

a <b>measure / degree of disorder / randomness</b> of a system	1												
<b>M1:</b> negative – molecules have less energy in the system	3												
<b>M2:</b> positive – solid being converted into an aqueous solution													
<b>M3:</b> negative – gaseous ions being converted into a solid													
(standard) Gibbs free energy <u>change</u>	1												
<b>M1:</b> $(\Delta)G = \Delta H - T\Delta S$	2												
<b>M2:</b> description of calculating the minimum value of T for which $\Delta G$ is zero / becomes negative <b>OR</b> $T = \Delta H / \Delta S$ [1]													
<table><tr><td>energy change</td><td>always positive</td><td>always negative</td><td>either negative or positive</td></tr><tr><td>lattice energy</td><td></td><td>✓</td><td></td></tr><tr><td>enthalpy of neutralisation</td><td></td><td>✓</td><td></td></tr></table>	energy change	always positive	always negative	either negative or positive	lattice energy		✓		enthalpy of neutralisation		✓		1
energy change	always positive	always negative	either negative or positive										
lattice energy		✓											
enthalpy of neutralisation		✓											
<b>both</b> [1]													
(energy change) when <b>1 mole</b> of solute is dissolved in an infinite amount of <b>water</b> to form a dilute solution	1												
calculation of $\Delta H^\circ_{\text{sol}}$ with –251, –1284 and –2035 only and two correct signs [1]	3												
calculation of $\Delta H^\circ_{\text{sol}}$ with –251, –1284 and –2035 only and correct signs <b>OR</b> calculation of $\Delta H^\circ_{\text{sol}}$ with $(-251 \times 3)$ , –1284 and –2035 only and two correct signs [2]													
$\Delta H^\circ_{\text{sol}} = (3 \times -251) + (-1284) - (-2035) = -2 \text{ (kJ mol}^{-1}\text{)}$ [3]													
$\text{Ca}^{2+}$ have a higher charge / greater charge density [1] <b>ora</b> <b>stronger</b> electrostatic forces between $\text{Br}^-$ and $\text{Ca}^{2+}$ [1]	2												
$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ [1]	1												
$T\Delta S$ is more positive <b>OR</b> $-T\Delta S$ becomes more negative [1]	1												
simple molecular / simple covalent	1												
<b>weak</b> London forces / id-id forces / VDW forces <b>or</b> London forces / id-id forces / VDW forces <b>AND</b> small amount of energy to break	1												
$\text{SiCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4\text{HCl}$ or $\text{SiCl}_4 + 4\text{H}_2\text{O} \rightarrow \text{Si(OH)}_4 + 4\text{HCl}$	1												
white solid	1												
steamy fumes / white fumes / misty fumes	1												
moles of $\text{SiCl}_4 = 0.8505 / 170.1 = 0.005$	1												
conc of $\text{H}^+ (0.005) \times 4 / 0.8 = 0.025$	1												
$\text{pH} = -\log(0.025) = 1.6$	1												
$-225.7 = 239.0 - (18.7 + 2x)$	1												
$x = +223$	1												
decrease in number of <b>moles of gas</b> /more <b>moles of gas</b> on left / reactants (ora)	1												
use of $\Delta G = \Delta H - T\Delta S$ with $\Delta G = 0 / \Delta G > 0$ <b>or</b> $T = \Delta H / \Delta S$ or $T = (640\,000 / 225.7)$	1												
2836 / 2840 (2835.6)	1												

4.	solubility increases down the group	1
	$\Delta H_{\text{latt}}$ and $\Delta H_{\text{hyd}}$ both <b>decrease</b> or $\Delta H_{\text{latt}}$ and $\Delta H_{\text{hyd}}$ both become less exothermic / more endothermic	1
	$\Delta H_{\text{latt}}$ decreases / changes more (than $\Delta H_{\text{hyd}}$ as $\text{OH}^-$ being smaller than $\text{M}^{2+}$ )	1
	$\Delta H_{\text{sol}}$ becomes more exothermic / more negative / less endothermic / less positive	1
	$\Delta H_{\text{r1}} - (538 + 2 \times 230 + 394) = -(1216 + 286)$ $\Delta H_{\text{r1}} - 1392 = -1502$	1
	$\Delta H_{\text{r1}} = \mathbf{-110}$	1
	let $\Delta H_{\text{f}}(\text{HCO}_3^-(\text{aq})) = y$ $2y - 538 = -1216 - 394 - 286 - 26$	1
	$y = \mathbf{-692}$	1
	$\Delta H_{\text{r3}} - 538 - 2(230 + 394) = -538 - 2(692)$ $\Delta H_{\text{r3}} = \mathbf{-136}$	1
	$\Delta H_{\text{r3}}$ will be identical to $\Delta H_{\text{r4}}$ , / unchanged	1
	as the reaction is the same, or: $2\text{OH}^-(\text{aq}) + 2\text{CO}_2(\text{g}) \longrightarrow 2\text{HCO}_3^-(\text{aq})$ or metal ions stay in solution/metal ions are unchanged / are spectators	1
	more <b>gaseous moles</b> are being consumed (in reaction 3) or more <b>CO<sub>2</sub> moles</b> are being consumed (in reaction 3)	1
	$\Delta S$ is therefore expected to be <b>more negative/less positive</b> for reaction 3.	1
	<b>Total:</b>	<b>13</b>
5.	<b>M1:</b> correct use of stoichiometry <b>M2:</b> answer + 189	<b>2</b>
	<b>M1:</b> States or uses correct form of Gibbs equation $\Delta G = \Delta H - T\Delta S$ <b>M2:</b> appreciates / includes $\Delta G = 0$ at temperature required <b>M3:</b> uses 1000 correctly and answer +624(.339) Award 3 marks for correct answer	<b>3</b>
6.	negative <b>and</b> decrease in number / amount of gas molecules a <b>measure / degree of disorder / randomness</b> of a system	<b>1</b> <b>1</b>
	<b>M1:</b> negative – molecules have less energy in the system <b>M2:</b> positive – solid being converted into an aqueous solution <b>M3:</b> negative – gaseous ions being converted into a solid	<b>3</b>
	(standard) Gibbs free energy <u>change</u>	<b>1</b>
	<b>M1:</b> $(\Delta)G = \Delta H - T\Delta S$ <b>M2:</b> description of calculating the minimum value of T for which $\Delta G$ is zero / becomes negative <b>OR</b> $T = \Delta H / \Delta S$ [1]	<b>2</b>

7.

solubility increases down the group	1
$\Delta H_{\text{latt}}$ and $\Delta H_{\text{hyd}}$ both <b>decrease</b> or $\Delta H_{\text{latt}}$ and $\Delta H_{\text{hyd}}$ both become less exothermic / more endothermic	1
$\Delta H_{\text{latt}}$ decreases / changes more (than $\Delta H_{\text{hyd}}$ as $\text{OH}^-$ being smaller than $\text{M}^{2+}$ )	1
$\Delta H_{\text{sol}}$ becomes more exothermic / more negative / less endothermic / less positive	1
$\Delta H_{\text{r1}} - (538 + 2 \times 230 + 394) = -(1216 + 286)$ $\Delta H_{\text{r1}} - 1392 = -1502$	1
$\Delta H_{\text{r1}} = -110$	1
let $\Delta H_{\text{f}}(\text{HCO}_3^-(\text{aq})) = y$ $2y - 538 = -1216 - 394 - 286 - 26$	1
$y = -692$	1
$\Delta H_{\text{r3}} - 538 - 2(230 + 394) = -538 - 2(692)$ $\Delta H_{\text{r3}} = -136$	1
$\Delta H_{\text{r3}}$ will be identical to $\Delta H_{\text{r4}}$ , / unchanged	1
as the reaction is the same, or: $2\text{OH}^-(\text{aq}) + 2\text{CO}_2(\text{g}) \longrightarrow 2\text{HCO}_3^-(\text{aq})$ or metal ions stay in solution/metal ions are unchanged / are spectators	1
more <b>gaseous moles</b> are being consumed (in reaction 3) or more <b>CO<sub>2</sub> moles</b> are being consumed (in reaction 3)	1
$\Delta S$ is therefore expected to be <b>more negative/less positive</b> for reaction 3.	1
<b>Total:</b>	<b>13</b>

8.

<b>M1</b> solubility decreases down the group	<b>4</b>
<b>M2</b> $\Delta H_{\text{latt}}$ and $\Delta H_{\text{hyd}}$ both become less exothermic / more endothermic	
<b>M3</b> $\Delta H_{\text{latt}}$ changes less (than $\Delta H_{\text{hyd}}$ as $\text{SO}_4^{2-}$ being larger than $\text{M}^{2+}$ )	
<b>M4</b> $\Delta H_{\text{sol}}$ becomes less exothermic / less negative	

<p><b>M1</b> <math>\text{CaO}_2</math> and <math>\text{Ca}^{2+}</math> has a smaller ionic radii/ <math>\text{Ca}^{2+}</math> has a higher charge density</p> <p><b>M2</b> anion/<math>\text{O}_2^{2-}</math> becomes more polarised /distorted</p>	2						
<p><math>\text{Mg}(\text{IO}_3)_2 \rightarrow \text{MgO} + 2.5\text{O}_2 + \text{I}_2</math></p>	1						
<p><b>M1</b> <math>K_{\text{sp}} = [\text{Ca}^{2+}][\text{IO}_3^-]^2</math></p> <p><b>M2</b> units = <math>\text{mol}^3 \text{dm}^{-9}</math></p>	2						
<p><math>K_{\text{sp}} = 4 \times (5.6 \times 10^{-3})^3</math> <math>K_{\text{sp}} = 7.03 \times 10^{-7}</math> 2sf min</p>	1						
<p><b>M1</b> <math>\text{Ca}(\text{IO}_3)_2</math> <b>AND</b> as solubility of <math>\text{Ca}(\text{IO}_3)_2</math> decreases</p> <p><b>M2</b> due to common ion effect</p>	2						
<p><b>M1</b> moles <math>\text{S}_2\text{O}_3^{2-}</math> = <math>0.002 \times 12.4/1000</math> = <math>2.48 \times 10^{-5}</math> moles of <math>\text{I}_2</math> = <math>1.24 \times 10^{-5}</math></p> <p><b>M2</b> moles of <math>\text{IO}_3^-</math> = <math>4.13 \times 10^{-6}</math> in <math>50 \text{ cm}^3</math> moles of <math>\text{IO}_3^-</math> = <math>2.07 \times 10^{-5}</math> in <math>250 \text{ cm}^3</math> mass of <math>\text{NaIO}_3</math> = <math>2.07 \times 10^{-5} \times 197.9</math></p> <p><b>M3</b> mass of <math>\text{NaIO}_3</math> = <b>0.0041</b></p>	3						
<p>It is feasible as the <math>E_{\text{cell}}</math> will be positive/+0.12 V</p>	1						
<p><b>M1</b> Rate = <math>k[\text{IO}_3^-][\text{SO}_3^{2-}][\text{H}^+]</math></p> <p><b>M2</b> units = <math>\text{mol}^{-2}\text{dm}^6\text{s}^{-1}</math></p>	2						
<p>0.10</p>	1						
<p style="text-align: center;">3d</p> <table border="1"><tr><td style="padding: 5px;"><math>(\text{Ni}^{2+})</math></td><td style="padding: 5px;"><math>\uparrow\downarrow</math></td><td style="padding: 5px;"><math>\uparrow\downarrow</math></td><td style="padding: 5px;"><math>\uparrow\downarrow</math></td><td style="padding: 5px;"><math>\uparrow</math></td><td style="padding: 5px;"><math>\uparrow</math></td></tr></table>	$(\text{Ni}^{2+})$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow$	$\uparrow$	1
$(\text{Ni}^{2+})$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow$	$\uparrow$		
<p><b>M1</b> d orbitals <b>split</b> into <b>two levels</b>/ lower and upper orbitals</p> <p><b>M2</b> <b>electron(s)</b> promoted / excited to a higher d-orbital</p> <p><b>M3</b> frequency of light <b>absorbed</b></p> <p><b>M4</b> observed colour is complement of light absorbed</p>	4						
<p>(addition of <math>\text{NH}_3</math>) increases <math>[\text{OH}^-]</math> (due to ionisation of <math>\text{NH}_3</math> in water) and shifts equilibrium 1 to the right (forming <math>\text{Ni}(\text{OH})_2</math>)</p>	1						
<p>(a large excess of <math>\text{NH}_3</math>) shifts eqm 2 to the right (forming <math>[\text{Ni}(\text{NH}_3)_6]^{2+}</math>) <b>AND</b> the <math>[\text{Ni}^{2+}]/[[\text{Ni}(\text{H}_2\text{O})_6]^{2+}]</math> decreases and eqm 1 shifts to the left (causing the ppt to dissolve)</p>	1						
<p><b>M1</b> two correct structures cis &amp; trans for <math>[\text{NiBr}_2(\text{CN})_2]^{2-}</math></p> <div style="display: flex; justify-content: space-around; align-items: center;"><div style="text-align: center;"><math>\begin{array}{c} \text{NC} \quad \text{Br} \\ \diagdown \quad \diagup \\ \text{Ni} \\ \diagup \quad \diagdown \\ \text{NC} \quad \text{Br} \end{array}</math></div><div style="text-align: center;"><math>\begin{array}{c} \text{Br} \quad \text{CN} \\ \diagdown \quad \diagup \\ \text{Ni} \\ \diagup \quad \diagdown \\ \text{NC} \quad \text{Br} \end{array}</math></div></div> <p><b>M2</b> type of stereoisomerism: cis-trans/geometric</p>	2						

9.

**M1**  $\Delta H_{\text{latt}}$  and  $\Delta H_{\text{hyd}}$  decrease / both become less exothermic / less negative

3

**M2**  $\Delta H_{\text{latt}}$  decreases / changes less/becomes less exothermic by a smaller extent **OR**  $\Delta H_{\text{hyd}}$  decreases / changes more / dominant factor

**M3**  $\Delta H_{\text{sol}}$  becomes less exothermic / less negative

**OR**  $\Delta H_{\text{sol}}$  becomes (more) endothermic / (more) positive

**OR**  $\Delta H_{\text{sol}} = \Delta H_{\text{hyd}} - \Delta H_{\text{latt}}$  expression **AND** reaction becomes less exothermic

Mg: fizzing

Ba: (fizzing and) white solid/ppt forms

1

**M1** solubility of  $\text{BaSO}_4$

$$= \sqrt{1.08 \times 10^{-10}} = 1.04 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$$

$$\textbf{M2} = 1.04 \times 10^{-5} \times 233.4 / 10 = 2.43 \times 10^{-4} \text{ (g per 100 cm}^3\text{ of solution) min 2sf}$$

2

$$-1473 = 180 + 503 + 965 + \Delta H_{\text{f}}^{\circ} - 2469$$

$$\Delta H_{\text{f}}^{\circ} \text{ of } \text{SO}_4^{2-}(\text{g}) = -652 \text{ kJ mol}^{-1}$$

**M1** correct five values used [1]

**M2** only correct five values used [1]

**M3** correct signs and evaluation [1]

3

- $\text{BaSO}_4$  is more negative/bigger
- as  $\text{Ba}^{2+}$  is smaller **OR**  $\text{Ba}^{2+}$  has a larger charge
- stronger force of attraction between the ions

One mark for two correct

Two marks for all three correct

2

$$\textbf{M1} \Delta G^{\circ} = 0 \text{ so } T = \Delta H_{\text{f}}^{\circ} / \Delta S^{\circ}$$

**M2**

$$T = 132 / 0.616 = 214.3 \text{ K}$$

$$T = -58.7^{\circ}\text{C min 2sf}$$

2

$$\textbf{M1} \Delta S^{\circ} = (203 + (70 \times 8) + (2 \times 192)) - (427 - (2 \times 95)) = +530 \text{ J K}^{-1} \text{ mol}^{-1}$$

$$\textbf{M2} \Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$$

$$\textbf{M3} \Delta G^{\circ} = 133 - (298 \times 0.530) = -24.9 \text{ kJ mol}^{-1} \text{ ecf 1dp min}$$

**M1** all five points plotted correctly

**M2** best-fit straight line (ruler) with negative gradient drawn

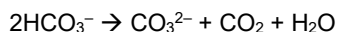
3

**M1** gradient correctly calculated **OR** gradient working seen

$$\textbf{M2} \text{ gradient} = -\Delta S^{\circ}$$

$$\Delta S^{\circ} \text{ evaluated correctly ecf } \Delta S^{\circ} = (+)160 \pm 10 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$$

2



**M1** ionic radius of  $\text{M}^{+}$  / cationic radius increases

**OR** charge density of ion /  $\text{M}^{+}$  decreases down Group 1

**M2** less distortion / polarisation of the anion /  $\text{HCO}_3^{-}$

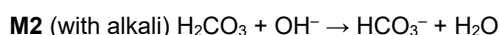
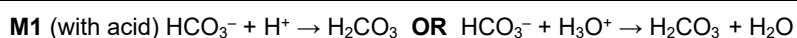
**OR** CO bond / C-O / C=O less weakened

1

**M1** solution which resists changes in pH when opposes / resists change in pH

**M2** when small amount of acid /  $\text{H}^{+}$  or alkali / base /  $\text{OH}^{-}$  is added

2



2

$$\textbf{M1} K_{\text{a}} = 10^{-6.35} = 4.47 \times 10^{-7}$$

$$\textbf{M2} [\text{H}^{+}] = 4.47 \times 10^{-7} / 14.1 = 3.17 \times 10^{-8} \text{ ecf}$$

$$\textbf{M3} \text{ pH} = -\log [\text{H}^{+}] = 7.5 \text{ ecf from a calculated } [\text{H}^{+}] \text{ min 2sf}$$

3

10.