YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	

CG		INDEX NO	

CHEMISTRY 9729/02

Paper 2 Structured Questions **1 September 2025**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number in the spaces at the top of this page.
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.

Answer **all** questions in the spaces provided on the Question Paper.
The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

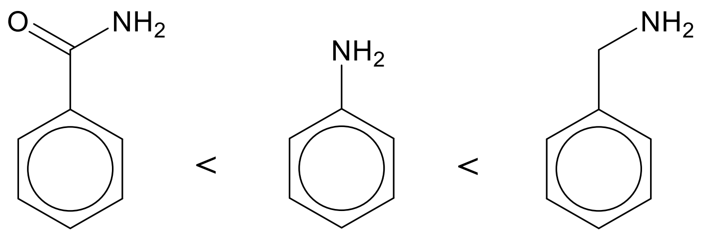
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use		
1		**/ 18**
2		**/ 24**
3		**/ 17**
4		**/ 16**
Penalty	**units**	**significant figures**
Overall		**/ 75**

This document consists of **21** printed pages and **3** blank pages.

Answer **all** the questions in the spaces provided.

1 **(a)** Compounds **A**, **B** and **C** are shown in order of increasing basicity. Explain this order.



A **B** **C**

....

....

....

....

....

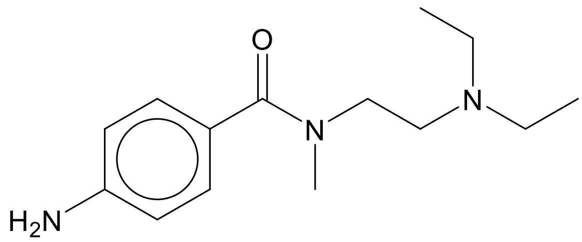
....

....

....

.... [3]

(b) Amides can be found in many drugs such as paracetamol and procainamide. Procainamide can be used for the treatment of cardiac arrhythmias.



procainamide

Predict the products obtained when procainamide undergoes reaction with hot, dilute H_2SO_4.

[2]

(c) Compound **J** can be synthesised by the following route in Fig. 1.1, with all the carbon atoms coming from compound **E**.

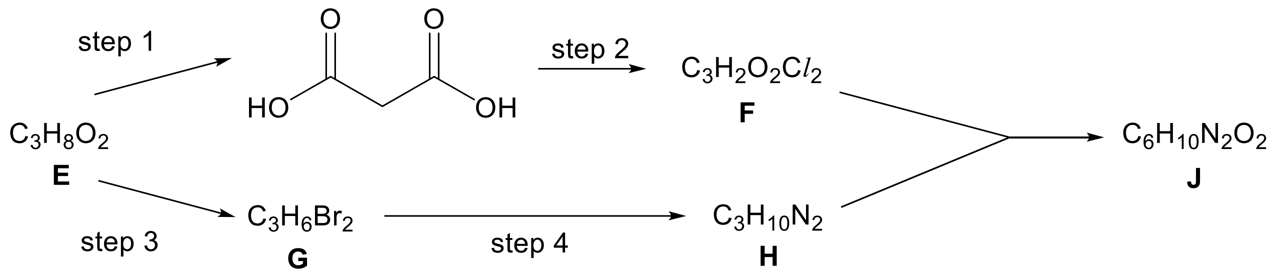
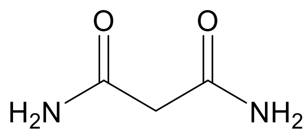


Fig. 1.1

- Compound **E** does not react with NaOH(aq) but reacts with Na to give a gas that extinguishes a lighted splint with a 'pop' sound.
- Compound **H** is soluble in dilute HC*l* and can also be obtained from the reaction of compound **K** with LiA*l*H$_4$.



K

- Compound **J** is neutral and is a cyclic molecule.

(i) Draw the structure of compounds **E** to **H**, and **J**.

E **F** **G**

H **J**

[5]

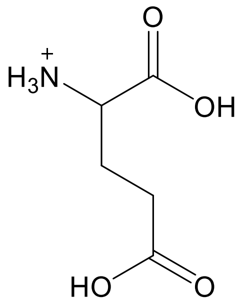
(ii) State the reagents and conditions for steps 2 and 4.

step 2 ....

step 4 ....

[2]

(d) The compounds responsible for the umami flavour of soy sauce are salts of glutamic acid.



glutamic acid

Glutamic acid has pK_a values of 2.1, 4.1 and 9.5. Draw the structure of the zwitterion. Suggest a pH at which the predominant species of glutamic acid is a zwitterion.

.... [2]

(e) A polypeptide contains 9 amino acid residues. It was partially hydrolysed to give a mixture of tripeptides.

asp-gly-tyr
glu-tyr-lys
gly-glu-tyr
met-asp-gly
tyr-ala-gly

Determine the sequence of amino acids that make up the primary structure of the polypeptide.

.... [1]

(f) Halogenoalkanes can react with NH_2^- to produce amines.

A sample that contains only one enantiomer of 2-bromobutane reacts completely with NH_2^- to produce a mixture that does not rotate plane-polarised light.

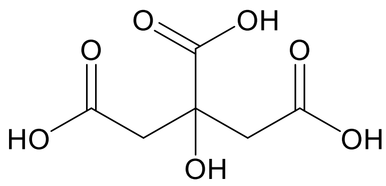
Draw a mechanism for the reaction between NH_2^- and 2-bromobutane. Include all relevant lone pairs, dipoles, curly arrows and charges.

[3]

[Total: 18]

2 Citric acid, $C_6H_8O_7$, is a naturally occurring weak organic acid found in citrus fruits. It has a wide range of applications in the food, cleaning products and healthcare industries.

It is triprotic and has the following structure.



(a) **(i)** Citric acid is a Brønsted-Lowry acid.

Explain what is meant by this statement.

....

.... [1]

(ii) The dissociation of citric acid in water occurs in three steps.

Using H_3A as a simplified representation of citric acid, the first dissociation step is as shown:

$$H_3A + H_2O \rightleftharpoons H_2A^- + H_3O^+$$

Write the balanced equation for the second dissociation step of citric acid in water.

.... [1]

(iii) Identify the two conjugate acid-base pairs in the dissociation step you have written in **(a)(ii)**.

acid .... conjugate base ....

base .... conjugate acid .... [1]

(iv) Explain why the carboxylic acid group on citric acid is a stronger Brønsted-Lowry acid than the hydroxyl group.

....

....

....

.... [1]

BLANK PAGE

(b) The pK_a values for citric acid are shown in Table 2.1.

Table 2.1

	pK_1	pK_2	pK_3
citric acid	3.1	4.8	6.4

(i) Calculate the pH of 0.10 mol dm^{-3} citric acid at 298 K (ignore the effect of pK_2 and pK_3 on the pH). Show your working.

[2]

(ii) A buffer solution with a pH of 3.40 is made by adding 50 cm^3 of solution **L** containing monosodium citrate to 100 cm^3 of 0.0200 mol dm^{-3} citric acid.

Calculate the concentration of monosodium citrate in solution **L**.

You may use NaH_2A to represent monosodium citrate, and H_3A to represent citric acid.

[3]

(iii) Using an equation, explain how the citric acid/monosodium citrate buffer solution in **(b)(ii)** resists pH changes when a small amount of acid is added to it.

....

....

.... [2]

(iv) 10 cm^3 of 0.100 mol dm^{-3} citric acid was titrated against 0.100 mol dm^{-3} sodium hydroxide. The titration curve is shown in Fig. 2.1.

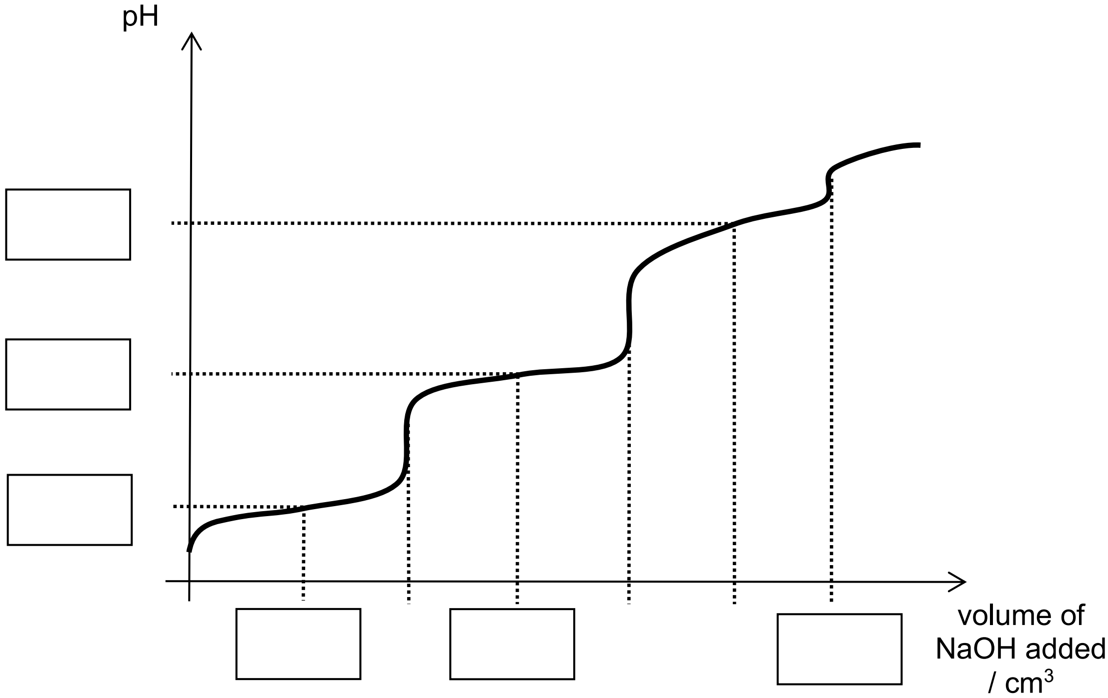
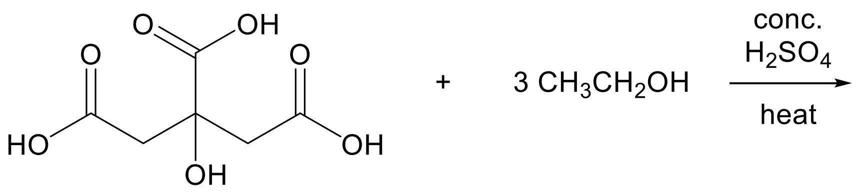


Fig. 2.1

Fill in the boxes above with the correct pH values and NaOH volumes. [2]

(c) A sample of citric acid is heated with excess ethanol in the presence of a small amount of concentrated sulfuric acid.

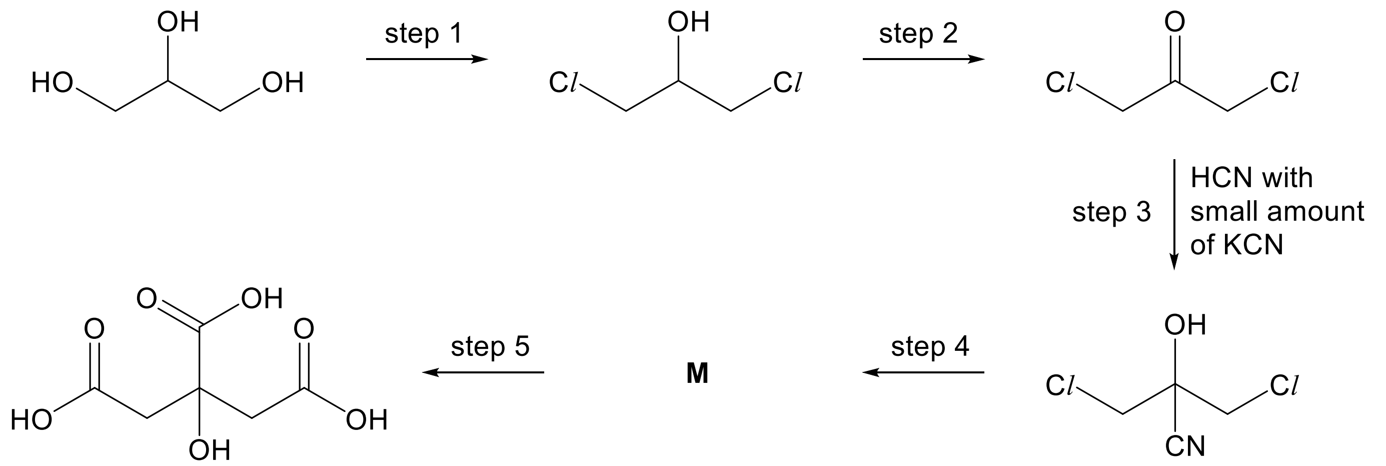


(i) In the box above, draw the skeletal structure of the organic product formed. [1]

(ii) State the type of reaction that has occurred.

.... [1]

(d) Citric acid can be synthesised from glycerol in 5 steps according to the following reaction scheme.



citric acid

(i) Step 1 is a nucleophilic substitution reaction. Using specific reagents and conditions, only the primary alcohol groups of glycerol are substituted to produce a chloroalkane.

Suggest why substitution occurs only at the primary alcohol groups.

....

....

....

[1]

(ii) Draw the mechanism for step 3 of the reaction scheme. Include all relevant lone pairs, dipoles, curly arrows and charges.

[3]

(iii) Draw the structure of the intermediate compound, **M**, and state the reagents and conditions for steps 4 and 5.

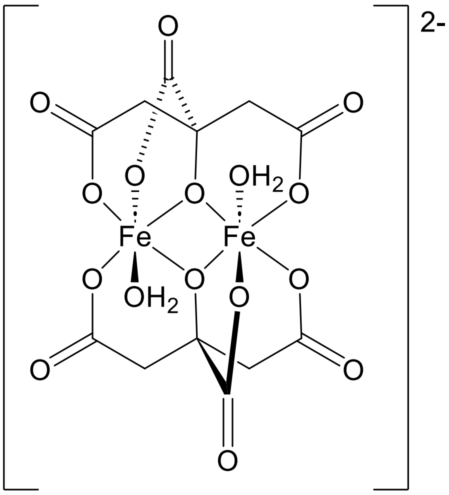
compound **M**

step 4 ....

step 5 ....

[3]

(e) Fully-deprotonated citric acid, $C_6H_4O_7^{4-}$, can form soluble complexes with iron ions. The structure of one such complex which involves two $C_6H_4O_7^{4-}$ as ligands is shown below.



(i) Determine the oxidation state of iron in this complex. Show how you arrived at your answer.

[1]

(ii) A solution containing $C_6H_4O_7^{4-}$ removes rust by forming a soluble complex with iron ions, while a solution containing citric acid removes rust via an acid-base reaction.

Suggest a reason why $C_6H_4O_7^{4-}$ is preferred over citric acid in removing rust from steel.

....

.... [1]

[Total: 24]

3 Silver azide, AgN_3, is sparingly soluble in water at 25 °C.

(a) The equation for the entropy change of solution is shown.

$$AgN_3(s) \rightarrow Ag^+(aq) + N_3^-(aq) \qquad \Delta S^\ominus_{sol} = +70.1 \text{ J K}^{-1} \text{ mol}^{-1}$$

The standard enthalpy change of formation for these species are shown in Table 3.1.

Table 3.1

species	$AgN_3(s)$	$Ag^+(aq)$	$N_3^-(aq)$
$\Delta H^\ominus_f$ / kJ mol^{-1}	+315.0	+105.9	+272.7

(i) Explain the significance of the sign of the entropy change for the dissolution of silver azide.

....

....

.... [1]

(ii) Calculate $\Delta H^\ominus_{sol}$ and $\Delta G^\ominus_{sol}$ for silver azide and use this information to explain why AgN_3 is only sparingly soluble in water at 25 °C.

Show your working.

....

....

.... [3]

(b) In an experiment, solid sodium azide, $NaN_3(s)$, was added slowly to a 1 dm^3 solution containing 2.00×10^{-4} mol of $Ag^+(aq)$, and the amount of AgN_3 precipitated out was measured.

Fig. 3.1 shows the graph of amount of AgN_3 precipitated out against amount of NaN_3 added. The graph is not drawn to scale.

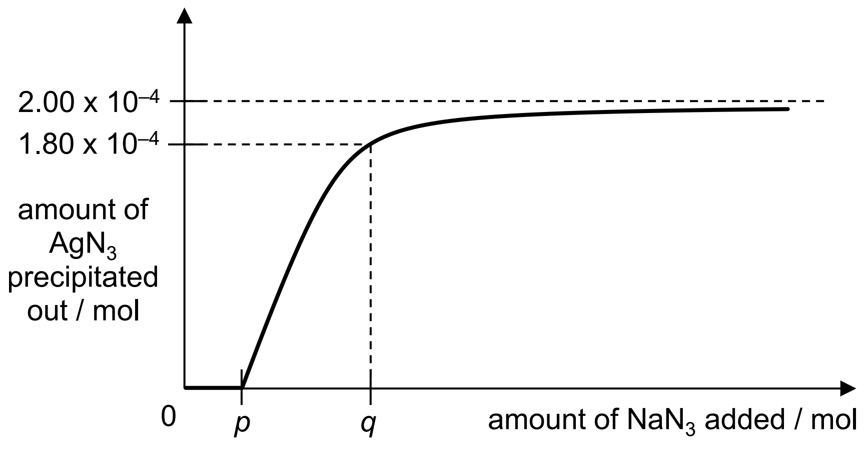


Fig. 3.1

The K_{sp} value of AgN_3 is 2.80×10^{-9}.

(i) Explain why AgN_3 is just about to precipitate out when p mol of NaN_3 was added.

....

.... [1]

(ii) Hence, or otherwise, determine the value of p.

[1]

(iii) Calculate the $[Ag^+]$ remaining in the solution when 1.80 x 10^{-4} mol of AgN_3 has precipitated out.

[1]

(iv) By considering your answer in **(b)(iii)** and the $[N_3^-]$ remaining in solution, determine the value of *q*, which is amount of NaN_3 to be added for 1.80 x 10^{-4} mol of AgN_3 to precipitate out.

[1]

(v) Comment on the change in gradient of the graph as it approaches 2.00 x 10^{-4} on the *y*-axis.

....

....

.... [1]

(c) Some information about N_3^- is provided in Table 3.2.

Table 3.2

shape of N_3^- ion	linear
N–N–N bond angle	180°

The bond length between nitrogen atoms in different molecules is shown in Table 3.3.

Table 3.3

molecule containing nitrogen-nitrogen bond	bond length / nm
N_2	0.110
N_3^-	0.116
$H_2N–NH_2$	0.145

Fig. 3.2 shows one possible arrangement of valence electrons and bonds in N_3^-.

Fig. 3.2

(i) Nitrogen atoms undergo the same type of hybridisation as carbon atoms.

Using Fig. 3.2 and/or information from Table 3.2, suggest the hybridisation of the central N atom in N_3^-.

Explain your answer.

....

....

.... [2]

(ii) Use information from Table 3.3 to explain why Fig. 3.2 does **not** represent an accurate model for the bonding in N_3^-.

....

....

.... [1]

BLANK PAGE

(d) N_3^- is frequently used as a nucleophile in organic reactions because it allows nitrogen to be introduced into an organic compound.

Fig. 3.3 shows how an acid chloride can be converted into an amine with the use of N_3^- as one of the reagents.

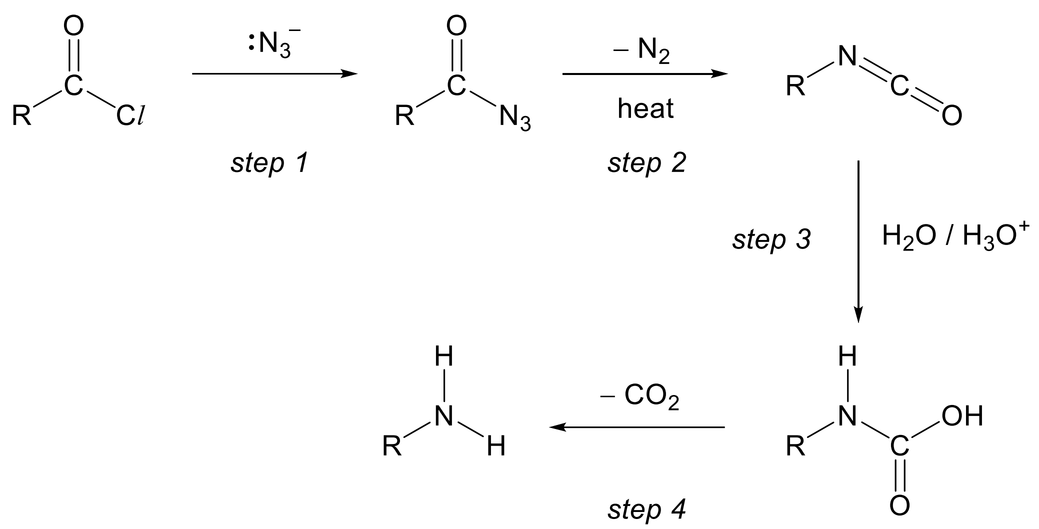


Fig. 3.3

(i) Suggest the type of reaction in *step 3*.

.... [1]

(ii) Draw the structure of the acid chloride that will be converted to phenylamine through the process shown in Fig. 3.3.

[1]

(iii) On Fig. 3.4, draw curly arrows to complete the mechanism for *step 3*. Show all relevant dipoles and lone pairs in your answer. [2]

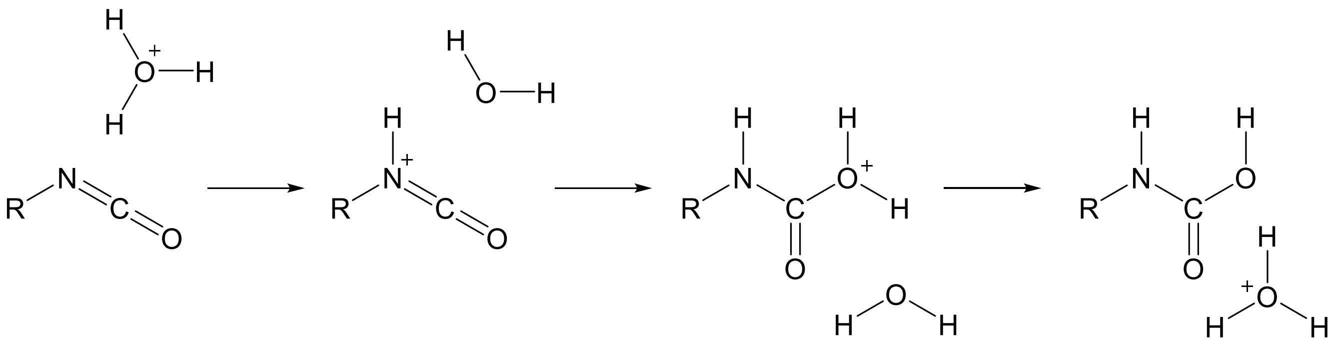


Fig. 3.4

(iv) In Fig. 3.4, H_3O^+ serves two roles. One of the roles it serves is that of a Brønsted-Lowry acid.

Deduce the other role of H_3O^+. Explain your answer.

....

.... [1]

[Total: 17]

4 This question is about the chemistry of noble gases in Group 18 of the Periodic Table.

(a) Noble gases are known for their behaviour that closely resembles an ideal gas, especially under certain conditions.

(i) State and explain the **two** conditions under which a real gas behaves most closely to an ideal gas.

....

....

....

.... [2]

(ii) Explain why Ne behaves more closely to an ideal gas than HF.

....

....

....

.... [2]

(b) A 3 dm^3 vessel containing He at 4.0 kPa is connected to an empty 2 dm^3 vessel at constant temperature.

(i) Show that the pressure of He after the two vessels are connected is 2.4 kPa.

[1]

Xe is then pumped into the connected vessels until the total pressure inside the vessels is 6.0 kPa.

(ii) Calculate the partial pressure of Xe in the vessels.

[1]

(iii) Hence, or otherwise, calculate the mole fraction of Xe.

[1]

Table 4.1 provides information on some noble gases.

Table 4.1

	He	Ne	Ar	Kr	Xe
relative atomic mass	4.0	20.2	39.9	83.8	131.3
atomic radius / nm	0.140	0.160	0.190	0.202	0.216
density / g dm^{-3}	0.179	0.900	1.78	3.71	5.85
first ionisation energy / kJ mol^{-1}	2370	2080	1520	1350	1170
boiling point / °C	−269	−246	−186	−152	−107

(c) Noble gases were long believed to be totally unreactive but stable compounds of Kr and Xe are now known. Highly electronegative elements such as fluorine and oxygen form many compounds with Xe, for example, XeF_2, XeF_4 and XeO_4. All of these compounds are simple covalent molecules.

(i) Ne is in period 2 and does not form any compound at all. Explain why.

....

....

.... [1]

(ii) Describe the covalent bond in a molecule of XeF_4.

....

....

.... [1]

(iii) Draw the 'dot-and-cross' diagram for XeO_4.

Use VSEPR theory to predict the shape of and bond angle in XeO_4. Explain your answer.

....

....

....

....

.... [3]

(iv) Xe can form XeF_2 and XeF_4 but Kr can only form KrF_2.

Use information from Table 4.1 to suggest a reason why Kr does not form a compound with four fluorine atoms.

....

....

.... [1]

(d) The first noble gas compound was synthesised by reacting Xe with PtF_6.

PtF_6 is a strong oxidant that is able to extract an electron from Xe, thus forming $Xe^{+}[PtF_6]^{-}$, which is an ionic compound.

(i) Explain why the Xe^{+} ion can be described as a radical.

....

.... [1]

(ii) Although PtF_6 is able to extract an electron from Xe, it is unable to do so from He and Ne. Use information from Table 4.1 to suggest why this is so.

....

....

.... [1]

(e) He has an unusually low abundance in earth's atmosphere despite being the most abundant Group 18 element in the solar system.

Use information from Table 4.1 to suggest a reason for the low abundance of He in earth's atmosphere.

....

....

.... [1]

[Total: 16]

BLANK PAGE