Past-paper walk-through

Enthalpies of solution and hydration ▪ 23.2

eXercise

Questions in this set

- 9701/41 N25 Q1 ▪ 15 marks
- 9701/42 N25 Q1 ▪ 7 marks
- 9701/44 N25 Q2 ▪ 18 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 1

9701/41 N25 ▪ Q1 ▪ 15 marks

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, $Sr(HCO_3)_2$.

Question 1

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

Explain this trend.

Question 1

(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.

Question 1

least soluble

most soluble

Question 1

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

Question 1

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

Explain your answer.

Question 1

(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.

Question 1

Question 1

Question 1

(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} =

Question 1

[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.

Question 1

[Total: 15]

Solution 1

(a)(i)

Mark scheme

- $Sr(HCO3)2 \rightarrow SrCO3 + CO2 + H2O$
- 1

Solution 1

(a)(ii)

Mark scheme

- M1: radius of cation / M2+ increases OR charge density of cation / M2+ decreases
- M2: less polarisation / less distortion of the anion / carbonate ion
- 2

Solution 1

(b)

Mark scheme

- M1: least soluble CaF2 $<$ SrF2 $<$ BaF2 most soluble
- M2: ΔHlatt and ΔHhyd both become less exothermic / less negative
- M3: ΔHhyd changes less / becomes less exothermic by a smaller extent
- OR ΔHlatt changes more / becomes less exothermic by a larger extent
- M4: ΔHsol becomes more exothermic / more negative
- 4

Solution 1

(c)(i)

Mark scheme

- enthalpy change when one mole of gaseous ions dissolve in water to form a solution
- 1

Solution 1

(c)(ii) Mark scheme

- M1: ionic radii AND ionic charge
- M2: (ionic) radii increase / charge density decreases AND H_{hyd} decreases/less exothermic AND less attraction between
- water molecules and (gaseous) ions
- OR
- as ionic charge increases / charge density increases AND H_{hyd} increases/more exothermic AND more attraction between
- water molecules and (gaseous) ions
- 2

Solution 1

(d)

Mark scheme

- M1: use of –2957 / –1926 / –505 AND 2 × (–505)
- M2: correct signs and evaluation
- Hsol of MgF2(s) = –1926 + (2 × –505) – (–2957) = (+)21 kJ mol–1
- 2

Solution 1

(e)(i)

Mark scheme

- M1: Ksp = [Hg22+] [F–]2
- M2: units = mol3 dm–9
- 2

Solution 1

(e)(ii)

Mark scheme

- Ksp = 22 × (9.20 × 10–3)3 = 3.11 × 10–6 min 2sf
- 1
- 9701/41
- October/November 2025

Question 1

9701/42 N25 ▪ Q1 ▪ 7 marks

1 Magnesium nitrate, $Mg(NO_3)_2$, and strontium nitrate, $Sr(NO_3)_2$, both decompose when heated to form the metal oxide and a mixture of gases.

(a) Write an equation for the thermal decomposition of $Mg(NO_3)_2$.

Question 1

(b) State which of $Mg(NO_3)_2$ or $Sr(NO_3)_2$ decomposes at a lower temperature.

Explain your answer.

Question 1

[2]

(c) Magnesium oxide, MgO, and strontium oxide, SrO, both react with dilute sulfuric acid.

MgO forms a soluble salt, **A**.

SrO forms an insoluble salt, **B**.

(i) Identify the products formed when MgO reacts with dilute sulfuric acid.

Question 1

(ii) Explain why **A** is more soluble than **B**.

Question 1

[Total: 7]

Solution 1

(a)

Mark scheme

- $Mg(NO3)2 \rightarrow MgO + 2NO2 + ½O2$ OR $2Mg(NO3)2 \rightarrow 2MgO + 4NO2 + O2$
- 1

Solution 1

(b)

Mark scheme

- M1: Mg(NO3)2 / magnesium nitrate
- AND magnesium ion / Mg2+
- AND is smaller / has higher charge density
- M2: nitrate ion / anion is more distorted / polarised
- 2

Solution 1

(c)(i)

Mark scheme

- magnesium sulfate and water / MgSO4 and H2O
- 1

Solution 1

(c)(ii)

Mark scheme

- M1: magnesium sulfate / A has a more exothermic ΔHlatt and ΔHhyd
- M2: difference in ΔHhyd is greater
- M3: magnesium sulfate / A has a more exothermic ΔHsol
- 3

Question 2

9701/44 N25 ▪ Q2 ▪ 18 marks

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.

Question 2

(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.

Question 2

(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.

Question 2

Question 2

Question 2

(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.

Question 2

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

State the formula of:

Question 2

Question 2

[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

Question 2

Question 2

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.

Question 2

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

Question 2

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

Include state symbols.

Question 2

(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.

Question 2

Question 2

(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.

Question 2

[Total: 18]

Solution 2

(a)

Mark scheme

- M1: (solubility) decreases down the group
- M2: ΔH_{latt} and ΔH_{hyd} decrease / become less exothermic / less negative
- M3: ΔH_{hyd} decreases / changes more / dominant factor / becomes less exothermic by a larger extent
- OR ΔH_{latt} decreases / changes less / changes slower
- M4: ΔH_{sol} becomes less exothermic / less negative OR ΔH_{sol} becomes (more) endothermic / (more) positive
- 4

Solution 2

(b)(i)

Mark scheme

- Ag2CrO4(s) 2Ag+(aq) + CrO42–(aq)
- 1

Solution 2

(b)(ii) Mark scheme

- M1: Ksp = [Ag+]2 [CrO42-]
- M2: $\sqrt{}(1.12\times$ 10−12 ÷ 4)
- 3
- = 6.54 × 10–5
- M3: [Ag+] = 2 × 6.54 × 10–5 = 1.31 × 10–4 (mol dm–3) min 2sf
- 3
- 9701/44
- October/November 2025

Solution 2

(c)(i)

Mark scheme

- Ka = 10–6.49 = 3.236 × 10–7

H+ 2 = 8.08984 × 10–9

- M1: [H+] = 8.99 × 10–5
- M2: pH = –log(8.99 × 10–5) = 4.05 min 2sf
- 2

Solution 2

(c)(ii)

Mark scheme

- conjugate acid
- H2CrO4
- AND
- conjugate base
- CrO42–
- 1

Solution 2

(d)(i)

Mark scheme

- (the energy change / released when) one mole of gaseous atoms become 1– ions / gain one mole of electrons
- 1

(d)(ii)

Mark scheme

- due to repulsion between negative ion and incoming / gained electron
- 1

Solution 2

(d)(iii)

Mark scheme

- 2Ag+(g) S2–(g) $\rightarrow$ Ag2S(s)
- 1

Solution 2

(d)(iv) Mark scheme

- M1: selection of correct six numbers only: –33, 731, 279, –200, 532, –2677
- M2: use of × 2 as only multiplier with Ag
- M3: correct signs and evaluation of data
- $-33 = 2\Delta\text{Hat} + (2 \times 731) + 279 + (-200) + 532 + (-2677)$
- $2\Delta\text{Hat} = 571\ (\text{kJ mol}-1)$
- $\Delta\text{Hat} = +285.5\ (\text{kJ mol}-1)$
- 3

Solution 2

(e)

Mark scheme

- Ag2S smaller / less negative / less exothermic lattice neergy AND larger ionic radius (of cation)
- 1
- 9701/44
- October/November 2025