RAFFLES INSTITUTION
2023 YEAR 5 TERM 3 COMMON TEST

Higher 2

CANDIDATE NAME

CLASS | INDEX NUMBER

CHEMISTRY 9729

6 July 2023

2 hours 15 minutes

Additional Materials: Multiple Choice Answer (OMR) Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, 6-digit exam index number and civics tutorial group in the spaces provided on the OMR sheet and the cover sheets on **pages 1 and 19**. Shade your 6-digit exam index number on the OMR sheet.
This paper consists of three sections, **A**, **B** and **C**.

Section A (15 marks) consists of 15 multiple-choice questions.

Answer this section first. The OMR sheet will be collected after the **first 30 minutes**.
For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in **soft pencil** on the OMR sheet. Each correct answer will score one mark. A mark will not be deducted for a wrong answer. Any rough working should be done in the question paper.

Section B (30 marks) consists of 3 structured questions.

Answer **all** questions in the spaces provided in the question paper.
If additional space is required, you should use the pages at the end of the booklet for Section B (pages 17 – 18). The question number must be clearly shown.

Section C (35 marks) consists of 2 free-response questions.

Answer **all** questions in the spaces provided in the question paper.
Answers to this section are to be written in the spaces provided in the question paper.
If additional space is required, you should use the pages at the end of the booklet for Section C (pages 29 – 30). The question number must be clearly shown.

Write in dark blue or black pen. You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

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

The number of marks is given in brackets [ ] at the end of each question or part question.

Question	Marks
B1	/ 11
B2	/ 10
B3	/ 9

Section A (15 marks)

For each question, there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 Which statement about relative molecular mass is correct?

A It is the ratio of the mass of a molecule to the mass of a carbon-12 atom.

B It is the ratio of the mass of one mole of molecules to $\frac{1}{12}$ the mass of a carbon-12 atom.

C It is the ratio of the average mass of a molecule to the mass of a carbon-12 atom.

D It is the ratio of the average mass of a molecule to $\frac{1}{12}$ the mass of a carbon-12 atom.

2 *Use of the Data Booklet is relevant to this question.*

In country A, the national environmental standard states that the average concentration of sulfur dioxide in air should not exceed 0.570 mg m^{-3}.

How many SO_2 molecules are there in 1 m^3 of air with an SO_2 concentration of 0.570 mg m^{-3}?

A 5.35×10^{18}

B 1.61×10^{19}

C 1.61×10^{21}

D 5.35×10^{21}

3 A sample of nickel contains only three isotopes, ^{58}Ni, ^{60}Ni and ^{62}Ni.

The isotopes ^{58}Ni and ^{60}Ni have a percentage abundance of 69.51% and 26.78% respectively.

The sample is reacted completely with chlorine-35 to form nickel(II) chloride.

$$Ni + {}^{35}Cl_2 \longrightarrow Ni^{35}Cl_2$$

What is the relative formula mass of nickel(II) chloride formed from this sample?

A 93.68

B 94.18

C 128.68

D 129.68

4 *Use of the Data Booklet is relevant to this question.*

Which pairs of species have the same number of electron pairs?

1 Mg and P
2 As and Ge
3 Ba and Pb^{2+}

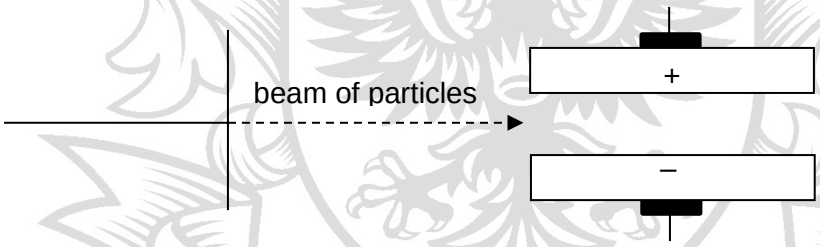
A 1 only
B 1 and 2 only
C 2 only
D 1, 2 and 3

5 **X** has a smaller nucleon number than **Y**.
X and **Y** has the same number of neutrons and electrons.

What is the possible identity of **X** and **Y**?

	X	Y
A	$^{36}_{18}Ar$	$^{32}_{14}Si^{4-}$
B	$^{33}_{14}Si^{4-}$	$^{36}_{18}Ar$
C	$^{32}_{14}Si^{4-}$	$^{36}_{18}Ar$
D	$^{33}_{14}Si^{4+}$	$^{37}_{18}Ar$

6 In three separate experiments, individual beams of $^{2}H^{+}$, $^{18}O^{2-}$ and $^{9}Be^{2+}$ particles, travelling at the same velocity, pass through an electric field as shown.



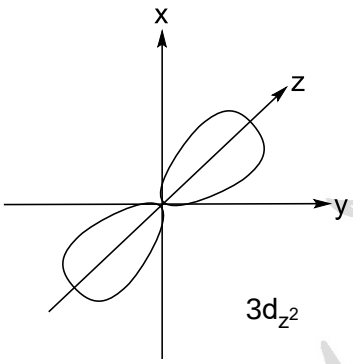
Which statements are correct?

1 $^{2}H^{+}$ particles are deflected to the smallest extent.
2 $^{9}Be^{2+}$ particles are deflected to a larger extent than the $^{18}O^{2-}$ particles.
3 $^{9}Be^{2+}$ particles are deflected towards the positively charged plate.
4 $^{18}O^{2-}$ particles are deflected towards the positively charged plate.

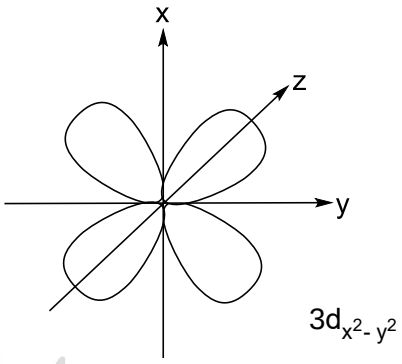
A 1 and 3 only
B 2 and 4 only
C 1, 2 and 3
D 1, 2 and 4

7 Which diagram shows a correctly labelled 3d orbital?

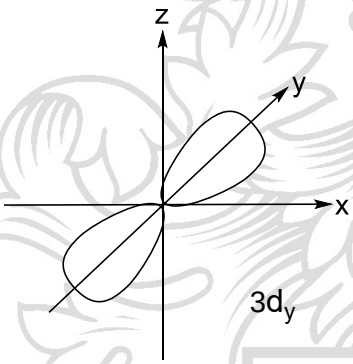
A



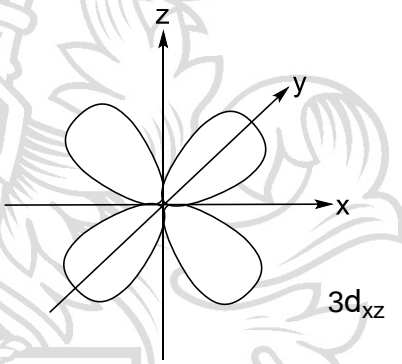
C



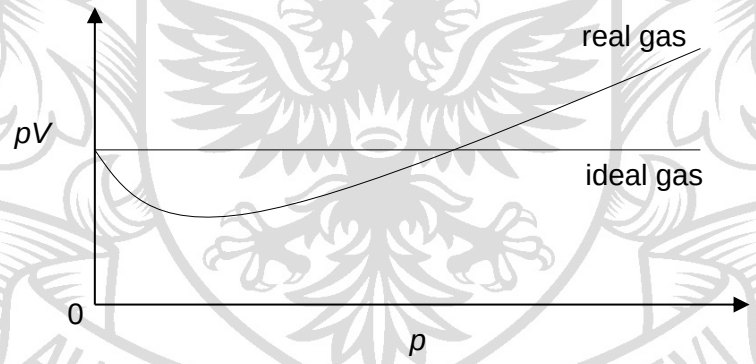
B



D



8 The value of *pV* is plotted against *p* for two gases, an ideal gas and a real gas, where *p* is the pressure and *V* is the volume of the gas.



Which gas shows the greatest deviation from ideality?

A ammonia

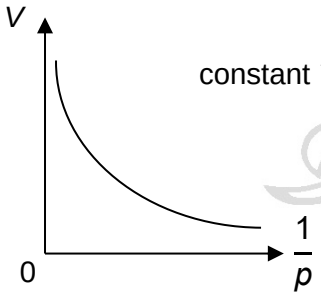
B neon

C methane

D hydrogen

9 Which graphs correctly describe the behaviour of a fixed mass of an ideal gas? (*T* is measured in K and *p* is measured in bar.)

1



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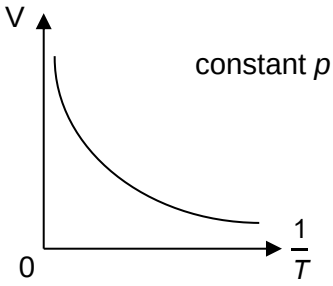

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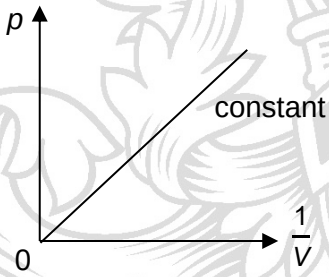

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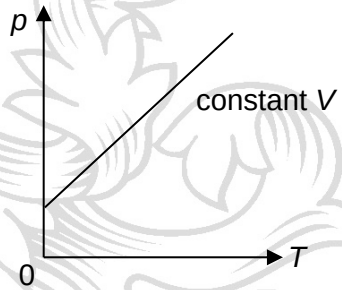


A 2 only

B 1 and 3

C 2 and 3

D 3 and 4

10 A sample of gas (M_r = 28.0) is found to occupy V cm^3 at T °C and p bar.

What is the mass of the gas, in grams, in this sample?

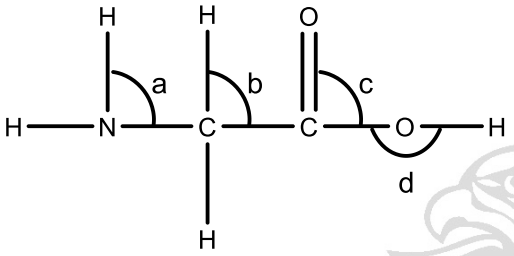
A $\dfrac{28.0 \times pV \times 273}{(273 + T) \times 22700}$

B $\dfrac{28.0 \times pV \times 273}{T \times 22700}$

C $\dfrac{28.0 \times pV \times (273 + T)}{T \times 22700}$

D $\dfrac{28.0 \times 22700 \times 273}{pV \times (273 + T)}$

11 What is the order of increasing bond angles?



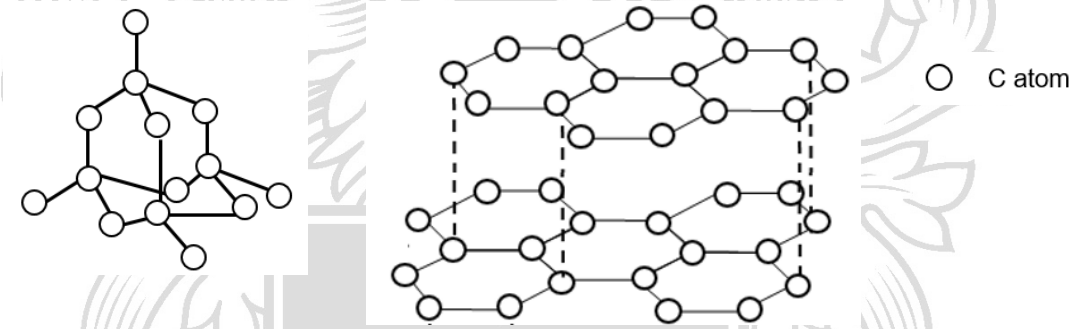
A a < b < c <d

B d < c < b < a

C b < a < c < d

D d < a < b < c

12 Diamond and graphite are allotropes of carbon with the following structures.



diamond graphite

Which statements are correct?

1 Diamond is harder than graphite because the C−C covalent bonds in diamond are stronger than the intermolecular forces between the layers in graphite.

2 Diamond has a lower entropy than graphite due to its more rigid structure.

3 Diamond can conduct electricity due to the continuous lattice of C−C covalent bonds.

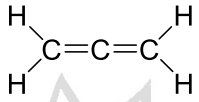
A 1 only

B 1 and 2 only

C 2 and 3 only

D 1, 2 and 3

13 Compound **Z** has the following structure.



How many σ and π bonds are present in compound **Z**?

	σ	π
A	4	2
B	4	4
C	6	2
D	6	4

14 When solid ammonium nitrate is added to water at room temperature, it is observed that the solid dissolves readily to give a cold solution.

What are the signs of $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ for this dissolution?

	$\Delta H^{\ominus}$	$\Delta S^{\ominus}$
A	–	–
B	–	+
C	+	–
D	+	+

15 Which reaction has the greatest increase in entropy?

A $FeO(s) + C(s) \longrightarrow Fe(s) + CO(g)$

B $FeO(s) + H_2(g) \longrightarrow Fe(s) + H_2O(l)$

C $FeO(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2O(l)$

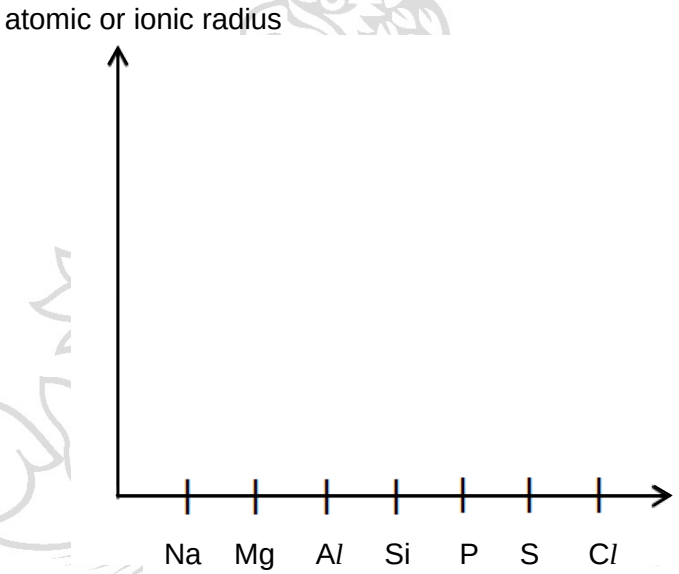
D $FeO(s) + \frac{1}{4}O_2(g) \longrightarrow \frac{1}{2}Fe_2O_3(s)$

Section B (30 marks)

This section consists of **3** questions.
Answer **all** the questions in this section in the spaces provided.

For examiner's use

1 (a) (i) Sketch and label, on the axes below, the general trends for atomic and ionic radii of the elements (Na to C*l*) across the third period of the Periodic Table.



[2]

(ii) Explain why the ionic radius of P^{3-} is larger than the atomic radius of P.

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……[2]

(iii) Explain why the ionic radius of Mg^{2+} is smaller than that of Na^{+}.

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……[2]

(b) Phosgene, $Cl_2C{=}O$, is a colourless, toxic gas. It is used in the production of pesticides, rubbers and adhesives.

For examiner's use

(i) State and explain, with reference to the Valence Shell Electron Pair Repulsion theory, the shape of a phosgene molecule.

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……[2]

(ii) Draw labelled diagrams to show how orbitals overlap to form

- a σ (sigma) bond;

- a π (pi) bond.

[2]

(iii) $Cl_2C{=}O$ reacts with CH_3NH_2 to form CH_3NCO. Draw a 'dot-and-cross' diagram to show the bonding present within CH_3NCO.

[1]

[Total: 11]

For examiner's use

2 **(a)** 0.890 g of solid vanadium was added to 50.0 cm^3 of 0.230 mol dm^{-3} sodium chromate(VI), Na_2CrO_4, in an alkaline medium.

A grey-green solid of chromium(III) hydroxide, $Cr(OH)_3$, is formed.

(i) Construct a half-equation for the formation of chromium(III) hydroxide in the above reaction.

……[1]

(ii) Assuming the solid vanadium and sodium chromate(VI) solution reacted completely, determine the final oxidation state of vanadium.

[2]

(iii) Compound **P** is another chromium-containing compound that reacts with solid vanadium. It also contains potassium and oxygen with a percentage by mass of 26.5% and 38.0% respectively.

Calculate the empirical formula of **P**.

[2]

For examiner's use

(b) 100 cm^3 of a gas mixture containing methane, CH_4, and methanal, HCHO, was burnt completely in 400 cm^3 of oxygen gas. After the reaction, the volume of the gaseous mixture was found to be 330 cm^3 when cooled to room temperature and pressure. The gas mixture was then bubbled through aqueous sodium hydroxide and the volume of gas decreased by 100 cm^3.

The equations for the complete combustion of CH_4 and HCHO are given below.

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$
$$HCHO + O_2 \longrightarrow CO_2 + H_2O$$

(i) Calculate the total volume of oxygen that reacted in the combustion of the methane-methanal gas mixture.

[1]

(ii) Hence, determine the percentage by volume of methane in the initial methane-methanal gas mixture.

[1]

(c) A solid sample of H_3AsO_4 (M_r = 141.9) was dissolved in 250 cm^3 of water. 25.0 cm^3 of this solution was reacted with 50.0 cm^3 of 1.00 mol dm^{-3} of $AgNO_3$ according to the following equation.

For examiner's use

$$H_3AsO_4 + 3Ag^+ \longrightarrow 3H^+ + Ag_3AsO_4$$

The amount of unreacted Ag^+ ions remaining in the resultant solution can be determined by titrating with standard potassium thiocyanate, KSCN, according to the following equation.

$$Ag^+ + SCN^- \longrightarrow AgSCN$$

Given that the end-point of the titration was reached when 22.00 cm^3 of 0.100 mol dm^{-3} KSCN was added, calculate the mass of H_3AsO_4 solid sample used.

[3]

[Total: 10]

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For examiner's use

For examiner's use

3 The process of bread making involves creating a dough by mixing flour, water and yeast. Fermentation of flour by yeast produces carbon dioxide in the dough. The carbon dioxide and water vapour in the dough help the dough to rise.

The dough consists of many gas units. Fig. 3.1 shows a gas unit comprising a gas bubble surrounded by a shell of dough. It is assumed that the gas bubble contains only $CO_2(g)$ and $H_2O(g)$ and both gases behave as ideal gases.

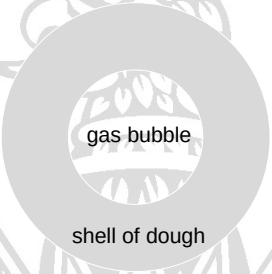

Fig. 3.1

When the dough is heated, more $CO_2(g)$ and $H_2O(g)$ in the dough diffuse into the gas bubble. The gas unit expands when the total pressure in the gas bubble, P_T, exceeds the atmospheric pressure, P_{atm}.

During the expansion of a gas unit, no additional $CO_2(g)$ is generated by the yeast and the total mass of $CO_2(g)$ in the gas unit remains constant.

increase in mass of CO_2 in gas bubble = decrease in mass of CO_2 in dough

Table 3.1 shows some data of the gas bubble at 300 K and 313 K.

Table 3.1

temperature / K	300	313
partial pressure of $CO_2(g)$, P_{CO_2} / atm	0.971	0.940
partial pressure of $H_2O(g)$, P_{H_2O} / atm	0.0313	0.0729
density of $CO_2(g)$ / g m^{-3}	1736	1611
volume of $CO_2(g)$, V_{CO_2} / m^3	2.36×10^{-11}	2.78×10^{-11}

(a) State two basic assumptions of the kinetic theory as applied to an ideal gas.

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……[2]

For examiner's use

(b) (i) Determine if the gas unit will expand at 313 K, given that atmospheric pressure is 1 atm.

[1]

(ii) Calculate the mole fraction of $H_2O(g)$ present in the gas bubble at 313 K.

[1]

(iii) Calculate the density of $H_2O(g)$, in g m^{-3}, present in the gas bubble at 300 K.

[1]

(iv) Calculate the decrease in mass of CO_2 in the dough when the dough was heated from 300 K to 313 K.

[2]

For examiner's use

(c) Fig. 3.2 shows how P_T and $\frac{(n_{CO_2})}{(n_{CO_2})_o}$ vary with time as the dough was heated.

P_T is the total pressure in the gas bubble.

$(n_{CO_2})_o$ is the initial amount of $CO_2(g)$ in the dough.

(n_{CO_2}) is the amount of $CO_2(g)$ in the dough at a particular time.

The solid line shows how P_T varies with time.

The dashed line shows how $\frac{(n_{CO_2})}{(n_{CO_2})_o}$ varies with time.

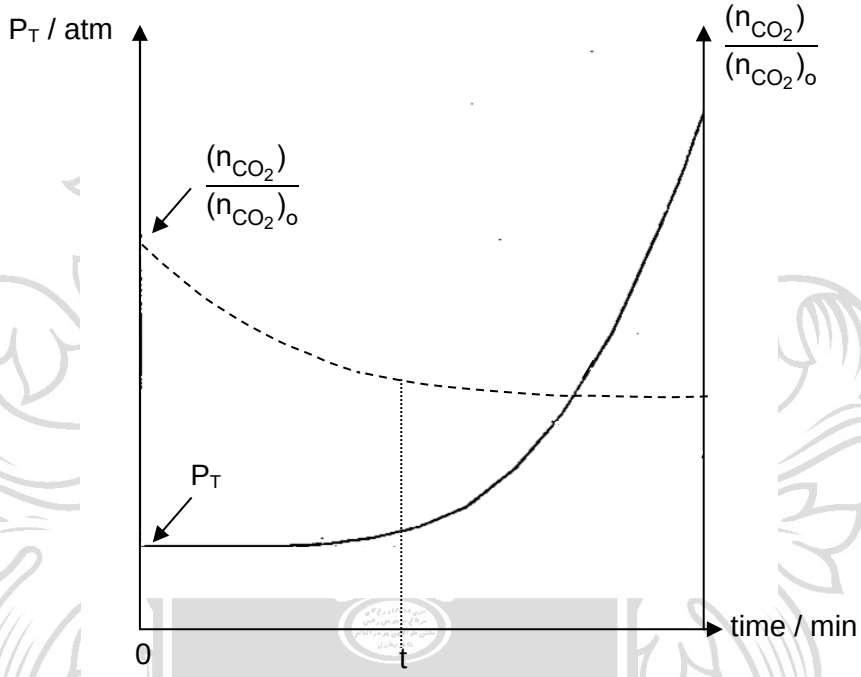

Fig. 3.2

Use the information from page **14** and Fig. 3.2 to answer **(c)(i)** and **(c)(ii)**.

(i) Deduce how the amount of $CO_2(g)$ in the **gas bubble** changes from time = 0 to t min.

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……[1]

(ii) From time = t min onwards, the volume of the gas bubble remains relatively constant.

Other than temperature change, suggest why P_T continues to increase from time = t min onwards.

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……[1]

[Total: 9]

Additional answer space

For examiner's use

If you use the following pages to complete the answer to any question, the question number must be clearly shown.

For examiner's use

RAFFLES INSTITUTION
2023 YEAR 5 TERM 3 COMMON TEST

Higher 2

C

CANDIDATE NAME

CLASS

INDEX NUMBER

For Examiner's Use Only

Section		Marks
A		/ 15
B	B1	/ 11
	B2	/ 10
	B3	/ 9
C	C1	/ 15
	C2	/ 20
Total		/ 80
Percentage		/ 100
Penalty		
Overall		/ 100
Grade		

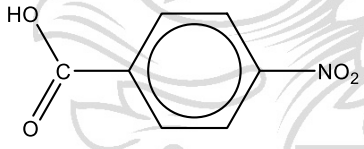
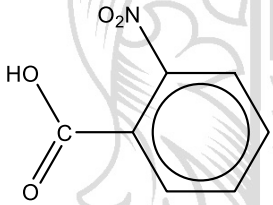
Section C (35 marks)

This section consists of **2** questions.
Answer **all** the questions in this section.

For examiner's use

1 Table 1.1 shows the structures and physical data for some compounds.

Table 1.1

compound	M_r	melting point / ^oC	solubility in water / g per 100 g of water at room temperature
Na_2SO_4 **A**	142	884	28.1
Na_2S **B**	78	1176	18.6
 **C**	167	239	0.1
 **D**	167	148	0.7

(a) (i) State the types of chemical bonds present in compound **A**. [1]

(ii) Draw the 'dot-and-cross' diagram for compound **A**. [2]

(iii) Explain why compound **B** has a higher melting point than compound **A**. [2]

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For examiner's use

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(b) (i) Explain, with the aid of a labelled diagram, why compound **D** has a lower melting point than compound **C.** [3]

(ii) By considering the processes involved when a solute dissolves in a solvent, suggest a reason why compound **D** is more soluble in water than compound **C**. [1]

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For examiner's use

(c) Fig. 1.1 shows the trend of the boiling points of some Group 17 hydrides.

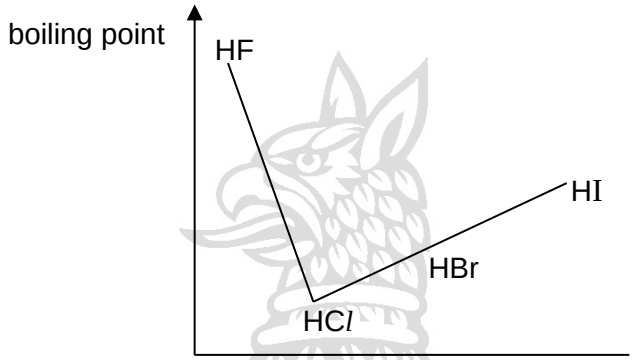

Fig. 1.1

(i) Describe how instantaneous dipole-induced dipole interactions arise. [2]

(ii) Arrange the four Group 17 hydrides in order of increasing polarity. Explain your reasoning. [2]

(iii) Explain the trend in boiling points of the Group 17 hydrides in Fig. 1.1. [2]

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[Total: 15]

For examiner's use

2 **(a)** Metals tend to lose electrons during chemical reactions to form cations.

(i) Define the term *first ionisation energy.* [1]

(ii) Sketch the trend of ionisation energy against the number of electrons removed for the first seven electrons removed from sodium. Explain the shape of your graph. [3]

(iii) Sodium metal is shiny when freshly cut under mineral oil, but when exposed to air, it is coated immediately with sodium oxide. Write the electronic configuration for the oxide anion. [1]

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(b) By drawing an energy cycle, use the data in Table 2.1 and the *Data Booklet* to calculate a value for the enthalpy change of formation of $OH^-(aq)$.

For examiner's use

Table 2.1

enthalpy change of atomisation of Na(s)	+107 kJ mol^{-1}
enthalpy change of formation of NaOH(aq)	−470 kJ mol^{-1}
enthalpy change of hydration of $Na^+(g)$	−406 kJ mol^{-1}

[3]

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(c) A sample of sodium hydroxide weighing 1.66 g is added to 50.0 cm^3 of water in a styrofoam cup. The temperature of the solution rises from 28.5 °C to 36.6 °C. Determine the enthalpy change of solution of NaOH.

For examiner's use

Assume the specific heat capacity and density of the solution are 4.18 J g^{-1} K^{-1} and 1.00 g cm^{-3} respectively. [2]

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For examiner's use

(d) Both hydrogen and ammonia are good alternative fuels to reduce carbon emissions.

During the complete combustion of gaseous ammonia, N_2 is formed as the only nitrogen-containing product.

(i) Write an equation which describes the standard enthalpy change of combustion of gaseous ammonia. [1]

Standard enthalpy change of formation data are shown in Table 2.2.

Table 2.2

species	$NH_3(g)$	$H_2O(l)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	−45.9	−285.8

(ii) Calculate the standard enthalpy change of combustion of gaseous ammonia. [1]

Table 2.3 shows some information about liquid hydrogen and liquid ammonia.

Table 2.3

fuel	$H_2(l)$	$NH_3(l)$
temperature at which it is liquefied at 1 bar / °C	−253	−33
density / kg m^{-3}	71	682
enthalpy change of combustion / kJ mol^{-1}	−241	−316

The energy produced per unit volume for $H_2(l)$ upon complete combustion is 8.56×10^6 kJ m^{-3}.

(iii) Calculate the energy produced per unit volume for $NH_3(l)$ upon complete combustion. [2]

(iv) Suggest two reasons why liquid ammonia is preferred over liquid hydrogen as an alternative fuel. [2]

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For examiner's use

For examiner's use

(e) Hydrazine, N_2H_4, has been commonly used as a rocket propellent.

(i) Equation 1 shows the synthesis of hydrazine.

equation 1 $NH_2Cl(g) + NH_3(g) \longrightarrow N_2H_4(g) + HCl(g)$ $\Delta H = -31$ kJ mol^{-1}

Use the data given and other data from the *Data Booklet* to calculate the N−N bond energy in hydrazine.

Show your working. [2]

(ii) In the rocket, liquid hydrazine decomposes to give gaseous ammonia and gaseous nitrogen only.

Write an equation, with state symbols, for the decomposition of liquid hydrazine. [1]

(iii) Using your equation in **(ii)**, explain how the decomposition of hydrazine makes it suitable as a propellant. [1]

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[Total: 20]

Additional answer space

For examiner's use

If you use the following pages to complete the answer to any question, the question number must be clearly shown.

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