UNIT 1

TOPIC 1: FORMULAE, EQUATIONS, AND AMOUNT OF SUBSTANCE

SECTION A

Answer ALL questions. Write your answers in the spaces provided.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

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1. There are 6.02×10^{23} atoms in 0.25 mol of

- ☒ **A** He
- ☒ **B** H_2O
- ☒ **C** BH_3
- ☒ **D** CH_4

2. Which aqueous solution has the **highest** concentration, in mol dm^{-3}, of chloride ions?

- ☒ **A** 0.1 g dm^{-3} HCl
- ☒ **B** 0.1 g dm^{-3} NaCl
- ☒ **C** 0.1 g dm^{-3} KCl
- ☒ **D** 0.1 g dm^{-3} $BaCl_2$

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3.

Which conversion has the **lowest** percentage atom economy (by mass) for the formation of $CaCl_2$?

- ☒ **A** $Ca + Cl_2 \rightarrow CaCl_2$
- ☒ **B** $Ca + 2HCl \rightarrow CaCl_2 + H_2$
- ☒ **C** $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$
- ☒ **D** $CaCO_3 + 2NaCl \rightarrow CaCl_2 + Na_2CO_3$

4.

Which of these compounds has the same empirical and molecular formulae?

- ☒ **A** C_2H_4
- ☒ **B** C_3H_8
- ☒ **C** C_4H_{10}
- ☒ **D** C_5H_{10}

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(Total for Question 1 = 1 mark)

5.

What is the relative formula mass of hydrated sodium carbonate, $Na_2CO_3.10H_2O$?

[A_r values: H = 1.0 C = 12.0 O = 16.0 Na = 23.0]

- ☒ **A** 106
- ☒ **B** 142
- ☒ **C** 263
- ☒ **D** 286

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6.

When $C_{20}H_{42}$ is cracked, each molecule produces one molecule of ethene, one molecule of butane and two molecules of hydrocarbon **E**.

What is the molecular formula of **E**?

- ☒ **A** C_7H_{13}
- ☒ **B** C_7H_{14}
- ☒ **C** $C_{14}H_{26}$
- ☒ **D** $C_{14}H_{28}$

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7.

Cyclohexene may be prepared by the dehydration of cyclohexanol.



cyclohexanol
$M_r = 100$

cyclohexene
$M_r = 82$

What mass of cyclohexene can be made from 12.5 g of cyclohexanol if the yield is 51.2%?

- ☒ **A** 5.25 g
- ☒ **B** 6.40 g
- ☒ **C** 7.80 g
- ☒ **D** 10.25 g

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8.

Which of these gases occupies 6.0 dm^3 at room temperature and pressure (r.t.p.)?

[molar volume of gas at r.t.p. = 24.0 dm^3 mol^{-1}

A_r values: He = 4.0 C = 12.0 N = 14.0 O = 16.0]

☒ **A** 2.0 g of helium

☒ **B** 4.0 g of oxygen

☒ **C** 11.0 g of carbon dioxide

☒ **D** 14.0 g of nitrogen

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9.

An oxide of lead contains 90.7 % by mass of lead.

What is the formula of this oxide?

[A_r values: O = 16.0 Pb = 207.2]

☒ **A** PbO

☒ **B** PbO_2

☒ **C** Pb_2O_3

☒ **D** Pb_3O_4

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10.

Propane burns completely in oxygen as shown.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$$

100 cm^3 of propane was mixed with 600 cm^3 of oxygen and the mixture was ignited.

What is the **total** volume, in cm^3, of the gas mixture at the end of the reaction?
All gas volumes were measured at room temperature and pressure.

- ☐ **A** 300
- ☐ **B** 400
- ☐ **C** 700
- ☐ **D** 800

11.

Which aqueous solution contains the greatest number of **ions**?

- ☐ **A** 200 cm^3 of 1.5 mol dm^{-3} $MgCl_2$
- ☐ **B** 400 cm^3 of 0.8 mol dm^{-3} $MgSO_4$
- ☐ **C** 500 cm^3 of 1.0 mol dm^{-3} NaCl
- ☐ **D** 1000 cm^3 of 0.25 mol dm^{-3} Na_2SO_4

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12.

A sample of seawater with a mass of 1 kg contains 6×10^{-9} g of gold.

How many atoms of gold, to one significant figure, are there in 1 g of this seawater?

[A_r value: Au = 197 Avogadro constant = 6×10^{23} mol^{-1}]

- ☐ **A** 2×10^{10}
- ☐ **B** 4×10^{12}
- ☐ **C** 2×10^{13}
- ☐ **D** 4×10^{15}

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13.

The maximum permitted concentration of sulfur in diesel fuel is 10 mg of sulfur in 1 kg of diesel fuel.

(a) What is this concentration of sulfur in ppm?

- ☒ **A** 0.00001
- ☒ **B** 0.01
- ☒ **C** 10
- ☒ **D** 10000

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(b) 3.2 kg of this diesel fuel is burned in air.

What is the maximum volume, in dm^3, of sulfur dioxide which can be produced, measured at room temperature and pressure (r.t.p.)?

[Molar volume of a gas at r.t.p. = 24 dm^3 mol^{-1}]

- ☒ **A** 0.024
- ☒ **B** 0.77
- ☒ **C** 2.4
- ☒ **D** 24

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14.

A mass of 0.23 g of sodium was added to 350 cm^3 water to form hydrogen and a solution of sodium hydroxide.

$$Na(s) + H_2O(l) \rightarrow NaOH(aq) + \tfrac{1}{2}H_2(g)$$

(a) What is the concentration, in mol dm^{-3}, of sodium hydroxide in the solution formed?

(1)

- ☒ **A** 0.010
- ☒ **B** 0.029
- ☒ **C** 0.29
- ☒ **D** 0.66

(b) What is the maximum volume, in cm^3, of hydrogen which could be formed, measured at r.t.p.?

[Molar volume of a gas at r.t.p. = 24 dm^3 mol^{-1}]

(1)

- ☒ **A** 120
- ☒ **B** 240
- ☒ **C** 480
- ☒ **D** 2800

(c) The sodium hydroxide solution was neutralised with sulfuric acid.

Which is the ionic equation for this reaction?

(1)

- ☒ **A** $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
- ☒ **B** $SO_4^{2-}(aq) + 2Na^+(aq) \rightarrow Na_2SO_4(aq)$
- ☒ **C** $H_2SO_4(aq) + 2Na^+(aq) + 2OH^-(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$
- ☒ **D** $2H^+(aq) + SO_4^{2-}(aq) + 2Na^+(aq) + 2OH^-(aq) \rightarrow 2Na^+(aq) + SO_4^{2-}(aq) + 2H_2O(l)$

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(d) Sodium hydroxide solution was added to magnesium sulfate solution.

The equation for the reaction is shown.

$$2NaOH(aq) + MgSO_4(aq) \rightarrow Mg(OH)_2(s) + Na_2SO_4(aq)$$

What is the atom economy (by mass) for the production of magnesium hydroxide?

[A_r values: H = 1.0 O = 16.0 Na = 23.0 Mg = 24.3 S = 32.1]

(1)

☒ **A** 29.1%

☒ **B** 41.0%

☒ **C** 48.4%

☒ **D** 50.0%

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15.

(c) What is the **total** number of ions present in 0.1 mol of the double salt?

[Avogadro constant (L) = 6.02×10^{23} mol^{-1}]

(1)

☒ **A** 1.80×10^{23}

☒ **B** 2.41×10^{23}

☒ **C** 3.01×10^{23}

☒ **D** 6.62×10^{23}

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16.

The concentration of nitrogen dioxide in a sample of air is 0.5 ppm.

What is the percentage of nitrogen dioxide molecules in this sample of air?

- ☒ **A** 0.5 %
- ☒ **B** 0.005 %
- ☒ **C** 0.00005 %
- ☒ **D** 0.0000005 %

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17.

The equation for the complete combustion of hexane is shown.

$$C_6H_{14} + 9\frac{1}{2}O_2 \rightarrow 6CO_2 + 7H_2O$$

How many molecules of carbon dioxide are formed when 2×10^{-3} mol of hexane undergoes complete combustion?

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

- ☒ **A** 1.20×10^{21}
- ☒ **B** 7.22×10^{21}
- ☒ **C** 8.43×10^{21}
- ☒ **D** 3.18×10^{23}

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18.

Iron(III) oxide is reduced by hydrogen in a two-step process.

Step 1: $3Fe_2O_3 + H_2 \rightarrow 2Fe_3O_4 + H_2O$

Step 2: $Fe_3O_4 + 4H_2 \rightarrow 3Fe + 4H_2O$

What is the maximum mass of iron that could be produced from 39.9 tonnes of Fe_2O_3?

[A_r values: H = 1.0 O = 16.0 Fe = 55.8]

- ☒ **A** 6.98 tonnes
- ☒ **B** 13.95 tonnes
- ☒ **C** 27.90 tonnes
- ☒ **D** 41.85 tonnes

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19.

Which of these solutions contains the greatest number of ions?

- ☒ **A** 20.0 cm^3 of 0.5 mol dm^{-3} KCl
- ☒ **B** 0.40 dm^3 of 0.03 mol dm^{-3} KCl
- ☒ **C** 10.0 cm^3 of 0.6 mol dm^{-3} $CaCl_2$
- ☒ **D** 0.15 dm^3 of 0.04 mol dm^{-3} $CaCl_2$

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20.

Potassium chlorate(V) decomposes on heating to form oxygen.

$$2KClO_3 \rightarrow 2KCl + 3O_2$$

What is the atom economy (by mass) for the formation of oxygen?

[A_r values: O = 16.0 Cl = 35.5 K = 39.1]

- ☒ **A** 13.1 %
- ☒ **B** 26.1 %
- ☒ **C** 39.2 %
- ☒ **D** 64.3 %

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21.

A sample of nitrogen gas contains 1.204×10^{22} molecules.

What is the mass of this sample?

[A_r N = 14.0 Avogadro constant (L) = 6.02×10^{23} mol^{-1}]

- ☒ **A** 0.14 g
- ☒ **B** 0.28 g
- ☒ **C** 0.56 g
- ☒ **D** 1.12 g

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22.

When magnesium oxide reacts with dilute sulfuric acid the equation is

$$MgO(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l)$$

What is the ionic equation for the reaction?

- ☒ **A** $MgO(s) + 2H^+(aq) + SO_4^{2-}(aq) \rightarrow Mg^{2+}(aq) + SO_4^{2-}(aq) + H_2O(l)$
- ☒ **B** $MgO(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2O(l)$
- ☒ **C** $Mg^{2+}(s) + SO_4^{2-}(aq) \rightarrow Mg^{2+}(aq) + SO_4^{2-}(aq)$
- ☒ **D** $O^{2-}(s) + 2H^+(aq) \rightarrow H_2O(l)$

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23.

A solution of sodium chloride, NaCl, is prepared by dissolving 10.0 g of the solid in distilled water and making the solution up to 250.0 cm^3.

What is the concentration of the solution, in mol dm^{-3}?

[M_r NaCl = 58.5]

- ☒ **A** 0.171
- ☒ **B** 0.684
- ☒ **C** 10.0
- ☒ **D** 40.0

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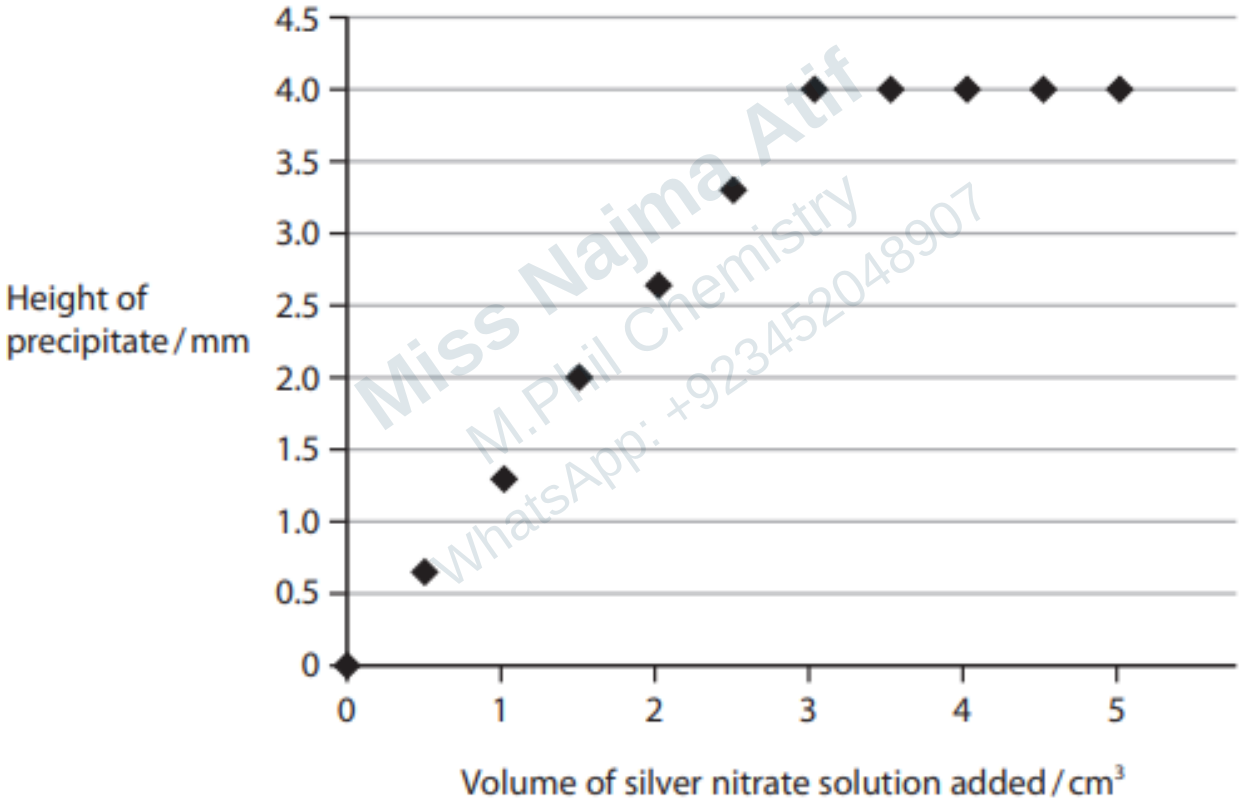
24.

5 Ten test tubes, each containing 1.0 cm^3 of a chromium chloride solution of concentration 0.1 mol dm^{-3}, were placed in a test tube rack.

Different volumes of silver nitrate solution of concentration 0.1 mol dm^{-3} were added to each test tube, giving a precipitate of silver chloride.

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

The precipitates formed were allowed to settle and their heights measured. The results were plotted on a graph.



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What is the formula of the chromium chloride?

- ☒ **A** $CrCl$
- ☒ **B** Cr_3Cl_4
- ☒ **C** Cr_4Cl_3
- ☒ **D** $CrCl_3$

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25.

Which mixture results in a displacement reaction?

- ☒ **A** iron and copper(II) sulfate solution
- ☒ **B** lead(II) nitrate solution and sodium iodide solution
- ☒ **C** dilute hydrochloric acid and sodium hydroxide solution
- ☒ **D** zinc and magnesium sulfate solution

26.

Which mixture results in a precipitation reaction?

- ☒ **A** dilute sulfuric acid and potassium hydroxide solution
- ☒ **B** iron and calcium chloride solution
- ☒ **C** chlorine water and potassium bromide solution
- ☒ **D** silver nitrate solution and potassium bromide solution

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27.

(b) A mixture of 40 cm^3 of butane and 20 cm^3 of oxygen reacts in a sealed system to form carbon monoxide and hydrogen.

What is the total volume of gas in the system at the end of the reaction, in cm^3?

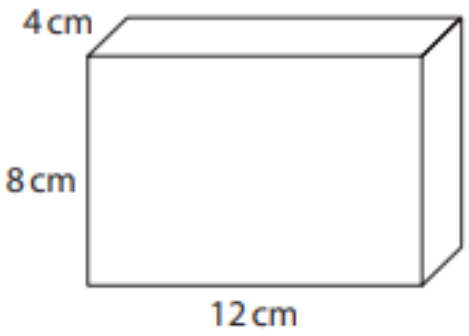
(1)

- ☒ **A** 30
- ☒ **B** 60
- ☒ **C** 90
- ☒ **D** 120

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28.

A piece of copper is shown.



How many moles of copper atoms are there in this piece of copper?

[Density of copper = 8.96 g cm^{-3}]

- ☒ **A** 0.675
- ☒ **B** 1.48
- ☒ **C** 6.05
- ☒ **D** 54.2

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29.

A mass of 4.08 g of hydrated copper(II) sulfate, $CuSO_4 \cdot 5H_2O$, was dissolved in deionised water to form 250 cm^3 of solution.

What is the concentration of the copper(II) sulfate solution formed, in mol dm^{-3}?

- ☒ **A** 0.0163
- ☒ **B** 0.0256
- ☒ **C** 0.0654
- ☒ **D** 0.102

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30.

A mass of 2.50 g of sodium chloride reacts with excess lead(II) nitrate solution forming lead(II) chloride with a yield of 95 %.

What is the mass of lead(II) chloride, $PbCl_2$, formed?

$$2NaCl + Pb(NO_3)_2 \rightarrow PbCl_2 + 2NaNO_3$$

[M_r values: NaCl = 58.5 $PbCl_2$ = 278.2]

- ☒ **A** 5.65 g
- ☒ **B** 5.94 g
- ☒ **C** 11.3 g
- ☒ **D** 11.9 g

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31.

Which compound contains 2.35×10^{22} molecules in 2.50 g?

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

M_r values: CO = 28.0 CO_2 = 44.0 SO_2 = 64.1 SO_3 = 80.1]

- ☒ **A** CO
- ☒ **B** CO_2
- ☒ **C** SO_2
- ☒ **D** SO_3

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32.

What is the concentration of hydroxide ions in a solution containing 5.00 g of $Ba(OH)_2$ in 250 cm^3?

[M_r $Ba(OH)_2 = 171.3$]

- ☒ **A** 0.0292 mol dm^{-3}
- ☒ **B** 0.0584 mol dm^{-3}
- ☒ **C** 0.1168 mol dm^{-3}
- ☒ **D** 0.2335 mol dm^{-3}

33.

A sample of 15.0 g of vanadium reacted completely with 7.07 g of oxygen.

What is the formula of the oxide?

[A_r values: V = 50.9 O = 16.0]

- ☒ **A** VO
- ☒ **B** V_2O_3
- ☒ **C** VO_2
- ☒ **D** V_2O_5

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34.

What is the pressure when 5.00 mol of nitrogen in a container with a volume of 1.50 m^3 is heated to 500 K?

[$pV = nRT$ $R = 8.31$ J K^{-1} mol^{-1}]

- ☒ **A** 13.9 Pa
- ☒ **B** 6 290 Pa
- ☒ **C** 13 900 Pa
- ☒ **D** 31 200 Pa

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35.

Which is the equation for the reaction of magnesium chloride solution with sodium hydroxide solution?

- ☒ **A** $Mg^{+}(aq) + OH^{-}(aq) \rightarrow MgOH(s)$
- ☒ **B** $Mg^{2+}(aq) + 2OH^{-}(aq) \rightarrow Mg(OH)_2(s)$
- ☒ **C** $MgCl(aq) + NaOH(aq) \rightarrow MgOH(aq) + NaCl(aq)$
- ☒ **D** $MgCl_2(aq) + 2NaOH(aq) \rightarrow Mg(OH)_2(aq) + 2NaCl(aq)$

36.

1 kg of seawater contains 64 mg of bromide ions.

[A_r of Br = 80 Avogadro constant, $L = 6.0 \times 10^{23}$ mol^{-1}]

(a) What is the concentration of bromide ions in parts per million (ppm) by mass?

(1)

- ☒ **A** 0.80
- ☒ **B** 64
- ☒ **C** 800
- ☒ **D** 64 000

(b) How many bromide ions are in 500 g of the sample?

(1)

- ☒ **A** 2.4×10^{20}
- ☒ **B** 4.8×10^{20}
- ☒ **C** 1.9×10^{22}
- ☒ **D** 3.8×10^{22}

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37.

0.15 mol of aluminium is added to 120 cm^3 of 1.50 mol dm^{-3} hydrochloric acid.

$$2Al(s) + 6H^+(aq) \rightarrow 2Al^{3+}(aq) + 3H_2(g)$$

The amount of **unused** reactant is

☒ **A** 0.06 mol aluminium

☒ **B** 0.09 mol aluminium

☒ **C** 0.03 mol hydrochloric acid

☒ **D** 0.13 mol hydrochloric acid

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38.

An organic compound contains 24.2 % carbon, 4.00 % hydrogen and 71.8 % chlorine by mass.

[A_r values: H = 1.0 C = 12.0 Cl = 35.5]

What is the empirical formula of the compound?

☒ **A** CHCl

☒ **B** CH_2Cl

☒ **C** $C_2H_4Cl_2$

☒ **D** $C_4H_4Cl_4$

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39.

Which solution contains the **smallest** number of ions?

- ☒ **A** 500 cm^3 of 0.06 mol dm^{-3} $Ca(NO_3)_2(aq)$
- ☒ **B** 500 cm^3 of 0.09 mol dm^{-3} $KI(aq)$
- ☒ **C** 250 cm^3 of 0.12 mol dm^{-3} $BaCl_2(aq)$
- ☒ **D** 250 cm^3 of 0.09 mol dm^{-3} $(NH_4)_2SO_4(aq)$

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40.

(b) 1.60 g of cyclohexa-1,4-diene is reduced to cyclohexane by reacting it with hydrogen gas.

[The molar volume of a gas is 24.0 dm^3 mol^{-1} at room temperature and pressure (r.t.p.)

M_r of cyclohexa-1,4-diene = 80]

What is the minimum volume, in dm^3, of hydrogen needed at r.t.p.?

(1)

- ☒ **A** 0.0400
- ☒ **B** 0.480
- ☒ **C** 0.960
- ☒ **D** 1.92

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41.

Excess calcium carbide and 10 g of water react to form the hydrocarbon ethyne, C_2H_2.

$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2$$

What is the mass of ethyne that forms, assuming a yield of 100 %?

[M_r values: $H_2O = 18.0$ $C_2H_2 = 26.0$]

(1)

☒ **A** 7.22 g

☒ **B** 14.4 g

☒ **C** 23.4 g

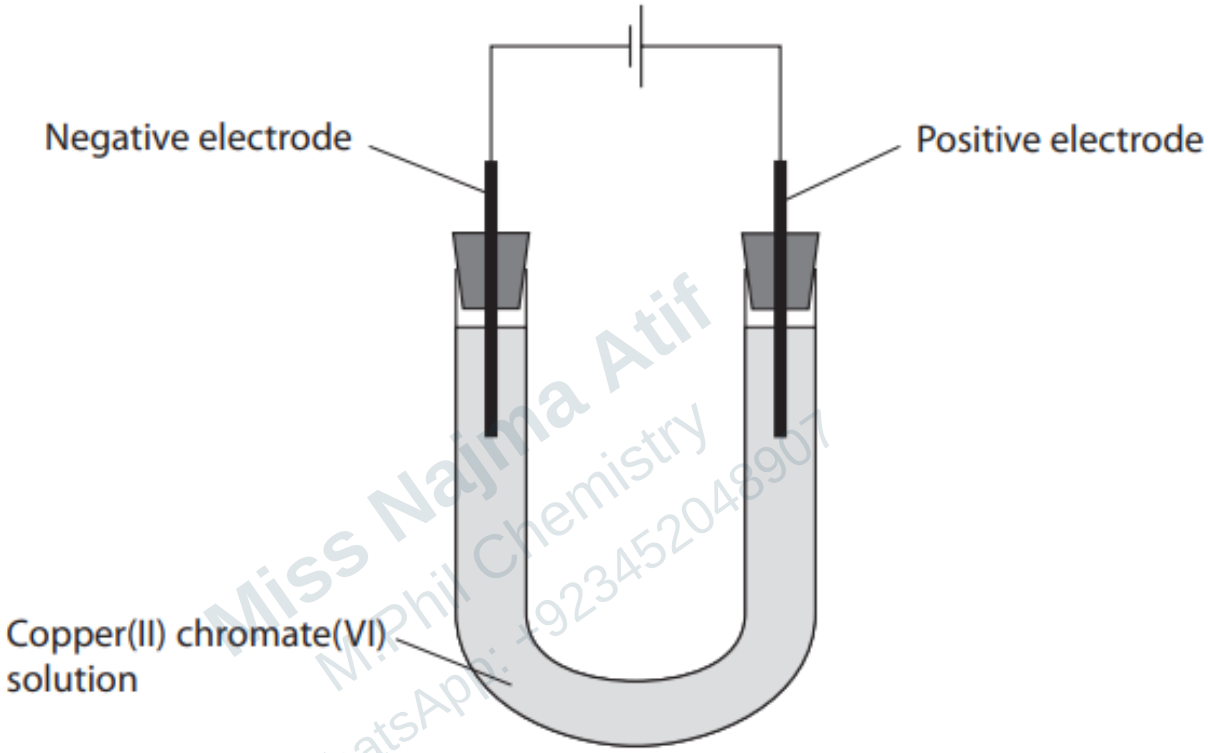
☒ **D** 28.9 g

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42.

A direct electrical current was passed through a green solution of copper(II) chromate(VI) in the apparatus shown.



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Which colours would be seen at each electrode after several minutes?

	Negative electrode	Positive electrode
☒ **A**	blue	green
☒ **B**	green	blue
☒ **C**	blue	yellow
☒ **D**	yellow	blue

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43.

Concentrations in mixtures can be given in units of parts per million (ppm).

(a) A sample of a gaseous mixture contains 2.19 % carbon dioxide by mass.

What is the concentration of carbon dioxide in parts per million (ppm) by mass in this sample?

(1)

☒ **A** 2.19×10^{6}

☒ **B** 2.19×10^{4}

☒ **C** 2.19×10^{-4}

☒ **D** 2.19×10^{-6}

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(b) A solution of lead nitrate has a concentration of 15 ppm by mass.

What is the mass of lead nitrate in 400 g of this solution?

(1)

☒ **A** 6.00×10^{-3} g

☒ **B** 6.00×10^{-6} g

☒ **C** 6.00×10^{-3} kg

☒ **D** 6.00×10^{0} kg

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44.

Which solution contains chloride ions with a concentration of 0.0500 mol dm^{-3}?

[A_r values: Ca = 40.1 Cl = 35.5 Na = 23.0]

	Solute	Mass of solute / g	Volume of solution / cm^3
☒ **A**	calcium chloride	1.39	250
☒ **B**	calcium chloride	1.39	500
☒ **C**	sodium chloride	1.46	250
☒ **D**	sodium chloride	1.46	1000

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45.

The formula of phosgene is $COCl_2$.
What is the total number of **atoms** in 9.9 g of phosgene?

[Avogadro constant (L) = 6.02×10^{23} mol^{-1} M_r value: $COCl_2$ = 99.0]

☒ **A** 1.51×10^{22}

☒ **B** 6.02×10^{22}

☒ **C** 1.81×10^{23}

☒ **D** 2.41×10^{23}

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46.

Which oxide of nitrogen contains 30% nitrogen by mass?

[A_r values: N = 14.0 O = 16.0]

- ☒ **A** NO
- ☒ **B** NO_2
- ☒ **C** N_2O
- ☒ **D** N_2O_3

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47.

Calculate the mass of sodium carbonate (Na_2CO_3) required to make up 250 cm^3 of a 0.100 mol dm^{-3} solution.

[A_r values: C = 12.0 O = 16.0 Na = 23.0]

- ☒ **A** 1.30 g
- ☒ **B** 2.65 g
- ☒ **C** 5.30 g
- ☒ **D** 10.6 g

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48.

A block of lead measuring 10 cm × 10 cm × 10 cm contains 3.295×10^{25} atoms.

Calculate the density of lead.

[A_r value: Pb = 207.2 Avogadro constant, $L = 6.02 \times 10^{23}\,mol^{-1}$]

- ☒ **A** $3.79\,g\,cm^{-3}$
- ☒ **B** $4.49\,g\,cm^{-3}$
- ☒ **C** $11.34\,g\,cm^{-3}$
- ☒ **D** $54.73\,g\,cm^{-3}$

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49.

An excess of sodium sulfate solution is added to $50\,cm^3$ of a $0.100\,mol\,dm^{-3}$ solution of barium chloride.

What is the mass of barium sulfate formed?

[M_r value: $BaSO_4$ = 233.4]

$$Na_2SO_4(aq) + BaCl_2(aq) \rightarrow 2NaCl(aq) + BaSO_4(s)$$

- ☒ **A** 1.167 g
- ☒ **B** 2.334 g
- ☒ **C** 11.67 g
- ☒ **D** 23.34 g

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50.

A sample of seaweed contains 30.0 mg of iodine per kg.

What is the number of iodine **atoms** in 10 kg of this seaweed?

[A_r value: I = 126.9 Avogadro constant $L = 6.02 \times 10^{23}\,mol^{-1}$]

- ☒ **A** 7.12×10^{19}
- ☒ **B** 1.42×10^{20}
- ☒ **C** 7.12×10^{20}
- ☒ **D** 1.42×10^{21}

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51.

The concentration of sulfur dioxide in a sample of polluted air is 0.4 ppm.

What is the percentage of sulfur dioxide molecules in this polluted air?

- ☒ **A** 0.4%
- ☒ **B** 0.004%
- ☒ **C** 0.00004%
- ☒ **D** 0.0000004%

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52.

How many **atoms** are there in 10 g of methane?

[A_r values: H = 1.0 C = 12.0 $L = 6.02 \times 10^{23}\,mol^{-1}$]

- ☒ **A** 3.76×10^{23}
- ☒ **B** 9.63×10^{23}
- ☒ **C** 1.88×10^{24}
- ☒ **D** 4.82×10^{24}

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53.

What is the maximum volume of butane that can be completely burned in 39 cm^3 of oxygen at room temperature and pressure?

$$C_4H_{10}(g) + 6.5O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$$

- ☒ **A** 6.0 cm^3
- ☒ **B** 12 cm^3
- ☒ **C** 24 cm^3
- ☒ **D** 45 cm^3

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54.

This question is about the production of ethanol by fermentation of glucose or by hydration of ethene.

(a) What is the percentage atom economy by mass for the production by fermentation?

$$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$$

(1)

- ☒ **A** 24.4%
- ☒ **B** 25.6%
- ☒ **C** 48.9%
- ☒ **D** 51.1%

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(b) What is the percentage atom economy by mass for the production by hydration?

$$C_2H_4 + H_2O \rightarrow CH_3CH_2OH$$

(1)

- ☒ **A** 39.1%
- ☒ **B** 60.9%
- ☒ **C** 78.2%
- ☒ **D** 100%

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55.

Which is the strongest **oxidising** agent in these displacement reactions?

$$Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$$

$$Br_2 + 2I^- \rightarrow 2Br^- + I_2$$

- ☒ **A** chlorine
- ☒ **B** bromide ions
- ☒ **C** bromine
- ☒ **D** iodide ions

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56.

Which pair of compounds will **not** react to form a precipitate?

- ☒ **A** $AgNO_3(aq)$ and $CaCl_2(aq)$
- ☒ **B** $Ca(OH)_2(aq)$ and $CO_2(g)$
- ☒ **C** $Ba(OH)_2(aq)$ and $HCl(aq)$
- ☒ **D** $KI(aq)$ and $Pb(NO_3)_2(aq)$

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57.

What is observed when iron(II) carbonate reacts with ethanoic acid?

- ☒ **A** colourless solution
- ☒ **B** colourless solution and effervescence
- ☒ **C** green solution and effervescence
- ☒ **D** green solution

58.

Which is the simplest ionic equation for an alkali reacting with an acid?

- ☒ **A** $2H^+(aq) + 2OH^-(aq) \rightarrow 2H_2O(l)$
- ☒ **B** $H^+(aq) + OH^-(aq) \rightarrow H_2O(aq)$
- ☒ **C** $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
- ☒ **D** $2H^+(aq) + O^{2-}(aq) \rightarrow H_2O(l)$

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59.

Magnesium azide is an ionic compound containing the azide ion, N_3^-.

The empirical formula of magnesium azide is

- ☒ **A** Mg_3N
- ☒ **B** MgN_2
- ☒ **C** MgN_3
- ☒ **D** MgN_6

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60.

How many oxygen **atoms** are there in 0.0100 mol of H_2SO_4?

[Avogadro constant, $L = 6.020 \times 10^{23}\ mol^{-1}$]

- ☒ **A** 6.020×10^{21}
- ☒ **B** 1.204×10^{22}
- ☒ **C** 2.408×10^{22}
- ☒ **D** 4.214×10^{22}

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61.

Two identical sealed flasks, containing different gases, are side by side. Each flask contains one gas, with the gases at the same temperature and pressure.

Flask **A** contains 4.0×10^{-3} mol of methane.

Flask **B** contains 160 mg of a different gas.

Which could be the gas in Flask **B**?

- ☒ **A** argon
- ☒ **B** carbon dioxide
- ☒ **C** helium
- ☒ **D** neon

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62.

Diphosphane, P_2H_4, reacts spontaneously with oxygen.

$$xP_2H_4 + yO_2 \rightarrow P_4O_{10} + zH_2O$$

The equation for this reaction is balanced when

- ☒ **A** $x = 1$ $y = 6$ $z = 2$
- ☒ **B** $x = 2$ $y = 6$ $z = 2$
- ☒ **C** $x = 2$ $y = 7$ $z = 4$
- ☒ **D** $x = 4$ $y = 9$ $z = 8$

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63.

Copper metal can displace silver from silver nitrate solution according to the equation shown.

$$Cu + 2AgNO_3 \rightarrow 2Ag + Cu(NO_3)_2$$

10 g of copper metal was added to an excess of silver nitrate solution.

The silver metal was collected, washed with deionised water and left to dry.

What is the mass of silver metal collected, assuming a 100% yield?

- ☒ **A** between 10 g and 20 g
- ☒ **B** 20 g
- ☒ **C** between 20 g and 40 g
- ☒ **D** more than 40 g

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64.

This question is about the thermal decomposition of calcium nitrate.

$$2Ca(NO_3)_2 \rightarrow 2CaO + 4NO_2 + O_2$$

What volume of gas is produced by the complete decomposition of 0.050 mol of calcium nitrate at room temperature and pressure (r.t.p.)?

[Molar volume of a gas at r.t.p. = 24 $dm^3 mol^{-1}$]

- ☒ **A** 600 cm^3
- ☒ **B** 1.20 dm^3
- ☒ **C** 3.00 dm^3
- ☒ **D** 6.00 dm^3

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65.

Ethanol is formed from glucose during fermentation.

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

What is the atom economy by mass for the formation of ethanol in this reaction?

- ☒ **A** 26%
- ☒ **B** 49%
- ☒ **C** 51%
- ☒ **D** 96%

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66.

The table shows some data about fundamental particles in an atom.

Particle	Mass / g
electron	0.0009×10^{-24}
neutron	1.6748×10^{-24}
proton	1.6725×10^{-24}

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(a) An atom of hydrogen can be represented as ^{1}H.

What is the mass, in grams, of this hydrogen atom?

(1)

- ☒ **A** 1.6725×10^{-24}
- ☒ **B** 1.6734×10^{-24}
- ☒ **C** 3.3473×10^{-24}
- ☒ **D** 3.3482×10^{-24}

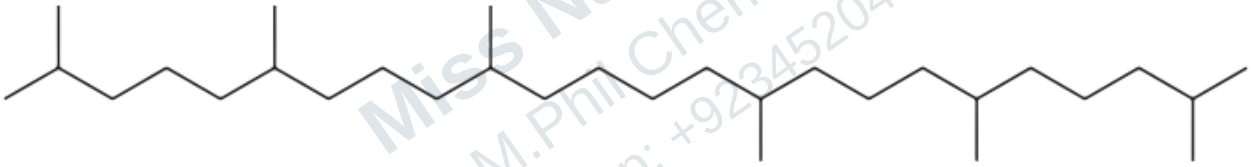
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SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

QUESTION NO 1:

This question is about the production of squalane, a liquid alkane which occurs naturally in human skin and is used in cosmetics.



squalane

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(b) Give the **molecular** formula of squalane.

(1)

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(ii) Squalane used in cosmetic products must contain no more than 0.2 ppm by mass of catalyst.

Calculate the maximum permitted mass of catalyst in a product containing 50 g of squalane.

(1)

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(iii) A reactor at 200°C contains 8500 mol of liquid squalene, and hydrogen gas at a pressure of 4.0×10^5 Pa.

Under these conditions, the complete hydrogenation of squalene requires 500 m^3 of hydrogen gas.

Calculate the number of C=C bonds in one molecule of squalene.

You **must** show your working.

[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}]

(4)

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(iv) Write the equation, using molecular formulae, for the complete hydrogenation of squalene to squalane.
State symbols are **not** required.

(1)

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(d) Globally, 2.8 million dm^3 of squalene is used each year.
Traditionally squalene was obtained exclusively from shark liver oil, which is a mixture of liquids.

The liver of a shark yields 300 g of squalene.

(i) Suggest the name of a suitable technique to obtain squalene from shark liver oil.

(1)

.....

(ii) Calculate the minimum number of sharks that would be needed to produce 2.8 million dm^3 of squalene.

[Density of squalene = 0.86 g cm^{-3}]

(2)

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(iii) Many large corporations now use squalane obtained entirely from plants.

Squalane can be obtained sustainably from corn starch with a yield of 23 % by mass.

The production of 1 tonne of corn starch requires 0.093 hectares of land.

Calculate the area of land, **in km^2**, required to produce 2500 tonnes of squalane from corn starch.

[1 tonne = 1000 kg 1 hectare = 0.01 km^2]

(3)

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TOTAL FOR QUESTION NO 1: 13

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QUESTION NO 2:

This question is about alkenes.

(a) An alkene has a molar mass of 112 g mol^{-1}.

Deduce the molecular formula of this alkene.

(1)

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(f) 0.0100 mol of an alkene reacts completely with exactly 600 cm^3 of hydrogen gas, measured at 298 K and 1.24×10^5 Pa pressure, to form an alkane.

Use the ideal gas equation to deduce the number of double bonds in **one** molecule of the alkene.
You **must** show your working.

[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}]

(4)

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QUESTION NO 3:

(c) Magnesium reacts with aqueous iron(II) sulfate in a displacement reaction.

Write the **ionic** equation for this reaction.
Include state symbols.

(2)

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(d) 25.00 g of a compound contains 6.98 g of iron and 6.03 g of sulfur.

The remaining mass is oxygen.

Calculate the **empirical** formula of this compound.

[A_r values: O = 16.0 S = 32.1 Fe = 55.8]

(3)

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(e) When 6.95 g of $FeSO_4.\mathbf{x}H_2O$ is heated, 2.00 g of iron(III) oxide, 0.80 g of sulfur dioxide and 1.00 g of sulfur trioxide are produced. The only other product is water.

Deduce the overall equation for the reaction using these data. State symbols are not required.

You **must** show your working.

[A_r values: H = 1.0 O = 16.0 S = 32.1 Fe = 55.8]

(5)

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TOTAL FOR QUESTION 3: 10

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QUESTION NO 4:

(c) Calcium silicate is formed in the removal of silicon dioxide impurities in the extraction of iron from its ores. A sample of calcium silicate composed of calcium, silicon and oxygen was found to contain 12.0 g of calcium, 8.43 g of silicon and 14.47 g of oxygen.

Determine the empirical formula of calcium silicate.
You **must** show your working.

(3)

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(d) Carbon dioxide is a gas at room temperature. A fizzy drink is canned at 5.0 °C and 1.3×10^5 Pa and contains approximately 3 g of carbon dioxide.

Calculate the volume, in cm^3, occupied by 3.00 g of carbon dioxide gas at 5.0 °C and 1.3×10^5 Pa.

[$pV = nRT$ $R = 8.31\ J\,mol^{-1}\,K^{-1}$]

(4)

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TOTAL FOR QUESTION 4: 7

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QUESTION NO 5:

(e) (i) Butane is used as a fuel.

The equation for the complete combustion of butane is shown.

$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$$

35.0 cm^3 butane is completely burned in 300 cm^3 oxygen.

Calculate the final total volume of gas in cm^3.

All volumes are measured at the same temperature and pressure.

(3)

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QUESTION NO 6:

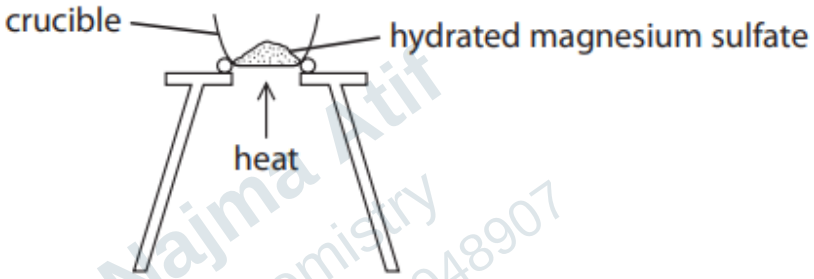
This question is about the amount of water of crystallisation in hydrated magnesium sulfate, $MgSO_4 \cdot \mathbf{x} H_2O$.

(a) The value of **x** in the formula was determined in an experiment.

Procedure

Step **1** A crucible was weighed, a spatula measure of hydrated magnesium sulfate was added and the crucible was reweighed.

Step **2** The crucible containing the hydrated magnesium sulfate was heated using the apparatus shown.



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Step **3** After heating for two minutes, the crucible containing the magnesium sulfate was allowed to cool and was reweighed.

(i) Complete the table of results.

(1)

Measurement	Mass / g
Mass of empty crucible	21.21
Mass of crucible and hydrated magnesium sulfate before heating	26.71
Mass of crucible and magnesium sulfate after heating for two minutes	24.12
Mass of magnesium sulfate after heating for two minutes	
Mass of water lost	

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(ii) Use these results to calculate the value of **x** in $MgSO_4 \cdot \mathbf{x} H_2O$.
Give your answer to the nearest whole number.

[A_r values: H = 1.0 O = 16.0 Mg = 24.3 S = 32.1]

(4)

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(b) The correct value of **x** is greater than the value calculated in (a) (ii).

Suggest a way of improving the method to obtain a more accurate result, using the same apparatus.
Justify your answer.

(2)

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QUESTION NO 7:

(iv) The relative atomic mass of copper in this sample is 63.4.

Calculate the percentage abundances of the isotopes ^{63}Cu and ^{65}Cu in this sample.
You **must** show your working.

(2)

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(c) Copper(II) sulfate, $CuSO_4$, can be made by reacting solid copper(II) carbonate with dilute sulfuric acid.

(i) Write an equation for the reaction that occurs.
State symbols are not required.

(1)

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(ii) An experiment was carried out to produce pure, dry crystals of hydrated copper(II) sulfate, $CuSO_4 \cdot 5H_2O$.
Copper(II) carbonate was mixed with 50.0 cm^3 of 1.00 mol dm^{-3} sulfuric acid until no more reacted.
The mass of $CuSO_4 \cdot 5H_2O$ obtained was 10.87 g.

Calculate the percentage yield for this reaction, giving your answer to an appropriate number of significant figures.

[Molar mass of $CuSO_4 \cdot 5H_2O$ = 249.6 g mol^{-1}]

(4)

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TOTAL MARKS FOR QUESTION 7: 7

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QUESTION NO 8:

A 0.210 g sample of a volatile organic liquid **C** is injected into a gas syringe and heated in an oven.
At 100 kPa and 358 K, the syringe contains 72.5 cm^3 of gas.

(a) Calculate the molar mass of **C**.

[$pV = nRT$ $R = 8.31\ J\,mol^{-1}\,K^{-1}$]

(4)

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(b) The organic liquid **C** is a hydrocarbon.

Give a possible name or formula for **C**, using your answer in (a).

(1)

TOTAL FOR QUESTION NO 8: 5

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QUESTION NO 9:

The element iron forms two chlorides: iron(II) chloride, $FeCl_2$, and iron(III) chloride, $FeCl_3$.

(a) A known mass of iron powder is added to 200 cm^3 of a hot solution of iron(III) chloride with a concentration of 0.500 mol dm^{-3}. When the reaction is complete, the solution only contains iron(II) chloride.
The unreacted iron is filtered, dried and weighed.

Initial mass of iron powder = 6.17 g
Final mass of iron powder = 3.38 g

(i) Calculate the number of moles of iron that react.

(2)

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(ii) Calculate the number of moles of iron(III) chloride that react.

(2)

(iii) Use your answers to (a)(i) and (a)(ii) to write the **ionic** equation for the reaction of iron with iron(III) chloride. Include state symbols.
You **must** show your working.

(3)

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(b) The concentration of the solution obtained in (a) is increased by heating it gently to remove some of the water. The solution is allowed to cool and pale green crystals of a hydrated iron(II) chloride, $FeCl_2 \cdot xH_2O$, form.
Analysis shows that these crystals contain 28.1% by mass of iron.

Calculate the number of moles of water of crystallisation, x, per mole of hydrated iron(II) chloride.

(4)

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TOTAL FOR QUESTION 9: 11 MARKS

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QUESTION NO 10:

(ii) 2.0 mol of zingiberene react completely with hydrogen at 150 °C and a pressure of 120 kPa.

Calculate the minimum volume of hydrogen needed under these conditions, stating your units.

[Ideal gas equation is $pV = nRT$ Gas constant (R) = 8.31 J mol^{-1} K^{-1}]

(4)

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QUESTION NO 11:

(ii) Calculate the mass of barium chloride needed to form 150 cm^3 of $BaCl_2(aq)$ with a concentration of 0.200 mol dm^{-3}.

Give your answer to an appropriate number of significant figures.

(2)

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(iii) The barium chloride solution is acidified to prevent carbonate ions giving a false positive result.

Write the **ionic** equation for the reaction of hydrochloric acid with carbonate ions. State symbols are not required.

(1)

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QUESTION NO 12:

(d) Another component of petrol, compound **X**, contains 92.3 % carbon and 7.7 % hydrogen by mass.

(i) Calculate the empirical formula of compound **X**.
You must show all your working.

(2)

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(ii) A sample of compound **X** has a mass of 0.267 g and vaporises at 85.0 °C and 104 kPa to produce a gaseous sample with a volume of 98.0 cm^3.

Calculate the molar mass of compound **X**.
You must show all your working.

[$pV = nRT$ $R = 8.31\ J\,mol^{-1}\,K^{-1}$]

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(iii) Deduce the molecular formula of compound **X**, using your answers to (d)(i) and (d)(ii).

(1)

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QUESTION NO 13:

(d) Germane is a compound with the formula GeH_4.

It can be formed by the reaction shown.

$$Na_2GeO_3 + NaBH_4 + H_2O \rightarrow GeH_4 + 2NaOH + NaBO_2$$

(i) Calculate the atom economy, by mass, for the formation of germane.
Use A_r of Ge = 72.6

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(iv) Germane is toxic and the maximum permitted concentration is $0.640\,mg\,m^{-3}$ in air.

Calculate the maximum number of germane molecules permitted in a laboratory with a volume of $231\,m^3$.

[Avogadro constant (L) = $6.02 \times 10^{23} mol^{-1}$]

(4)

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(e) A halide of germanium, GeX_4, reacts with water as shown.

$$GeX_4 + 2H_2O \rightarrow GeO_2 + 4HX$$

1.50 g of GeX_4 was added to excess water.
The insoluble GeO_2 was removed by filtration.
The solution of hydrogen halide formed was then added to excess magnesium carbonate, forming 335.5 cm^3 of carbon dioxide at room temperature and pressure (r.t.p.).

$$MgCO_3 + 2HX \rightarrow MgX_2 + CO_2 + H_2O$$

[Molar volume of a gas at r.t.p. = 24 000 $cm^3 mol^{-1}$]

(i) Calculate the number of moles of carbon dioxide formed.

(1)

(ii) Deduce the number of moles of HX formed when GeX_4 reacted with the excess water.

(1)

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(iii) Deduce the number of moles of GeX_4 that reacted with the excess water.

(1)

(iv) Calculate the molar mass of GeX_4 and hence identify X.

(2)

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QUESTION NO 14:

(ii) Orange peel contains 1.63 % of limonene by mass.

A chewing gum remover contains 30 cm^3 of limonene per bottle.

Calculate the mass of orange peel, in kg, needed to obtain 30 cm^3 of limonene.

[Density of limonene = 0.841 $g\,cm^{-3}$]

(3)

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QUESTION NO 15:

(b) Hospital patients sometimes need to breathe air with a higher than normal concentration of oxygen.
The oxygen concentration can be increased to 90 % by passing dry air through a tube filled with zeolite which adsorbs most of the nitrogen.

(i) Dry air contains 21.0 % oxygen by volume.
The average human breath has a volume of 500 cm^3.

Calculate the volume of air, in dm^3, that would have to pass over the zeolite to obtain 500 cm^3 of gas containing 90 % oxygen by volume.

(2)

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(c) Liquid oxygen is transported across the world.
Liquid oxygen has a density of 1140 g dm^{-3}.

(i) Calculate the volume of gas, **in m^3**, measured at room temperature and pressure (r.t.p.) that can be obtained from a bottle containing 13.9 dm^3 of liquid oxygen.

(4)

[Molar volume at r.t.p. = 24.0 dm^3 mol^{-1}]

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(ii) The total mass of the bottle is 80.0 kg when it is full of oxygen.

Calculate the mass of an empty bottle, using your working from (c)(i).
Give your answer to an appropriate number of significant figures.

(1)

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(iii) Explain why the container needs to have such a large mass.

(2)

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QUESTION NO 16:

(b) Aluminium trichloride reacts vigorously with water to produce hydrogen chloride and aluminium hydroxide, $Al(OH)_3$.

Write the equation for this reaction.
State symbols are not required.

(1)

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(c) Aluminium trichloride also reacts with sodium hydroxide.

$$AlCl_3(g) + 3NaOH(aq) \rightarrow Al(OH)_3(s) + 3NaCl(aq)$$

Calculate the maximum mass of aluminium hydroxide precipitated when excess aluminium trichloride reacts with 150 cm^3 of 1.5 mol dm^{-3} sodium hydroxide.

(3)

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QUESTION NO 17:

(a) Barium chloride, $BaCl_2$, can be prepared by the reaction of barium carbonate with hydrochloric acid.

$$BaCO_3(s) + 2HCl(aq) \rightarrow BaCl_2(aq) + CO_2(g) + H_2O(l)$$

(i) Write the ionic equation for this reaction.
State symbols are not required.

(1)

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(ii) Calculate the atom economy by mass for this preparation of barium chloride.

[A_r values: H = 1.0 C = 12.0 O = 16.0 Cl = 35.5 Ba = 137.3]

(2)

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(b) Barium chloride reacts with Group 1 sulfates, M_2SO_4.

$$M_2SO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + 2MCl(aq)$$

A solution is made by dissolving 7.98 g of a Group 1 sulfate in deionised water.

Excess aqueous barium chloride is added to this solution and the precipitate is filtered, dried and weighed.

The mass of the barium sulfate precipitate is 10.72 g.

Identify the Group 1 element.

[A_r values: Ba = 137.3 S = 32.1 O = 16.0]

(4)

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QUESTION NO 18:

(b) The half-equations for the electrolysis reactions are shown.

Negative electrode $2Al^{3+} + 6e^- \rightarrow 2Al$

Positive electrode $3O^{2-} \rightarrow 1½O_2 + 6e^-$

The oxygen produced reacts with the graphite electrode.

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

(i) Calculate the maximum volume, in dm^3, of CO_2, measured at r.t.p. which could be produced when 1.00 kg aluminium is extracted using this process.

[The molar volume of a gas is 24.0 dm^3 mol^{-1} at r.t.p.]

(4)

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QUESTION NO 19:

(b) Butane, C_4H_{10}, is found in the refinery gases fraction of crude oil.
It is used as a propellant in pharmaceutical inhalers.
An inhaler that provides a total of 120 doses contains 1.55 g of butane.

Calculate the volume, in cm^3, of propellant used for each dose at 25 °C and 100 kPa.

Use the ideal gas equation and give your answer to an appropriate number of significant figures.

[$pV = nRT$ $R = 8.31\ J\ K^{-1}\ mol^{-1}$]

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QUESTION NO 20:

This question is about minerals containing metallic elements.

(a) The green mineral zaratite contains basic nickel(II) carbonate, $Ni_3CO_3(OH)_4 \cdot 4H_2O$.

Basic nickel(II) carbonate can be formed by the reaction of nickel(II) sulfate with sodium carbonate under alkaline conditions, as shown.

$$3NiSO_4(aq) + Na_2CO_3(aq) + 4NaOH(aq) + 4H_2O(l) \rightarrow Ni_3CO_3(OH)_4 \cdot 4H_2O(s) + 3Na_2SO_4(aq)$$

[A_r values: H = 1.0 C = 12.0 O = 16.0 Na = 23.0 S = 32.1 Ni = 58.7]

(i) Calculate the relative formula mass of basic nickel(II) carbonate, $Ni_3CO_3(OH)_4 \cdot 4H_2O$.

(1)

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(ii) Calculate the atom economy by mass for the formation of basic nickel(II) carbonate by the reaction shown.

(2)

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(iii) Give the reason why use of the term 'relative molecular mass' is not appropriate in (a)(i).

(1)

.....

.....

.....

.....

(b) Chemists often simplify full chemical equations into ionic equations by removing spectator ions.

(i) Give the electronic configuration of the nickel ion present in nickel(II) compounds.

(1)

.....

(ii) Write the **ionic** equation for the formation of basic nickel(II) carbonate from nickel(II) sulfate.
State symbols are not required.

$$3NiSO_4(aq) + Na_2CO_3(aq) + 4NaOH(aq) + 4H_2O(l) \rightarrow Ni_3CO_3(OH)_4 \cdot 4H_2O(s) + 3Na_2SO_4(aq)$$

(1)

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(c) Another basic carbonate found in minerals contains the metal element **X** and is formed by the reaction shown.

$$2\mathbf{X}SO_4 + 2Na_2CO_3 + H_2O \rightarrow \mathbf{X}_2CO_3(OH)_2 + 2Na_2SO_4 + CO_2$$

1.995 g of $\mathbf{X}SO_4$ is reacted with excess Na_2CO_3 forming 150.0 cm^3 of carbon dioxide gas, CO_2, at room temperature and pressure, r.t.p.

[Molar volume of a gas at r.t.p. = 24.0 $dm^3\,mol^{-1}$]

(i) Calculate the relative formula mass of $\mathbf{X}SO_4$, using these data.

(4)

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(ii) Deduce the identity of **X**, using your answer to (c)(i).

(1)

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QUESTION NO 21:

(d) Magnesium sulfate can be made by reacting magnesium with dilute sulfuric acid.

(i) Write an equation for the reaction that occurs.
Include state symbols in your answer.

(2)

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QUESTION NO 22:

(e) Hydrated crystals of magnesium sulfate, $MgSO_4 \cdot 7H_2O$, can be made by reacting magnesium with sulfuric acid.
In an experiment, magnesium was added to $30.0\,cm^3$ of $0.500\,mol\,dm^{-3}$ sulfuric acid.

[M_r value: $MgSO_4 \cdot 7H_2O = 246.4$ A_r value: Mg = 24.3]

(i) Calculate the number of moles of sulfuric acid used in this experiment.

(1)

(ii) Calculate the mass of magnesium needed to react with the sulfuric acid.

(1)

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(v) The magnesium sulfate solution was allowed to crystallise.
The crystals were dried and weighed.
The mass of the hydrated crystals, $MgSO_4 \cdot 7H_2O$, was 2.78 g.
Calculate the percentage yield in this experiment.

(2)

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QUESTION NO 23:

Boric acid is a white solid often used as an antiseptic.

(a) Boric acid contains 17.48% by mass of boron, 77.67% of oxygen and the remainder is hydrogen. The molar mass of boric acid is 61.8 g mol^{-1}.
[A_r values: H = 1 B = 10.8 O = 16]

Show that the molecular formula of boric acid is H_3BO_3.

You must show all your working.

(4)

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QUESTION NO 24:

The density of an unknown gas is 0.656 g dm^{-3} at 20°C and 101 000 Pa.
[$pV = nRT$ $R = 8.31\ J\ mol^{-1}\ K^{-1}$]

(a) Calculate the molar mass of the unknown gas.

(5)

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(b) The unknown gas is a hydrocarbon.

Give the name or formula for the unknown gas using your answer to (a).

(1)

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QUESTION NO 25:

This question is about silver.

(a) Silver chloride decomposes in light. This reaction was used in the first photographic plates.

Write an equation for this decomposition.
Include state symbols.

(2)

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(b) Silver can form in displacement reactions.

(i) State **two** observations that are made when copper metal is added to silver nitrate solution.

(2)

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(ii) Write an equation for this displacement reaction.
Include state symbols.

(2)

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QUESTION NO 26:

Baking powder is added to cake mixtures to make cakes 'rise' by releasing a gas during cooking.

Baking powder contains an acidic derivative of tartaric acid and about 30% by mass of sodium hydrogencarbonate.

Baking powder releases the gas in two types of reaction during cooking, one of which is neutralisation.

(a) (i) Give the name of the second type of reaction.

(1)

.....

(ii) Suggest why neutralisation does not occur in an unopened container of baking powder.

(1)

.....

.....

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(b) (i) The acidic derivative of tartaric acid contains 20.8% potassium, 25.5% carbon, 2.66% hydrogen by mass and the rest is oxygen.

Calculate the empirical formula.

(2)

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(ii) The acidic derivative of tartaric acid can be represented by the formula $H^+K^+A^{2-}$.

Write the equation for the neutralisation of sodium hydrogencarbonate by $H^+K^+A^{2-}$.

State symbols are not required.

(2)

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(iii) Calculate the maximum volume, in **cm^3**, of carbon dioxide gas released by the neutralisation reaction in (b)(ii) from 5.00 g of baking powder, in an oven at 190°C at 101 000 Pa.

Baking powder contains 30% sodium hydrogencarbonate by mass.
[$pV = nRT$]

(5)

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(iv) Calculate the decrease in volume when the carbon dioxide gas is cooled to 20°C.

(2)

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QUESTION NO 27:

Sodium hydroxide can be obtained as a hydrate, $NaOH \cdot xH_2O$.
When heated, the water of crystallisation is lost, leaving anhydrous sodium hydroxide, NaOH, as shown in the equation.

$$NaOH \cdot xH_2O \rightarrow NaOH + xH_2O$$

An experiment was carried out to determine the value of x in $NaOH \cdot xH_2O$.

Procedure

Step **1** Weigh and record the mass of a clean, dry crucible.

Step **2** Add approximately 1.0 g of $NaOH \cdot xH_2O$ to the crucible and record the mass.

Step **3** Heat the crucible and its contents until a constant mass has been reached.

Step **4** After allowing to cool, reweigh the crucible and the anhydrous solid.

Step **5** Calculate and record the mass of the anhydrous solid.

Repeat Steps **1** to **5** using a different mass of the hydrated sodium hydroxide.

Results

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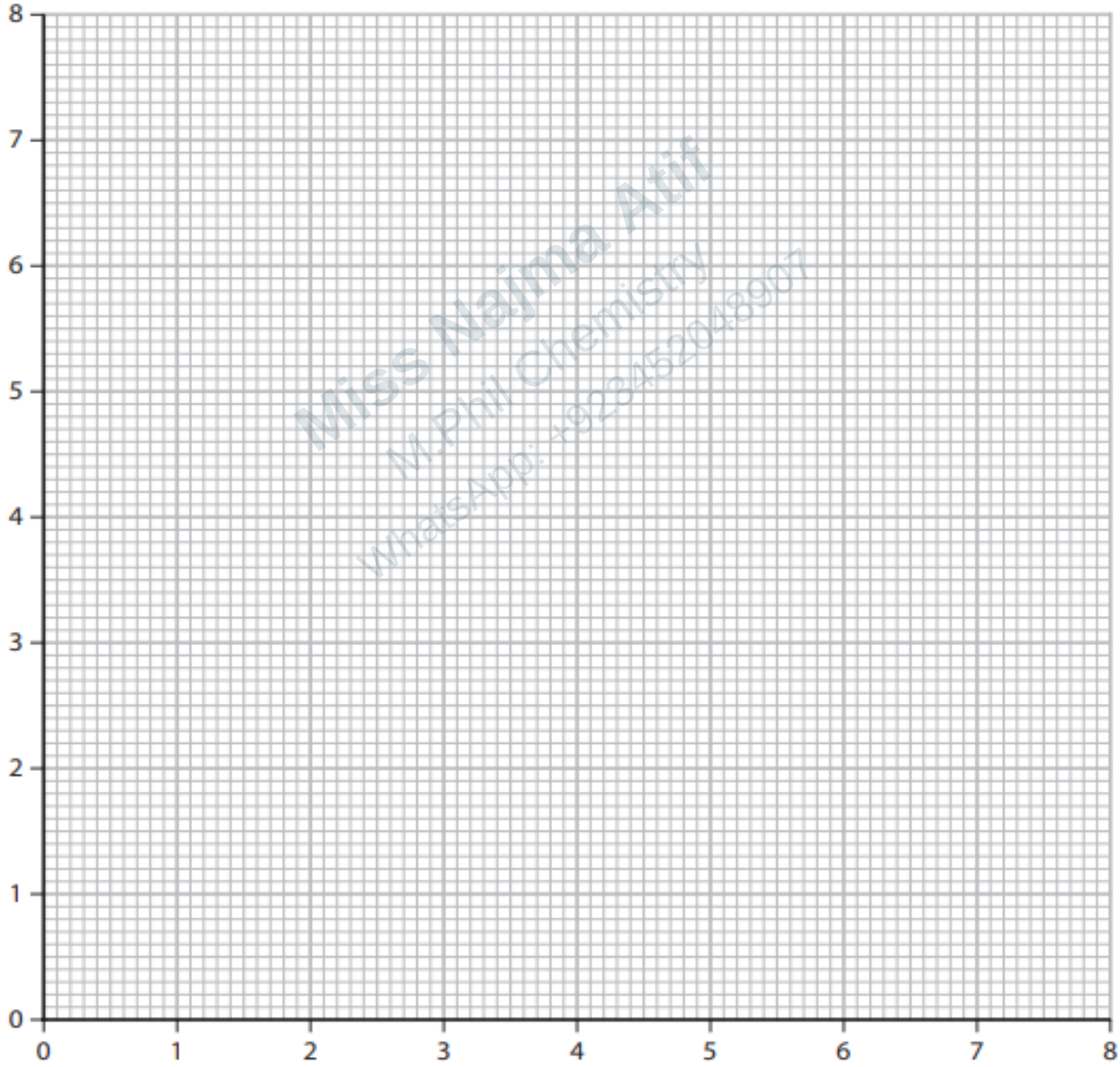
Mass of $NaOH \cdot xH_2O$ / g	Mass of NaOH / g
1.00	0.69
2.10	1.45
3.50	2.41
4.90	3.38
6.60	4.55
8.00	5.52

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(a) (i) Complete a graph of the results by

- plotting the points
- labelling the axes
- including a straight line of best fit.

(3)



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(ii) Use your graph to determine the mass of $NaOH \cdot xH_2O$ needed to form 4.0 g of NaOH. You must show your working on the graph.

(1)

.....

(iii) Calculate the value of x in $NaOH \cdot xH_2O$ using your answer to (a)(ii) and the equation for the reaction.

$$NaOH \cdot xH_2O \rightarrow NaOH + xH_2O$$

(3)

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(b) Sodium hydroxide also forms a heptahydrate, $NaOH \cdot 7H_2O$.

Calculate the mass of this heptahydrate needed to make 250 cm^3 of a solution of sodium hydroxide of concentration 0.150 $mol\,dm^{-3}$.

(2)

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QUESTION NO 28:

(iii) One of the chlorinated compounds contains 44.1% carbon and 6.9% hydrogen by mass.

Calculate the molecular formula of this compound.

(3)

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QUESTION NO 29:

(b) Aluminium chloride is a solid at room temperature.
At the relatively low temperature of 453 K it sublimes.

(i) A sample of 5.00 g of aluminium chloride was heated to 455 K at a pressure of 1.01×10^5 Pa.
When all the aluminium chloride had vaporised, the final volume of gas was 700 cm^3.

Show that the data is consistent with the formula of aluminium chloride in the gas phase being Al_2Cl_6.

[Gas constant $R = 8.31\ J\,mol^{-1}\,K^{-1}$ Ideal gas equation $pV = nRT$]

(3)

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