Gold Paper
AS & A Level

Question Paper 4

Level	A Level
Subject	Chemistry
Exam Board	OCR
Paper	AS & A Level
Booklet	Question Paper 4

Time allowed: **85 minutes**

Score: **/63**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E
>85%	73%	60%	47%	34%	21%

Successive ionisation energies of four elements in Period 3 are shown below.

Which letter could represent magnesium?

	Ionisation energy/kJ mol^{-1}				
	1st	**2nd**	**3rd**	**4th**	**5th**
A	1251	2298	3822	5159	6542
B	738	1451	7733	10543	13630
C	496	4563	6913	9544	13352
D	578	1817	2745	11577	14842

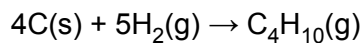**[1]**

The enthalpy change of formation of butane can be calculated using the enthalpy changes of combustion, $\Delta_c H$, below.

Substance	C(s)	H_2(g)	C_4H_{10}(g)
$\Delta_c H$/kJ mol^{-1}	–394	–286	–2877

Calculate the enthalpy change of formation of C_4H_{10}(g).

$$4C(s) + 5H_2(g) \rightarrow C_4H_{10}(g)$$

A -2197 kJ mol^{-1}

B -129 kJ mol^{-1}

C $+129$ kJ mol^{-1}

D $+2197$ kJ mol^{-1}

[1]

Chlorine reacts with 1-chloropropane in the presence of ultraviolet radiation via a radical substitution mechanism.

Which equation shows a propagation step in the mechanism for this reaction?

A Cl_2 $\rightarrow$ $\bullet Cl + \bullet Cl$

B $\bullet Cl + \bullet C_3H_6Cl$ $\rightarrow$ $C_3H_6Cl_2$

C $C_3H_7Cl + \bullet Cl$ $\rightarrow$ $C_3H_6Cl_2 + \bullet H$

D $\bullet Cl + C_3H_7Cl$ $\rightarrow$ $\bullet C_3H_6Cl + HCl$

[1]
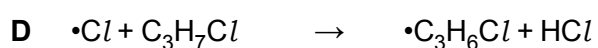
The 1st to 8th successive ionisation energies, in kJ mol^{-1}, of an element in period 3 are:

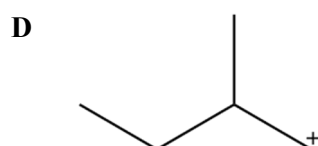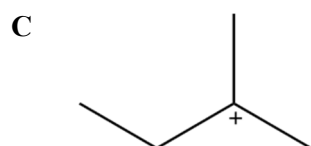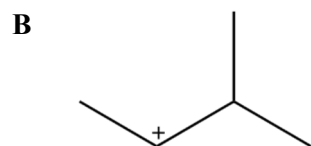   1012   1903   2912   4957   6274   21 269   25 398   29 855
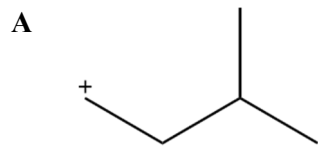
What is the element?

A   Al

B   Si

C   P

D   S

[1]

Hydrogen bromide reacts with 3-methylbut-1-ene.

What is the structure of the major intermediate formed in the mechanism?

A

B

C

D

[1]

This question is about four enthalpy changes, **A**–**D**, that can be linked to the dissolving of potassium sulfate, K_2SO_4, in water.

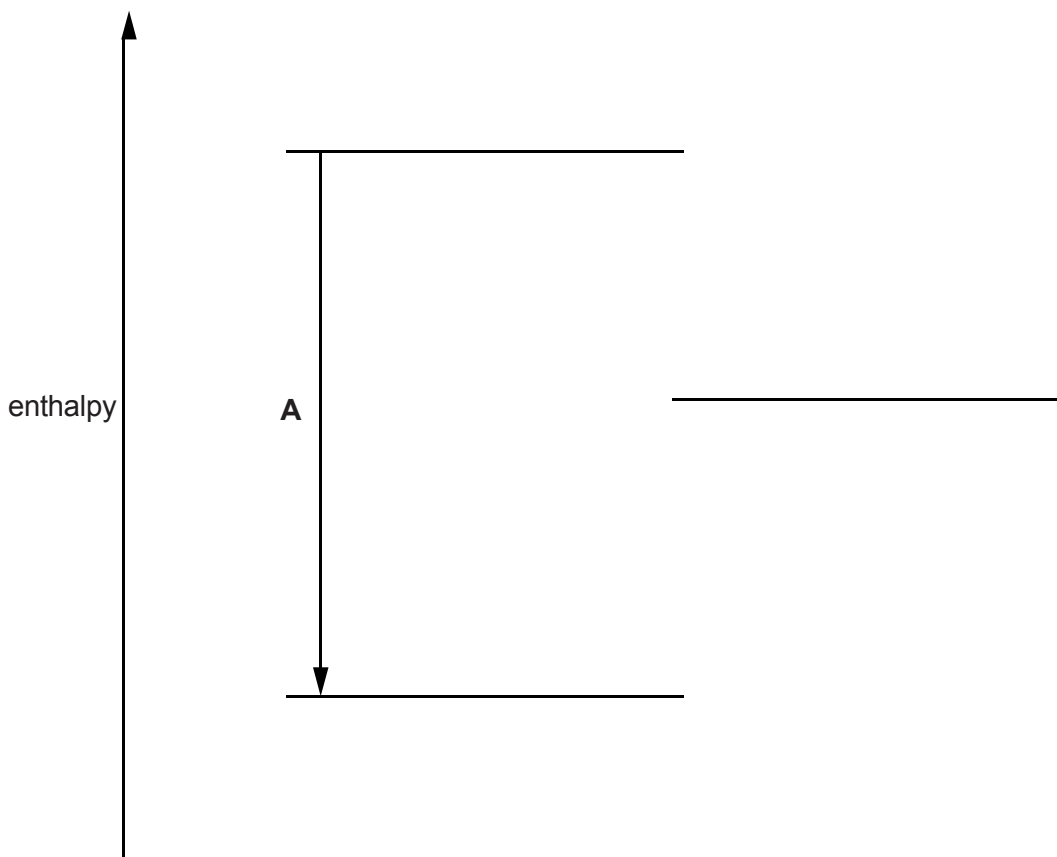|	Name of enthalpy change	Enthalpy change /kJ mol^{-1}
A	lattice enthalpy of potassium sulfate	−1763
B	enthalpy change of solution of potassium sulfate	+24
C	enthalpy change of hydration of potassium ions	−320
D	enthalpy change of hydration of sulfate ions	

Table 3.1

(a) Define the term *enthalpy change of hydration*. [2]

(b) The diagram below is an incomplete energy cycle linking the four enthalpy changes in **Table 3.1**. One of the four energy levels is missing.

Include state symbols for all species.

(i) Complete the energy cycle as follows.

- Add the missing energy level to the diagram. Add the species on all **four** energy levels.

- Add arrows to show the direction of the three missing enthalpy changes. Label these enthalpy changes using the letters **B–D** from **Table 3.1**.

[5]

(ii) Calculate the enthalpy change of hydration of sulfate ions.

[1]

(c) The entropy change of solution of K_2SO_4 is $+225\,J\,K^{-1}\,mol^{-1}$.

(i) Suggest, in terms of the states of the particles involved, why this entropy change is positive.

[1]

(ii) Explain, using a calculation, why K_2SO_4 dissolves in water at 25 °C, despite the enthalpy change of solution being endothermic.
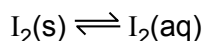
[3]

[Total: 12 Marks]

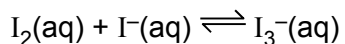Iodine, I_2, is a grey-black solid that is not very soluble in water.
Equilibrium 1 is set up with the equilibrium position well to the left.

$$I_2(s) \rightleftharpoons I_2(aq) \qquad \textbf{Equilibrium 1}$$

Solid iodine is much more soluble in an aqueous solution of potassium iodide, $KI(aq)$, than in water.
Equilibrium 2 is set up.

$$I_2(aq) + I^-(aq) \rightleftharpoons I_3^-(aq) \qquad \textbf{Equilibrium 2}$$

(a) Suggest why I_2 is **not** very soluble in water.   [1]

(b) A student dissolves I_2 in $KI(aq)$.
The resulting 200 cm^3 equilibrium mixture contains:
4.00×10^{-5} mol $I_2(aq)$
9.404×10^{-2} mol $I^-(aq)$
1.96×10^{-3} mol $I_3^-(aq)$.

Calculate K_c for **equilibrium 2**.

Give your answer to an **appropriate** number of significant figures.   [4]

(c) The student adds an excess of aqueous silver nitrate, $AgNO_3(aq)$, to the equilibrium mixture.

Predict what would be observed.

Explain the observations in terms of both **equilibrium 1** and **equilibrium 2** and any species formed.   [4]

(d) Two redox reactions of iodine are described below.

Reaction 1: Iodine is reacted with oxygen to form a compound with a molar mass of $333.8\,g\,mol^{-1}$.

Reaction 2: In alkaline conditions, iodine disproportionates to form iodide ions, iodate(V) ions and water.

Construct equations for these **two** reactions.

State symbols are **not** required.   [3]

[Total: 12 Marks]

Table 21.1 below gives the standard electrode potentials for seven redox systems.
You need to use this information to answer the questions below.

Redox system	Equation	$E^{\ominus}$/V
1	$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51
2	$Cr_2O_7{}^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$	+1.33
3	$Br_2(aq) + 2e^- \rightleftharpoons 2Br^-(aq)$	+1.09
4	$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
5	$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
6	$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	−0.76
7	$Ce^{3+}(aq) + 3e^- \rightleftharpoons Ce(s)$	−2.33

Table 21.1

(a) **(i)** Outline an experimental setup that could be used in the laboratory to measure the standard cell potential of an electrochemical cell based on redox systems **4** and **5**.

In your answer you should include details of the apparatus, solutions and the standard conditions required to measure this standard cell potential.

[4]

(ii) An electrochemical cell can be made based on redox systems **2** and **4**.
The standard cell potential is +0.53 V.

State and explain the effect on the cell potential of this cell if the concentration of silver ions is increased.

[2]

(b) From **Table 21.1**, predict the oxidising agent(s) that **will not** oxidise $Fe^{2+}(aq)$ to $Fe^{3+}(aq)$.

[1]

(c) An aqueous solution of iron(II) bromide is mixed with an excess of acidified solution containing manganate(VII) ions.

Using **Table 21.1**, give the formulae of the products of any reactions that take place.

[2]

[Total: 9 Marks]

A student carries out a number of experiments on transition metal compounds.

4.800 g of a green hydrated crystalline solid **A** are heated in a crucible to remove the water of crystallisation. 1.944 g of water are removed to leave 0.0180 mol of solid residue **B**.

Solid **B** contains 32.8%, by mass, of the transition metal.

All of **B** is reacted with $AgNO_3(aq)$ to form 7.695 g of a white precipitate, **C**.

The green crystalline solid **A** is dissolved in water to produce a green solution containing a complex ion, **D**.

When aqueous sodium hydroxide is added to solution of **D**, a grey–green precipitate, **E**, is observed, which dissolves in excess aqueous sodium hydroxide to form a green solution.

(a) Determine the formulae of **A, B, D** and **E**.

[9]

(b)* Transition metal complexes often have different shapes and may form a number of stereoisomers.

Describe the different shapes and the different types of stereoisomerism found in transition metal chemistry.

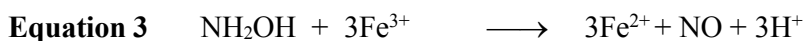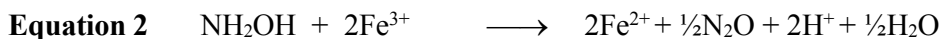Use suitable examples and diagrams in your answer. **[6]**

[Total: 15 Marks]

Hydroxylamine, NH_2OH, is a strong reducing agent.

When heated in aqueous solution, NH_2OH reduces Fe^{3+} ions to Fe^{2+} ions.

A student suggests the three possible equations for the reaction, shown below.

Equation 1 $NH_2OH + Fe^{3+} \longrightarrow Fe^{2+} + \frac{1}{2}N_2 + H^+ + H_2O$

Equation 2 $NH_2OH + 2Fe^{3+} \longrightarrow 2Fe^{2+} + \frac{1}{2}N_2O + 2H^+ + \frac{1}{2}H_2O$

Equation 3 $NH_2OH + 3Fe^{3+} \longrightarrow 3Fe^{2+} + NO + 3H^+$

The student plans to carry out an investigation to determine which equation is correct.

The method is outlined below.

Stage 1   Using a pipette, add 25.0 cm^3 of 4.32×10^{-2} mol dm^{-3} NH_2OH to a conical flask.
Add 10 cm^3 of 1 mol dm^{-3} H_2SO_4 to the conical flask followed by an excess of a solution
containing 0.0400 mol dm^{-3} Fe^{3+}(aq).

Stage 2   Boil the mixture for 5 minutes and allow to cool.

**Stage 3**   Titrate the cooled mixture with 2.00×10^{-2} mol dm^{-3} $KMnO_4$(aq).

(a)   Determine the minimum volume of 0.0400 mol dm^{-3} Fe^{3+}(aq) that the student should plan to use in
Stage 1.

Explain your reasoning.

[4]

(b) In the student's titration, 21.6 cm^3 of $KMnO_4$(aq) is required to reach the end point.

The equation that takes place during the titration is shown below.

$$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$$
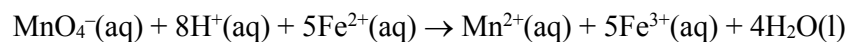
Analyse the student's results to determine which of the three equations is correct.

[3]

(c) The student intends to repeat the procedure to check their results.

There is insufficient time for the student to repeat all three stages and the student decides to omit **Stage 2**, the boiling stage. Unfortunately the resulting titre is much less than the original titre.

The student rejects the results from the repeated procedure.

(i) Suggest the purpose of the boiling in **Stage 2** and reasons for the second titre being much less than the original titre.

[2]

(ii)   The main reason for insufficient time is the need to boil and cool the mixture for each titration.

Suggest how the procedure could be modified so that **Stage 2** does not need to be carried out repeatedly.

Give your reasoning.

[1]

[Total: 10 Marks]