Paya Lebar Methodist Girls' School (Secondary)
Preliminary Examination 2024
Secondary 4 Express / G3

CANDIDATE NAME		CLASS		CLASS INDEX NUMBER	

CENTRE NUMBER	S						INDEX NUMBER				

CHEMISTRY **6092/02**

Paper 2 **14 August 2024**

1 hour 45 minutes

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and index number on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer all questions.
Write your answers in the spaces provided.

Section B
Answer **one** question.
Write your answers in the spaces provided.

The number of marks is given in brackets [ ] at the end of each question or part question.
A copy of the Periodic Table is printed on page 27.

The use of an approved scientific calculator is expected, where appropriate.

For Examiner's Use	
Section A	/70
Section B	/10
Total	/80

This document consists of **27** printed pages.

Section A

Answer **all** questions.

1. Barium hydroxide, $Ba(OH)_2$ is a strong base.

Fig 1.1 shows a reaction scheme involving barium hydroxide.

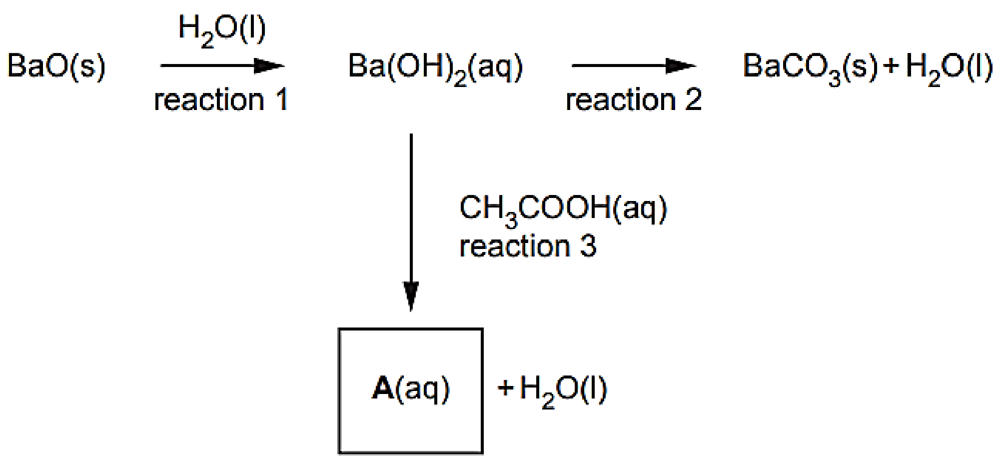

Fig. 1.1

(a) State what is observed in reaction 1.

.... [1]

(b) Suggest a reactant for reaction 2.

.... [1]

(c) Identify **A**.

.... [1]

(d) $Ba(OH)_2$ is made by reaction of Ba with water. Write a balanced chemical equation for this reaction.

.... [1]

(e) The mineral barytocalcite contains both $BaCO_3$ and $CaCO_3$. Both compounds decompose on heating.

(i) Using your knowledge on the reactivity of metals, predict which compound decomposes first when barytocalcite is heated.
Explain your answer.

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(ii) Construct an equation for the complete thermal decomposition of barium carbonate.

…………………………………………………………………………………………… [1]

[Total: 7]

2. The elements phosphorus, sulfur and chlorine are elements in Period 3 of the Periodic Table.

Table 2.1 shows some properties of these three elements.

property	P	S	C*l*
number of valence electrons	5	6	7
formula of most common ion	P^{3-}	S^{2-}	Cl^{-}

Table 2.1

(a) P^{3-}, S^{2-} and Cl^{-} have the same number of electrons.

Describe and explain the trend in ionic radius shown by P^{3-}, S^{2-} and Cl^{-}.

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…………………………………………………………………………………………… [2]

(b) Chlorine forms various ions with different oxidation states. Table 2.2 shows some of the ions of chlorine.

Ion	chlorate	perchlorate	hypochlorite	chloride
formula	ClO_3^-	ClO_4^-	ClO^-	Cl^-
oxidation state of chlorine				

Table 2.2

(i) Fill in Table 2.2 with the oxidation state of the chlorine in the various ions. [2]

(ii) A disproportionation reaction is a reaction where an element is both reduced and oxidised at the same time.

Potassium chlorate, $KClO_3$ decomposes according to equation below.

$$4KClO_3 \rightarrow 3KClO_4 + KCl$$

Explain why the above reaction is a disproportionation reaction.

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…………………………………………………………………………………………… [2]

(c) A student does two tests on separate samples of $NaCl$(aq).

Complete Table 2.3 with the correct observations for each test.

test	observation
addition of a few drops of Br_2(aq)	
addition of a few drops of $AgNO_3$(aq)	

[2]

Table 2.3

[Total: 8]

3. $POCl_3$ has a melting point of 1°C and a boiling point of 106°C.

(a) Based on the information provided, suggest the structure and bonding in $POCl_3$.

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

…………………………………………………………………………………………………… [1]

(b) **Phosphorus shares a double bond with oxygen**. Draw the 'dot and cross' diagram to show the bonding in $POCl_3$. Show only the outermost electrons.

[2]

(c) $POCl_3(g)$ forms when $PCl_3(g)$ reacts with $O_2(g)$.

$$2PCl_3(g) + O_2(g) \longrightarrow 2POCl_3(g)$$

Table 3.1 shows some relevant information on energy changes.

Process	value/ $kJ\ mol^{-1}$
enthalpy change for breaking bonds in one mole of PCl_3	+289
enthalpy change for forming bonds in one mole of $POCl_3$	-592
$O_2\ (g) \rightarrow 2O\ (g)$	+496

Table 3.1

Calculate the enthalpy change, ΔH, for the reaction shown in the equation in **(c)**.

enthalpy change = ………………. kJ [2]

(d) Hence, draw the energy profile diagram in Fig. 3.1 for the reaction shown in **(c).** Indicate clearly the **value** of the activation energy and enthalpy change on Fig. 3.1.

Fig. 3.1 [3]

[Total: 8]

4. Concentrated aqueous magnesium iodide and molten magnesium iodide are electrolysed separately using graphite electrodes.

(a) Describe one similarity and one difference in terms of the products formed at the electrodes for the different electrolytes.

One similarity: …………………………………………………………………………..
………………………………………………………………………………………… [1]

One difference: …………………………………………………………………………...
………………………………………………………………………………………… [1]

(b) Describe and explain what is observed when aqueous chlorine is bubbled into aqueous magnesium iodide.

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……………………………………………………………………………………………
………………………………………………………………………………………… [2]

(c) Iodide ions react with manganese (IV) oxide as shown in the equation.

$$2I^- + MnO_2 + 4H^+ \rightarrow Mn^{2+} + I_2 + 2H_2O$$

Explain the role played by the iodide ions in the reaction, in terms of oxidation state.

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

(d) Iodine has several radioactive isotopes. Two of the isotopes, iodine-131 and iodine-123 has clinical usage. Tiny amounts of radiation that are emitted by the radioactive iodine isotopes help the doctor to see how the organ is functioning or to treat certain cancers. Radiation emitted can be in the form of a beta particle, ${}_{-1}^{0}\beta$.

(i) Explain whether iodine-131 and iodine-123 will have similar chemical properties.

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…………………………………………………………………………………………………

……………………………………………………………………………………………… [1]

(ii) The equation below shows iodine-131 breaking down to produce a beta particle.

$${}_{53}^{131}I \rightarrow {}_{54}^{131}Xe + {}_{-1}^{0}\beta$$

Radioactive phosphorus-32 also breaks down to produce a beta particle, similar to radioactive iodine-131. Write an equation to show this reaction.

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

[Total: 8]

5. A piece of copper ore containing copper (II) oxide has a mass of 0.567g. It is dissolved in an acid, giving 100.0 cm^3 of a blue solution in which all the copper is present as Cu^{2+} ions.

An excess of KI (aq) is added to a **25.0 cm^3 sample** of this solution.

All the copper is precipitated as white CuI(s).

Cu^{2+} ions are the only component in the solution that react with KI (aq).

This is reaction 1.

reaction 1 $$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$$

The liberated iodine is then titrated with 0.0200 mol/dm^3 of $S_2O_3^{2-}$. This is reaction 2.

reaction 2 $$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$$

The titration requires 20.10 cm^3 of 0.0200 mol/dm^3 of $S_2O_3^{2-}$ to reach the end point.

(a) Calculate the number of moles of I_2 that are reduced in the titration.

number of moles of I_2 = ……………… mol [1]

(b) Calculate the number of moles of copper in the **original** piece of ore.

number of moles of copper in the original piece of ore = …………………… mol [2]

(c) Calculate the percentage of copper in the ore.

% of copper in the ore = ……………. % [2]

(d) Pure copper is usually converted to an alloy before being used to make water pipes.

Describe and explain the advantage of using an alloy of copper over pure copper.

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

[Total: 7]

6. An experiment is set up to investigate the rate of diffusion of solutions. Aqueous barium nitrate is added from one side of a 10 cm length of black paper, while aqueous copper (II) sulfate is added from the other side at the same time. The time taken for a white precipitate to appear on the black paper is recorded. Fig. 6.1 shows the experimental set up.

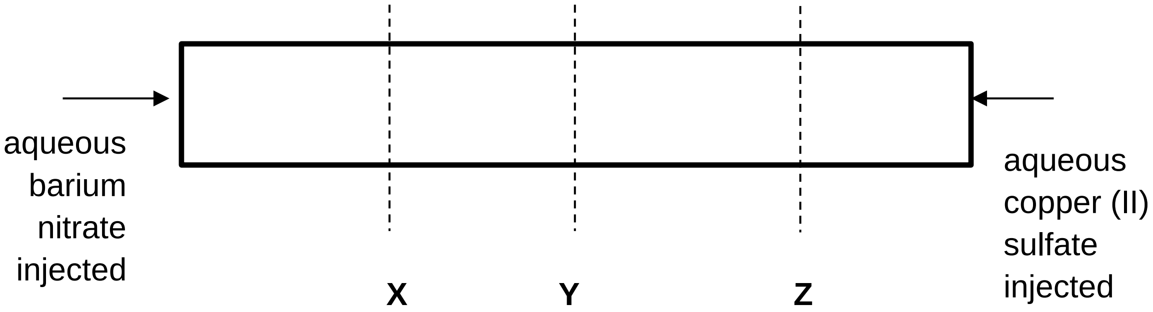

Fig. 6.1

(a) Write the ionic equation for the formation of the white precipitate.

…………………………………………………………………………………………… [1]

(b) Predict the position of the white precipitate on the black paper. Will the white precipitate appear at position marked **X, Y** or **Z**? Provide an explanation for your answer.

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……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………… [2]

(c) Instead of using aqueous barium nitrate, aqueous barium hydroxide is used, with all other reactants and conditions kept constant. Describe what will be observed.

Observation: ………………………………………………………………………… [1]

(d) Copper (II) sulfate is made by adding excess copper (II) carbonate to sulfuric acid, at room temperature and pressure.

The equation for reaction is shown below.

$$CuCO_3\ (s) + H_2SO_4\ (aq) \rightarrow CuSO_4\ (aq) + CO_2\ (g) + H_2O\ (l)$$

The volume of gas collected as the reaction proceeds in shown in Fig. 6.2.

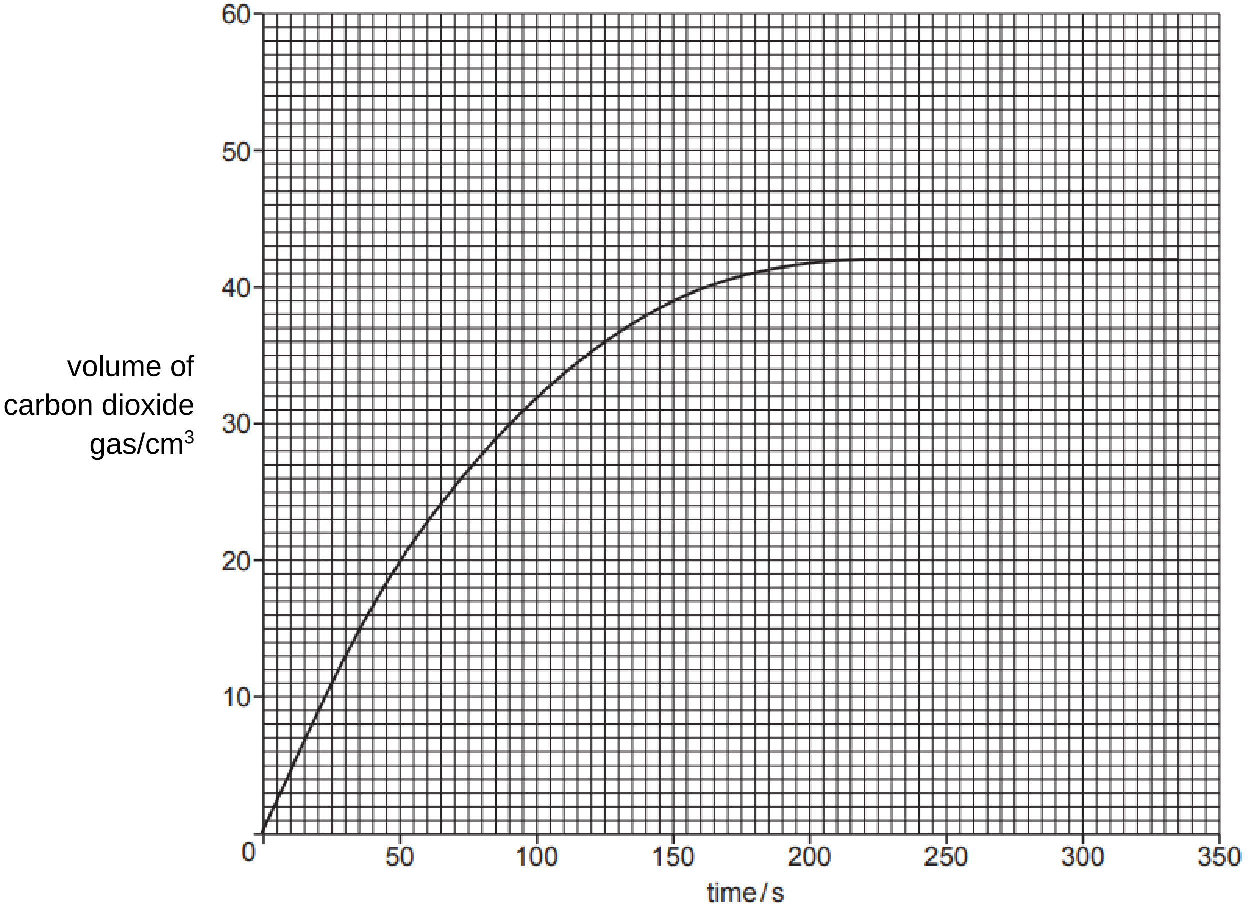

Fig. 6.2

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

number of moles of sulfuric acid = ……………………. mol [2]

(ii) If the concentration of sulfuric acid used is 0.0500 mol/dm^3, calculate the volume of sulfuric acid used.

volume of sulfuric acid = ………………….. cm^3 [1]

(iii) The experiment is repeated with the same volume of sulfuric acid in **(ii)** but concentration of sulfuric acid is 0.0643 mol/dm^3, and all other conditions are kept constant.

Calculate the volume of carbon dioxide produced.

volume of carbon dioxide = ……………………… cm^3 [2]

(iv) Use ideas about collisions between particles to explain how the change in concentration of sulfuric acid in **(iii)** affects the rate of reaction.

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

(v) Hence, sketch the graph obtained for the experiment in **(iii)** on Fig. 6.2. [1]

[Total: 12]

7. Plastics can be categorised into 7 types. Fig. 7.1 shows three of the most used plastics. The plastics industry depends on non-renewable resources. More than 90% of global plastic production consists of primary plastics—which are newly manufactured, rather than recycled—made from petroleum products. This production requires a huge amount of energy and produces greenhouse-gas emissions. By 2050, emissions from plastic production could amount to 15% of the estimated carbon budget needed to keep global warming below 1.5 °C.

Credits: https://www.scientificamerican.com/article/why-its-so-hard-to-recycle-plastic/

type of plastic	name	ease of recycling
1 PET	polyethylene terephthalate	easy
2 HDPE	high density polyethylene	easy
3 PVC	polyvinyl chloride	almost impossible

Fig. 7.1

(a) Explain why the production of plastic is not environmentally sustainable and harmful to the environment.

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

(b) PET and HDPE are easy to recycle. Describe how plastics can be recycled using a physical and chemical method.

Physical method: ……………………………………………………………………………..

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……………………………………………………………………………………………… [1]

Chemical method: ……………………………………………………………………………

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……………………………………………………………………………………………… [1]

(c) The structure of PET and PVC are shown in Fig. 7.2

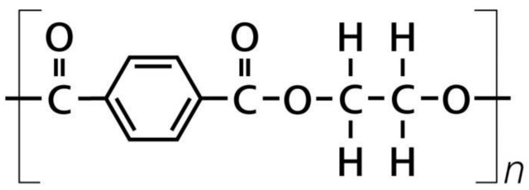
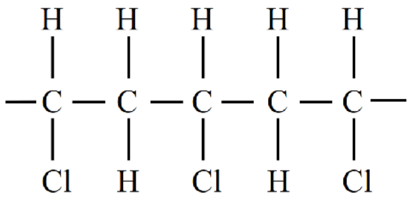
PET	PVC
	

Fig. 7.2

(i) Draw the monomer(s) that are used to make PET and PVC.

Monomers of PET	Monomer of PVC

[2]

[Turn Over

(ii) PET and PVC are made by different methods of polymerisation.

Identify the polymer formed by:

addition polymerisation : ………………………………….

condensation polymerisation: ……………………………. [1]

(iii) Describe **one** difference between addition and condensation polymerisation.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

…………………………………………………………………………………………… [1]

[Total: 8]

8. Infrared spectroscopy can be used to detect bonds and atoms present in organic molecules. As the bonds and types of atoms differ, the molecules absorb radiation at different wavelengths, represented by a wavenumber. As the bonds absorb radiation, they stretch. Table 8.1 shows the wavenumber at which the different bonds absorb radiation.

Bond	Wavenumber/ cm^{-1}
C-C	1100 - 750
C-O	1300 - 1000
C=C	1680 – 1650
C=O	1725 – 1700
C-H	2990 – 2600
O-H (in carboxylic acids)	3200 - 2900
O-H (in alcohols)	3700 - 3300

Table 8.1

Fig. 8.1 shows the infrared spectrum of ethanol. In an infrared spectrum, the vertical axis shows an increasing transmittance while the horizontal axis shows a **decreasing** wavenumber.

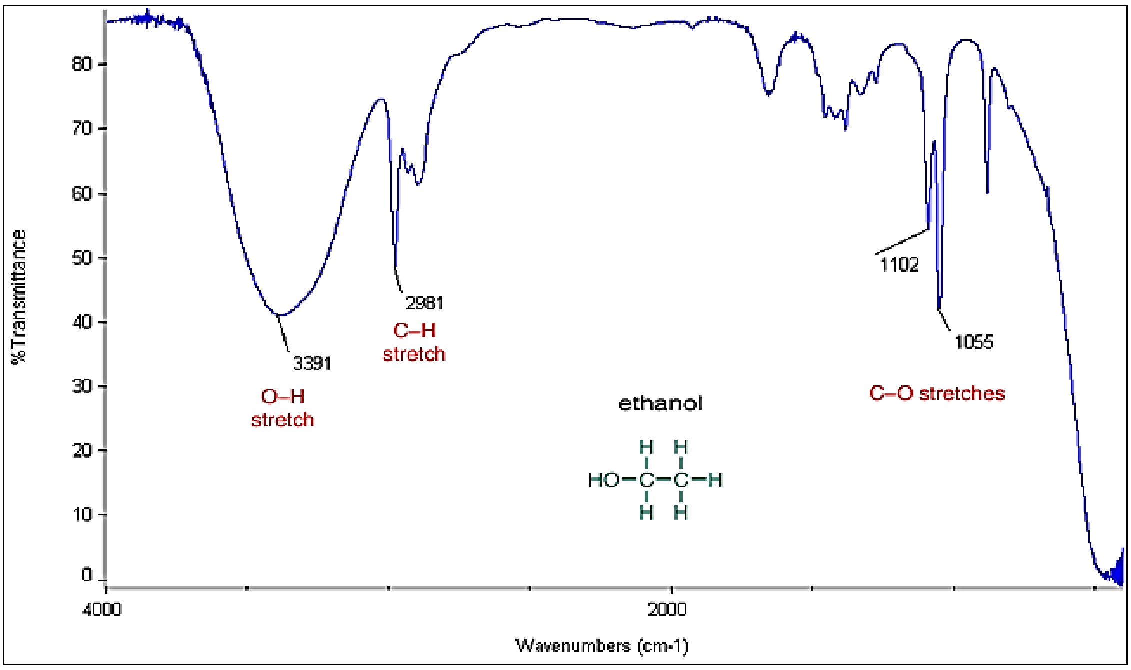


Fig. 8.1

A peak at 3391 cm^{-1} corresponds to a O-H bond as it falls in the region of 3700- 3300 cm^{-1}.
A peak at 2981 cm^{-1} corresponds to a C-H bond as it falls in the region of 2990- 2850 cm^{-1}.
A peak at 1102 and 1055 cm^{-1} corresponds to a C-O bond as it falls in the region of 1300- 1000 cm^{-1}.

Alcohols fall into different classes depending on how the hydroxyl group, -O-H is positioned on the chain of carbon atoms. Table 8.2 shows the differences between the different classes of alcohol for butanol.

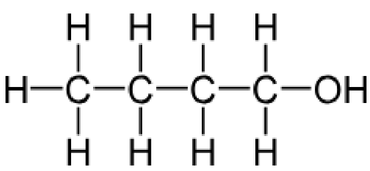
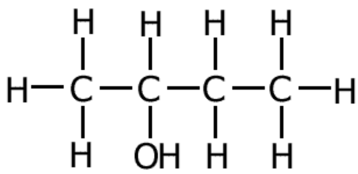
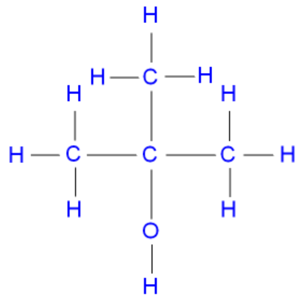
Primary (1^0)	Secondary (2^0)	Tertiary (3^0)
		
butan-1-ol	butan-2-ol	2-methylpropan-2-ol
In a primary (1^0) alcohol , the carbon which carries the -OH group is attached to only one *alkyl* group.	In a secondary (2^0) alcohol , the carbon which carries the -OH group is attached to two *alkyl* groups, which may be same or different.	In a tertiary (3^0) alcohol , the carbon which carries the -OH group is attached to three *alkyl* groups, which may be same or different.

Table 8.2

An *alkyl* group is a group such as methyl, $-CH_3$, or ethyl, $-CH_3CH_2$. These are groups containing chains of carbon atoms which may be straight or branched. Alkyl groups are given the general symbol **R**.

Alcohols have a higher boiling point than that of an alkane with the same number of carbon atoms as shown in Fig. 8.2 due to the presence of hydrogen bonding. Hydrogen bonding occurs in molecules due to the hydroxyl functional group, -O-H. The weak intermolecular forces of attraction between the molecules and hydrogen bonding determine the boiling point of an alcohol.

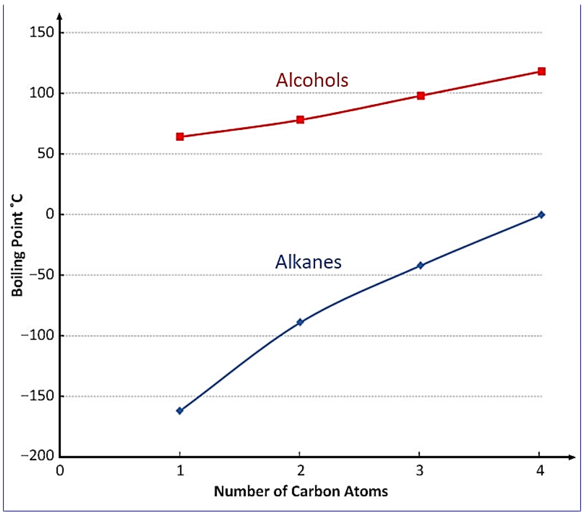


Fig. 8.2

(a) What is the phenomenon exhibited by the three different molecules of butanol shown in Table 8.2?

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

(b) Table 8.3 shows three alcohols **P, Q** and **R**.

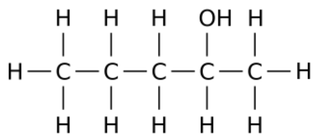
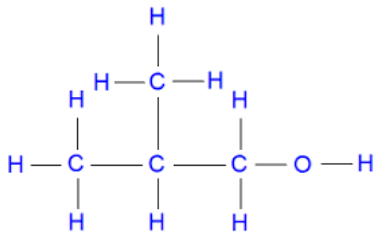
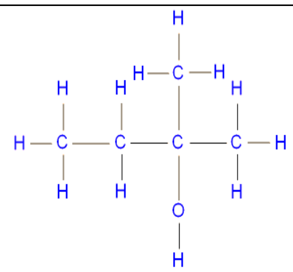
Alcohol	**P**	**Q**	**R**
Structural formula			
Class of alcohol			
Name		2-methylpropan-1-ol	2-methylbutan-2-ol

Table 8.3

Fill in the missing blanks in Table 8.3 with the correct class and name of the alcohols **P, Q** and **R**. [2]

(c) A molecule **T**, with two hydroxyl groups has the structure shown in Fig. 8.3.

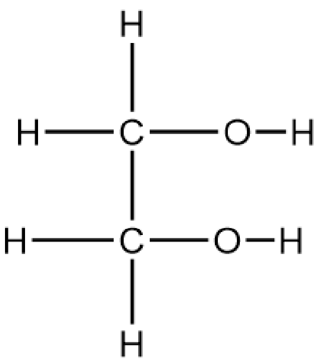


Fig 8.3

Using information from Fig 8.2, predict the boiling point of molecule **T**. Provide an explanation for your prediction.

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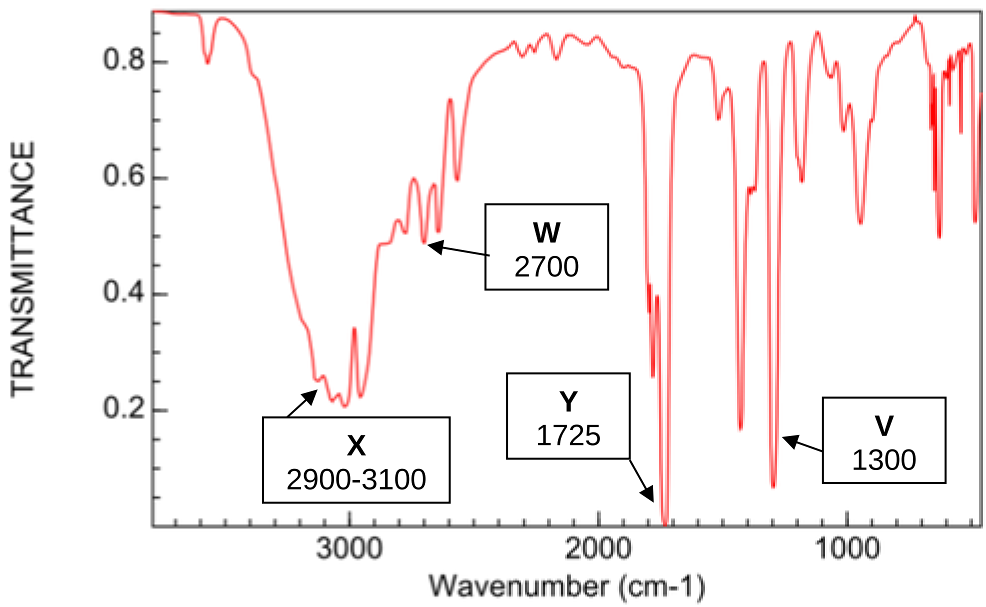
…………………………………………………………………………………………… [3]

(d) Fig. 8.4 shows the infrared spectrum of a molecule **Z**.



NIST Chemistry WebBook (https://webbook.nist.gov/chemistry)

Fig. 8.4

(i) Based on Fig 8.4 and Table 8.1, identify the bonds represented by the peaks at **V, W**, **X** and **Y**. Bonds represented by **X** and **Y** make up the only functional group of molecule **Z**.

V represents bond: ………………………………………………………………..

W represents bond: ………………………………………………………………

X represents bond: ………………………………………………………………

Y represents bond: ……………………………………………………………… [2]

(ii) State the homologous series molecule **Z** is in.

……………………………………………………………………………………… [1]

(iii) Molecule **Z** has a total of two carbon atoms. Hence, draw the displayed formula of molecule **Z**.

[2]

(iv) Name the reagents that can react to produce molecule **Z**.

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

[Total: 12]

[Turn Over

Section B

Answer **one** question from this section.

9. Table 9.1 shows the melting points and relative electrical conductivities of three elements.

	carbon (graphite)	magnesium	iodine
melting point/^{0}C	3652	649	114
relative electrical conductivity of solid	good	good	poor

Table 9.1

(a) Use ideas about bonding and structure to explain:

(i) the difference in the melting points of magnesium and iodine.

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.... [3]

(ii) the difference in the electrical conductivities of graphite and iodine.

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.... [2]

(b) A compound of phosphorus, oxygen and chlorine contains 20.2% phosphorus, 10.4% oxygen and 69.4% chlorine by mass.

Deduce the empirical formula of this compound.

empirical formula .... [2]

(c) The cell reaction for an electrochemical cell is shown below.

$$Cl_2\ (aq)\ +\ 2Fe^{2+}\ (aq)\ \rightarrow\ 2Fe^{3+}\ (aq)\ +\ 2Cl^{-}\ (aq)$$

Table 9.2 shows some standard electrode potentials.

Half - reaction	Standard Electrode Potential, E° (volts)
$2Fe^{3+}$ (aq) + $2e^-$ → $2Fe^{2+}$ (aq)	+ 0.77
Cl_2 (aq) + $2e^-$ → $2Cl^-$ (aq)	+ 1.36

Table 9.2

(i) Use the information in Table 9.2 to calculate the potential difference of the electrochemical cell in **(c).**

potential difference = …………………… V [1]

(ii) Describe the colour change of the solution in the electrochemical cell as electricity is being generated.

……………………………………………………………………………………

…………………………………………………………………………………… [1]

(iii) Describe a simple test to determine that all the chlorine is fully used up. Aqueous chlorine behaves the same way as chlorine gas.

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

[Total: 10]

10. Solid fuel used for outdoor cooking is made of hexamine. A student suggested using moth balls made of naphthalene as solid fuels instead. Table 10.1 shows some information about hexamine and naphthalene.

Solid fuel	Molecular formula	Enthalpy of combustion kJ/mol
hexamine	$C_6H_{12}N_4$	-4 200
naphthalene	$C_{10}H_8$	-5 133

Table 10.1

Energy density is the amount of energy released per gram of fuel combusted, kJ/g.

(a) Calculate the energy densities of hexamine and naphthalene.

energy density of hexamine = …………………… kJ/g [1]

energy density of naphthalene = ………………….kJ/g [1]

(b) Hence, explain whether moth balls containing naphthalene are a better alternative to solid fuel containing hexamine for camping, with reference to their energy densities and mass.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

………………………………………………………………………………………………… [1]

(c) Burning hexamine solid fuels may be more harmful than burning moth balls as a harmful air pollutant is produced. Name the air pollutant produced and describe the harmful effect caused by this air pollutant.

air pollutant ………………………………………………………………………………….. [1]

effect of air pollutant …………………………………………………………………………

………………………………………………………………………………………………..

……………………………………………………………………………………………… [1]

(d) Aluminium nitrate decomposes on heating according to the equation below.

$$4Al(NO_3)_3\ (s) \rightarrow\ 2Al_2O_3\ (s)\ +\ 12NO_2\ (g)\ +\ 3O_2\ (g)$$

Student A then adds aqueous hydrochloric acid while student B adds aqueous potassium hydroxide to the solid left after decomposition.

(i) Describe what will be observed by:

Student A ……………………………………………………………………………………

Student B ………………………………………………………………………………… [1]

Explanation for observations: ………………………………………………………………..

………………………………………………………………………………………………..

……………………………………………………………………………………………… [1]

(ii) Use ideas of structure and bonding to explain why aluminium oxide exists as a solid while nitrogen dioxide exists as a gas at room conditions.

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

[Total: 10]

END OF PAPER

The Periodic Table of Elements

Group																	
1	2											13	14	15	16	17	18
				Key			1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9			proton (atomic) number atomic symbol name relative atomic mass								5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og 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, $L = 6.02 \times 10^{23}\ mol^{-1}$