RIVER VALLEY HIGH SCHOOL
JC 2 PRELIMINARY EXAMINATIONS

CANDIDATE NAME						
CLASS	2	4	J			INDEX NUMBER

H1 CHEMISTRY 8873/02

Paper 2 Structured Questions

16 September 2025

2 Hours

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

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, highlighters, glue or correction fluid.

Section A
Answer **all** questions in the spaces provided on the Question Paper. The question number must be clearly shown.

Section B
Answer **one** question.

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.

This paper consists of **24** printed pages.

For Examiner's Use	
Paper 1	/30
Paper 2	
1	/11
2	/8
3	/6
4	/10
5	/7
6	/10
7	/8
8	/20
9	/20
s.f.	
units	
Paper 2	/80
Total	/110

Section A

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

1 Iron ore deposits are found globally, with significant reserves in Australia, Brazil, Russia, China, and India. A company refining iron ore would only purchase more ores from distributors if the percentage of iron in each ore is >60%. If it is any lower than this, then the cost of refining the ore will be considered expensive.

(a) Define the term *mole*.

……..

……..

…….. [1]

(b) An experiment was carried out to determine the percentage of iron in a sample of iron ore.

A 3.35 g piece of ore was reacted with dilute sulfuric acid, in the absence of air, so that all the iron atoms were converted to iron(II) ions. The resulting solution was made up to 250 cm^3. Other substances in the ore do not react and are filtered out of the mixture.

A 25.0 cm^3 sample of this iron(II) solution was further acidified with 10.0 cm^3 of sulfuric acid and titrated with 0.0250 mol dm^{-3} purple potassium manganate(VII). 32.00 cm^3 of the potassium manganate(VII) solution was required for complete reaction.

The relevant half-equations for the reaction are shown below.

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

$$Fe^{3+} + e^- \rightarrow Fe^{2+}$$

(i) Write a balanced equation for the reaction between the iron in the ore and the sulfuric acid.

…… [1]

(ii) State the role of potassium manganate(VII) in the reaction with the iron(II) solution. Explain your answer in terms of oxidation number.

……

…… [2]

(iii) Given that $Fe^{3+}(aq)$ is yellow in colour, determine the colour change at the end point in this titration.

…… [1]

(iv) Using the two half-equations, construct an overall equation for the reaction between manganate(VII) ions and iron(II) ions in acidic solution.

……

……

…… [1]

(v) Calculate the amount of manganate(VII) ions used in the titration.

[1]

(vi) Calculate the total amount of iron(II) ions in 250 cm^3 of the solution.

[1]

(vii) Hence, calculate the percentage by mass of iron in the 3.35 g piece of ore.

If you were unable to obtain a value in **(b)(vi)**, use the value of 3.00×10^{-2} mol. This is **not** the correct answer.

State whether ores can be purchased from this distributor.

[3]

[Total: 11]

2 In water treatment, ammonia reacts with hypochlorous acid to form monochloramine, a long-lasting disinfectant that produces fewer harmful by-products.

$$HOCl + NH_3 \rightarrow NH_2Cl + H_2O$$

(a) (i) Given that O and N are the central atoms in HO*Cl* and NH_2C*l,* respectively, draw the 'dot-and-cross' diagrams for HO*Cl* and NH_2C*l*.

[2]

(ii) Explain the differences in shape and bond angles of HO*Cl* and NH_2C*l* using the Valence Shell Electron Pair Repulsion (VSEPR) theory.

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…… [3]

(iii) Deduce whether HO*Cl* is a polar molecule. Explain your answer.

……..

…….. [1]

(b) Explain, in terms of structure and bonding, whether HO*Cl* or CsC*l* has a higher boiling point.

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……

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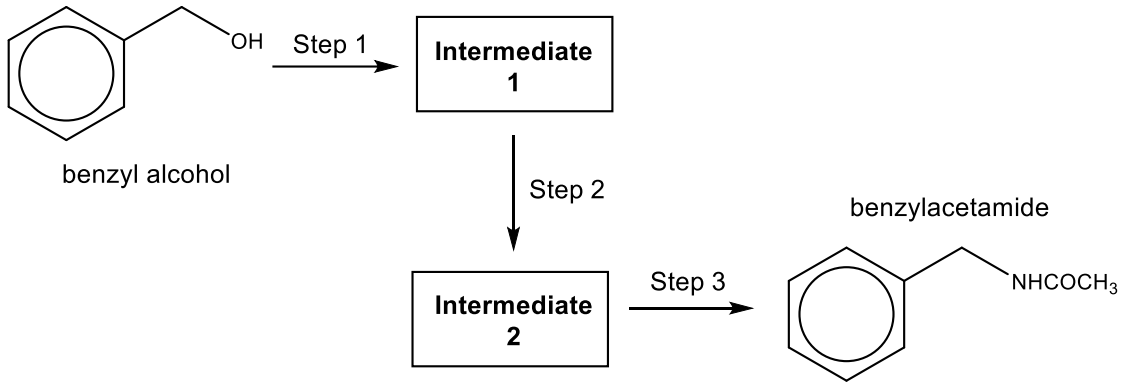
…… [2]

[Total: 8]

3 Benzylacetamide can be formed from benzyl alcohol via a three-step synthesis.



(a) Draw the structures of **Intermediate 1** and **Intermediate 2**.

Intermediate 1	**Intermediate 2**

[2]

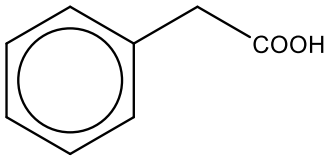
(b) State the reagents and conditions required for each of the three steps.

Step 1: .....

Step 2: .....

Step 3: ..... [3]

(c) Draw the structure formed when benzyl alcohol and phenylacetic acid are heated in the presence of a few drops of concentrated sulfuric acid.



phenylacetic acid

[1]

[Total: 6]

4 An experiment is performed to determine the maximum change in temperature for the following reaction:

$$Mg(s) + CuSO_4(aq) \rightarrow Cu(s) + MgSO_4(aq)$$

25.0 cm^3 of 1.00 mol dm^{-3} $CuSO_4(aq)$ is transferred to a polystyrene cup.

The initial temperature of $CuSO_4(aq)$ is 25.0 ºC.

The temperature of $CuSO_4(aq)$ is recorded every 0.5 minute for 2.5 minutes before 1.00 g of Mg is added into the polystyrene cup at exactly 3.0 minutes. The mixture is stirred thoroughly, and temperature is continuously recorded every 0.5 minute from 3.5 minutes to 9.0 minutes.

The results are shown in Fig. 4.1.

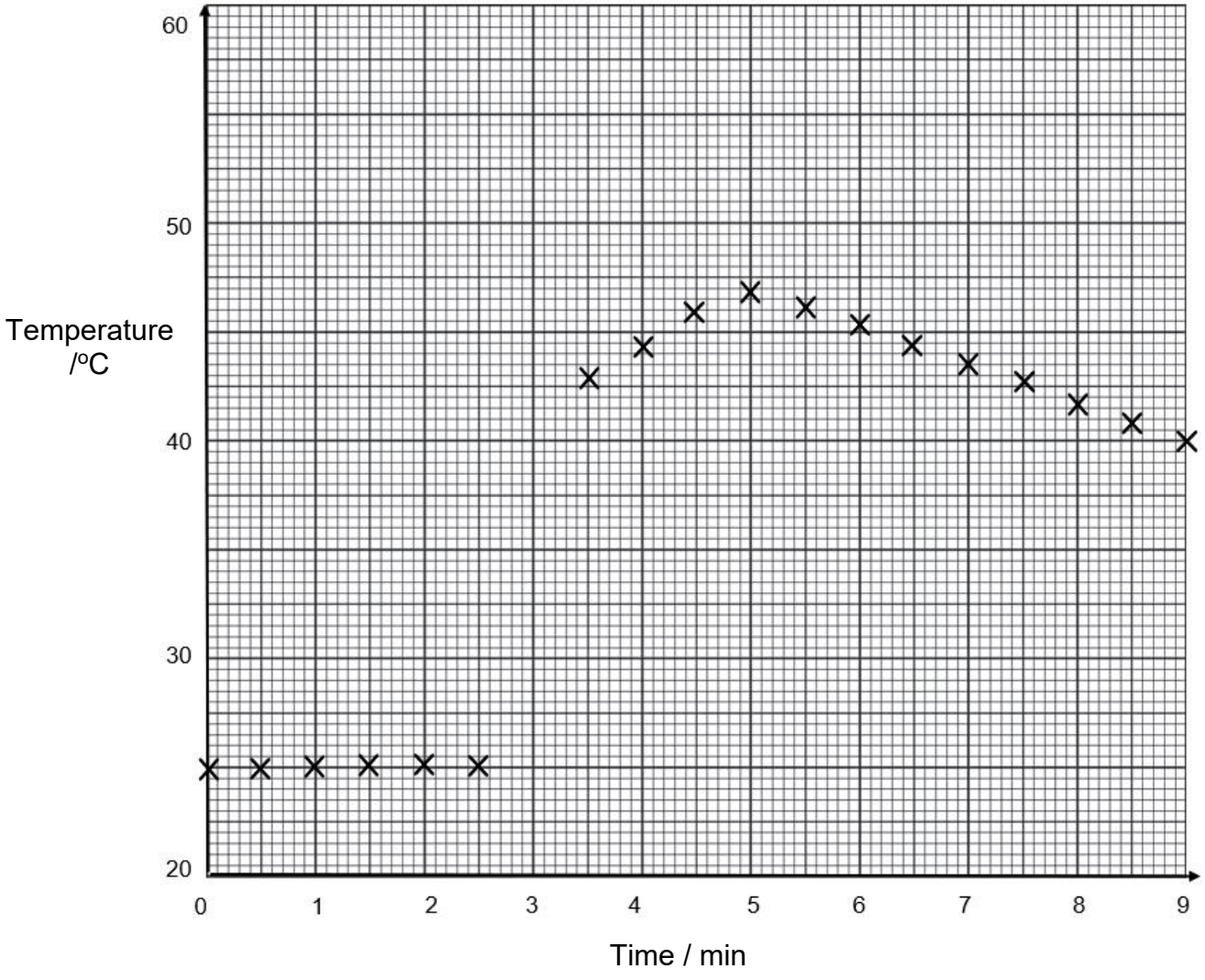


Fig. 4.1

(a) (i) Draw two separate straight lines of best fit.

The first line should take into account all the points before 3.0 minutes.

The second line should take into account all of the points after the temperature of the mixture starts to fall steadily.

Extrapolate both lines to 3.0 minutes.

Use your graph to estimate the maximum temperature of the mixture at 3.0 minutes.

Show your working.

Maximum temperature = _____ [2]

(ii) Using the value in **(a)(i)**, determine the maximum temperature rise produced by the reaction.

[1]

(iii) With reference to *Data Booklet* and using your answer in **(a)(ii)**, calculate the energy, in kJ, evolved during the reaction.

[1]

(iv) Using your answer to **(a)(iii),** calculate a value for the enthalpy change of reaction, in kJ mol^{-1}, between Mg(s) and $CuSO_4$(aq) adjusted by cooling curve correction.

If you were unable to obtain a value in **(a)(iii)**, use the value of 3.00 kJ. This is **not** the correct answer.

[2]

(b) Sodium reacts with oxygen to form a stable compound, sodium oxide.

Describe the reaction between sodium oxide with water and give the pH of the solution. Include any equations involved.

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[2]

(c) Explain why rubidium is a stronger reducing agent than sodium.

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…… [2]

[Total: 10]

5 In a catalytic converter of a car, harmful exhaust gases such as nitrogen dioxide, NO_2, and carbon monoxide, CO, are converted into less harmful gases. One important reaction that takes place is:

$$NO_2(g) + CO(g) \rightarrow 2CO_2(g) + NO(g)$$

This reaction occurs on the surface of a solid platinum catalyst. Platinum acts as a heterogeneous catalyst.

A chemist conducts a series of experiments to investigate the effect of changes in the concentration on the rate of this reaction.

The initial concentrations and initial rate data obtained for each experiment are given in Table 5.1.

Table 5.1

experiment	initial [NO_2] / mol dm^{-3}	initial [CO] / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
1	1.50×10^{-3}	2.50×10^{-3}	1.80×10^{-3}
2	3.00×10^{-3}	2.50×10^{-3}	3.60×10^{-3}
3	3.00×10^{-3}	3.75×10^{-3}	5.40×10^{-3}

(a) Determine the order of reaction with respect to each reactant using the data from Table 5.1 to explain your answers.

[2]

(b) Hence, deduce the rate equation for this reaction.

……..... [1]

(c) Sketch a graph of $[NO_2]$ vs time when [CO] is in excess.

[1]

(d) Outline, in three stages, the mode of action as platinum catalyses the reaction between NO_2 and CO in the catalytic converter.

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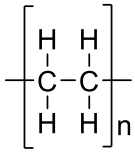
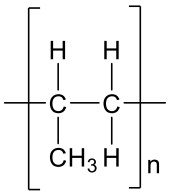
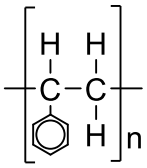
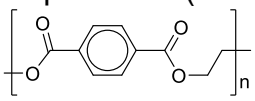
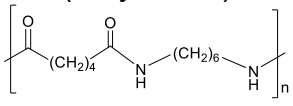
[3]

[Total: 7]

6 The Great Pacific Garbage Patch (GPGP) is a large area in the North Pacific Ocean where plastic waste accumulates due to converging ocean currents. Under the effects of sun exposure and marine life, some of the plastic waste can degrade into smaller microplastics.

A 2023 ocean trawl collected plastic samples from the GPGP. Researchers recorded the simplified breakdown of the key physical properties of the polymers found. The density of seawater is 1.03 g cm^{-3}. Table 6.1 shows the properties of polymers found in the GPGP.

Table 6.1

Polymer	Typical Offshore Source	Density/ g cm^{-3}	Mass / %	Tensile Strength/ MPa	Melting Point / °C
Poly(ethylene) (PE) 	Plastic bags, cling wraps, crates, bottles	0.92	71	20	110
Poly(propene) (PP) 	Rope, caps	0.90	24	35	160
Polystyrene (PS) 	Foam buoys	1.05	3	30	~240
Polyethylene terephthalate (PET) 	Drink bottles	1.38	1	55	260
Nylon-6,6 (Polyamide) 	Fishing line	1.20	1	80	~265

(a) Define the term *polymer*.

……

…… [1]

(b) Using the data in Table 6.1, suggest a reason why PE and PP together account for 95 % of the plastic debris found **floating** in GPGP.

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…… [1]

(c) Explain why the melting points of PE and PP are relatively lower than that PS.

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…… [1]

(d) Explain, in terms of the structure, why PET can be used as drinking bottles but not for storing alkaline cleaning materials.

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…… [1]

(e) Classify offshore sources of polyethylene (PE) debris into low density poly(ethene) (LDPE) and high density poly(ethene) (HDPE).

LDPE	HDPE

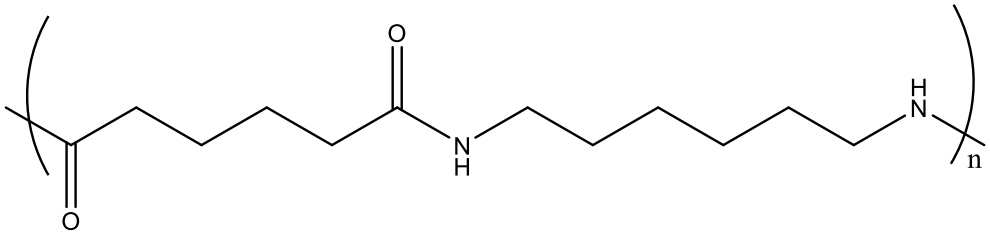
Suggest a reason.

……

……

…… [2]

(f) Nylon-6,6 is observed to have the repeating unit shown below.



Draw the monomers of Nylon-6,6.

[2]

(g) State one environmental **advantage** and one **trade-off** of recycling plastics.

……

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…… [2]

[Total: 10]

7 **(a)** The following is an extract from an article “The safety of nanoparticles in sunscreens: An update for general practice” published by The Royal Australian College of General Practitioners.

“Recent media coverage has raised public awareness regarding the safety of sunscreens containing zinc oxide, ZnO, and titanium dioxide, TiO_2 nanoparticles. The inorganic filters ZnO and TiO_2 are able to protect against UVA and UVB. As conventional micronised particles in sunscreen, they have several unfavourable characteristics, including difficulty in application, leaving white residue on the skin. This led to the development of smaller nanoparticles, the use of which vastly improves aesthetic and ease of application of sunscreens while maintaining photo-protective qualities.”

(i) Define the term *nanoparticles*.

……

…… [1]

(ii) Explain, in terms of surface-to-volume ratio, why nanoscale sunscreen can be attractive to consumers.

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…… [2]

(iii) Suggest why nanoparticles of TiO_2 in sunscreen could present a risk to human health.

……

…… [1]

(b) At the nanoscale, new properties may emerge in certain compounds.

Graphene is known to have very high tensile strength and high electrical conductivity. Describe the structure of graphene and explain how its structure relates to these two properties.

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[4]

[Total: 8]

Section B

Answer **one** question from this section in the spaces provided.

8 **(a)** **(i)** Using pent-2-enoic acid, $CH_3CH_2CH=CHCOOH$, as an example, define what is meant by the term *acid* using the Arrhenius theory of acids and bases.

……. [1]

(ii) Draw a labelled diagram, in terms of orbitals overlap, the bonding of the two carbon atoms of the C=C bond in $CH_3CH_2CH=CHCOOH$.

[2]

(iii) Draw the displayed formula of $CH_3CH_2CH=CHCOOH$.

Hence or otherwise, deduce the number of σ and π bonds in this molecule.

……. [2]

(iv) Draw and identify the *cis* and *trans* isomers of $CH_3CH_2CH=CHCOOH$.

[2]

(v) Suggest a chemical test to confirm the presence of the alkene functional group in $CH_3CH_2CH=CHCOOH$.

……. [1]

(vi) For the chemical test suggested in **(v)**, state the observation that confirms the presence of the alkene functional group.

……. [1]

(b) The dissociation of water is a reversible reaction.

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The ionic product of water, K_w, measures the extent of dissociation of water.

Fig. 8.1 shows the variation of K_w between 0 ºC and 60 ºC.

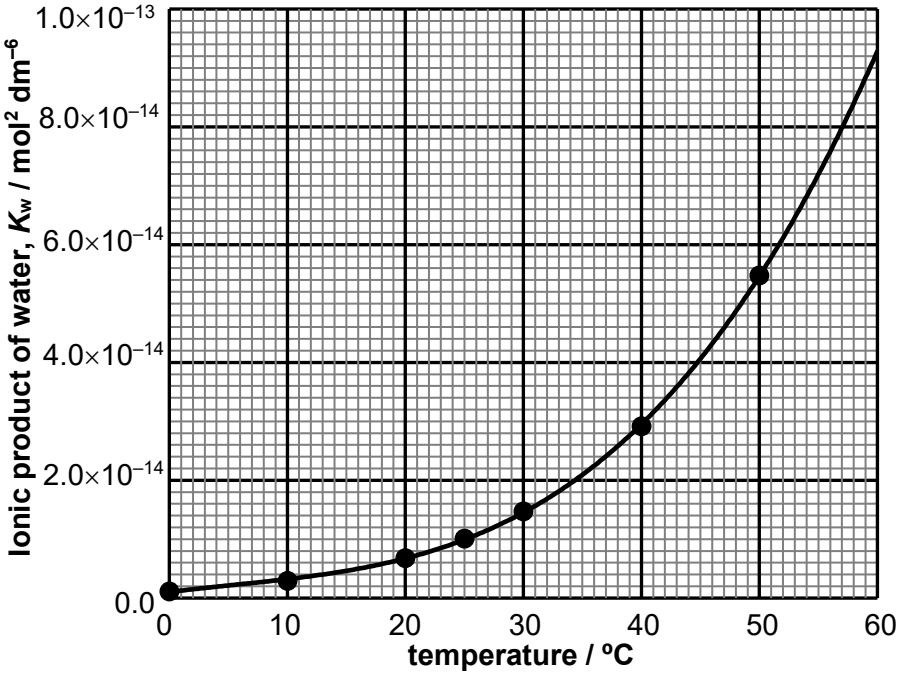

Fig. 8.1

(i) Using Fig. 8.1, explain whether the dissociation of water is an exothermic or endothermic process.

……

……

……

……. [2]

(ii) Write an expression for the term ionic product of water, K_w.

expression: ……. [1]

(iii) Calculate the pH of water at 50 °C.

[2]

(iv) A student suggests that pure water is acidic at 50 °C. State whether you agree with the student. Explain your answer.

……

…… [1]

(c) In humans, it is important for blood to be maintained at a pH between 7.35 and 7.45. One of the ways it does this is by using a buffer of H_2CO_3(aq) and HCO_3^-(aq).

During vigorous exercise, the muscles produce lactic acid. Lactic acid is transported by the blood to the liver to be broken down.

(i) State what is meant by the term *buffer solution*.

……

…… [1]

(ii) State the effect that exercise will have on the pH of blood if there is no buffer present.

…… [1]

(iii) With the aid of an equation, explain how the H_2CO_3(aq)/ HCO_3^-(aq) buffer system helps to maintain the pH of blood between 7.35 and 7.45 during exercise.

……

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……

……

…… [3]

[Total: 20]

9 **P**, **Q**, **R** and **S** are consecutive elements in the Periodic Table.

(a) The successive ionisation energies, in kJ mol^{-1}, of element **Q** are given below.

1681 3374 6050 8407 11020 15160 17870 92040 106400

State which group element **Q** belongs to. Explain your answer.

……

……

……

…… [2]

(b) **P**, **Q** and **S** form ions that are isoelectronic with atom **R**.

(i) State the charge on the ions of **P**, **Q** and **S**.

……

…… [1]

(ii) Arrange the ions of **P**, **Q** and **S** in decreasing ionic radius.

…… [1]

The group of halogens is the only group that contains elements in all three main states of matter at standard temperature and pressure.

(c) Explain, in terms of bonding and structure, the trend in volatility of the halogens.

……

……

……

…… [2]

(d) Under certain conditions the hydrogen halides decompose into their elements.

$$2HX \rightarrow H_2 + X_2 \text{ (where X = C}l\text{, Br, I)}$$

Describe what will be observed if X is iodine.

…… [1]

(e) Explain how the ease of decomposition of the hydrogen halides varies from HC*l* to HI.

……

……

……

…… [3]

(f) Methanol may be manufactured catalytically from *synthesis gas*, a mixture of CO, CO_2 and H_2. The CO is reacted with H_2 to form methanol, CH_3OH.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91 \text{ kJ mol}^{-1}$$

From your understanding of Le Chatelier's Principle, state how pressure and temperature be used in order to produce a high yield of methanol.

In **each** case, explain why the yield would increase.

condition 1 ……

explanation ……

……

condition 2 ……

explanation ……

…… [4]

(g) Methanol is a critical reagent in the trans-esterification of triglycerides (found in vegetable oils) to produce biodiesel, which is composed primarily of fatty acid methyl esters (FAMEs). As a renewable fuel, biodiesel can be used directly or blended with petrodiesel in conventional diesel engines without modification.

The trans-esterification reaction of biodiesel synthesis is shown below:

$$(RCOO)_3C_3H_5(l) + 3CH_3OH(l) \rightleftharpoons C_3H_5(OH)_3(l) + 3RCOOCH_3(l)$$

triglyceride	methanol	glycerol	methyl esters (biodiesel)

This reaction is an example of a dynamic equilibrium.

(i) Explain what is meant by the term *dynamic equilibrium*.

……

…… [1]

(ii) Write an expression for the equilibrium constant, K_c, of this reaction.

……

…… [1]

(iii) A mixture containing 0.50 mol of triglyceride and 1.50 mol of methanol is set up and allowed to reach equilibrium at 298 K. The equilibrium amount of biodiesel is found to be 1.20 mol.

Assuming that the final volume of the solution is V dm^3, calculate the value of K_c at 298 K.

[3]

(iv) State an advantage of using biodiesel as compared to traditional fossil fuels.

……

…… [1]

[Total: 20]

END OF PAPER

Additional writing space