5. Molten zinc chloride undergoes electrolysis in an electrolytic cell at 450 °C.

(a) Deduce the half-equations for the reaction at each electrode. [2]

Cathode (negative electrode):

. . . . . .

. . . . . .

Anode (positive electrode):

. . . . . .

. . . . . .

(b) Deduce the overall cell reaction including state symbols. Use section 7 of the data booklet. [2]

. . . . . .

. . . . . .

Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

Wednesday 18 May 2022 (afternoon)

1 hour 15 minutes

Candidate session number

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.

12 pages

2222–6117

Answer **all** questions. Answers must be written within the answer boxes provided.

1. 3.40 g of $FeSO_4 \cdot xH_2O$ was dissolved in water to form 250.0 cm^3 of solution.

A 25.00 cm^3 sample of this solution was acidified and titrated with 0.0200 mol dm^{-3} $KMnO_4(aq)$.

(a) Complete the ionic equation for the reaction. [1]

$MnO_4^-(aq) + 5Fe^{2+}(aq) + \ldots\ldots.H^+(aq) \rightarrow \ldots\ldots.(aq) + 5Fe^{3+}(aq) + \ldots\ldots.H_2O(l)$

(b) 20.00 cm^3 of this $KMnO_4(aq)$ solution was required to react fully with the Fe^{2+} ions present in the sample.

Calculate the number of moles of $KMnO_4(aq)$ used in the titration. [1]

(c) Calculate the number of moles of $Fe^{2+}(aq)$ present in the 25.00 cm^3 sample. [1]

(d) Calculate the amount of $FeSO_4$ in 3.40 g $FeSO_4 \cdot xH_2O$. [1]

(e) Calculate the relative formula mass of $FeSO_4 \cdot xH_2O$. [1]

(This question continues on the following page)

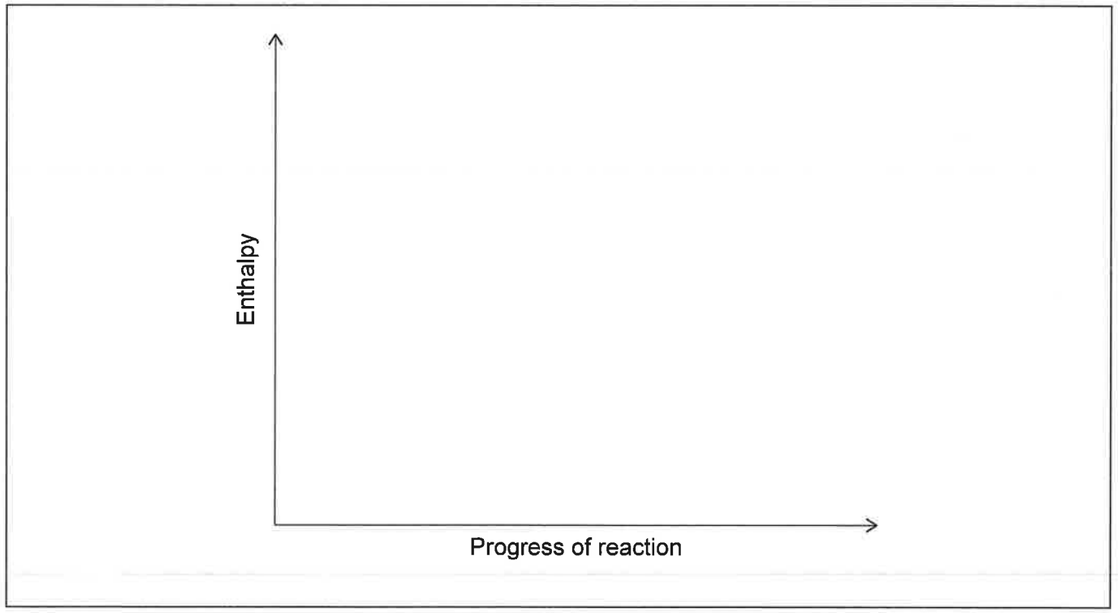
(Question 4 continued)

(e) Chlorine reacts with methane.

$$CH_4(g) + Cl_2(g) \rightarrow CH_3Cl(g) + HCl(g)$$

(i) Calculate the enthalpy change of the reaction, ΔH, using section 11 of the data booklet. [3]

(ii) Draw and label an enthalpy level diagram for this reaction. [2]



(Question 4 continued)

(d) But-2-ene reacts with hydrogen bromide.

(i) Draw the full structural formula of but-2-ene. [1]

(ii) Write the equation for the reaction between but-2-ene and hydrogen bromide. [1]

. . . . . .
. . . . . .

(iii) State the type of reaction. [1]

. . . . . .
. . . . . .

(iv) Suggest **two** differences in the ^{1}H NMR of but-2-ene and the organic product from (d)(ii). [2]

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question 1 continued)

(f) Determine the value of x in $FeSO_4 \cdot xH_2O$. [2]

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(g) State how random and systematic errors can be minimized. [2]

Random:

. . . . . .
. . . . . .

Systematic:

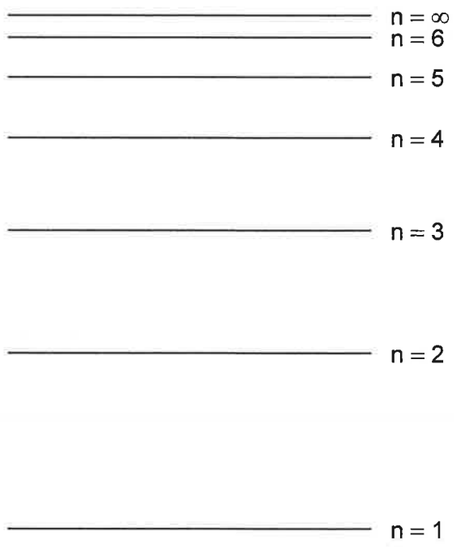
. . . . . .
. . . . . .

2. Electrons are arranged in energy levels around the nucleus of an atom.

(a) Explain why the first ionization energy of calcium is greater than that of potassium. [2]

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(b) The diagram represents possible electron energy levels in a hydrogen atom.



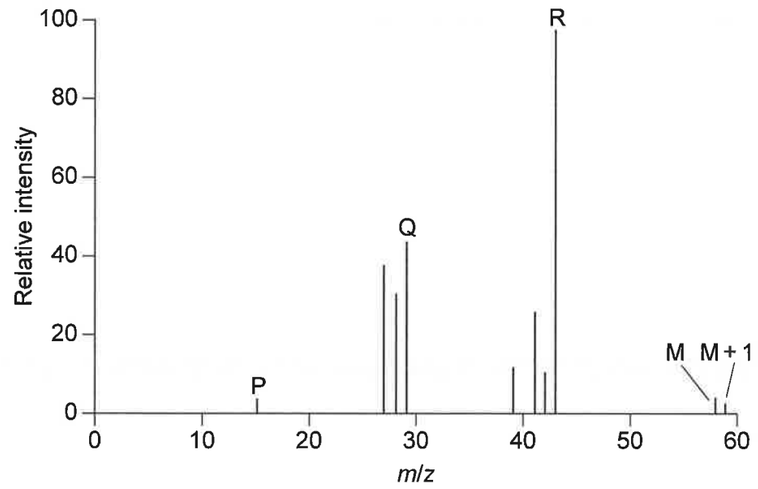
(i) All models have limitations. Suggest **two** limitations to this model of the electron energy levels. [2]

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question 4 continued)

(ii) Suggest the fragment causing peak **R** in the mass spectrum of butane. [1]



. . . . . .

(c) Describe a test and the expected result to indicate the presence of carbon–carbon double bonds. [2]

Test:

. . . . . .
. . . . . .

Result:

. . . . . .
. . . . . .

(This question continues on the following page)

4. Carbon forms many compounds.

(a) C_{60} and diamond are allotropes of carbon.

(i) Outline **one** difference between the bonding of carbon atoms in C_{60} and diamond. [1]

. . . . . .
. . . . . .
. . . . . .

(ii) Explain why C_{60} and diamond sublime at different temperatures and pressures. [2]

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(b) (i) State two features showing that propane and butane are members of the same homologous series. [2]

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question 2 continued)

(ii) Draw an arrow, labelled **X**, to represent the electron transition for the ionization of a hydrogen atom in the ground state. [1]

(iii) Draw an arrow, labelled **Z**, to represent the lowest energy electron transition in the visible spectrum. [1]

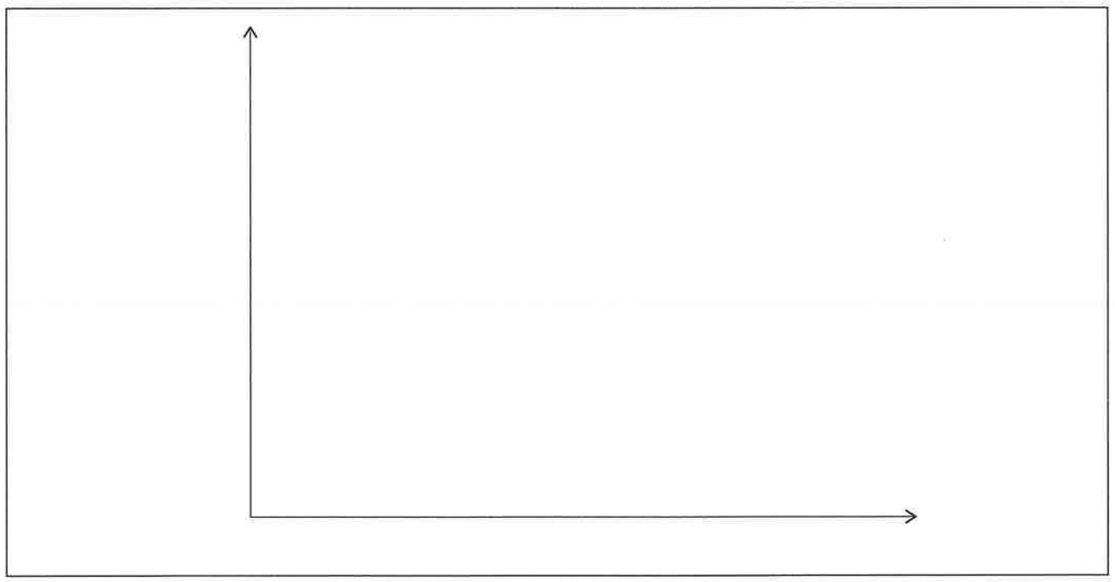
3. Sulfur trioxide is produced from sulfur dioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196\,kJ\,mol^{-1}$$

(a) Outline, giving a reason, the effect of a catalyst on a reaction. [2]

(b) The reaction between sulfur dioxide and oxygen can be carried out at different temperatures.

(i) On the axes, sketch Maxwell–Boltzmann energy distribution curves for the reacting species at two temperatures T_1 **and** T_2, where $T_2 > T_1$. [3]



(ii) Explain the effect of increasing temperature on the yield of SO_3. [2]

(This question continues on the following page)

(Question 3 continued)

(c) (i) State the product formed from the reaction of SO_3 with water. [1]

(ii) State the meaning of a strong Brønsted–Lowry acid. [2]

(d) Nitric acid, HNO_3, is another strong Brønsted–Lowry acid. Its conjugate base is the nitrate ion, NO_3^-

(i) Draw the Lewis structure of NO_3^-. [1]

(ii) Explain the electron domain geometry of NO_3^-. [2]