

1. June/2022/Paper_41/No.1(b- e)

(b) Describe what is observed when magnesium and barium are reacted separately with an excess of dilute sulfuric acid.

magnesium

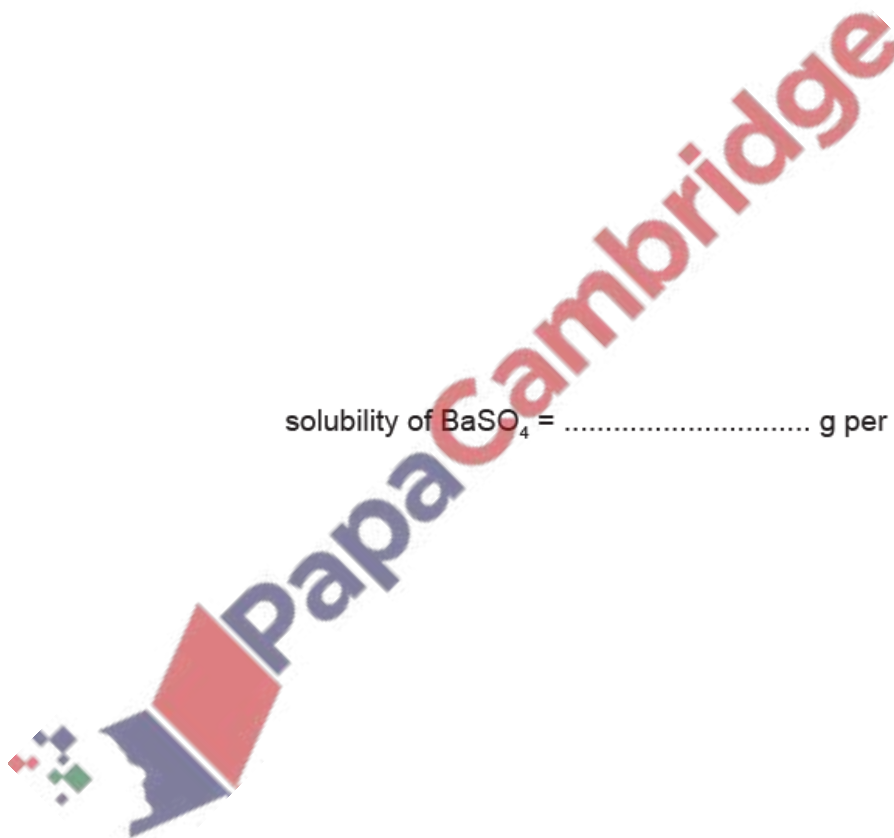
barium

[1]

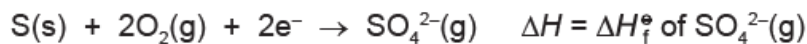
(c) The solubility product, K_{sp} , of $BaSO_4$ is $1.08 \times 10^{-10} \text{ mol}^2 \text{ dm}^{-6}$ at 298 K.

Calculate the solubility of $BaSO_4$ in g per 100 cm^3 of solution.

solubility of $BaSO_4$ = g per 100 cm^3 of solution [2]



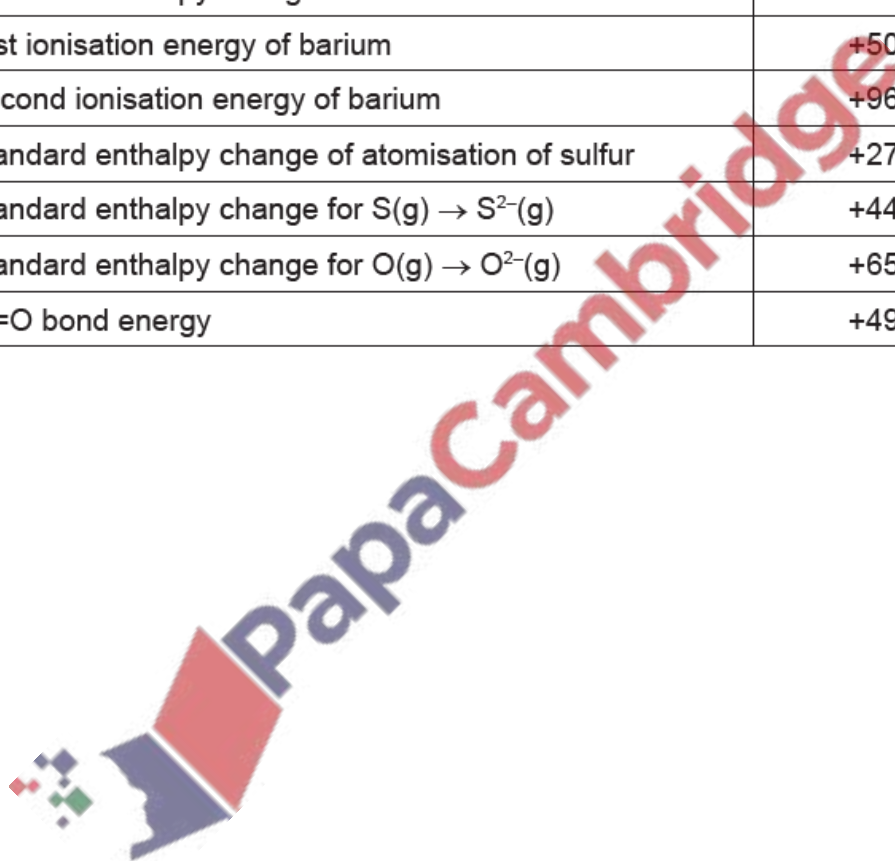
(d) (i) The equation for the formation of a gaseous sulfate ion is shown.



Calculate the standard enthalpy change of formation, ΔH_f° , of $\text{SO}_4^{2-}(\text{g})$. It may be helpful to draw a labelled energy cycle. Use relevant data from Table 1.1 in your calculations.

Table 1.1

energy change	value / kJ mol ⁻¹
lattice energy of barium sulfate, BaSO ₄ (s)	-2469
standard enthalpy change of formation of barium sulfate	-1473
standard enthalpy change of atomisation of barium	+180
first ionisation energy of barium	+503
second ionisation energy of barium	+965
standard enthalpy change of atomisation of sulfur	+279
standard enthalpy change for S(g) → S ²⁻ (g)	+440
standard enthalpy change for O(g) → O ²⁻ (g)	+657
O=O bond energy	+496



ΔH_f° of $\text{SO}_4^{2-}(\text{g}) = \dots\dots\dots$ kJ mol⁻¹ [3]

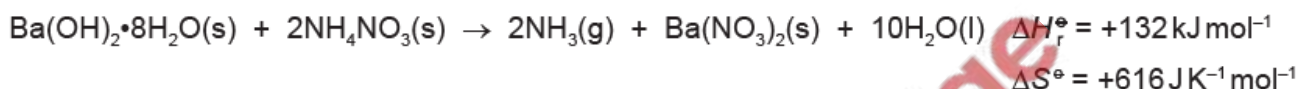
- (ii) Suggest how the lattice energy of $\text{BaSO}_4(\text{s})$ differs from the lattice energy of $\text{Cs}_2\text{SO}_4(\text{s})$. Explain your answer.

.....

 [2]

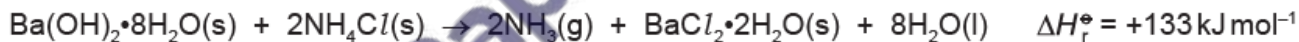
(e) The reaction of solid hydrated barium hydroxide, $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$, with ammonium salts is endothermic.

- (i) Calculate the **minimum** temperature at which the reaction of $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$ with NH_4NO_3 becomes feasible. Show all your working.



temperature = °C [2]

- (ii) Barium hydroxide reacts readily with ammonium chloride on mixing at room temperature.



Some relevant standard entropies are given in Table 1.2.

Table 1.2

substance	$\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}(\text{s})$	$\text{NH}_4\text{Cl}(\text{s})$	$\text{NH}_3(\text{g})$	$\text{BaCl}_2 \cdot 2\text{H}_2\text{O}(\text{s})$	$\text{H}_2\text{O}(\text{l})$
$S^\ominus / \text{JK}^{-1} \text{ mol}^{-1}$	427	95	192	203	70

Calculate the standard Gibbs free energy change, ΔG^\ominus , for this reaction at 25 °C.

$\Delta G^\ominus = \dots\dots\dots \text{ kJ mol}^{-1}$ [3]

2. June/2022/Paper_42/No.1(b)

(b) The solubility of $\text{Be}(\text{OH})_2$ in water is $2.40 \times 10^{-6} \text{ g dm}^{-3}$ at 298 K.

(i) Write an expression for the solubility product, K_{sp} , of $\text{Be}(\text{OH})_2$ and state its units.

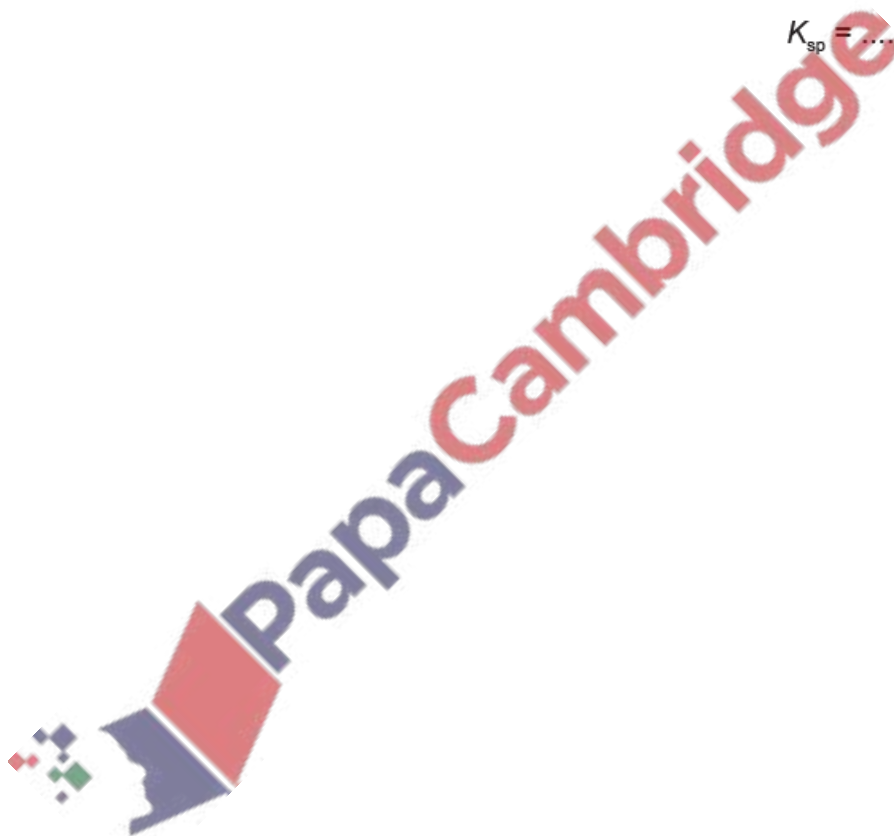
$K_{\text{sp}} =$

units =

[2]

(ii) Calculate the numerical value of K_{sp} for $\text{Be}(\text{OH})_2$ at 298 K.

$K_{\text{sp}} =$ [2]



(a) (i) Define first electron affinity.

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..... [2]

(ii) The first electron affinity of an atom is usually an exothermic process, whereas the second electron affinity is an endothermic process.

Suggest why.

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..... [1]

(iii) Describe the general trend in first electron affinities for Cl, Br and I. Explain your answer.

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..... [2]

(b) Table 3.1 shows energy changes to be used in this question and in (c).

Table 3.1

energy change	value / kJ mol ⁻¹
standard enthalpy change of atomisation of zinc	+131
first ionisation energy of zinc	+906
second ionisation energy of zinc	+1733
standard enthalpy change of formation of ZnI ₂ (s)	-208
lattice energy, $\Delta H_{\text{latt}}^{\circ}$, of zinc iodide, ZnI ₂ (s)	-2605
first ionisation energy of iodine	+1008
second ionisation energy of iodine	+1846
I-I bond energy	+151
enthalpy change of sublimation of iodine, I ₂ (s) → I ₂ (g)	+62

Calculate the first electron affinity for iodine. Use relevant data from Table 3.1 in your working. It may be helpful to draw a labelled energy cycle. Show all working.

first electron affinity for iodine = kJ mol⁻¹ [3]

- (c) Predict how $\Delta H_{\text{latt}}^{\ominus}$ of CdI₂(s) differs from $\Delta H_{\text{latt}}^{\ominus}$ of ZnI₂(s). Place a tick (✓) in the appropriate box in Table 3.2.

Table 3.2

$\Delta H_{\text{latt}}^{\ominus}$ of CdI ₂ (s) is less negative than $\Delta H_{\text{latt}}^{\ominus}$ of ZnI ₂ (s)	$\Delta H_{\text{latt}}^{\ominus}$ of CdI ₂ (s) is the same as $\Delta H_{\text{latt}}^{\ominus}$ of ZnI ₂ (s)	$\Delta H_{\text{latt}}^{\ominus}$ of CdI ₂ (s) is more negative than $\Delta H_{\text{latt}}^{\ominus}$ of ZnI ₂ (s)
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Explain your answer.

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 [1]

[Total: 9]

(a) Calcium carbonate decomposes on heating.



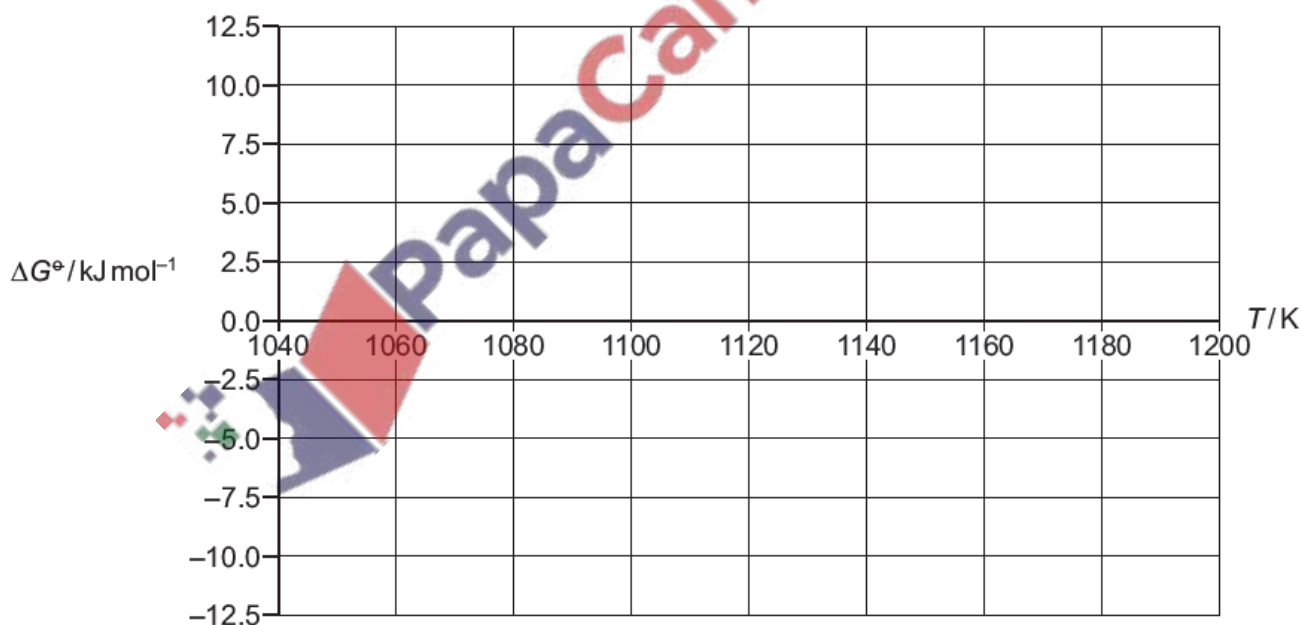
Table 4.1 shows the values of the Gibbs free energy change, ΔG° , for this reaction at various temperatures.

Table 4.1

T/K	$\Delta G^\circ/\text{kJ mol}^{-1}$
1050	9.9
1085	4.3
1120	-1.3
1148	-5.8
1176	-10.3

Assume the standard enthalpy change, ΔH° , and the standard entropy change, ΔS° , for this reaction remain constant over this temperature range.

(i) Use the data in Table 4.1 to plot a graph of ΔG° against T on the grid.



[2]

(ii) Calculate the gradient of your graph. Determine the ΔS° in $\text{JK}^{-1} \text{mol}^{-1}$ for this reaction. Show all working.

$$\Delta S^\circ = \dots\dots\dots \text{JK}^{-1} \text{mol}^{-1} \quad [2]$$

(b) Group 1 hydrogencarbonates, MHCO_3 , decompose on gentle heating to give the corresponding metal carbonate, carbon dioxide and water vapour.

(i) Write an ionic equation for the decomposition of the hydrogencarbonate ion.

..... [1]

(ii) The thermal stability of Group 1 hydrogencarbonates increases down the group.

Suggest an explanation for the trend in thermal stability of the Group 1 hydrogencarbonates.

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..... [2]

