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

1 The Periodic Table currently used is derived from that proposed in 1869 by Mendeleev who had noticed patterns in the physical and chemical properties of the elements he had studied.

(a) **(i)** The atomic radius of the Period 3 elements decreases from Na to C*l*. Explain why this is so.

……

……

……

……

……[2]

(ii) Write the electronic configurations of the sodium atom and its ion.

Na $1s^2$……

Na^+ $1s^2$……

[1]

(iii) Explain the difference in the radius of the sodium atom and the radius of its ion, Na^+.

……[1]

(b) **(i)** Complete Table 1.1 by describing the acid/base behaviour of Al_2O_3 and SO_3.
Provide equation(s) to illustrate the behaviour of each oxide.

Table 1.1

oxide	acid/base behaviour	equation(s) illustrating behaviour of each oxide
Al_2O_3		
SO_3		

[4]

(ii) State **one** source of SO_2 pollution.

……[1]

(iii) State an environmental consequence of SO_2.

……[1]

(c) A diagonal relationship is said to exist between certain pairs of diagonally adjacent elements in the second and third Periods. The elements and their compounds in these pairs are observed to share similar properties.

An example of such a pair is beryllium and aluminium.

(i) Draw the dot-and-cross diagram for A*l*C*l*$_3$ and state the C*l*−A*l*−C*l* bond angle.

dot-and-cross diagram of A*l*C*l*$_3$

[1]

bond angle: …… [1]

(ii) Unlike A*l*C*l*$_3$ which dimerises to form A*l*$_2$C*l*$_6$, BeC*l*$_2$ polymerises and exists as long chains in the solid state.

Draw a section of one chain with three BeC*l*$_2$ monomers, showing clearly the bonding within the chain.

[1]

(iii) With a small amount of water, $BeCl_2$ hydrolyses in the same manner as $AlCl_3$.

Write an equation for the hydrolysis of $BeCl_2$.

……[1]

[Total: 14]

2 This question concerns the chemistry of the halogens and hydrogen halides.

(a) Fluorine, F_2, and chlorine, Cl_2, are halogens that exist as gases at room temperature and pressure.

(i) With reference to their structures and bonding, explain why Cl_2 has a higher boiling point than F_2.

……

……

……

……

……

……[2]

(ii) Use data from the *Data Booklet* to compare the oxidising strengths of F_2 and Cl_2.

……

……

……

……

……[2]

(b) Chlorine gas was bubbled through an aqueous solution of potassium iodide. Hexane was subsequently added and the mixture was shaken in a test tube. Table 2.1 gives the densities of water and hexane.

Table 2.1

compound	density / g cm^{-3}
water	1.00
hexane	0.655

(i) Write an equation for the reaction that occurs between chlorine gas and potassium iodide solution.

……[1]

(ii) Complete Fig. 2.1 by stating the colours observed in the test tube.

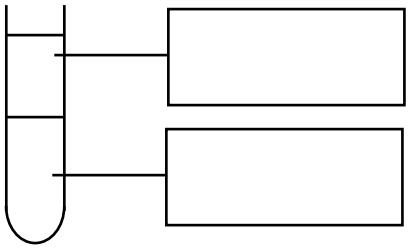


Fig. 2.1

[1]

(c) Vapour pressure is defined as the pressure exerted by a vapour in equilibrium with its liquid in a closed system. Table 2.2 shows the vapour pressures of HF and HC*l* measured at 25 °C.

Table 2.2

compound	vapour pressure / kPa
HF	122
HC*l*	4660

Give a reason for the higher vapour pressure of HC*l*.

……..……...

……..……...

……..….[1]

[Total: 7]

3 The Sabatier reaction describes the *reversible reaction* between carbon dioxide and hydrogen in the following equation:

$$CO_2(g) + 4H_2(g) \rightleftharpoons CH_4(g) + 2H_2O(g) \qquad \Delta H = -126 \text{ kJ mol}^{-1}$$

The reactants are passed through a solid support coated with ruthenium metal as a catalyst, where the reaction occurs.

(a) **(i)** Define the term *reversible reaction*.

……..…..

……[1]

(ii) Write the K_p expression for this reaction.

[1]

(iii) State the type of catalyst used in this reaction.

……[1]

(b) 0.05 mol of carbon dioxide and 0.05 mol of hydrogen were introduced in a 1 dm^3 vessel at 353 °C.

The Sabatier reaction occurred and an equilibrium was established. The equilibrium partial pressure of methane was measured to be 20 kPa.

(i) Calculate the initial partial pressure, in kPa, of carbon dioxide in the vessel.

[2]

(ii) Determine the equilibrium partial pressures, in kPa, of:

- carbon dioxide
- hydrogen
- water

[2]

(c) **(i)** Describe and explain how the position of equilibrium will change when the volume of the vessel is decreased from 1 dm^3 to 0.5 dm^3.

……..….

……..….

……[2]

Fig. 3.1 shows how the forward and backward rates of the Sabatier reaction change with time at 353 °C.

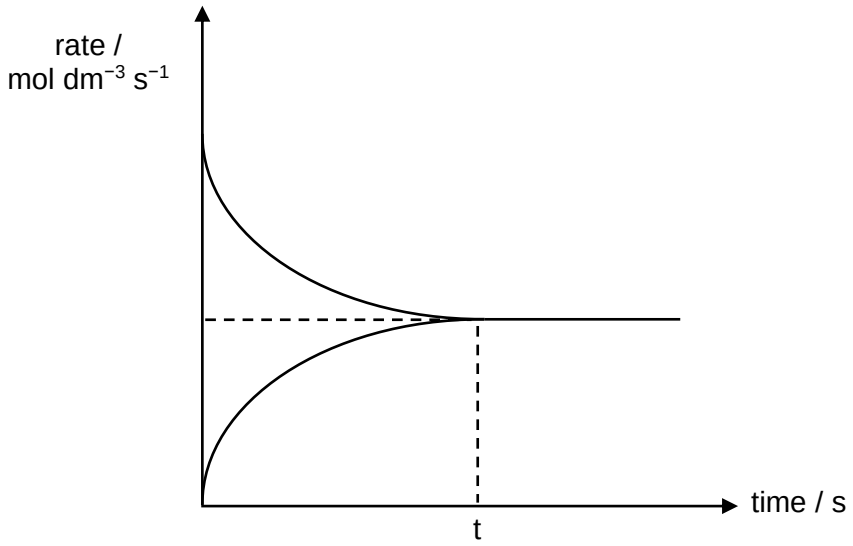


Fig. 3.1

(ii) The temperature is then increased from 353 °C to 400 °C.

Sketch in Fig. 3.1 how the following would change at the higher temperature.

- time at which equilibrium is reached
- forward and backward rates of the Sabatier reaction [2]

(iii) State and explain how the K_c value for the Sabatier reaction changes when the temperature is increased from 353 °C to 400°C.

……

……

……

……[2]

(d) Suggest a reagent that can be used to remove carbon dioxide from the equilibrium mixture.

……[1]

(e) With the aid of a labelled Boltzmann distribution, explain how the addition of ruthenium metal increases the rate of the reaction.

……

……

……

……

……[3]

[Total: 17]

4 In potentiometric titrations, the electrode potential, *E*, is measured against the volume of a solution added from the burette. To determine the concentration of acidified $FeCl_2$ solution, 25.0 cm^3 of this solution was placed in a beaker and titrated against 0.02 mol dm^{-3} acidified $K_2Cr_2O_7$ from a burette. It was found that 20.80 cm^3 of $K_2Cr_2O_7$ was needed to reach the end–point.

The electrode potential, *E*, was measured against the standard hydrogen electrode. All measurements were made at 298 K.

Fig. 4.1 shows the setup for this titration.

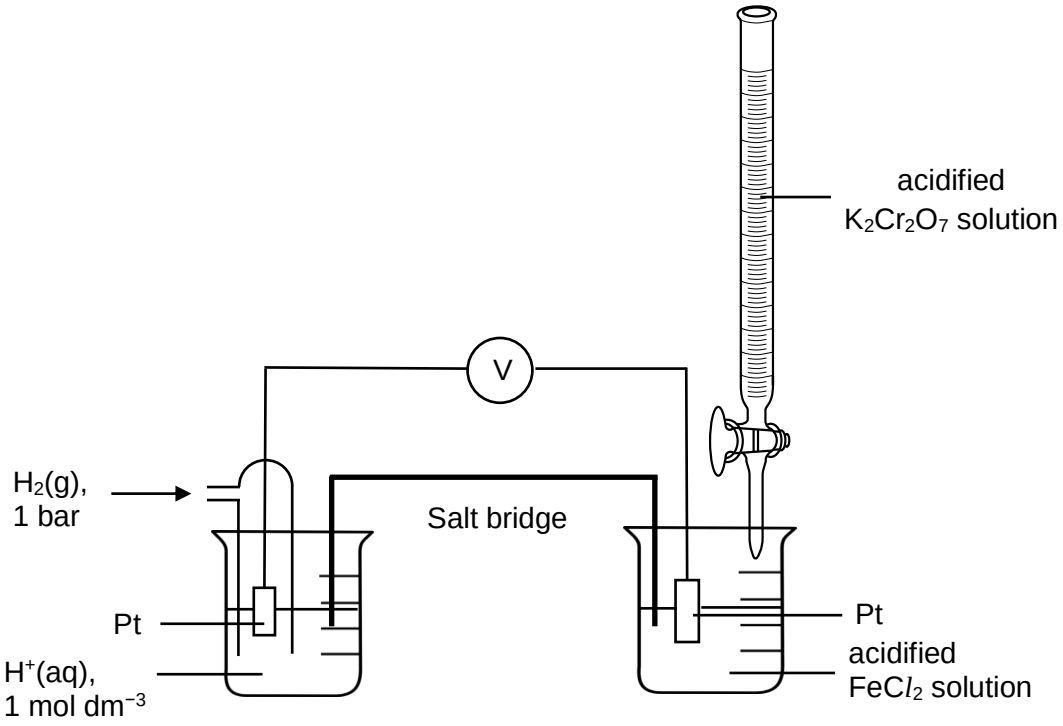


Fig. 4.1

(a) **(i)** State why platinum electrodes are used in this experiment.

……[1]

(ii) Before the addition of any $K_2Cr_2O_7$, suggest what would be observed in the beaker containing $FeCl_2$ if the platinum electrode there was replaced with iron.

……[1]

(b) **(i)** The reaction between Fe^{2+} and $Cr_2O_7^{2-}$ can be represented by the **unbalanced** equation:

$$Fe^{2+} + Cr_2O_7^{2-} \longrightarrow Fe^{3+} + Cr^{3+}$$

Write the balanced equation for this reaction.

……[1]

(ii) Determine the concentration of the $FeCl_2$ solution.

[2]

(iii) Calculate the $\Delta G^{\ominus}$ of the reaction in **(b)(i)**.

[2]

(c) The measured electrode potential, *E*, changes during the titration.

The Nernst Equation describes how the relative concentrations of Fe^{2+} and Fe^{3+} change the electrode potential, *E*, from the standard electrode potential, $E^{\ominus}$.

Nernst Equation $$E = E^{\ominus} - 0.0592 \lg \frac{[Fe^{2+}]}{[Fe^{3+}]}$$

After a certain volume of $K_2Cr_2O_7$ was added, an electrode potential of +0.77 V was recorded on the voltmeter.

(i) State the volume of $K_2Cr_2O_7$ that was added. Explain your answer.

……

……[2]

(ii) On Fig. 4.1, indicate the direction of electron flow across the voltmeter. [1]

(iii) Explain how the electrode potential, *E*, value would change as the titration proceeds up to the end-point.

……

……

……

……[2]

(d) **(i)** In another experiment, molten $FeCl_2$ was electrolysed using platinum electrodes. The process was carried out using a current of 0.1 A.

Calculate the time taken to deposit 0.1 g of Fe on the electrode.

[2]

(ii) The electrolysis was repeated using a dilute aqueous solution of $FeCl_2$ and platinum electrodes.

State the products obtained at the cathode and at the anode.

By quoting relevant electrode potentials from the *Data Booklet*, explain why these products were obtained.

product at cathode: ……

explanation: ……...

……..……..

……..……..

……..……..

……..……..

……..……..

product at anode: ……...

explanation: ……

……..……..

……..……..

……..……..

……..……..

……..……..[4]

[Total: 18]

5 Styrene is a precursor of the polystyrene, a commonly used thermoplastic polymer.

Styrene undergoes free radical polymerisation to form long chains of the polymer shown in Fig. 5.1. As a thermoplastic polymer, polystyrene becomes moldable when heated to 100 ^{o}C and solidifies at lower temperatures.

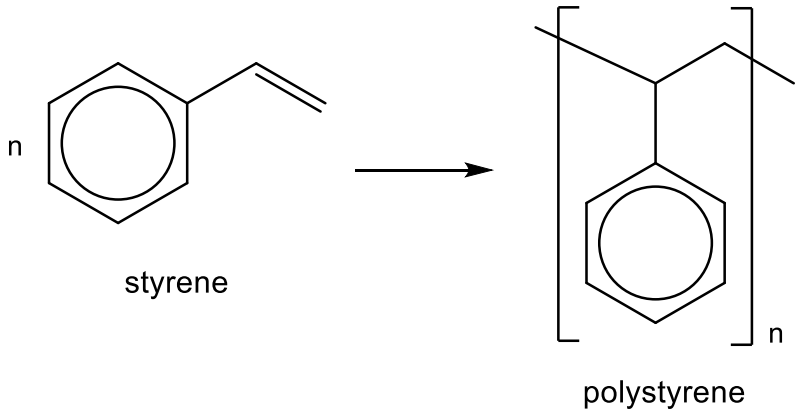


Fig. 5.1

(a) Describe, in terms of orbital overlap, the bonding present in the alkene functional group of styrene. Draw a labelled diagram to illustrate your answer.

……

……

……[2]

(b) Styrene can be converted to (1-bromoethyl)benzene and compound **A** through a series of reactions shown in Fig. 5.2.

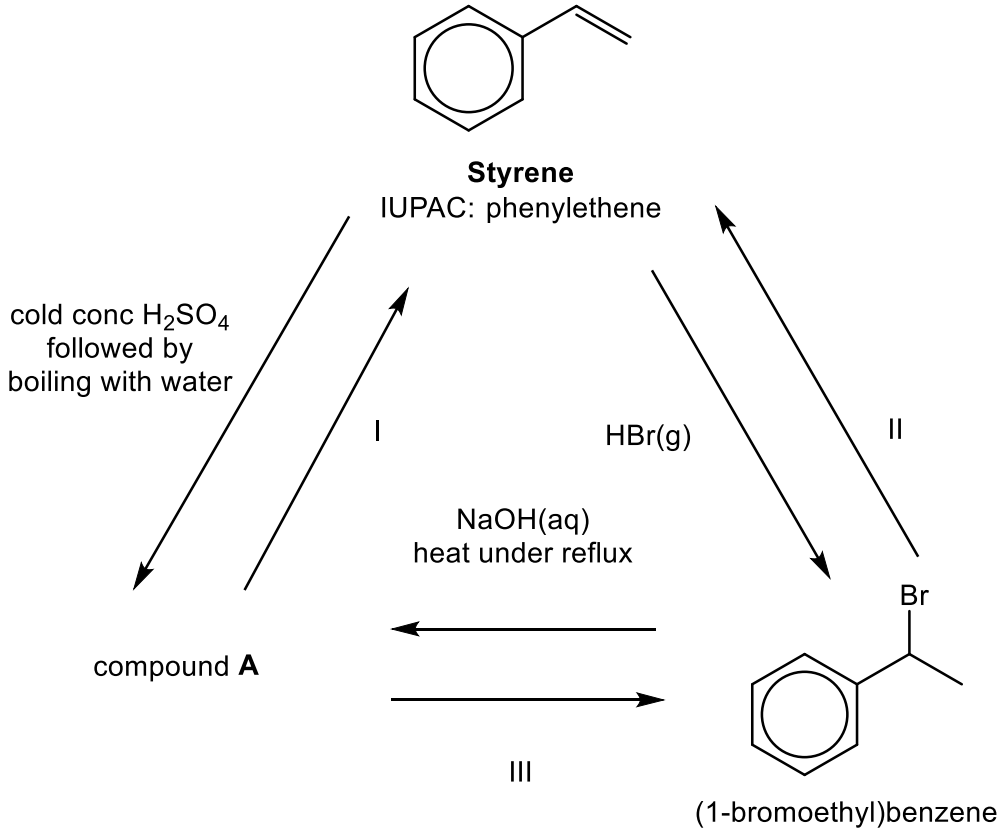


Fig. 5.2

(i) Draw the structure of compound **A** and state the reagents and conditions for steps I, II and III.

compound **A**

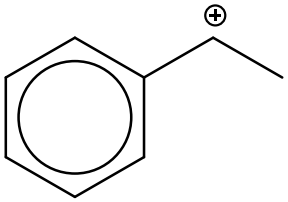
step I: ……

step II: ……

step III: ……

[4]

(ii) When styrene reacts with HBr(g) to form (1-bromoethyl)benzene, the following intermediate is formed.



intermediate

State the type of reaction and account for the stability of the intermediate.

type of reaction: ……..…….……

explanation: ….……..…..

……..…..

……[3]

(iii) When enantiomerically pure (1-bromoethyl)benzene is heated under reflux with aqueous NaOH, the same carbocation intermediate as in **(b)(ii)** is formed.
Name and draw the mechanism for this reaction.

[3]

(iv) With reference to your mechanism in **(b)(iii)**, suggest and explain whether the product in **(b)(iii)** is optically active.

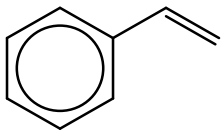
……

……

……

……[2]

(c) Under standard conditions, styrene undergoes combustion according to the following equation.



(l) + 10 O_2(g) ⟶ 8 CO_2(g) + 4 H_2O(l)

(i) Use relevant bond energy values in the *Data Booklet* to calculate the standard enthalpy change of combustion of styrene.

[2]

(ii) The standard enthalpy changes of formation of styrene, carbon dioxide and water are given in Table 5.1. Use these values to calculate another value for the standard enthalpy change of combustion of styrene.

Table 5.1

compound	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
styrene(l)	–148.3
CO_2(g)	–393.5
H_2O(l)	–285.8

[2]

(iii) Account for the difference between your answers in **(c)(i)** and **(c)(ii)**.

……..…..

……[1]

[Total: 19]