RAFFLES INSTITUTION
2024 YEAR 5 TERM 3 TIMED PRACTICE

Higher 2

CHEMISTRY 9729

2 July 2024

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 sheet on **page 7**. 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 (pages 30 – 32). 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.
If additional space is required, you should use the pages at the end of the booklet (pages 30 – 32). 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.

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

Which of the following contains the same number of atoms or ions as there are atoms in 0.2 g of oxygen gas?

A 0.225 g of water

B 1.275 g of aluminium oxide

C 0.300 dm^3 of neon gas at r.t.p.

D 0.284 dm^3 of nitrogen gas at s.t.p.

2 Tin(II) ions can be oxidised to tin(IV) ions by iodate(V) ions, IO_3^-. The equation for the oxidation is shown below.

$$Sn^{2+} \rightarrow Sn^{4+} + 2e^-$$

In an experiment, 25.0 cm^3 of 0.0250 mol dm^{-3} IO_3^- was found to react with 31.20 cm^3 of 0.0400 mol dm^{-3} Sn^{2+}.

What is the oxidation number of iodine in the iodine-containing product?

A –1 **B** 0 **C** +1 **D** +3

3 The table shows the fifth ionisation energies of four consecutive elements in the Periodic Table.

element	Q	R	S	T
fifth ionisation energy / kJ mol^{-1}	32828	37832	9445	10989

What is the formula of the chloride of Q?

A QCl_2 **B** QCl_3 **C** QCl_4 **D** QCl_5

4 Beams of charged particles are deflected by an electric field.

$^7Li^+$ ions are deflected by an electric field through an angle of +x°.

Which particle will be deflected through an angle of more than +x°?

	proton number	nucleon number	number of electrons
A	7	14	9
B	8	16	9
C	13	27	10
D	17	35	10

5 Which of the following shows the species quoted in order of increasing bond angle about the central atom?

A XeF_2 < BrF_2^+ < NO_2
B BrF_2^+ < NO_2 < XeF_2
C NO_2 < BrF_2^+ < XeF_2
D NO_2 < XeF_2 < BrF_2^+

6 Hydroxylamine, NH_2OH, reacts with BF_3 to form an adduct, $F_3B{\bullet}NH_2OH$.

Which statements about $F_3B{\bullet}NH_2OH$ are correct?

1 Intramolecular hydrogen bonding can exist in $F_3B{\bullet}NH_2OH$.
2 The bonds around B atom are tetrahedrally arranged.
3 The H–N–O angle is larger than the H–O–N angle.

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

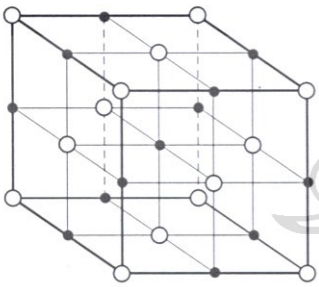
7 Which groups of compounds contain one that is ionic, one that is simple molecular and one that is giant molecular?

1 Si, A*l*F_3, HC*l*
2 SiCl_4, Al_2O_3, HBr
3 A*l*Cl_3, SiO_2, BaI_2

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

8 Which diagram best represents the structure of solid sodium chloride?

A



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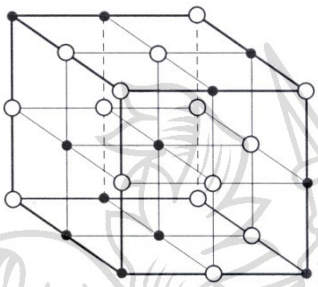

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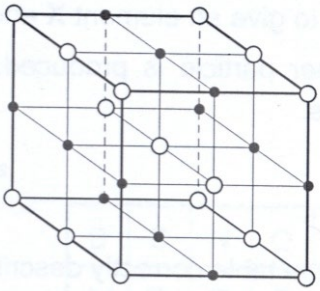

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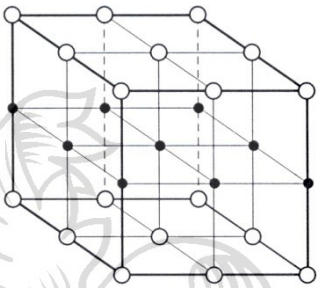


9 A sealed container contains two gases, **X** and **Y**, with a mole ratio of 1 : 2. The total pressure is P atm.

A third gas, **Z**, is introduced into the same container and the total pressure becomes 2P atm.

What is the partial pressure, in atm, of gas **X** after the introduction of gas **Z**, assuming that the temperature and volume of container remain constant?

A $\frac{P}{6}$ **B** $\frac{P}{3}$ **C** $\frac{2P}{3}$ **D** P

10 During the operation of a refrigerator, the coolant is constantly being liquefied under pressure, and vaporised once the pressure is released. Under these conditions, the gas does not behave as an ideal gas.

Which statement best describes why the gas liquefies under pressure?

A Increasing the pressure causes the boiling point of the gas to decrease.

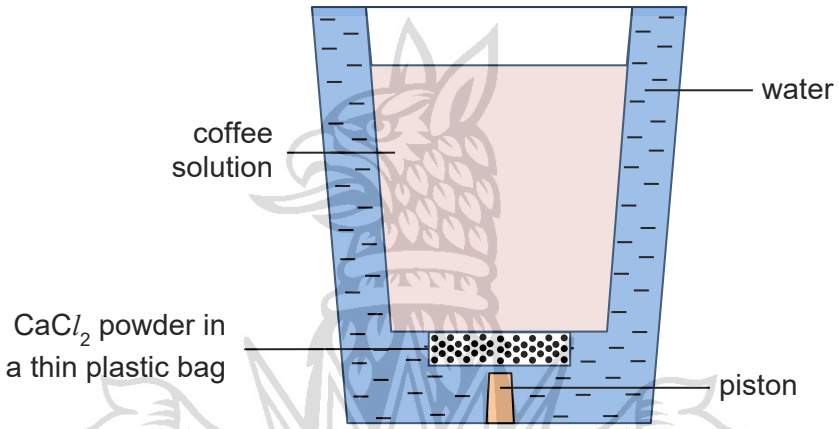
B Increasing the pressure decreases the kinetic energy of the molecules, creating the ordered liquid state.

C Increasing the pressure decreases the size of the molecules, and so increases the intermolecular attractions.

D Increasing the pressure pushes the molecules closer together, and so the short-range intermolecular forces of attraction are more effective.

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

The design for an experimental self-heating can for coffee is shown below.



The outer container is filled with water that surrounds the inner container holding the coffee solution. When the piston is pressed, it punctures the plastic bag and allows the $CaCl_2$ powder to dissolve in the water in an exothermic reaction.

$$CaCl_2(s) \longrightarrow Ca^{2+}(aq) + 2Cl^-(aq) \qquad \Delta H = -83 \text{ kJ mol}^{-1}$$

Sufficient energy must be released to heat *both* the water and coffee from 25 °C to 70 °C. Each can contains 76 cm^3 of the coffee solution and 70 cm^3 of water.

Assume the following for both the $CaCl_2$ and coffee solution:
density = 1.0 g cm^{-3}
specific heat capacity = 4.18 J g^{-1} K^{-1}

Assuming negligible heat loss, what mass of $CaCl_2$ powder is required in this design?

A 8.8 g **B** 17.6 g **C** 19.1 g **D** 36.8 g

12 Which reaction has an enthalpy change equal to the lattice energy of lithium fluoride?

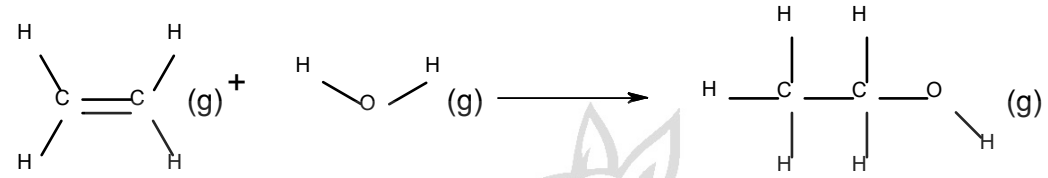
A $Li(g) + F(g) \longrightarrow LiF(s)$

B $Li(s) + \frac{1}{2}F_2(g) \longrightarrow LiF(s)$

C $Li^+(g) + F^-(g) \longrightarrow LiF(g)$

D $Li^+(g) + F^-(g) \longrightarrow LiF(s)$

13 Which of the following estimates the enthalpy change of the reaction below?



A BE(C–O) + BE(C–C) – BE(O–H) – BE(C=C)

B BE(C=C) + BE(O–H) – BE(C–C) – BE(C–O)

C BE(C=C) + BE(O–H) – BE(C–C) – BE(C–O) – BE(C–H)

D BE(C–H) + BE(C–O) + BE(C–C) – BE(O–H) – BE(C=C)

14 Hydrogen can be made from steam.

$$H_2O(g) + C(s) \longrightarrow H_2(g) + CO(g)$$

The Gibbs free energy change of reaction at two different temperatures are shown.

ΔG_1 = +78 kJ mol^{-1} at 378 K
ΔG_2 = –58 kJ mol^{-1} at 1300 K

Which row of the table gives the correct signs of ΔH and ΔS for this reaction?

	ΔH	ΔS
A	–	–
B	–	+
C	+	–
D	+	+

15 In which reactions do the entropy increase?

1 $H_2O(l)$ at 308 K $\longrightarrow$ $H_2O(l)$ at 298 K

2 $H_2O(s)$ at 273 K $\longrightarrow$ $H_2O(l)$ at 273 K

3 $F_2(g) \longrightarrow 2F(g)$

A 1 only

B 1 and 3

C 2 and 3

D 3 only

RAFFLES INSTITUTION
2024 YEAR 5 TERM 3 TIMED PRACTICE

Higher 2

CANDIDATE NAME			
CLASS		INDEX NUMBER	

For Examiner's Use Only

Section		Marks
A		/ 15
B	B1	/ 7
	B2	/ 8
	B3	/ 15
C	C1	/ 14
	C2	/ 21
Total		/ 80
Percentage		/ 100
Penalty		
Overall		/ 100

Section B (30 marks)

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

1 Fig 1.1 shows the successive ionisation energies of two elements, with atomic numbers less than 20.

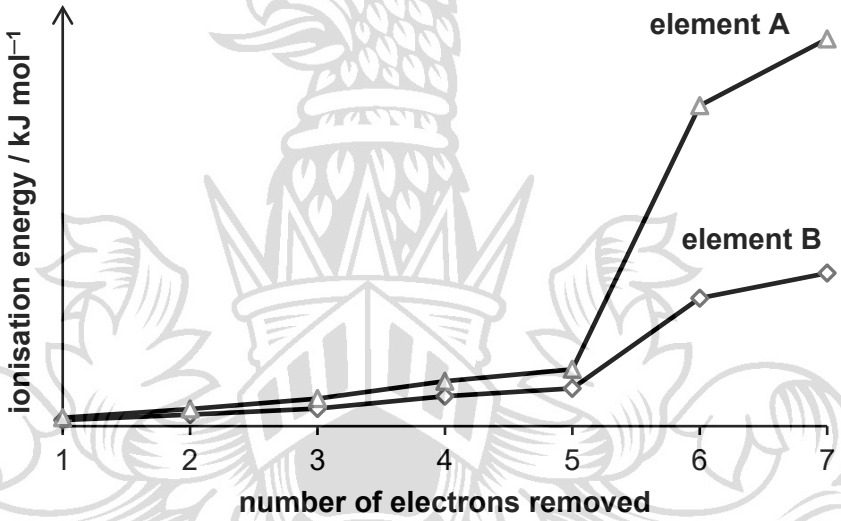


Fig. 1.1

(a) Explain the general increase in successive ionisation energies for any atom.

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……[2]

(b) For each element, there is an observed large jump in Fig 1.1.

Explain the large jump in element **A** and suggest why it is more significant than in element **B**.

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……[2]

(c) Write the full electronic configuration of element **A**.

……[1]

(d) Explain the difference in the first ionisation energy of element **A** and that of the noble gas in the same period.

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……[2]

[Total: 7]

2 Chlorine readily forms compounds with a variety of elements. Metal chlorides are usually good conductors of electricity in the molten and aqueous states.

(a) Magnesium chloride is an active ingredient found in magnesium supplements. Draw the dot-and-cross diagram to show the bonding in magnesium chloride.

[1]

(b) Caesium, found in the same group as potassium, reacts with chlorine in a similar manner. Explain, in terms of structure and bonding, why caesium chloride has a lower melting point than potassium chloride.

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……[2]

(c) Ionic compounds conduct electricity in aqueous medium due to mobile charged ions. This can be measured by the ionic conductivity of the ions, Cs^+ and Na^+, as shown in Table 2.1. Larger ions may experience more resistance from the surrounding medium, making them less mobile.

Table 2.1

ion	ionic radius / nm	value of ionic conductivity in aqueous medium
Cs^+	0.170	7.72×10^{-3}
Na^+	0.095	5.01×10^{-3}

(i) Draw a labelled diagram to show the significant force of attraction between a Na^+ ion and water. Your diagram should show at least three water molecules.

[1]

(ii) Suggest a reason why Na^+, despite having a smaller ionic radius, has a lower ionic conductivity than Cs^+.

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……[2]

(d) The nature of bonding in a chemical compound is dependent on the difference in electronegativities of the atoms in the compound. Table 2.2 shows the electronegativity values of two elements.

Table 2.2

element	electronegativity / Pauling units
A*l*	1.61
C*l*	3.16

The difference in electronegativities (ΔEN) can be used to calculate the percentage ionic character of a chemical bond using the formula below.

$$\text{Percentage ionic character} = (1 - e^{-0.25\,(\Delta EN)}) \times 100\%$$

where $\Delta EN = |\chi_A - \chi_B|$ and χ_A and χ_B are the respective electronegativities of atoms **A** and **B**.

(i) Calculate the percentage ionic character of the A*l*–C*l* bond.

[1]

(ii) Hence, explain why aluminium chloride does not conduct electricity in the molten state.

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……[1]

[Total: 8]

3 **(a)** Dinitrogen pentoxide, N_2O_5, is used as an oxidiser in some rockets and a nitrating agent in industries.

Given that gaseous N_2O_5 is a symmetrical molecule with one of the O atoms directly bonded to both N atoms, draw the dot-and-cross diagram of the N_2O_5 molecule.

Hence, explain the shape, and suggest the bond angle, around this O atom.

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……[3]

(b) $N_2O_5(g)$ is unstable and can decompose completely to produce $NO_2(g)$, and $O_2(g)$ under specific conditions.

1.242 g of a mixture containing only the products of decomposition is collected in a 1.00 dm^3 canister and is found to exert a pressure of 72.46 kPa at 30 ^oC.

(i) Calculate the amount of gas in the gas canister and the average M_r of the mixture.

[2]

(ii) Hence, or otherwise, calculate the mole fraction and partial pressure of NO_2 present in the mixture.

[2]

(c) The volume of a sample of oxygen is measured at different pressures with the temperature kept at 1000 K. Table 3.1 shows the data obtained.

Table 3.1

pressure / kPa	volume / m^3
6.0	0.060
12.0	0.030
18.0	0.020

(i) Use information from Table 3.1 to show that the sample of oxygen exhibits ideal gas behaviour under these conditions.

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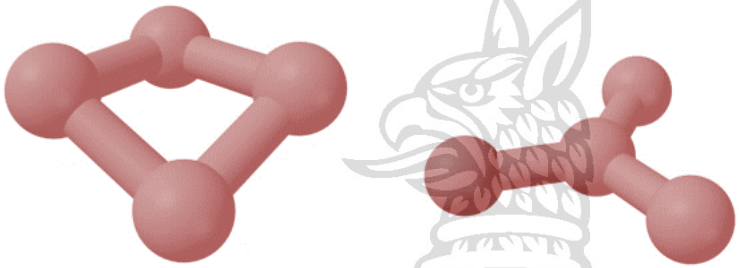
……[1]

(ii) Suggest why the sample of oxygen exhibits ideal gas behaviour.

……[1]

(d) Tetraoxygen, O_4, is an allotrope of oxygen. Tetraoxygen molecules are found to be unstable and short-lived.

Fig. 3.1 shows three possible structures of tetraoxygen.



O_4 [puckered ring] O_4 [pinwheel] O_4 [square]

Fig. 3.1

(i) Use the Valence Shell Electron Pair Repulsion theory to explain why O_4 [square] is unstable.

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……[2]

(ii) Define the term *standard enthalpy change of formation*.

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(iii) The standard enthalpy change of formation of O_4 [pinwheel] (l) is +480 kJ mol^{-1}. The O_4 [pinwheel] (l) is 89.3 kJ mol^{-1} higher in energy than O_4 [puckered ring] (l).

Use the given information to complete Fig. 3.2.

Hence, calculate the standard enthalpy change of formation of O_4 [puckered ring] (l).

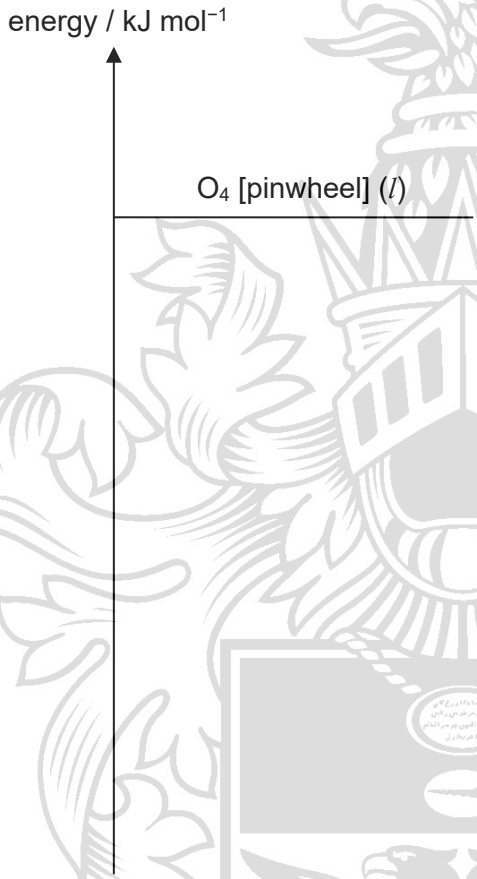

Fig. 3.2

[3]

[Total: 15]

Section C (35 marks)

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

1 **(a)** Halogens can react with each other to form interhalogen compounds. The general formula of most interhalogen compounds is AX_n, where n = 1, 3, 5 or 7.

There are generally 4 types of interhalogen compounds:

AX type: C*l*F, BrF, BrC*l*, IC*l*, IBr
AX_3 type: ClF_3, BrF_3, $(ICl_3)_2$
AX_5 type: ClF_5, BrF_5, IF_5
AX_7 type: IF_7

(i) With the aid of a fully labelled diagram showing the orbitals involved, describe the bonding in C*l*F. You should show clearly the relative sizes of these orbitals. [2]

(ii) Suggest a reason why FCl_3 does not exist. [1]

(iii) ICl_3 is the only interhalogen compound that exists as a planar dimer, I_2Cl_6.
Draw a suitable diagram to illustrate the shape and bonding in I_2Cl_6. [1]

(iv) Suggest a reason why IF_7 exists, but ClF_7 does not exist. [1]

(v) At room temperature, bromine, Br_2, is a liquid, while iodine monochloride, IC*l*, is a solid.

Explain why in terms of structure and bonding. [3]

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(b) SO_2 is commonly added to fruit juices to act as a preservative. Due to health concerns, the maximum concentration of SO_2 that is allowed is 350 ppm (parts per million).
[1 ppm = 1 mg dm^{-3}]

To analyse the concentration of SO_2 in a sample of lemon juice, 100 cm^3 of the lemon juice was reacted with excess $KClO_3(aq)$, where ClO_3^- was reduced to Cl^-. Upon adding excess $AgNO_3(aq)$ to the resultant solution, 0.0370 g of solid AgCl was obtained.

(i) State the oxidation number of Cl in ClO_3^-. [1]

(ii) The half-equation for the oxidation of SO_2 is shown below:

$$SO_2 + 2H_2O \longrightarrow SO_4^{2-} + 4H^+ + 2e^-$$

Construct a half-equation for the reduction of ClO_3^- and hence, write the balanced equation for the reaction between SO_2 and ClO_3^-. [2]

(iii) Calculate the mass of SO_2 in 100 cm^3 of this sample of lemon juice. [2]

(iv) Hence, deduce whether the concentration of SO_2 in this sample of lemon juice has exceeded the maximum concentration allowed. [1]

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[Total: 14]

2 **(a)** To monitor the haze situation, samples of air were analysed and found to contain elevated amounts of SO_2 and gas **D**.

By careful measurement and extrapolation, the value of $\frac{\rho}{p}$ for gas **D** has been found to be 1.24×10^{-2} at 0 °C and very low pressure as shown in Fig. 2.1.

[ρ is the density of the gas in g m^{-3} and p is the pressure of the gas in Pa.]

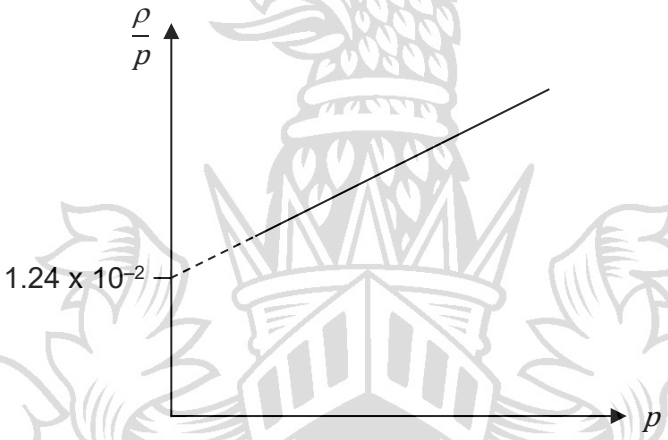

Fig. 2.1

(i) Describe two ways in which the properties of an ideal gas differ from those of real gases. [2]

(ii) Draw a suitable line in Fig. 2.1 to show the relationship of $\frac{\rho}{p}$ against p, if gas **D** were to behave like an ideal gas.

Label this line as 'ideal gas'. [1]

(iii) Calculate a value for the relative molecular mass of **D**. [1]

(iv) Gas **D** is a toxic pollutant and exists as diatomic molecules. Identify **D**. [1]

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(b) Natural gas is a fossil fuel and a naturally occurring mixture of gaseous hydrocarbons consisting primarily of methane. Low levels of other gases such as carbon dioxide, nitrogen and hydrogen are also usually present.

Fig. 2.2 illustrates the behaviour of 1 mol of methane, CH_4, at 293 K.

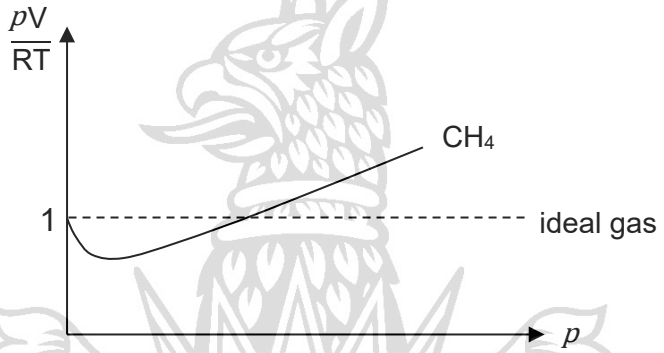

Fig. 2.2

(i) On Fig. 2.2, sketch and label the corresponding graph for 1 mol of CO_2 at 293 K. Explain your answer. [3]

The enthalpy change of combustion for CH_4 and H_2 at 293 K and 1 atm are given in Table 2.1.

Table 2.1

gas	ΔH_c / kJ mol^{-1}
CH_4	–880
H_2	–280

In an experiment, 100 cm^3 of a 70:1 mixture of CH_4 and H_2 was ignited in excess oxygen at room temperature and pressure.

(ii) Write two balanced equations that represent the enthalpy change of combustion, ΔH_c, of CH_4 and H_2. [2]

(iii) Calculate the heat evolved in this combustion experiment. [2]

(iv) Using your answer to **(b)(ii)**, explain if the combustion of H_2 is spontaneous at all temperatures. [2]

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(c) NH_4Cl is a white crystalline solid which is very soluble in water.

(i) Define the term *standard enthalpy change of hydration* of an ion. [1]

(ii) Use the following data to construct an energy cycle and calculate the lattice energy of NH_4Cl. [4]

standard enthalpy change of formation of $NH_4Cl(s)$	–314 kJ mol^{-1}
standard enthalpy change of formation of $NH_4^+(aq)$	–133 kJ mol^{-1}
standard enthalpy change of formation of $Cl^-(aq)$	–167 kJ mol^{-1}
standard enthalpy change of hydration of $NH_4^+(g)$	–307 kJ mol^{-1}
standard enthalpy change of hydration of $Cl^-(g)$	–381 kJ mol^{-1}

(iii) Hence, or otherwise, calculate the standard enthalpy change of solution of NH_4Cl. [1]

(iv) By considering your answer in **(c)(iii)**, suggest a possible use of NH_4Cl. [1]

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Additional answer space

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

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