CHEMISTRY

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 provided on the Question Paper.
The use of an approved scientific calculator is expected, where appropriate.

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

This document consists a total of **10** printed pages.

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1 **(a)** Unionised sulfuric acid is a volatile liquid at standard conditions. With appropriate chemical equations whose enthalpy change reflect the terms below, define the following for unionised sulfuric acid:

(i) *standard enthalpy change of atomisation*; [2]

(ii) *standard enthalpy change of formation*; [2]

(iii) and *the bond energy of the* S=O *bond*. [2]

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(b) When water is added to unionised sulfuric acid, the resultant solution increases in temperature, releasing enough heat to cause vigourous boiling.

(i) With reference to bond formation, interactions and reactions between sulfuric acid and water molecules, explain the above observation. [2]

(ii) Suggest whether you should make a solution of aqueous sulfuric acid of a dilute concentration by

- adding unionised sulfuric acid to water;
- **or** adding water to unionised sulfuric acid. [1]

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(c) Unionised sulfuric acid is a dehydrating agent. For example, under strong heating at 425 to 450 K, ethanol is converted to ethene. You should assume that at these conditions, both molecules are gases.

(i) Calculate the enthalpy change of this dehydration reaction in such conditions. [2]

Ethanol: C_2H_5OH; Ethene: C_2H_4
Enthalpy change of vapourisation of liquid water: +41.0 kJ mol^{-1}

(ii) Explain whether the entropy change of this reaction is positive or negative. [1]

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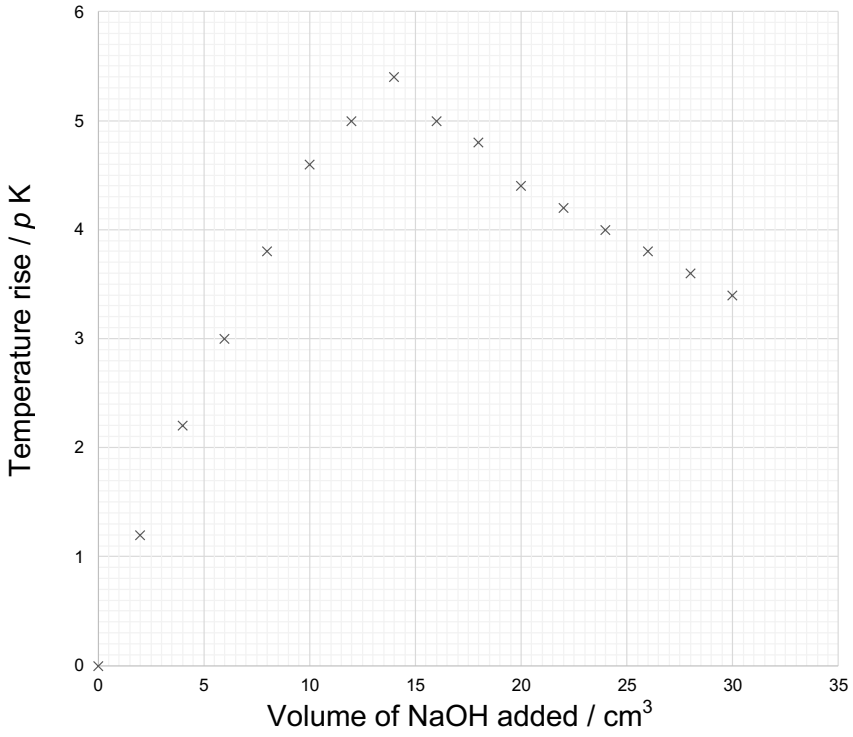
(d) 25.0 cm^3 of 1.00 mol dm^{-3} aqueous sulfuric acid was titrated against a solution of sodium hydroxide. The temperature rise of the solution against volume of NaOH added was recorded, and plotted on the graph below. You should assume that there was no heat loss or gain from the surroundings.



The enthalpy change of neutralisation is -57.1 kJ mol^{-1}.

(i) Determine the concentration of NaOH. [2]

(ii) Determine *p*. Assume that the specific heat capacity of all solutions is 4.18 J g^{-1} K^{-1}, and the density of all solutions is 1.00 g cm^{-1}. [2]

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[Total: 16]

2 This question is about Group 2 salts.

(a) Draw the dot-and-cross diagram for magnesium carbonate. [1]

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(b) The *lattice energy* of magnesium carbonate is -3123 kJ mol^{-1}.

(i) What is meant by the *lattice energy of magnesium carbonate*? [1]

(ii) Explain why the *lattice energy* of magnesium carbonate is negative. [1]

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(c) The decomposition of magnesium carbonate was studied at 2 temperatures, to determine the ideal temperature for the industrial production of magnesium oxide. The products were bubbled into limewater and the observations are as follows:

Temperature / K	Effect on limewater
1050	White precipitate
400	No white precipitate

(i) At a certain temperature, it was found that the reaction ceases to be feasible. Given the following data, determine this temperature. [2]

Compound	$\Delta S_f^{\ominus}$ / J mol^{-1} K^{-1}
$MgCO_3(s)$	65.7
$MgO(s)$	26.9
$CO_2(g)$	213.6

The enthalpy change of the decomposition reaction is +100 kJ mol^{-1}.

(ii) Suggest the effect of increasing the temperature on the spontaneity of the reaction. [1]

(iii) Using the data provided and relevant data from the *Data Booklet*, construct an appropriate fully-labelled energy cycle to calculate the lattice energy of magnesium carbonate. [4]

Enthalpy Term	ΔH / kJ mol^{-1}
Enthalpy change of atomisation of magnesium	+148
Sum of 1st and 2nd electron affinities of oxygen	+657
Enthalpy change of formation of magnesium carbonate	–1096
Enthalpy change of formation of $CO_2(g)$	–393
$O^{2-}(g) + CO_2(g) \rightarrow CO_3^{2-}(g)$	–778

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(d) Data concerning some Group II sulfates and hydroxides, at 298 K, are given in the table below. Further data may be found in the Data Booklet.

	solubility / mol dm^{-3}	– lattice energy / kJ mol^{-1}	$\Delta H_{hydration}$ of M^{2+} / kJ mol^{-1}	$\Delta H_{hydration}$ of SO_4^{2-} / kJ mol^{-1}
$MgSO_4$	2.2	2959	–1890	–1160
$CaSO_4$	1.5×10^{-2}	2704	–1562	–1160
$SrSO_4$	7.1×10^{-3}	2572	–1414	–1160

	solubility / mol dm^{-3}	– lattice energy / kJ mol^{-1}	$\Delta H_{hydration}$ of M^{2+} / kJ mol^{-1}	2 x $\Delta H_{hydration}$ of OH^- / kJ mol^{-1}
$Mg(OH)_2$	1.6×10^{-4}	2993	–1890	–1100
$Ca(OH)_2$	2.5×10^{-2}	2644	–1562	–1100
$Sr(OH)_2$	3.4×10^{-2}	2467	–1414	–1100

(i) Define, with the aid of an equation, $\Delta H_{hydration}$ of M^{2+}. Explain, with the aid of a labelled diagram, why $\Delta H_{hydration}$ of M^{2+} is negative. [4]

(ii) Explain why

1. The magnitude of the lattice energy of Group II sulfates decreases from $MgSO_4$ to $SrSO_4$.

2. The $\Delta H_{hydration}$ of M^{2+} becomes less exothermic from Mg^{2+} to Sr^{2+}. [2]

Part **(d)** continues on the next page.

(iii) Hence, suggest **qualitatively** why the solubility of Group II sulfates decreases from $MgSO_4$ to $SrSO_4$, while the solubility of Group II hydroxides increases from $Mg(OH)_2$ to $Sr(OH)_2$. [2]

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