

A-Level Chemistry

Paper 4

Unsolved Topical

Past Papers with Marking Schemes

All Variants

2014-2021

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PREFACE

Excellence in learning cannot be claimed without application of concepts in a dexterous way. In this regard one of the logical approach is to start in chunks; like chapter wise learning and applying the concept on exam based questions.

This booklet provides an opportunity to candidates to practice topic wise questions from previous years to the latest. Extensive working of Team MS Books has tried to take this booklet to perfection by collaborating with top of the line teachers.

We have added answer key / marks scheme at the end of each topic for the candidate to compare the his/her answer to the best.

MS Books strives to maintain actual spacing between consecutive questions and within options as per CAIE format which gives students a more realistic feel of attempting question.

Review, feedback and contribution in this booklet by various competent teachers of a subject belonging to renowned school chains make it most valuable resource and tool for both teachers and students.

With all belief in strength of this resource material I can confidently claim that it is worth in achieving brilliance.

Our sincere thanks and gratification to **Mr. Muhammad Ali** who took out special time to help compile and manage this booklet. We would also like to appreciate chemistry faculty for reviewing and indorsing it.

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CHEMISTRY PAPER 4

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Enthalpy and Born-Haber Cycles

Q2(d)/42/M/J/14

- 1 (d) (i) Write an equation to represent the lattice energy of PbCl_2 . Show state symbols.

.....

- (ii) Use the following data, together with appropriate data from the *Data Booklet*, to calculate a value for the lattice energy of PbCl_2 .

electron affinity of chlorine	=	-349 kJ mol^{-1}
enthalpy change of atomisation of lead	=	$+195 \text{ kJ mol}^{-1}$
enthalpy change of formation of $\text{PbCl}_2(\text{s})$	=	-359 kJ mol^{-1}

lattice energy = kJ mol^{-1}

- (iii) How might the lattice energy of PbCl_2 compare to that of PbBr_2 ? Explain your answer.

.....

.....

.....

[6]

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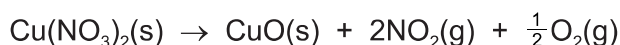
Q2(c)/43/M/J/14

- 2 (c) Copper(I) oxide and copper(II) oxide can both be used in the ceramic industry to give blue, green or red tints to glasses, glazes and enamels.

The table lists the ΔH_f° values for some compounds.

compound	$\Delta H_f^\circ / \text{kJ mol}^{-1}$
$\text{Cu}_2\text{O(s)}$	-168.6
CuO(s)	-157.3
$\text{Cu(NO}_3)_2\text{(s)}$	-302.9
$\text{NO}_2\text{(g)}$	+33.2

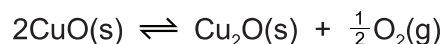
- (i) Copper(II) oxide can be produced in a pure form by heating copper(II) nitrate. Use suitable ΔH_f° values from the table to calculate the ΔH° for this reaction.



$$\Delta H^\circ = \dots\dots\dots \text{kJ mol}^{-1}$$

- (ii) Copper(I) oxide can be produced from copper(II) oxide.

- Use suitable ΔH_f° values from the table to calculate ΔH° for the reaction.



$$\Delta H^\circ = \dots\dots\dots \text{kJ mol}^{-1}$$

- Hence suggest whether a low or a high temperature of oxidation would favour the production of copper(I) oxide. Explain your reasoning.

.....

.....

Q3(e)/42/O/N/14

3 (e) (i) What is meant by the term *lattice energy*?

.....

.....

(ii) Explain why the lattice energy of calcium phosphate is **less** exothermic than that of magnesium phosphate.

.....

.....

[3]

Q1(b(ii))/43/O/N/14

4 (b) (ii) Use the following data, together with relevant data from the *Data Booklet*, to calculate a value for the lattice energy of strontium chloride. You may find it helpful to construct a Born-Haber cycle.

electron affinity per mole of chlorine atoms	-349 kJ mol^{-1}
standard enthalpy of atomisation of Sr(s)	$+164 \text{ kJ mol}^{-1}$
standard enthalpy of formation of $\text{SrCl}_2(\text{s})$	-830 kJ mol^{-1}

lattice energy = kJ mol^{-1}

[5]

Q1(d,e)/42/O/N/15

5 (d) (i) What is meant by the term *standard enthalpy change of hydration*, $\Delta H_{\text{hyd}}^{\circ}$?

.....

.....

..... [2]

- (ii) Use the following data to calculate the lattice energy, $\Delta H_{\text{latt}}^{\ominus}$, of calcium nitrate, $\text{Ca}(\text{NO}_3)_2(\text{s})$. You may find it helpful to construct an energy cycle.

enthalpy change	value
$\Delta H_{\text{hyd}}^{\ominus}(\text{Ca}^{2+}(\text{g}))$	$-1650 \text{ kJ mol}^{-1}$
$\Delta H_{\text{hyd}}^{\ominus}(\text{NO}_3^{-}(\text{g}))$	-314 kJ mol^{-1}
enthalpy change of solution for $\text{Ca}(\text{NO}_3)_2(\text{s})$	-19 kJ mol^{-1}

$$\Delta H_{\text{latt}}^{\ominus} \text{Ca}(\text{NO}_3)_2(\text{s}) = \dots\dots\dots \text{ kJ mol}^{-1} \quad [3]$$

- (e) The standard enthalpy change of hydration for Ba^{2+} , $\Delta H_{\text{hyd}}^{\ominus}(\text{Ba}^{2+}(\text{g}))$, is $-1305 \text{ kJ mol}^{-1}$.

Suggest an explanation for why the $\Delta H_{\text{hyd}}^{\ominus}$ of the Ba^{2+} ion is **less** exothermic than the $\Delta H_{\text{hyd}}^{\ominus}$ of the Ca^{2+} ion.

.....

 [2]

Q1(a,b)/43/O/N/15

- 6 (a) The dissolving of an ionic compound in water is accompanied by an energy change, the enthalpy change of solution, ΔH_{sol} .



Describe, in terms of bond breaking and bond making, what happens to the solid ionic lattice when an ionic compound dissolves in water.

.....

 [2]

- (b) (i) What is meant by the term *enthalpy change of solution*, ΔH_{sol} ?

.....
 [1]

- (ii) Use the following data to calculate the standard enthalpy change of hydration, $\Delta H_{\text{hyd}}^{\ominus}$, of chloride ions, $\text{Cl}^{-}(\text{g})$.

You may find it helpful to construct an energy cycle.

enthalpy change	value
$\Delta H_{\text{hyd}}^{\ominus} (\text{Mg}^{2+}(\text{g}))$	$-1925 \text{ kJ mol}^{-1}$
lattice energy of $\text{MgCl}_2(\text{s})$	$-2524 \text{ kJ mol}^{-1}$
enthalpy change of solution for $\text{MgCl}_2(\text{s})$	-155 kJ mol^{-1}

$$\Delta H_{\text{hyd}}^{\ominus} (\text{Cl}^{-}(\text{g})) = \dots\dots\dots \text{ kJ mol}^{-1} \quad [2]$$

- (iii) The enthalpy change of hydration for Na^{+} , $\Delta H_{\text{hyd}}^{\ominus} (\text{Na}^{+}(\text{g}))$, is -410 kJ mol^{-1} .

Suggest an explanation for why the $\Delta H_{\text{hyd}}^{\ominus}$ of the Na^{+} ion is **less** exothermic than the $\Delta H_{\text{hyd}}^{\ominus}$ of the Mg^{2+} ion.

.....

 [2]

Q8(b,c)/42/M/J/16

7 (b) Calcium reacts vigorously with $\text{HCl}(\text{aq})$ producing $\text{H}_2(\text{g})$.



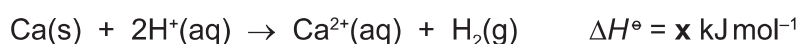
- (i) How would you expect the enthalpy change for this reaction to compare with the enthalpy change for the reaction where $\text{HNO}_3(\text{aq})$ is used in place of HCl but all other conditions are the same?

Explain your answer.

.....

..... [1]

- (ii) The ionic equation for this reaction is shown.



Construct a **fully labelled** Hess' Law cycle to connect each side of this equation to the relevant gas phase ions.

Use your cycle, the following data, **and** data from the *Data Booklet*, to calculate a value for **x**.

standard enthalpy of atomisation of $\text{Ca}(\text{s})$, $\Delta H_{\text{at}}^\ominus(\text{Ca})$	+178 kJ mol ⁻¹
standard enthalpy of hydration of $\text{Ca}^{2+}(\text{g})$, $\Delta H_{\text{hyd}}^\ominus(\text{Ca}^{2+})$	-1576 kJ mol ⁻¹
standard enthalpy of hydration of $\text{H}^+(\text{g})$, $\Delta H_{\text{hyd}}^\ominus(\text{H}^+)$	-1090 kJ mol ⁻¹

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BOOKS

$x = \dots\dots\dots \text{ kJ mol}^{-1}$ [4]

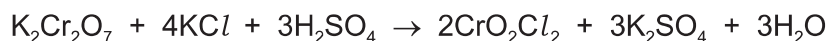
- (c) The standard enthalpy change for the reaction between Ca(s) and CH₃CO₂H(aq) is **less negative** than **x** by 2 kJ mol⁻¹.

Suggest an explanation for this.

.....
 [2]

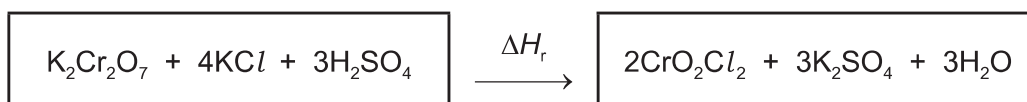
Q8/43/M/J/16

- 8 (a) Chromyl chloride, CrO₂Cl₂, can be prepared by heating a mixture of potassium dichromate(VI) and potassium chloride with concentrated sulfuric acid.



Use the following data to complete the Hess' Law cycle and calculate the enthalpy change of the reaction, ΔH_r .

compound	enthalpy change of formation, $\Delta H_f^\circ / \text{kJ mol}^{-1}$
K ₂ Cr ₂ O ₇	-2061
KCl	-437
H ₂ SO ₄	-814
CrO ₂ Cl ₂	-580
K ₂ SO ₄	-1438
H ₂ O	-286



elements

$\Delta H_r = \dots\dots\dots \text{kJ mol}^{-1}$ [2]

(b) There are two isomeric complex ions with the formula $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]^+$. One is green and the other is violet.

(i) Suggest the *type of isomerism* shown by these complex ions.

..... [1]

(ii) Explain why these two complex ions

- are coloured,

.....

.....

.....

- have **different** colours.

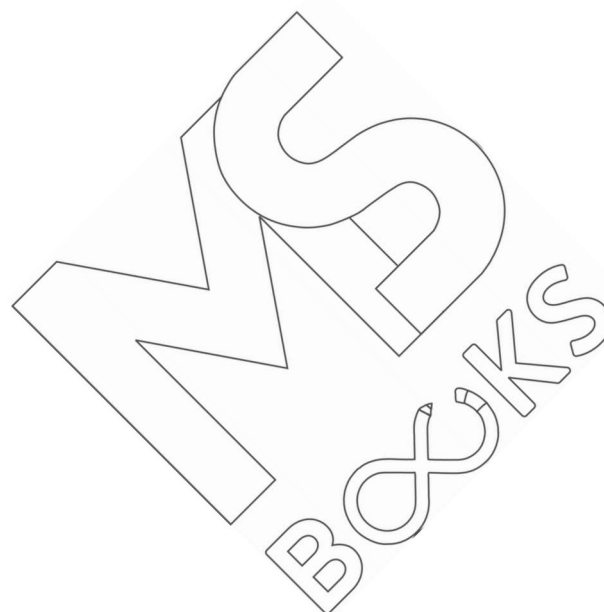
.....

.....

.....

[4]

[Total: 7]



Q2(d)/42/M/J/14



(ii) $\Delta H_f = \Delta H_{\text{at}} + E(\text{Cl} - \text{Cl}) + 1^{\text{st}} \text{IE} + 2^{\text{nd}} \text{IE} + 2 \times E_{\text{A}}(\text{Cl}) + \text{LE}$
 $-359 = 195 + 242 + 716 + 1450 - 2 \times 349 + \text{LE}$
 $\text{LE} = 2 \times 349 - 359 - 195 - 242 - 716 - 1450$
 $\text{LE} = -2264 \text{ (kJ mol}^{-1}\text{)}$ [3]



because Cl^- / chloride anion has smaller radius/size than Br^- / bromide [1]

[6]

Q2(c)/43/M/J/14

2 (c) (i) $\Delta H^\circ = +2 \times 33.2 - 157.3 + 302.9 = (+) 212 \text{ kJ mol}^{-1}$ ecf [2]

(ii) $\Delta H^\circ = -168.6 + 2 \times 157.3 = (+) 146 \text{ kJ mol}^{-1}$ **allow** ecf from (c)(i) [1]
 high T / temperature since ΔH is positive / endothermic [1]

Q3(e)/42/O/N/14 Q 3

- (e) (i) (enthalpy change) when 1 mole of an ionic compound is formed from its gaseous ions 1
 1
- (ii) Mg^{2+} has a smaller (ionic) radii than Ca^{2+} 1 [3]
OR Mg^{2+} is smaller than Ca^{2+}

Q1(b(ii))/43/O/N/14 Q 4

(ii) Lattice energy = $\Delta H_f(\text{SrCl}_2) - (\Delta H_{\text{atom}}(\text{Sr}) + \Delta H_{\text{f}}(\text{Sr}) + \Delta H_{\text{f}}(\text{Cl}) + 2\Delta H_{\text{ea}}(\text{Cl}))$ 1
 $= (+ 830) - (+ 164 + 548 + 1060 + 242 + (2 \times 349))$ 1
 $= -2146 \text{ (kJ mol}^{-1}\text{)}$ 1 [3]

Q1(d,e)/42/O/N/15 Q 5

- (d) (i) (energy change when) 1 mole of ions 2

gaseous (ions) dissolve in **water** (to form an infinitely dilute solution)
 or **gaseous** (ions) form an **aqueous** solution

(ii) $\Delta H_{\text{latt}}^\circ \text{Ca}(\text{NO}_3)_2 + \Delta H_{\text{sol}}^\circ \text{Ca}(\text{NO}_3)_2 = \Delta H_{\text{hyd}}^\circ \text{Ca}^{2+} + 2\Delta H_{\text{hyd}}^\circ \text{NO}_3^-$ 3
 $\Delta H_{\text{latt}}^\circ - 19 = -1650 + (2x - 314)$
 $-2259 \text{ kJ mol}^{-1}$

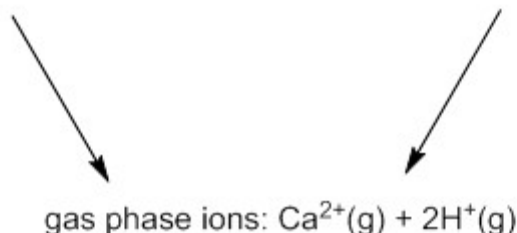
- (e) $\text{Ca}^{(2+)}$ is a smaller (ion) **or** $\text{Ca}^{(2+)}$ has a larger charge density 2
 $\text{Ca}^{(2+)}$ has a stronger attraction / bond to H_2O

Q1(a,b)/43/O/N/15 Q 6

- 1 (a) ionic bonds break / bonds between Mg^{2+} and Cl^- break 2
 forces / bonds / attractions form between the ions and water
- (b) (i) (the energy change) when 1 mole of a substance dissolves in water / becomes aq 1
- (ii) $\Delta H_{\text{latt}}^\circ \text{MgCl}_2 + \Delta H_{\text{sol}}^\circ \text{MgCl}_2 = \Delta H_{\text{hyd}}^\circ \text{Mg}^{2+} + 2\Delta H_{\text{hyd}}^\circ \text{Cl}^-$ 2
 $-2524 - 155 = -1925 + 2\Delta H_{\text{hyd}}^\circ \text{Cl}^-$
 $= -377 \text{ kJ mol}^{-1}$
- (iii) magnesium/ Mg is higher charge / sodium/ Na is smaller charge 2
 magnesium/ Mg is smaller / sodium/ Na is larger
 Mg stronger attraction for water / Na weaker attraction for water
 any two

Q8(b,c)/42/M/J/16 Q 7

(b) (i) Should be the same/ similar (enthalpy change), as (both acids) are fully ionised/ strong acids



$$x = \Delta H_{\text{lat}}(\text{Ca}) + \text{IE}(1) + \text{IE}(2) - 2\Delta H_{\text{hyd}}(\text{H}^+) + \Delta H_{\text{hyd}}(\text{Ca}^{2+}) - 2\text{IE}(\text{H}) - E(\text{H-H})$$

$$x = 178 + 590 + 1150 + 2(1090) - 1576 - 2(1310) - 436$$

$$x = -534 \text{ kJ mol}^{-1}$$

(c) $\text{CH}_3\text{CO}_2\text{H}$ is incompletely ionised/ weak acid / weaker acid
 enthalpy change of ionisation (of CH_3COOH) is $+2 \text{ kJ mol}^{-1}$
 or energy needed to ionise/dissociate (CH_3COOH)

Q8/43/M/J/16 Q 8

8 (a) $\Delta H = [2(-580) + 3(-286) + 3(-1438)] - [-2061 + 4(-437) + 3(-814)]$
 $= -81 \text{ kJ mol}^{-1}$ [2]

(b) (i) *cis-trans* OR geometrical [1]

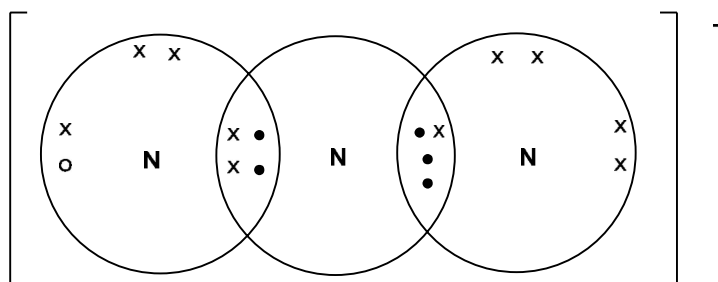
(ii) in a complex the d-orbitals are split into 2 energy levels [1]
 colour is due to absorption of light (in visible region) [1]
 electron promotion to higher orbital absorbs a photon [1]
 the d-d energy gap is different for the two complexes, hence different colours [1]

[Total: 7]

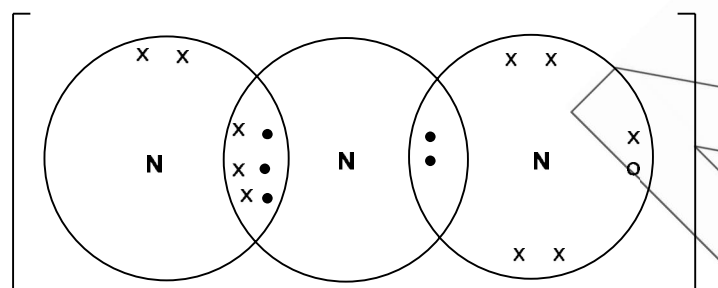
Q2/42/O/N/16 Q 9



2(b)



all atoms must have 8 outer electrons

coding for electrons correct = 16 ($10 \times 5 \cdot 1 \square$)central N must have 8 **bonding** electrons (inc. 5 \cdot and no non-bonded electrons)
allow

2(c)(i) (energy change) when **1 mole** of an (ionic) **compound is formed** 1
 or (energy change) when **1 mole** of an ionic solid/lattice/crystal **is formed** (from)

gas (phase) ions/ gaseous ions (under standard conditions) 1

2(c)(ii) **forming** an (ionic) bond 1

- 2(c)(iii) use of ΔH_{f1} 494 (kJ mol⁻¹) 1
 $\Delta H_f^\circ = +107 + 494 + 142 - 732$ 1
 $\Delta H_f^\circ = +11$ (kJ mol⁻¹) 1
- 2(c)(iv) (ionic) radius/size of Na⁺ is smaller (so stronger attraction to azide ion) 1
OR ionic radius increases down the group

Q1(c)/42/M/J17 Q 10

- 1(c)(i) LE = $\Delta H_f - 2(\Delta H_{at} + IE) - \frac{1}{2}(\text{O}=\text{O}) - (\text{EA}_1 + \text{EA}_2)$ 1
 = $-361 - 2(89) - 2(418) - 496/2 - (-141 + 798)$ 1
 = **-2280** (kJ mol⁻¹) correct answer scores [3] 1

- 1(c)(ii) LE of Na₂O will be **more negative** AND as Na⁽⁺⁾ is smaller / larger charge density / smaller radii AND so greater attraction (between the ions) OR (ionic) bonds will be stronger

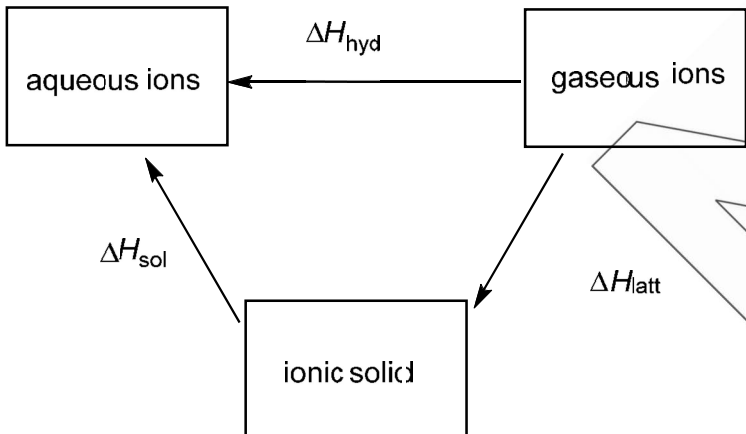
Q5/42/O/N/17 Q 11

- 5(a) (Na⁺) 0.095 / 0.181 = 0.525 **and** octahedral **and** co-ordination no. = 6 1
 (Mg²⁺) 0.065 / 0.181 = 0.359 **and** tetrahedral **and** co-ordination no. = 4 1
- 5(b) enthalpy change = $(-642) - (2 \times -106) = \mathbf{-430}$ 1
- 5(c)(i) $-106 = 147 + 121 + 736 + (-349) + \text{lattice energy}$ 3
 lattice energy = -761
- 5(c)(ii) MgCl₂ more exothermic / negative / bigger than MgCl **and** NaCl more exothermic / negative / 1
 bigger than MgCl (reason for MgCl₂) higher charge / lower radius of Mg²⁺ cation 1
 (reason for NaCl) smaller radius of Na⁺ cation 1
- 5(d) energy change when 1 mole of atoms / ions each gain an electron 1
or energy change when 1 mole of atoms / ions gain 1 mole of electrons
 gaseous

Q1(d,e)/41/M/J/18 Q 12

- 1(d) use of (2×109) or 218 and (2×494) or 988 1
 use of (0.5×496) or 248 1
 use of 416, 142, 844 1
 evaluation of expression correctly 1
 $\Delta H_{lat} = -416 - (2 \times 109) - (0.5 \times 496) - (2 \times 494) - (-142 + 844) = -2572$
- 1(e) the lattice energy of Na₂S is less exothermic 1
 the sulfide ion is larger than the oxide ion / S²⁻ larger than O²⁻ / 1
 ionic radii quoted 0.184 nm and 0.140 nm
AND less attraction (between the ions)/bonds are weaker

Q4(c)/42/O/N/18 Q 13

- 4(c)  3

arrow label and direction correct [1] x 3

Q6/41/M/J/19 Q 14

6(a)

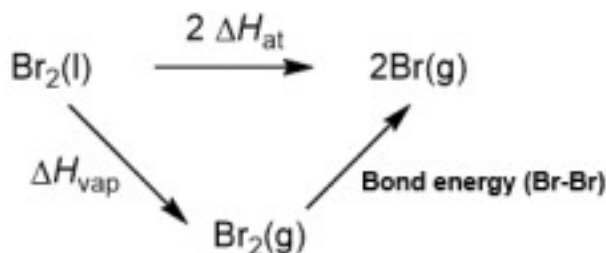
energy change	always positive	always negative	either negative or positive
bond energy	✓		
enthalpy of formation			✓

both ticks correct

6(b)

(energy change) when **1 mole** of **gaseous atoms** are formed (from an element in its standard state)

6(c)

**M1**: correct cycle: formulae and state symbols**M2**: use of 1×193 and $2 \times (112)$ **M3**: for the correct sum and answer ecf from M2 $\Delta H_{\text{vap}}^{\circ} = (2 \times 112) - (193) = +31 \text{ kJ mol}^{-1}$ [scores M2 and M3]

6(d)

more endothermic **and** greater Van der Waals / London / induced dipole-dipole forces **both**

6(e)(i)

(energy change) when **1 mole** of **gaseous ions** is dissolved in (an excess of) water

6(e)(ii)

M1: Br has a smaller ionic radii**M2**: stronger (ion-dipole) attractions with water molecules

Q5(a,b,c,d)/42/M/J/19 Q 15

5(a)

energy change	always positive	always negative	either negative or positive
lattice energy		✓	
enthalpy of neutralisation		✓	

both [1]

5(b)

(energy change) when **1 mole** of solute is dissolved in an infinite amount of **water** to form a dilute solution

5(c)

calculation of $\Delta H_{\text{sol}}^{\circ}$ with -251 , -1284 and -2035 only and two correct signs [1]calculation of $\Delta H_{\text{sol}}^{\circ}$ with -251 , -1284 and -2035 only and correct signs**OR** calculation of $\Delta H_{\text{sol}}^{\circ}$ with (-251×3) , -1284 and -2035 only and two correct signs [2] $\Delta H_{\text{sol}}^{\circ} = (3 \times -251) + (-1284) - (-2035) = -2 \text{ (kJ mol}^{-1}\text{)}$ [3]

5(d)

 Ca^{2+} have a higher charge / greater charge density [1] **ora** **stronger** electrostatic forces between Br^- and Ca^{2+} [1]

Q7/42/M/J/20 Q 16

7(a)(i)

- energy change
- when one electron is added
- to each atom /ion in one mole of
- gaseous atoms /ions

Award one mark for two correct statements. Award two marks for four correct statements

7(a)(ii)

M1 energy change when 1 mole of an ionic compound is formed**M2** from gas phase ions/ gaseous ions