Section A (70 marks)
Answer all the questions.

1 **(a)** Some chemical equations, **A** to **F**, are shown.

A $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$
B $CO_3^{2-}(aq) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l)$
C $Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$
D $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
E $2I^-(aq) + Br_2(aq) \rightarrow I_2(aq) + 2Br^-(aq)$
F $NH_4^+(aq) + OH^-(aq) \rightarrow H_2O(l) + NH_3(aq)$

Answer the following questions using the equations.

Each equation may be used once, more than once or not at all.

Give the letter, **A** to **F**, for the equation which shows:

(i) the formation of a gas that turns moist red litmus paper blue

.... [1]

(ii) a reaction that forms a white precipitate

.... [1]

(iii) a displacement reaction

.... [1]

(b) Ammonium ion, NH_4^+, is a polyatomic ion. Ammonium ion is formed when ammonia reacts with hydrogen ion.

The nitrogen atom in ammonia contributes and donates a pair of valence electrons to one hydrogen ion to form a covalent bond.

Draw a 'dot and cross' diagram to show the covalent bonding in ammonium ion using the key provided.

Show outer electrons only.

Key:

x : electron of hydrogen

• : electron of nitrogen

[2]

[Total: 5]

2 Copper is a transition element. The flowchart in Fig. 2.1 shows how copper can be made from copper(II) carbonate, either in the industry, or on a small scale in the laboratory.

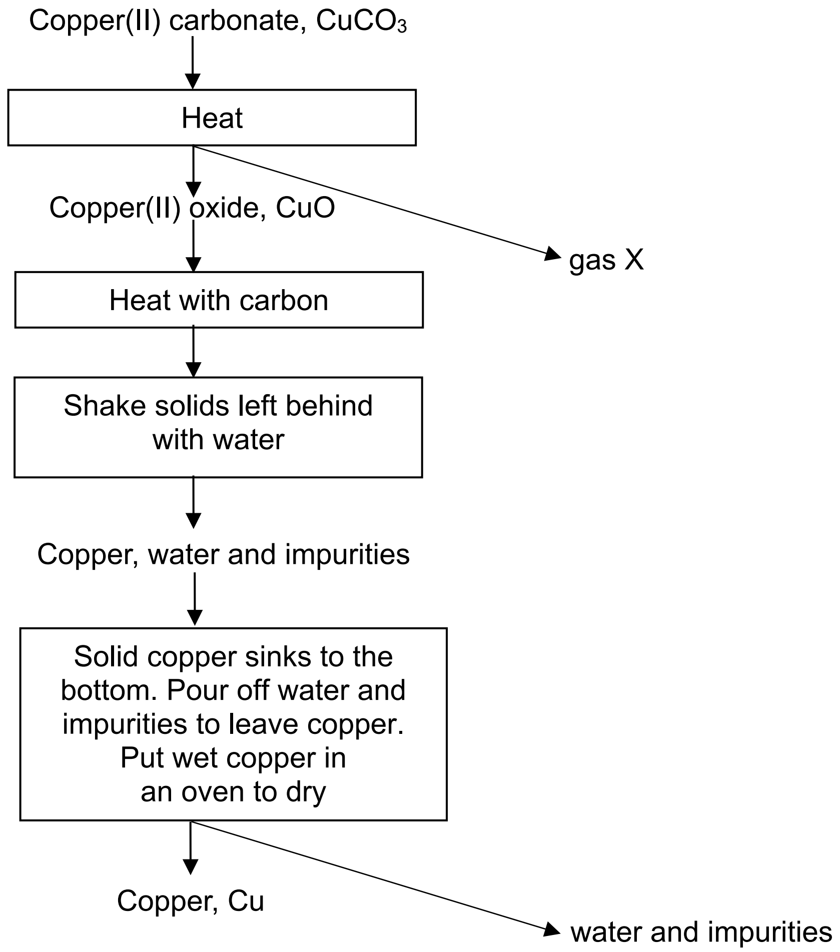


Fig. 2.1

(a) **(i)** Identify gas X.

.... [1]

(ii) State the type of reaction that takes place when copper(II) oxide is heated with carbon.

.... [1]

(iii) Write an equation for the reaction in **(a)(ii)**.

.... [1]

(b) Jane uses the procedure in the flowchart to make copper in the laboratory. She uses the following graph shown in Fig. 2.2 to predict the theoretical yield of copper.

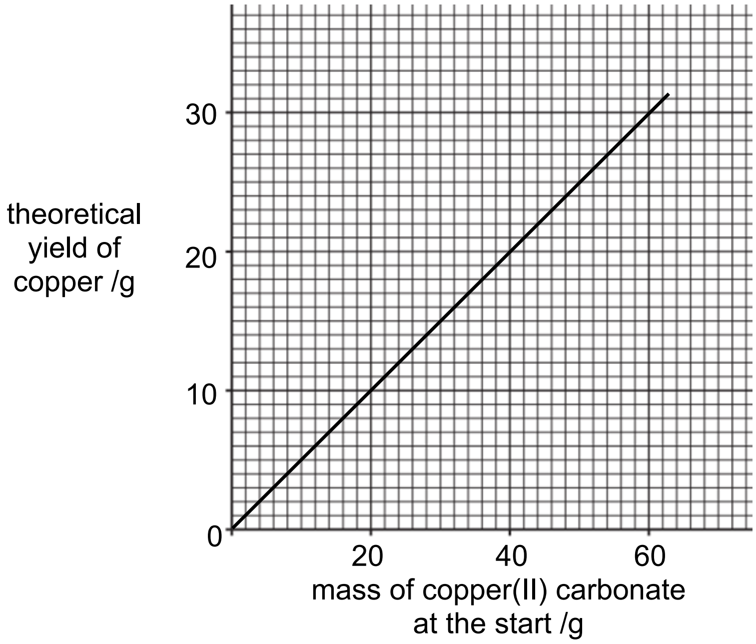


Fig. 2.2

(i) Explain why the line on the graph in Fig. 2.2 starts at 0 on both axes.

....

.... [1]

(ii) Jane wants to make a theoretical yield of 40.0 g of copper.

Using the graph in Fig. 2.2, predict the starting mass of copper(II) carbonate she should use. Explain your answer.

....

....

....

.... [2]

(iii) Jane conducts the experiment. The mass of copper that she obtained is higher than the maximum yield of 40.0 g.

Which two mistakes could lead to an incorrectly high yield?

Tick (✓) **two** boxes.

She did not use enough copper carbonate. ☐

She did not dry the copper at the end. ☐

She did not heat the copper oxide for long enough. ☐

She used copper that contains solid impurities. ☐

[2]

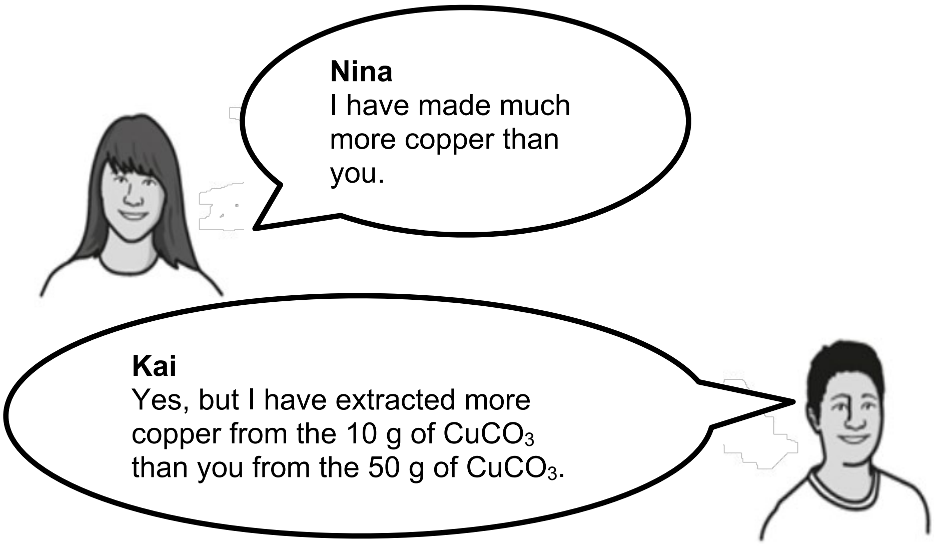
(c) Nina and Kai also follow the flowchart to make some copper.

They compare the mass of copper they make at the end with each other as shown in Table 2.1.

Table 2.1

Student	Mass of copper(II) carbonate at the start / g	Theoretical yield of copper / g	Mass of copper made / g
Nina	50.0	26.0	18.0
Kai	10.0	5.0	4.8

They make statements about their results.



Using the data in Table 2.1, explain why Kai is correct with the help of chemical calculations.

[2]

[Total: 10]

3 Magnesium is one of the most abundant elements on Earth. It is used extensively in the production of magnesium-aluminum alloys. It is produced by the electrolysis of molten magnesium chloride. A schematic diagram of the electrolytic cell is shown in Fig 3.1.

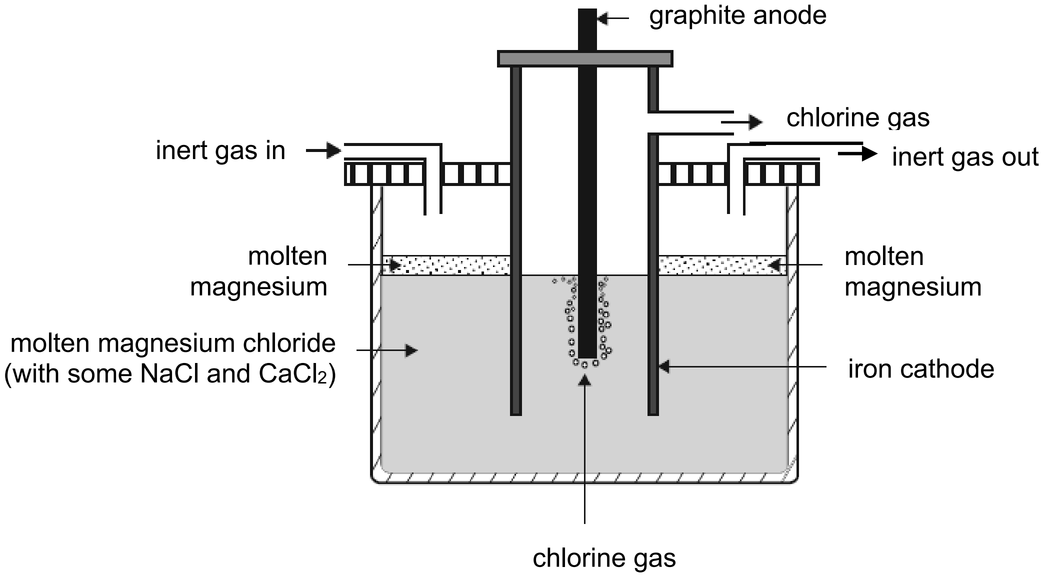


Fig. 3.1

(a) Write a balanced half-equation for the reactions occurring at the

Cathode: .... [1]

Anode: .... [1]

(b) Explain why an inert gas is constantly blown through the surface of the molten magnesium.

....

.... [1]

(c) Explain why it is necessary to lower the melting point of magnesium chloride by adding sodium chloride and calcium chloride.

....

....

....

.... [1]

(d) The graphite anode is now replaced with an iron rod.

With the help of a half-equation, explain the difference in the observation at the anode.

....

....

....

....

.... [2]

[Total: 6]

4 Propanone, CH_3COCH_3, reacts with iodine, I_2, to form colourless products.

The reaction is catalysed by hydrochloric acid.

Table 4.1 shows how the relative rate of this reaction changes when different concentrations of propanone, iodine and hydrochloric acid are used.

Table 4.1

experiment	concentration of CH_3COCH_3 in mol/dm^3	concentration of I_2 in mol/dm^3	concentration of HCl in mol/dm^3	relative rate of reaction
1	0.025	0.024	0.12	5.1
2	0.050	0.024	0.12	10.2
3	0.050	0.024	0.06	5.1
4	0.050	0.012	0.06	5.1

(a) Use the information in Table 4.1 to describe how increasing the concentration of each of these substances affects the relative rate of reaction.

Propanone: ....

....

....

Iodine: ....

....

.... [2]

(b) Increasing the temperature increases the rate of this reaction.

Use ideas about energy and collisions to explain the effect of temperature on the rate of reaction.

....

....

....

.... [2]

(c) Sketch two graphs in Fig. 4.1 to show the effect of concentration of hydrochloric acid on the rate of reaction between propanone and iodine. Label your graphs with the chosen experiments.

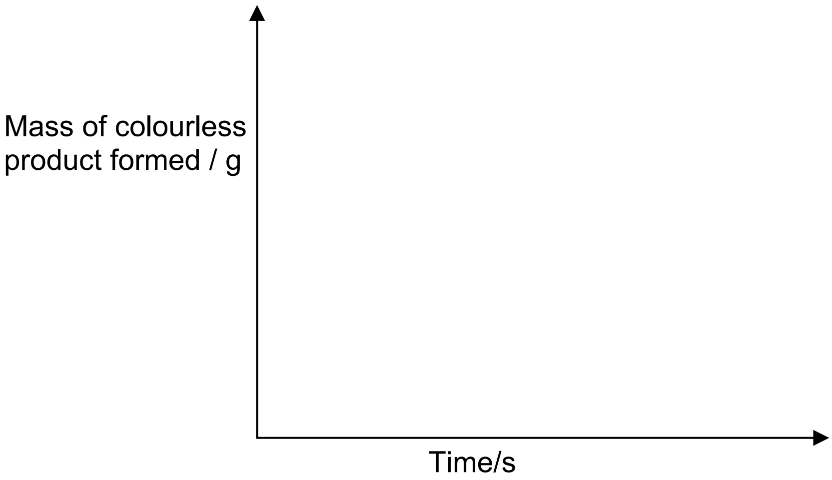


Fig. 4.1

[1]

(d) Iodine has many isotopes. Iodine–127 and Iodine–130 are two common isotopes of iodine.

Complete Table 4.2 to show the number of particles in these two isotopes of iodine.

Table 4.2

isotope	number of electrons	number of neutrons
Iodine–127		
Iodine–130		

[2]
[Total: 7]

5 Methylamine, CH_3NH_2, is a weak base. Its properties are similar to those of ammonia.

(a) When methylamine is dissolved in water, the following equilibrium is set up.

$$CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$$

(i) Suggest why the arrows are **not** the same length.

.... [1]

(ii) Explain why methylamine behaves as a base in this reaction.

.... [1]

(b) An aqueous solution of the strong base, sodium hydroxide, is pH 12.

Predict the pH of an aqueous solution of methylamine which has the same concentration as aqueous sodium hydroxide. Explain your reasoning.

....

....

.... [2]

(c) Methylamine is a weak base like ammonia.

(i) Methylamine can neutralize acids.

$$2CH_3NH_2 + H_2SO_4 \rightarrow (CH_3NH_3)_2SO_4$$

methylammonium sulfate

Write an equation, similar to the one above, for the reaction between methylamine and hydrochloric acid. Include the name of the salt formed.

[2]

(ii) When aqueous methylamine is added to aqueous iron(III) sulfate, a reddish brown precipitate is formed.

Write an ionic equation for the formation of the reddish brown precipitate.

.... [1]

[Total: 7]

6 This question is about fuels and energy production.

(a) Table 6.1 gives the characteristics of 3 kinds of common fuels.

Table 6.1

Fuel	Content	Melting point / °C	Enthalpy change of combustion in kJ / g
Bio-ethanol	C_2H_5OH	-114	-30.5
Diesel	hydrocarbons	About -24	-44.8
Petrol	hydrocarbons	About -57	-47.3

(i) Explain why the melting point of bio-ethanol is exact but the melting point of diesel and petrol are approximate values.

[1]

....

(ii) Bio-ethanol is produced by fermentation of sugar cane.

State the conditions required for this reaction.

....

[2]

....

(iii) One of the advantages of using bio-ethanol as a fuel is that it is considered carbon neutral.

State another advantage of using bio-ethanol as a fuel for cars instead of petrol.

....

[1]

....

(iv) Calculate the enthalpy change of combustion when 1 mol of bio-ethanol burns.

Enthalpy change = …………………. [1]

(b) The fractional distillation of petroleum produces fractions as shown in Fig. 6.1, such as liquified petroleum gas (LPG) and diesel, which are used as fuels.

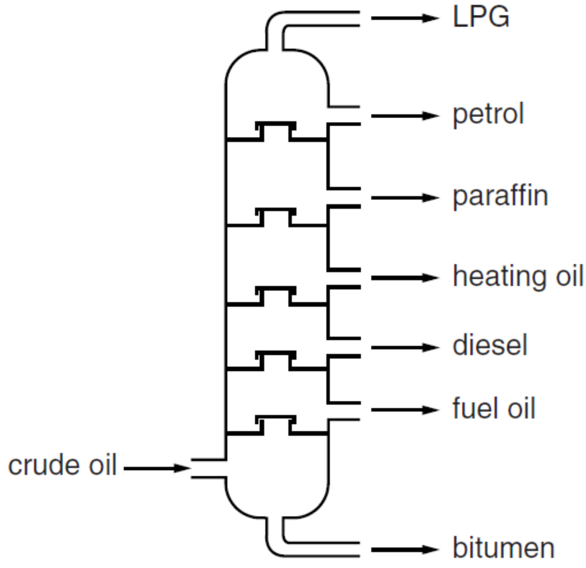


Fig. 6.1

Explain why LPG has a lower boiling point than diesel.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [3]

[Total: 8]

7 This question is on macromolecules.

(a) Nylon 66 is a high performing engineering plastic. It is a type of polyamide and is usually used in fibres for textiles, carpets, and moulded parts.

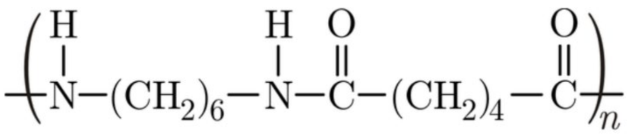
Nylon 66 undergoes depolymerisation through acid hydrolysis. This process helps in recycling nylon 66 by breaking them down into simpler molecules that can be used to make new products according to the word equation:

Nylon 66 + H_2O $\rightarrow$ hexamethylendiamine + adipic acid

(i) Define *depolymerisation*.

.... [1]

(ii) The polymer of nylon 66 is shown.



Complete the table in Fig. 7.1 by drawing the structural formula of the simpler molecules formed when nylon 66 undergoes acid hydrolysis.

Simpler molecules formed	Structural Formula
Hexamethylendiamine	
Adipic acid	

Fig. 7.1

[2]

(b) **(i)** Polyacrylonitrile is a plastic used to make synthetic fibres. The structure of its monomer is $CH_2=CH-CN$.

Draw the structure of polyacrylonitrile, showing two repeat units.

[2]

(ii) Polyacrylonitrile and nylon 66 undergo addition and condensation polymerisation respectively.

Describe two differences between addition and condensation polymerisation reactions.

....

....

....

....

.... [2]

[Total: 7]

8 The carbon cycle in Fig. 8.1 shows how carbon atoms enter and leave the atmosphere through various processes such as combustion, respiration, photosynthesis, and decomposition.

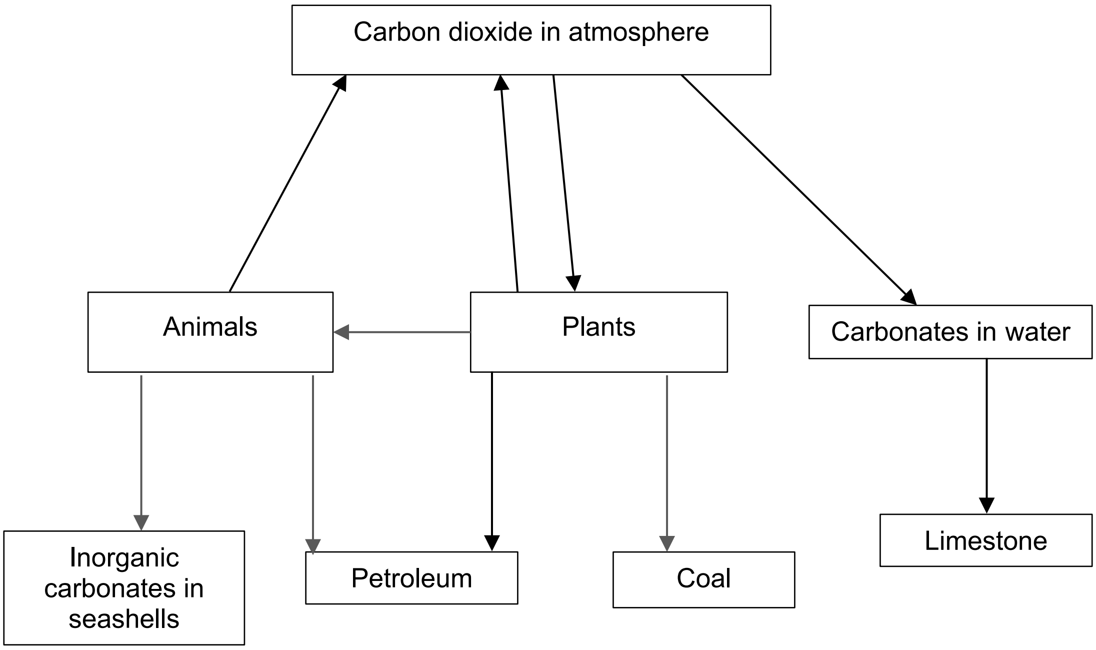


Fig. 8.1

(a) Using the letters, W and X, for the following processes, indicate where they occur in adding or removing carbon atoms in the atmosphere.

W - respiration

X – photosynthesis

[2]

(b) Complete the diagram in Fig. 8.1 by drawing arrow(s), labelled Z, to show the role of combustion of fuels in the carbon cycle.

[1]

(c) **(i)** Identify the source of petrol and kerosene in the carbon cycle.

.... [1]

(ii) Explain how this substance in c (i) is formed.

....

....

.... [1]

(d) Explain how carbonates in water are formed.

....

....

.... [1]

(e) Explain, with the help of an equation, whether the use of hydrogen as a fuel will affect the carbon cycle.

....

....

.... [2]

[Total: 8]

9 Drying agents, also called desiccants, come in various forms, and have found widespread use in the foods, pharmaceuticals, packing, electronics, and manufacturing industries.

A desiccant is a hygroscopic or deliquescent substance that reduces moisture in the surrounding air. A comparison of hygroscopic and deliquescent substances is shown in Table 9.1.

Table 9.1

Hygroscopic Substances	**Deliquescent Substances**
They may be amorphous solids or liquids.	They are crystalline solids.
When exposed to the atmosphere at room temperature, they absorb moisture or adsorb moisture but do not dissolve in it.	When exposed to the atmosphere at room temperature, they absorb moisture and dissolve in it.
No change in physical state on exposure to air.	Change in physical state on exposure to air.

Silica Gel

Silica gel is an amorphous and porous form of silicon dioxide (silica), consisting of an irregular 3-dimensional network of alternating silicon and carbon atoms with nanometer-scale voids and pores. The voids and pores are empty spaces found in the structure. The void may contain water or some other liquids or may be filled by a gas or is a vacuum.

The high surface area to volume ratio in silica gel allows it to ***adsorb*** water readily, making it useful as a desiccant. The silica gel removes moisture by ***adsorption*** onto the surface of its numerous pores rather than by ***absorption*** into the bulk of the gel.

Silica gel can **adsorb** up to about 40% of its own mass in moisture in high-humidity environments. This moisture can be released upon heating at 120°C for extended periods of time. This makes it a reusable desiccant.

Calcium chloride

When anhydrous calcium chloride powder is used as a desiccant, it ***absorbs*** moisture from air, becomes clumpy and dissolves in it. This is especially when the air is high in humidity. Water molecules initially occupy spaces inside the structure of calcium chloride. Thus, anhydrous calcium chloride attracts water of hydration and becomes hydrated calcium chloride. When the amount of absorbed moisture increases, the calcium chloride dissolves in the water. The high solubility of calcium chloride is what makes it a deliquescent substance.

Calcium chloride can **absorb** up to 300% of its own mass in high humidity environment at room temperature. The anhydrous calcium chloride is regenerated when the hydrated crystals are heated to 250°C for about an hour.

Crystalline and Amorphous

An amorphous solid has a network of particles with less order in the arrangement compared to the solid with the crystalline form, as shown in Fig. 9.1.

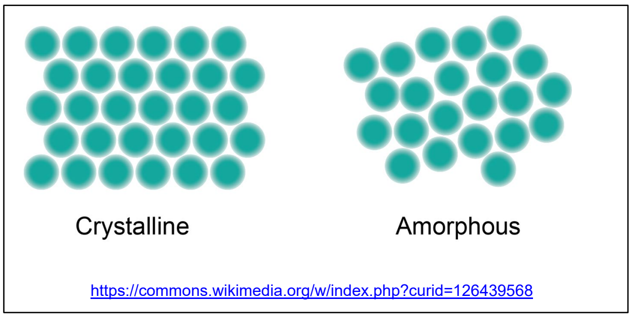
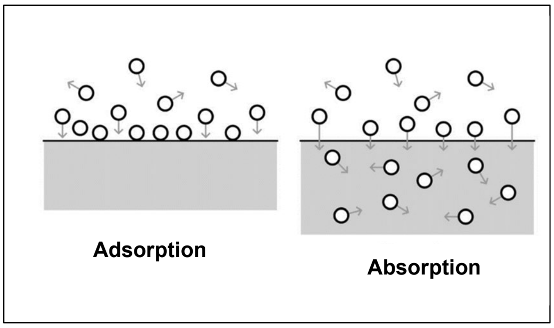


Fig. 9.1

Adsorption and Absorption

A comparison between the processes of adsorption and absorption is shown in Fig. 9.2.



Adsorption	Absorption
The adhesion of atoms, ions or molecules from a gas, liquid or dissolved solid to a surface.	A process in which atoms, molecules or ions enter some bulk phase (liquid or solid material).
Examples are activated carbon filters, chromatography	Examples are paper towels absorbing water, CO_2 from air enters aqueous NaOH.

Fig. 9.2

(a) Explain how the following processes occur in terms of forces of attraction or bonds,

(i) ***adsorption*** of moisture on silica gel
(ii) ***absorption*** of moisture in calcium chloride
(iii) ***deliquescence*** in calcium chloride

....

....

....

....

....

....

....

....

.... [3]

(b) An experiment was conducted to find the formula of hydrated calcium chloride by heating a known mass of the solid. The results are shown in Table 9.2.

Table 9.2

Mass of empty crucible / g	20.00
Mass of crucible with hydrated calcium chloride / g	36.50
Mass of crucible with anhydrous calcium chloride after heating / g	32.50

Deduce the formula of the hydrated calcium chloride.
Show all relevant workings clearly.

formula of hydrated calcium chloride…………………………[3]

(c) Calculate the mass of water removed from the air by 1 mole of silicon dioxide and 1 mole of calcium chloride.

mass of water removed by 1 mole of silicon dioxide ..…………………..

mass of water removed by 1 mole of calcium chloride ………..……… [2]

(d) Draw the dot and cross diagram of calcium chloride, showing only the valence electrons.

[2]

(e) **(i)** State the separation method used to regenerate anhydrous calcium chloride.

[1]

....

(ii) Explain why this is a suitable method to regenerate anhydrous calcium chloride from its hydrated form.

....

....

....

.... [1]

.[Total: 12]

Class	Index Number

Name : ______________________________________

Section B (10 marks)
Answer **one** question from this section.

10 Some physical properties of Group 2 metals and transition metals are given in Table 10.1.

Table 10.1

Metal	Density / g / cm^3	Melting point / °C	Boiling point / °C	Colour of aqueous M^{2+} ions
Magnesium	1.74	650	1091	colourless
Calcium	1.55	842	1484	colourless
Barium	3.51	727	1870	
Manganese	7.26	1246	2061	pale pink
Iron	7.86	1535	2750	
Nickel	8.90	1455	2730	green
Copper	8.92	1083	2567	blue

(a) Complete the table on the colour of aqueous ions of barium and iron. [1]

(b) Explain why the densities of transition metals are higher than those of Group 2 metals.

....

....

.... [1]

(c) Other than the physical properties in the table, state one other characteristic of transition metals.

....

.... [1]

(d) Table 10.2 shows the standard electrode potentials of the Group 2 metals and transition metals.

Table 10.2

Electrode reaction	Standard electrode potential / V
$Mg^{2+} + 2e^- \rightleftharpoons Mg$	– 2.38
$Ca^{2+} + 2e^- \rightleftharpoons Ca$	– 2.87
$Ba^{2+} + 2e^- \rightleftharpoons Ba$	– 2.90
$Mn^{2+} + 2e^- \rightleftharpoons Mn$	– 1.18
$Fe^{2+} + 2e^- \rightleftharpoons Fe$	– 0.44
$Ni^{2+} + 2e^- \rightleftharpoons Ni$	– 0.25
$Cu^{2+} + 2e^- \rightleftharpoons Cu$	+ 0.34

(i) State the relationship between the reactivity of metals and the standard electrode potential.

....

.... [1]

(ii) Hence, suggest what the standard electrode potential measures.

....

....

.... [1]

(iii) Explain the positive standard electrode potential in copper.

....

....

.... [1]

(e) An experiment on displacement reactions was conducted to determine the reactivity of manganese, iron and copper.

- Describe the observations that identify the most reactive metals.
- Explain the reactions with the help of at least one appropriate ionic equation.

You may organize the observations in a table.

....

....

....

....

....

....

....

....

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....

....

....

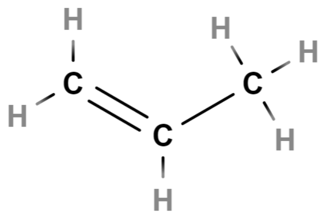
....

[4]

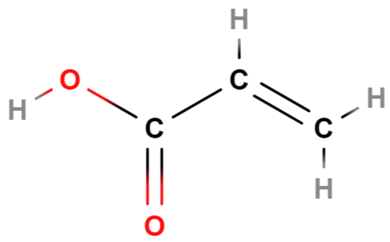
....

[Total: 10]

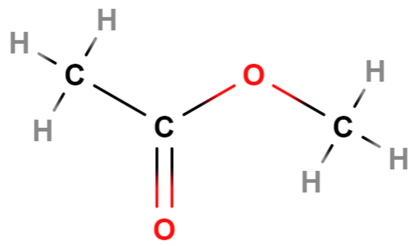
11 The structures of three compounds, A, B and C are shown in Fig 11.1.



Compound A



Compound B



Compound C

Fig. 11.1

(a) An experiment was conducted to find out whether any of the three compounds is saturated.

- Describe the observations that identify the unsaturated compound(s).
- Explain the reactions with the help of at least one chemical equation.

[4]

(b) Compound C has an isomer.
Write the displayed formula of an isomer of compound C.

[1]

(c) Determine the percentage composition of the elements in compound C.

....

.... [2]

(d) Explain why the percentage composition of compound C and its isomer are the same.

....

.... [1]

(e) Compound C can be produced in an experiment in the laboratory.

Name the carboxylic acid and alcohol used and the experimental condition required in the experiment.

....

....

....

.... [2]

[Total: 10]

END OF PAPER

The Periodic Table of Elements

Key

proton (atomic) number
atomic symbol
name
relative atomic mass

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

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

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

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