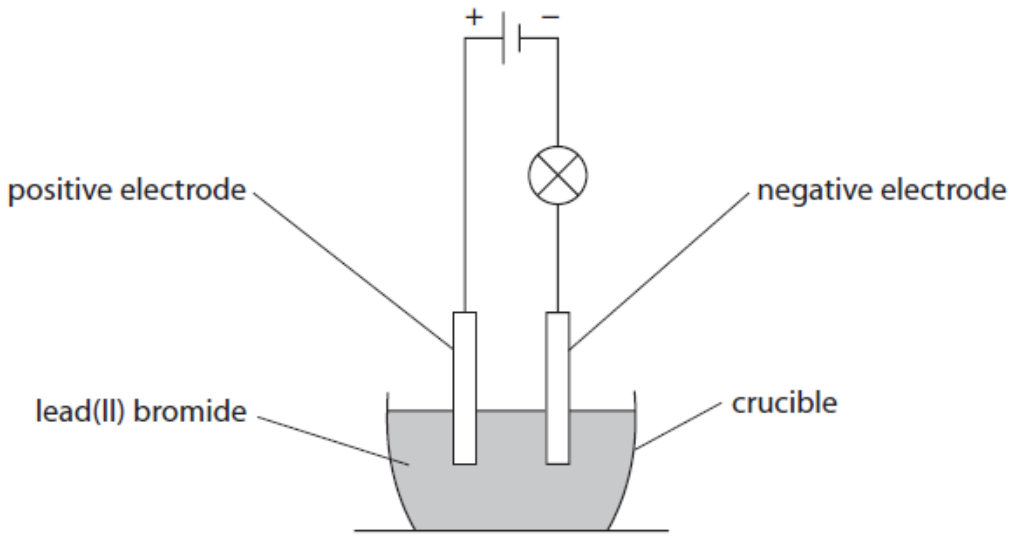
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(b) The teacher then sets up a circuit in a fume cupboard using the pure, dry sample of lead(II) bromide.




Explain why the lamp does not light when the lead(II) bromide is solid.

**(2)**

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(c) The teacher heats the lead(II) bromide.

When the lead(II) bromide is molten, the lamp lights and bromine forms at the positive electrode.

(i) State what observation would be made at the positive electrode.

**(1)**

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(ii) Explain how bromide ions in the molten lead(II) bromide become bromine molecules at the positive electrode.

**(4)**

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(d) Write an ionic half-equation for the reaction that occurs at the negative electrode.

Include state symbols in your equation.

**(2)**

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**(Total for question = 12 marks)**

Q14.

A sample of a gaseous hydrocarbon, X, has a volume of 600 $cm^3$ at room temperature and pressure (rtp).

(a) Calculate the amount, in moles, of hydrocarbon X in the sample.

[molar volume of a gas = 24 000 $cm^3$ at rtp]

**(2)**

amount of hydrocarbon X = ..... mol

(b) The mass of the sample of hydrocarbon X is 1.45 g.

Show that the relative molecular mass ($M_r$) of X is 58

**(2)**

$M_r$ = .....

(c) Hydrocarbon X is an alkane.

Show that the molecular formula of X is $C_4H_{10}$

**(1)**

(d) Give the displayed formula of the branched-chain isomer of hydrocarbon X.

**(1)**

**(Total for question = 6 marks)**

Q15.

In the presence of an iron catalyst, nitrogen reacts with hydrogen to form ammonia.

The reaction conditions used are a temperature of 450°C and a pressure of 200 atmospheres.

This is the equation for the reaction.

$$N_2 + 3H_2 \leftrightarrow 2NH_3 \quad \Delta H = -92 \text{ kJ/mol}$$

(a)(i) State what the symbol ↔ represents.

**(1)**

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(ii) Give the reason for using a catalyst.

**(1)**

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(b) (i) The reaction mixture is kept at a pressure of 200 atmospheres, but the temperature is increased to 550 °C.

Explain the effect of this change on the yield of ammonia at equilibrium.

**(2)**

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(ii) The reaction mixture is kept at a temperature of 450 °C, but the pressure is increased to 300 atmospheres.

Explain the effect of this change on the yield of ammonia at equilibrium.

**(2)**

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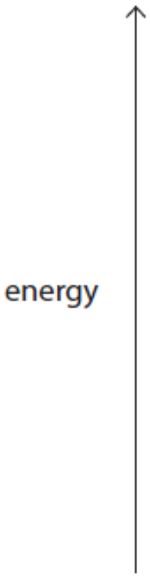
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(c) Draw an energy level diagram for the reaction between nitrogen and hydrogen.

Include the reactants, products and $\Delta H$ in your diagram.

**(3)**




(d) At the start of the reaction, 48 $dm^3$ of nitrogen is added to 120 $dm^3$ of hydrogen at rtp.

$$N_2 + 3H_2 \leftrightarrow 2NH_3$$

[molar volume of any gas at rtp = 24 $dm^3$]

(i) Show by calculation that the nitrogen is in excess.

**(3)**

(ii) The yield of ammonia at equilibrium is 20 %.

Calculate the volume, in $dm^3$, of ammonia formed from 120 $dm^3$ of hydrogen.

**(3)**

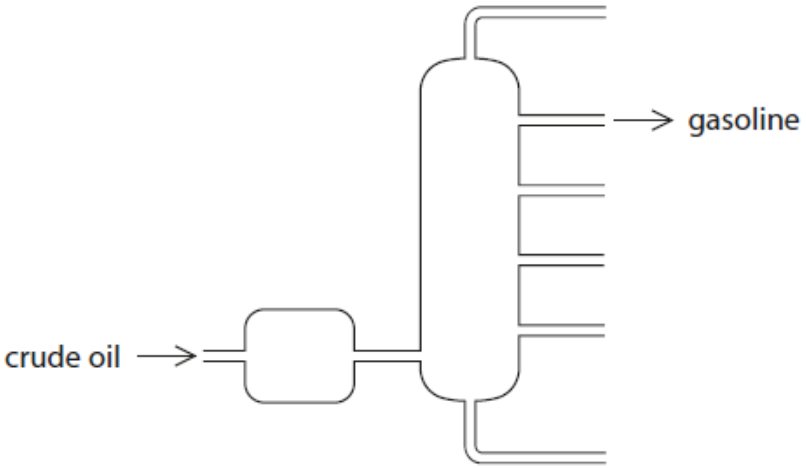
volume of ammonia = ..... $dm^3$

**(Total for question = 15 marks)**

Q16.

This question is about octane ($C_8H_{18}$) which is produced in the gasoline fraction during fractional distillation of crude oil.

(a) The diagram shows a fractionating column.




Describe how crude oil is separated into fractions in the fractionating column.

**(4)**

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(b) Octane can also be produced by the process of cracking.

Give the conditions for cracking.

**(2)**

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(c) A car is driven at constant speed for 4.00 km.

The exhaust gases are collected and their volume at room temperature and pressure (rtp) is $5.02 \times 10^5$ $cm^3$.

The exhaust gases include carbon dioxide and oxides of nitrogen.

The carbon dioxide is removed from the exhaust gases. The volume of the remaining gases at rtp is $2.96 \times 10^5$ $cm^3$.

(i) Explain how oxides of nitrogen form in a car engine.

**(2)**

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(ii) Give a reason why oxides of nitrogen should not be released into the atmosphere.

**(1)**

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(iii) Show that the car produces less than 100 g of carbon dioxide per km.

[molar volume of carbon dioxide at rtp = 24 000 $cm^3$]

**(5)**

**(Total for question = 14 marks)**

Q17.

(a) An organic compound has this percentage composition by mass.

C = 40% H = 6.7% O = 53.3%

(i) Show that the empirical formula of the compound is $CH_2O$

**(2)**

(ii) Draw the structural formula of a compound with the molecular formula $C_2H_4O_2$

**(1)**

(b) Methanoic acid (HCOOH) reacts with sodium carbonate solution to give three products.

(i) Complete the equation for this reaction.

**(2)**

$2HCOOH + Na_2CO_3 \rightarrow$ ..... + ..... +

.....

(ii) State what you would observe in this reaction.

**(1)**

.....

.....

(c) Methanoic acid also reacts with propanol to form an ester.

The equation for the reaction is

$$HCOOH + C_3H_7OH \leftrightarrow HCOOC_3H_7 + H_2O$$

(i) Give the name of the ester that forms.

**(1)**

.....

(ii) State what is meant by the ↔ symbol.

**(1)**

.....

(iii) When this reaction occurs in a sealed container, the reaction can reach dynamic equilibrium.

Give one characteristic of a reaction at dynamic equilibrium.

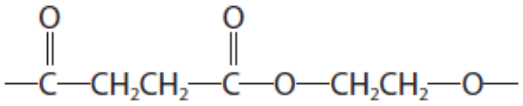
**(1)**

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(d) A polyester forms when butanedioic acid reacts with ethanediol.

The diagram shows the repeat unit of the polyester that forms.




(i) Give the name of this type of polymerisation.

**(1)**

.....

(ii) Draw the structural formulae of the two monomers used to make this polyester.

**(2)**

| | |
|---|---|
| | |

**(Total for question = 12 marks)**

Q18.

(a) Ethanol, $C_2H_5OH$, can be oxidised to produce ethanoic acid, $CH_3COOH$, by heating it with potassium dichromate(VI).

(i) Name one other reactant needed for this reaction to occur.

**(1)**

.....

(ii) Which colour change occurs during this reaction?

**(1)**

☒ **A** colourless to green

☒ **B** green to orange

☒ **C** orange to colourless

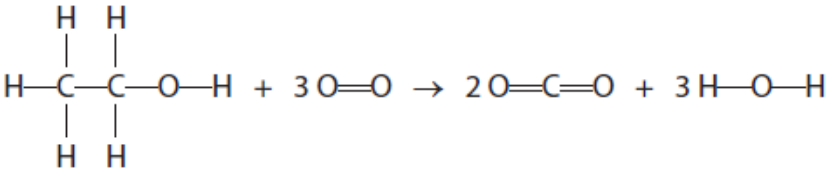
☒ **D** orange to green

(b) When ethanol is burned in air, complete combustion can occur.

The equation for this reaction is

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

This equation can also be written using displayed formulae to show all the covalent bonds in the molecules.



The table gives the bond energies for these bonds.

| Bond | C—C | C—H | C—O | O—H | O=O | C=O |
|---|---|---|---|---|---|---|
| Bond energy in kJ/mol | 346 | 412 | 358 | 463 | 496 | 743 |

(i) Use values from the table to calculate the energy needed to break all the bonds in the reactants.

**(2)**

energy needed ..... kJ

(ii) Use values from the table to calculate the energy released when all the bonds in the products are formed.

**(2)**

energy released ..... kJ

(iii) Calculate the molar enthalpy change ($\Delta H$) in kJ/mol, for the complete combustion of ethanol.

Include a sign in your answer.

**(1)**

$\Delta H$ = ..... kJ/mol

(c) Ethanol reacts with methanoic acid, HCOOH, in the presence of an acid catalyst to form an ester.

The equation for the reaction is

$$C_2H_5OH + HCOOH \Leftrightarrow HCOOC_2H_5 + H_2O$$

(i) Give the name of the ester that forms.

**(1)**

.....

(ii) Draw the displayed formula for this ester.

**(2)**

(iii) When this reaction takes place in a sealed container, the reaction can reach dynamic equilibrium.

Give two characteristics of a reaction at dynamic equilibrium.

**(2)**

1 .....

.....

2 .....

.....

(d) Methanoic acid reacts with sodium carbonate to form sodium methanoate, carbon dioxide and water.

The equation for the reaction is

$$2HCOOH + Na_2CO_3 \rightarrow 2HCOONa + CO_2 + H_2O$$

Calculate the volume, in $cm^3$, of carbon dioxide gas produced when 2.3 g of methanoic acid reacts completely with sodium carbonate.

[$M_r$ of HCOOH = 46]

[molar volume of carbon dioxide at rtp = 24 $dm^3$]

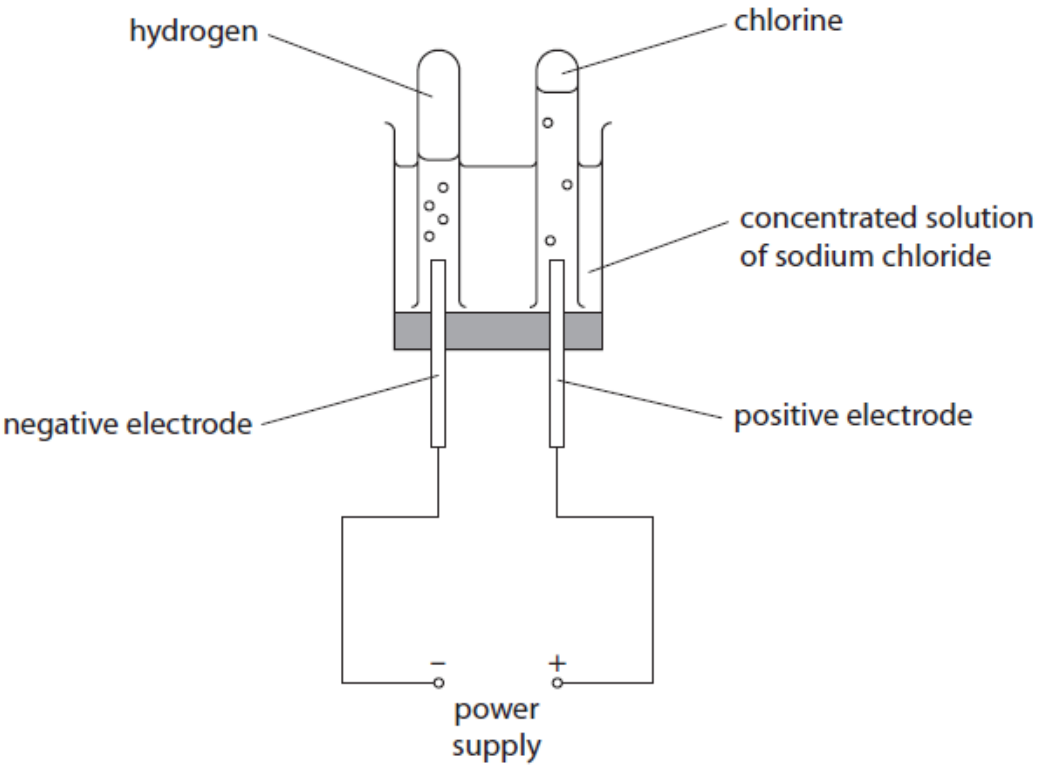
**(4)**

volume of carbon dioxide = ..... $cm^3$

**(Total for question = 16 marks)**

Q19.

The diagram shows how hydrogen gas and chlorine gas can be prepared in the laboratory by electrolysis of a concentrated solution of sodium chloride.




(a) (i) Give a test for hydrogen gas.

**(1)**

.....

.....

(ii) Give a test for chlorine gas.

**(2)**

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(b) The ionic half-equation for the formation of chlorine at the positive electrode is

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

(i) State why this reaction is an oxidation reaction.

**(1)**

.....

.....

(ii) Give the ionic half-equation for the formation of hydrogen at the negative electrode.

**(1)**

.....

(iii) State why it is safer to do this electrolysis in a fume cupboard.

**(1)**

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(iv) Suggest why the volume of chlorine collected during this electrolysis is less than the volume of hydrogen collected.

**(1)**

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(c) In the chemical industry, chlorine can be produced by the electrolysis of molten sodium chloride.

The overall equation for this reaction is

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

(i) Explain why sodium chloride needs to be molten rather than solid for electrolysis to occur.

**(2)**

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(ii) Calculate the maximum volume, in $dm^3$, of chlorine gas at rtp that can be obtained from 23.4 tonnes of molten sodium chloride.

[1 tonne = $10^6$ g]

[$M_r$ of NaCl = 58.5]

[molar volume of chlorine at rtp = 24 $dm^3$]

Give your answer in standard form.

**(4)**

volume = ..... $dm^3$

**(Total for question = 13 marks)**

Q20.

This question is about ammonia gas, $NH_3$

(a) Ammonia can be prepared in a laboratory from the reaction between ammonium chloride, $NH_4Cl$, and sodium hydroxide. The other products of the reaction are sodium chloride and water.

(i) Give a chemical equation for this reaction.

**(1)**

.....

(ii) Give a test for ammonia gas.

**(2)**

.....

.....

(b) In industry, ammonia is produced from nitrogen and hydrogen.

The equation for this reaction is

$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$$

In a sealed container, the reaction can reach a position of dynamic equilibrium.

Explain the meaning of the term **dynamic equilibrium**.

**(2)**

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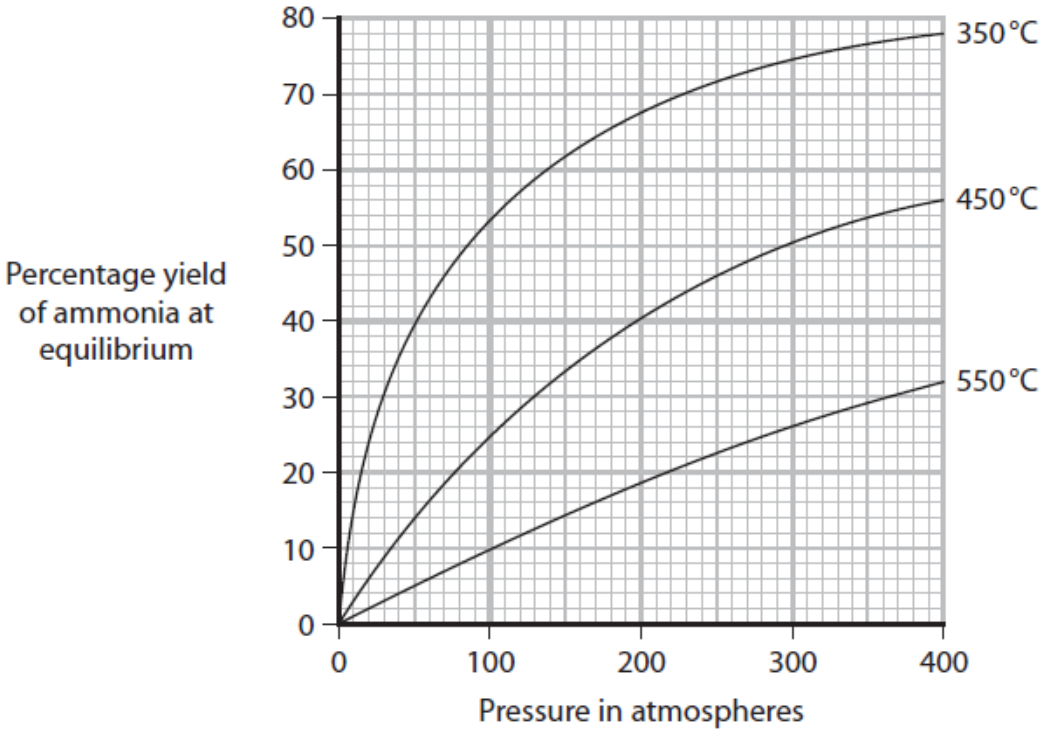
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(c) The graph shows the percentage yield of ammonia at equilibrium for different temperatures

and pressures.




Using the graph, explain if the forward reaction is exothermic or endothermic.

**(2)**

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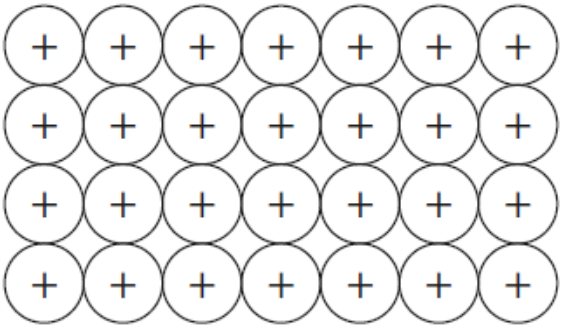
**(Total for question = 7 marks)**

Q21.

This question is about the metal aluminium.

(a) Aluminium is malleable and conducts electricity.

The diagram shows the arrangement of the ions in aluminium metal.




(i) Explain why aluminium is malleable.

**(2)**

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(ii) Explain why aluminium conducts electricity.

**(2)**

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(b) Aluminium cannot be extracted by heating a mixture of carbon and aluminium oxide.

Give a reason why heating a mixture of aluminium oxide and carbon does not produce aluminium.

**(1)**

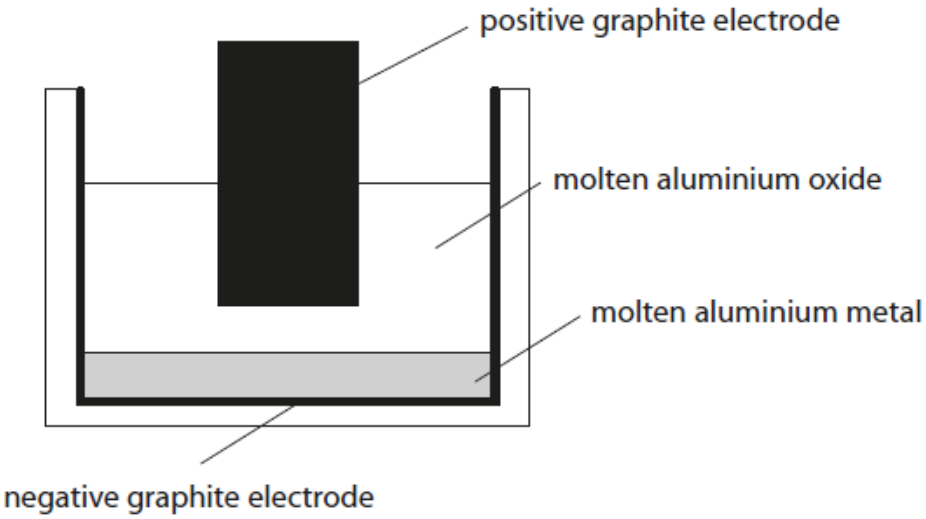
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(c) Aluminium is extracted industrially by the electrolysis of molten aluminium oxide $Al_2O_3$ at a temperature of about 950 °C.

Aluminium metal forms at the negative electrode and oxygen gas forms at the positive electrode. The positive and negative electrodes are made of graphite.

The diagram shows the apparatus used.




(i) Explain how aluminium metal forms at the negative electrode.

**(2)**

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.....

(ii) Write an ionic half-equation for the formation of oxygen gas at the positive electrode.

**(1)**

..... → .....

(iii) Suggest why carbon dioxide gas is also produced at the positive electrode.

**(2)**

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(d) Aluminium reacts with iron(III) oxide. The reaction is exothermic.

The equation for the reaction is

$$2Al + Fe_2O_3 \rightarrow Al_2O_3 + 2Fe$$

(i) State how the equation shows that iron(III) oxide is reduced.

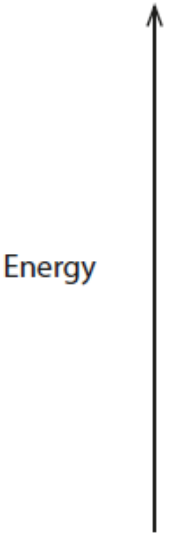
**(1)**

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(ii) Draw an energy level diagram for the reaction between aluminium and iron(III) oxide.

**(3)**




**(Total for question = 14 marks)**

Q22.

(a) The box gives the names of some metals.

| calcium | copper | iron | magnesium | silver | zinc |
|---|---|---|---|---|---|

(i) Identify the metal from the box that burns with a bright white flame.

**(1)**

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(ii) In the Earth, metals are found either in ores or as uncombined elements.

Explain which metal from the box is most likely to be found as an uncombined element.

**(2)**

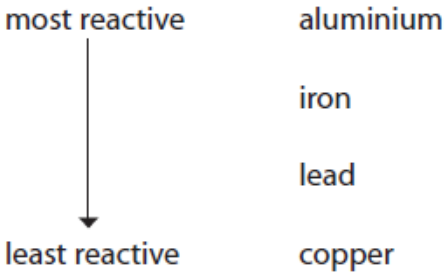
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(b) This is the order of reactivity of four metals.




The method used to obtain a metal from its oxide depends on the reactivity of the metal.

Two possible methods are

Method 1 heating the metal oxide with carbon

Method 2 electrolysis

Explain which method should be used to obtain lead from lead(II) oxide, PbO

Include an equation for the formation of lead in your answer.

**(3)**

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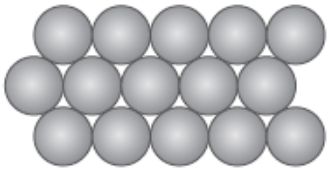
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(c) The diagram shows the arrangement of the particles in a pure metal.



Metals are often made into alloys to make them harder.

Explain why alloys are harder than pure metals.

Draw a diagram to support your answer.

**(4)**

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**(Total for question = 10 marks)**

Q23.

The table shows some properties of four substances, **P**, **Q**, **R** and **S**.

| Substance | Melting point /°C | Boiling point /°C | Conducts electricity when | |
|---|---|---|---|---|
| | | | solid | liquid |
| **P** | 3410 | 5930 | yes | yes |
| **Q** | 734 | 1435 | no | yes |
| **R** | −95 | 69 | no | no |
| **S** | 2507 | 3900 | no | no |

Use the information in the table to answer the following questions.
You may use each letter once, more than once or not at all.

Choose a substance that:

(a) is a solid at 3000 °C.

**(1)**

☒ **A** substance **P**

☒ **B** substance **Q**

☒ **C** substance **R**

☒ **D** substance **S**

(b) is a liquid at 25 °C.

**(1)**

☒ **A** substance **P**

☒ **B** substance **Q**

☒ **C** substance **R**

☒ **D** substance **S**

(c) is an ionic compound.

**(1)**

☒ **A** substance **P**

☒ **B** substance **Q**

☒ **C** substance **R**

☒ **D** substance **S**

(d) is a metal.

**(1)**

☒ **A** substance **P**

☒ **B** substance **Q**

☒ **C** substance **R**

☒ **D** substance **S**

**(Total for question = 4 marks)**

Q24.

This question is about sodium and potassium.

A trough is filled with water and a few drops of phenolphthalein indicator are added.

(a) A small piece of sodium is dropped into the water. One of the products of the reaction is an alkali.

(i) Complete the chemical equation for the reaction of sodium with water.

**(2)**

_____Na(.....) + _____$H_2O(l)$ → _____NaOH(.....) + $H_2(g)$

(ii) Identify the ion that causes the solution to become alkaline.

**(1)**

.....

(iii) Give three observations that would be made when sodium reacts with water.

**(3)**

1 .....

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2 .....

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3 .....

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(b) Explain why potassium is more reactive than sodium.

Refer to the electronic configurations of the atoms in your answer.

**(3)**

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**(Total for question = 9 marks)**

Q25.

This question is about reactions involving gases.

(a) Potassium carbonate reacts with dilute hydrochloric acid to produce carbon dioxide gas.

The equation for the reaction is

$$K_2CO_3(s) + 2HCl(aq) \rightarrow 2KCl(aq) + H_2O(l) + CO_2(g)$$

Calculate the volume, in $cm^3$, of carbon dioxide gas produced when 6.9 g of potassium carbonate reacts with excess dilute hydrochloric acid.

[*M*r of $K_2CO_3$ = 138]

[molar volume of $CO_2$ at rtp = 24 $dm^3$]

**(3)**

volume = ..... $cm^3$

(b) This reaction involving gases is in dynamic equilibrium at a temperature of 225 °C.

$$H_2(g) + CO_2(g) \rightleftharpoons CO(g) + H_2O(g) \qquad \Delta H = +41\,kJ/mol$$

(i) Predict the effect on the yield of CO(g) at equilibrium when the temperature is increased without changing the pressure.

Give a reason for your answer.

**(2)**

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(ii) Predict the effect on the yield of CO(g) at equilibrium when the pressure is increased without changing the temperature.

Give a reason for your answer.

**(2)**

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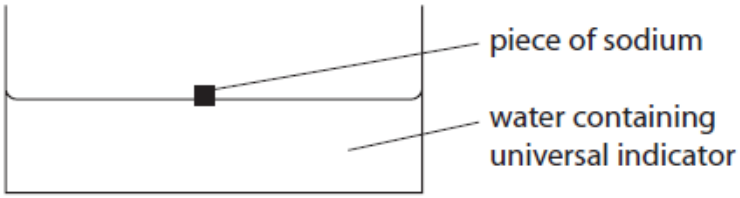
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**(Total for question = 7 marks)**

Q26.

This question is about the reactions of Group 1 metals with water.

(a) A teacher adds a piece of sodium to some water containing universal indicator.




The equation for this reaction is

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

The sodium floats on the surface of the water and the universal indicator changes colour because an alkaline solution is formed.

(i) Give two other observations.

**(2)**

1 .....

.....

2 .....

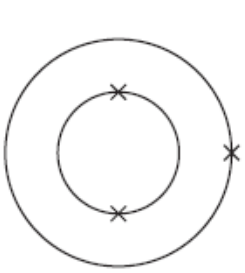
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(ii) Give the final colour of the universal indicator.

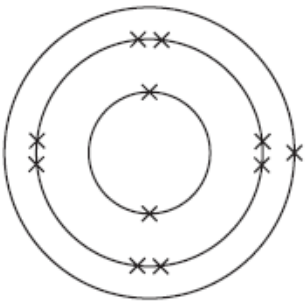
**(1)**

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(b) The diagram represents an atom of lithium and an atom of sodium.



lithium



sodium

(i) Give a reason why lithium and sodium have similar reactions with water.

**(1)**

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(ii) Explain why lithium is less reactive than sodium.

**(3)**

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(c) The teacher adds 0.150 g of lithium to an excess of water and collects the hydrogen gas produced.

The equation for the reaction is

$$2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$$

The teacher collects 254 $cm^3$ of hydrogen gas at room temperature and pressure (rtp).

Show by calculation that 1 mol of hydrogen gas has a volume of approximately 24 000 $cm^3$ at rtp.

**(4)**

**(Total for question = 11 marks)**

Q27.

Zinc metal is obtained from sulfide ores.

The most common ore of zinc is sphalerite, which contains zinc sulfide (ZnS) and a small amount of cadmium sulfide (CdS).

The stages involved in the extraction of zinc from sphalerite are:

Stage 1 Sphalerite is strongly heated in air.

$$2ZnS(s) + 3O_2(g) \rightarrow 2ZnO(s) + 2SO_2(g)$$

$$2CdS(s) + 3O_2(g) \rightarrow 2CdO(s) + 2SO_2(g)$$

Stage 2 The mixture of oxides is reacted with sulfuric acid.

$$ZnO(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2O(l)$$

$$CdO(s) + H_2SO_4(aq) \rightarrow CdSO_4(aq) + H_2O(l)$$

Stage 3 Zinc dust is added to the solution containing zinc sulfate and cadmium sulfate to remove the cadmium ions.

$$Cd^{2+}(aq) + Zn(s) \rightarrow Cd(s) + Zn^{2+}(aq)$$

Stage 4 The solid cadmium is filtered off and the pure zinc sulfate solution is electrolysed.

(a) State how the reaction in stage 3 shows that zinc is more reactive than cadmium.

**(1)**

.....

.....

(b) (i) During the electrolysis in stage 4, zinc is deposited on the cathode.

Write an ionic half-equation for the reaction that occurs.

**(1)**

.....

(ii) Complete the ionic half-equation for the reaction occurring at the anode.

..... $H_2O \rightarrow$ .....$H^+ + O_2 +$ ..... $e^-$

**(1)**

(iii) Explain how the pH of the solution surrounding the anode changes during the electrolysis.

**(2)**

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(c) Zinc is mixed with copper to make the alloy brass.

Explain why brass is harder than pure copper.

**(3)**

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**(Total for question = 8 marks)**

Q28.

(a) The box lists words that may be used to explain the term **saturated solution**.

| solute | solvent | temperature |
|---|---|---|

Explain, using all the words in the box, the term **saturated solution**.

**(2)**

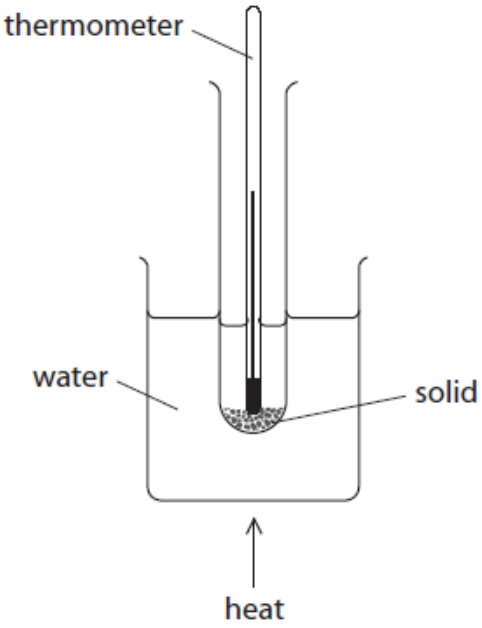
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(b) The diagram shows the apparatus a student uses to make a saturated solution.




This is the student's method.

Step 1 add 4.5 g of solid to a boiling tube

Step 2 measure exactly 10.0 $cm^3$ of pure water and pour into the boiling tube

Step 3 place the boiling tube in the beaker of water and heat gently, stirring the mixture continuously until all the solid dissolves

Step 4 remove the boiling tube from the beaker and allow it to cool

Step 5 record the temperature when crystals start to form in the boiling tube

The recorded temperature shows when the solution becomes saturated.

(i) Name the piece of apparatus that the student should use in Step 2 to measure exactly 10.0 $cm^3$ of pure water.

**(1)**

.....

(ii) Suggest why the boiling tube is not heated directly using a Bunsen burner in Step 3.

**(1)**

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(iii) Suggest how the student could improve the reliability of her recorded temperature in Step 5.

**(1)**

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(iv) In Step 5, crystals start to form at 26 °C.

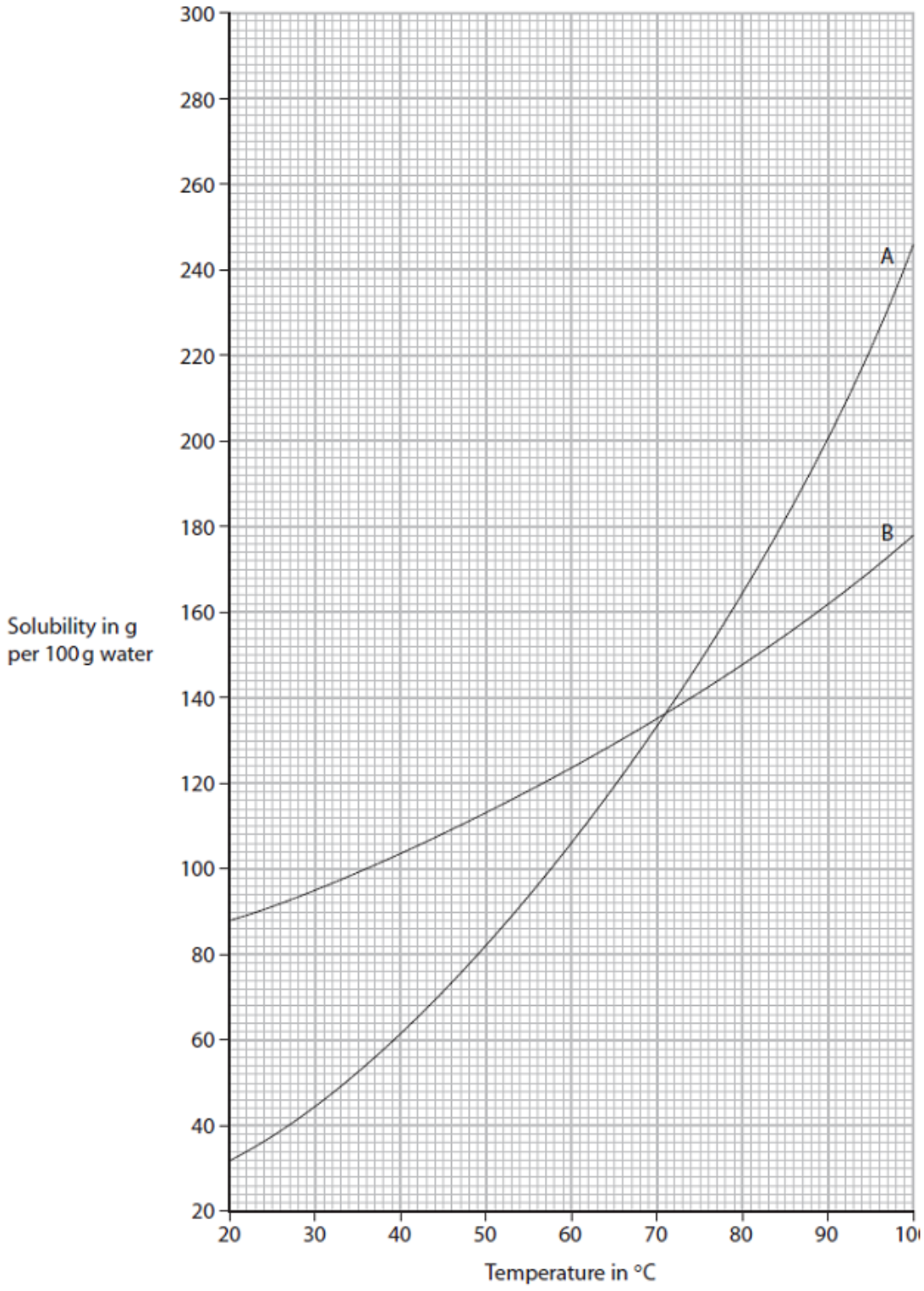
Calculate the solubility of the solid, in g per 100 g of water, at 26 °C.

[1.0 $cm^3$ of pure water has a mass of 1.0 g]

**(2)**

solubility = ..... g per 100 g of water

(c) The solubility curves for two solids, A and B, are shown on the grid.




(i) State the temperature when A and B have the same solubility.

**(1)**

temperature = ..... °C

(ii) Calculate the mass of B that will dissolve in 250 g of water at 60 °C.

Show your working.

**(2)**

mass = ..... g

(iii) Suggest why the values for the solubility of A and B may be less accurate at 95 °C than at lower temperatures.

**(1)**

.....

.....

.....

**(Total for question = 11 marks)**

Q29.

Crude oil is a mixture of hydrocarbons.

(a) Name the process used to separate crude oil into fractions.

**(1)**

.....

(b) Give one use of the kerosene fraction.

**(1)**

.....

(c) One of the hydrocarbons in the refinery gas fraction is an alkane with the structural formula $CH_3CH_2CH_2CH_3$

(i) Give the name of this alkane.

**(1)**

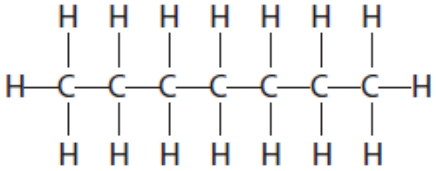
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(ii) Calculate the relative molecular mass ($M_r$) of this alkane.

**(1)**

$M_r$ .....

(d) One of the alkanes in the gasoline fraction has the displayed formula



(i) Determine the molecular formula of this alkane.

**(1)**

.....

(ii) Give the general formula for the alkanes.

**(1)**

.....

(e) Catalytic cracking is used to convert long-chain alkanes into shorter-chain alkanes.

(i) Name the catalyst used in catalytic cracking.

**(1)**

.....

(ii) Explain why it is necessary to convert long-chain alkanes into shorter-chain alkanes.

**(2)**

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(f) Catalytic cracking also produces alkenes.

$C1_1H_{24}$ can undergo cracking to give pentane ($C_5H_{12}$) and two different alkenes.

Complete the equation for this cracking reaction.

**(2)**

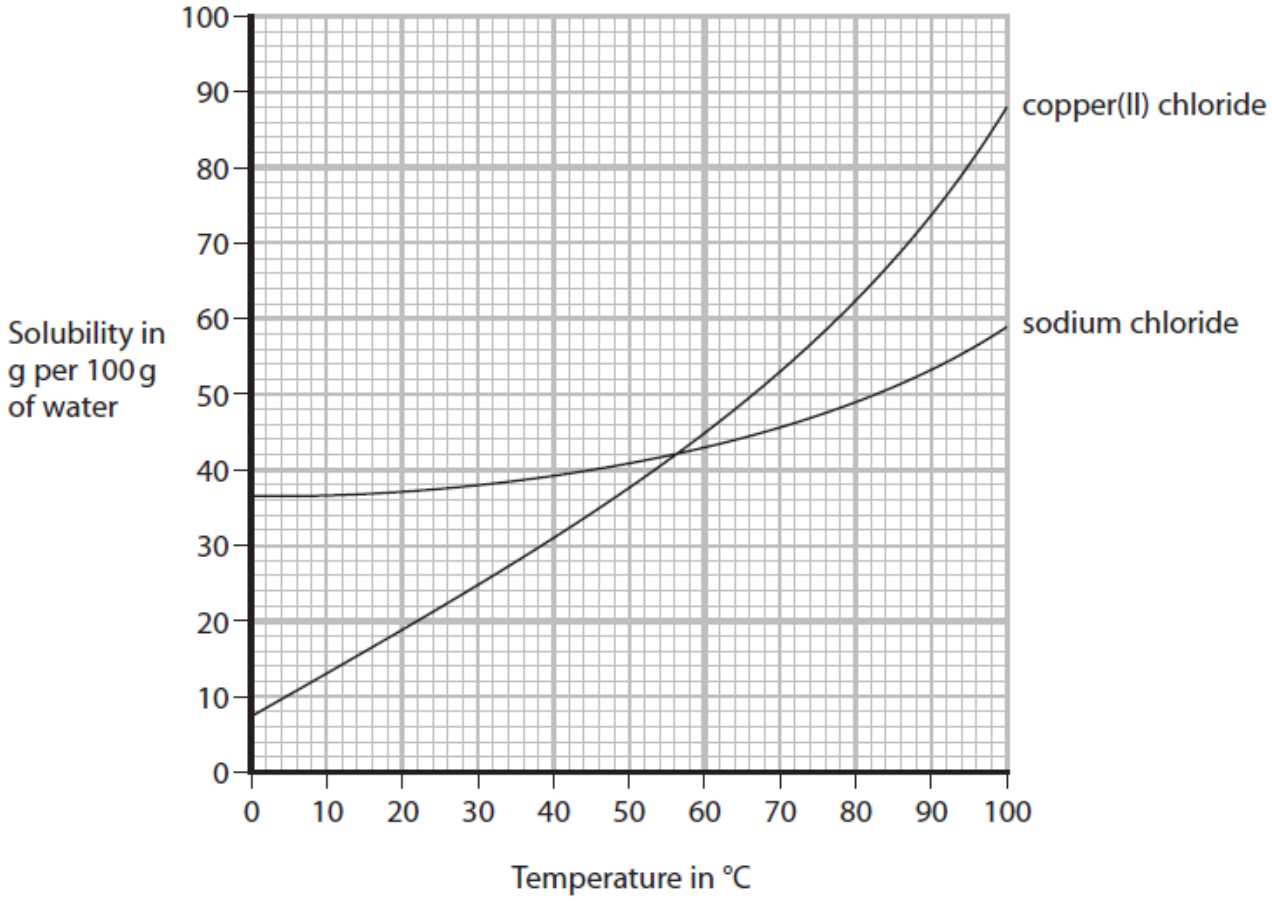
$C_{11}H_{24} \rightarrow C_5H_{12}$ + ..... + .....

**(Total for question = 11 marks)**

Q30.

This question is about solubility.

(a) The graph shows the solubilities of copper(II) chloride and sodium chloride at different temperatures.




(i) Determine the temperature at which copper(II) chloride and sodium chloride have the same solubility.

Show on the graph how you obtained your answer.

**(2)**

temperature = ..... °C

(ii) A saturated solution of copper(II) chloride in 100 g of water is cooled from 40 °C to 10 °C.

Determine the mass, in grams, of copper(II) chloride that crystallises.

**(2)**

mass of copper(II) chloride = ..... g

(b) A student uses this method to determine the solubility of potassium chloride in water at room temperature.

- record the mass of an empty evaporating basin
- pour some saturated potassium chloride solution into the evaporating basin
- record the mass of the evaporating basin and saturated potassium chloride solution
- heat the evaporating basin to remove all the water
- record the mass of the evaporating basin and the dry potassium chloride

The table shows the student's results.

| | Mass in grams |
|---|---|
| evaporating basin | 58.1 |
| evaporating basin and saturated potassium chloride solution | 78.2 |
| evaporating basin and dry potassium chloride | 63.2 |

(i) Calculate the mass of dry potassium chloride obtained.

**(1)**

mass = ..... g

(ii) Calculate the mass of water removed.

**(1)**

mass = ..... g

(iii) Calculate the solubility of potassium chloride in grams per 100 grams of water.

**(2)**

solubility = ..... g per 100g of water

(iv) Suggest why the student's method is **not** suitable for determining the solubility of hydrated copper(II) sulfate.

**(1)**

.....

.....