1 **(a)** Solutions of Group 2 hydrogencarbonates, $M(HCO_3)_2$, decompose on heating to give the corresponding metal carbonate, carbon dioxide and water.

(i) Write an equation for the decomposition of strontium hydrogencarbonate, $Sr(HCO_3)_2$.

..... [1]

(ii) The thermal stability of Group 2 carbonates increases down the group.

Explain this trend.

.....

.....

.....

..... [2]

(b) The hydroxides and fluorides of Group 2 elements show similar trends in solubility.

Describe the trend in the solubility of the fluorides of calcium, strontium and barium.

Explain your answer.

....
least soluble most soluble

explanation .....

.....

.....

.....

.....

.....

..... [4]

(c) (i) Define enthalpy change of hydration, ΔH_{hyd}.

.....

.....

..... [1]

(ii) State the main factors that affect the magnitude of enthalpy change of hydration.

Explain your answer.

.....

.....

.....

..... [2]

(d) Table 1.1 shows various energy changes.

Table 1.1

energy change	value / kJ mol^{-1}
lattice energy of MgF_2	–2957
enthalpy change of hydration, ΔH_{hyd}, of Mg^{2+}	–1926
enthalpy change of hydration, ΔH_{hyd}, of F^-	–505

Use data from Table 1.1 to calculate the enthalpy change of solution, ΔH_{sol}, for $MgF_2(s)$.

It may be helpful to draw a labelled energy cycle. Show your working.

ΔH_{sol} of $MgF_2(s)$ = ... kJ mol^{-1} [2]

(e) Mercury(I) fluoride, Hg_2F_2, is sparingly soluble in water.

The cation in Hg_2F_2 exists as the diatomic ion Hg_2^{2+} with a covalent Hg–Hg bond.

(i) Write the expression for the solubility product, K_{sp}, of Hg_2F_2. Include the units.

K_{sp} =

units .....
[2]

(ii) The solubility of Hg_2F_2 is 9.20×10^{-3} mol dm^{-3} at 298 K.

Calculate the value of K_{sp} of Hg_2F_2 at 298 K.

K_{sp} = ... [1]

[Total: 15]

4 **(a)** Define enthalpy change of atomisation, ΔH_{at}.

.....

..... [1]

(b) Define first electron affinity, EA.

.....

..... [1]

(c) Explain why the first electron affinity of chlorine is more exothermic than the first electron affinity of iodine.

.....

.....

.....

..... [2]

(d) The enthalpy change for the reaction $Cl_2(g) + 2e^- \rightarrow 2Cl^-(g)$ is $-486\,kJ\,mol^{-1}$.

The first electron affinity of chlorine is $-364\,kJ\,mol^{-1}$.

Calculate the enthalpy change of atomisation of chlorine.

ΔH_{at} of chlorine = ... $kJ\,mol^{-1}$ [2]

[Total: 6]

2 **(a)** The Group 2 sulfates and the Group 2 chromates show similar trends in solubility.

Suggest the trend in the solubility of the Group 2 chromates down the group.

Explain your answer.

.....

.....

.....

.....

.....

..... [4]

(b) Silver(I) chromate, Ag_2CrO_4, is sparingly soluble in water.

(i) Write an ionic equation to show the equilibrium between solid Ag_2CrO_4 and its aqueous solution.

Include state symbols.

..... [1]

(ii) The value of the solubility product, K_{sp}, of Ag_2CrO_4 is 1.12×10^{-12} at 298 K.

Calculate the equilibrium concentration of Ag^+, in mol dm^{-3}, in a saturated solution of Ag_2CrO_4 at 298 K.

equilibrium concentration of Ag^+ = ... mol dm^{-3} [3]

(c) The hydrogenchromate ion, $HCrO_4^-$, is a weak acid. The pK_a of $HCrO_4^-$ is 6.49.

(i) Calculate the pH of a 0.0250 mol dm^{-3} $HCrO_4^-$ solution.

pH = ... [2]

(ii) $HCrO_4^-$ can show amphoteric behaviour.

State the formula of:

- the conjugate acid of $HCrO_4^-$ .....
- the conjugate base of $HCrO_4^-$. .....

[1]

(d) Table 2.1 shows some energy changes.

Table 2.1

energy change	value / kJ mol^{-1}
first ionisation energy of silver	+731
second ionisation energy of silver	+2074
first ionisation energy of sulfur	+1000
second ionisation energy of sulfur	+2251
first electron affinity of sulfur	–200
second electron affinity of sulfur	+532
enthalpy change of atomisation of sulfur	+279
enthalpy change of formation of silver(I) sulfide, $Ag_2S(s)$	–33
lattice energy of silver(I) sulfide, $Ag_2S(s)$	–2677

(i) Define the term first electron affinity.

.....

.....

..... [1]

(ii) Explain why the value for the second electron affinity of sulfur is positive.

.....

.....

..... [1]

(iii) Construct an equation for the lattice energy of Ag_2S.

Include state symbols.

..... [1]

(iv) Calculate the enthalpy change of atomisation, ΔH_{at}, in $kJ\,mol^{-1}$, of silver using relevant data from Table 2.1.

It may be helpful to draw a labelled Born–Haber cycle.

Show your working.

ΔH_{at} of silver = ... $kJ\,mol^{-1}$ [3]

(e) Suggest how the magnitude for the lattice energy of $Ag_2S(s)$ differs from the lattice energy of $Cu_2S(s)$.

Explain your answer.

.....

.....

..... [1]

[Total: 18]

3 **(a)** Define the term entropy.

.....

..... [1]

(b) **(i)** Place **one** tick (✓) in each row of Table 3.1 to show the sign of the entropy change, ΔS, for each process.

Table 3.1

process	ΔS is negative	ΔS is positive
steam condensing into water		
solid KCl dissolving in water		

[1]

(ii) Chlorine trifluoride, ClF$_3$, decomposes on heating into its elements, as shown.

reaction 1 $2Cl F_3(g) \rightarrow Cl_2(g) + 3F_2(g)$

Standard entropies are shown in Table 3.2.

Table 3.2

substance	ClF$_3$(g)	Cl_2(g)	F$_2$(g)
$S^{\ominus}$ / J K^{-1} mol^{-1}	+281.6	+223.1	+203.0

Calculate the standard entropy change, $\Delta S^{\ominus}$, in J K^{-1} mol^{-1}, for reaction 1.

$\Delta S^{\ominus}$ for reaction 1 = ... J K^{-1} mol^{-1} [2]

(c) Group 2 carbonates decompose on heating. The decomposition for one of the Group 2 carbonates, MCO_3, is shown in reaction 2.

reaction 2 $MCO_3(s) \rightarrow MO(s) + CO_2(g)$

(i) Predict the sign of the entropy change, ΔS, for reaction 2.

Explain your answer.

.....

..... [1]

(ii) The Gibbs equation is shown.

$$\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$$

Fig. 3.1 shows values of the Gibbs free energy change, $\Delta G^{\ominus}$, in kJ mol^{-1}, at different temperatures, T, in K, for reaction 2.

Assume $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ values for this reaction remain constant over this temperature range.

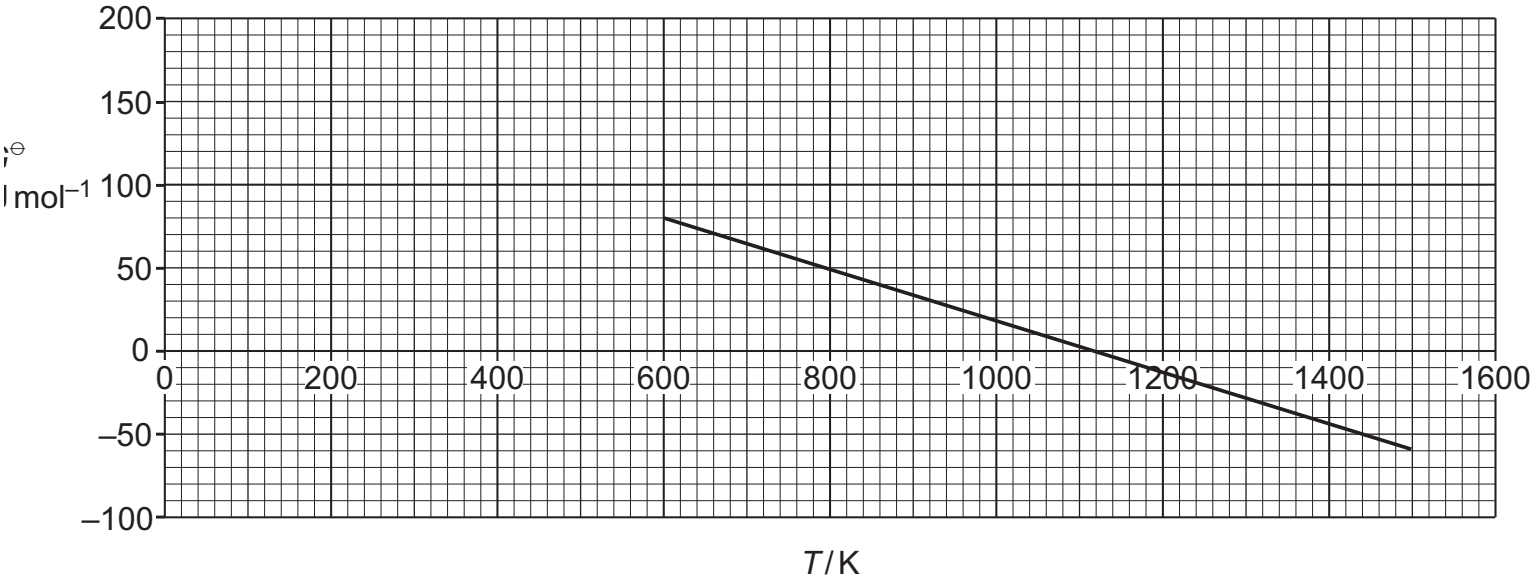

Fig. 3.1

Use the gradient and intercept on the y-axis in Fig. 3.1 and the Gibbs equation to determine:

- $\Delta S^{\ominus}$, in J K^{-1} mol^{-1}, for reaction 2
- the minimum temperature, T, in K, at which the reaction is feasible
- $\Delta H^{\ominus}$, in kJ mol^{-1}, for reaction 2.

$\Delta S^{\ominus}$ for reaction 2 = ... J K^{-1} mol^{-1}

minimum temperature, T = ... K

$\Delta H^{\ominus}$ for reaction 2 = ... kJ mol^{-1}

[4]

[Total: 9]