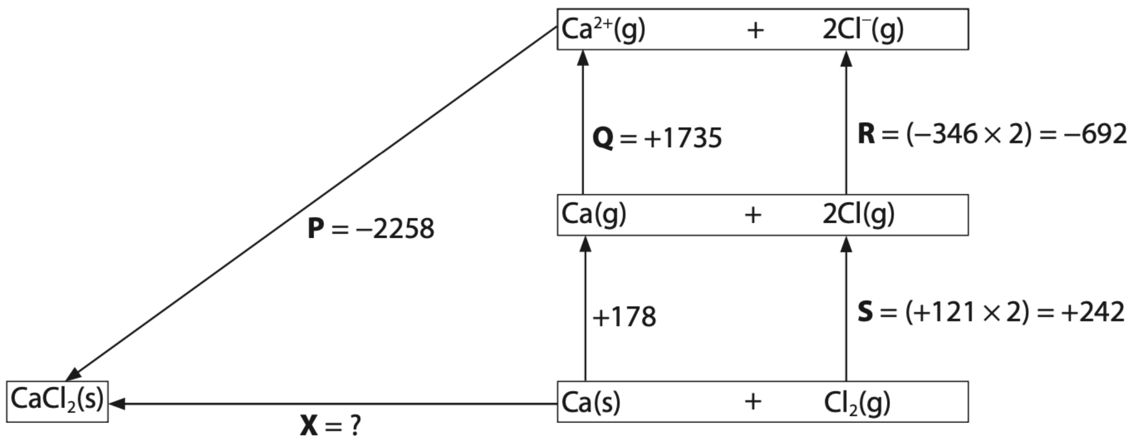
Q1.

The diagram shows a Born-Haber cycle for calcium chloride. It is not drawn to scale.
All units are in kJ mol^{-1}.



(a) Which enthalpy change is correctly labelled on the diagram?

(1)

☒ **A** Enthalpy change for the formation of calcium chloride (**P**).

☒ **B** First ionization energy of calcium (**Q**).

☒ **C** Electron affinity of chlorine (**R**).

☒ **D** Twice the enthalpy change of atomization of chlorine (**S**).

(b) What is the value of **X**, in kJ mol^{-1}?

(1)

☒ **A** +795

☒ **B** −795

☒ **C** +3721

☒ **D** −3721

Q2.

The table shows some data about metal ions, non-metal ions and their compounds.

Ion	Enthalpy change of hydration / kJ mol^{-1}	Compound	Lattice energy / kJ mol^{-1}
Mg^{2+}(g)	–1921	$MgCl_2$(s)	–2526
Cl^-(g)	–340		
Cs^+(g)	–276	CsF(s)	–747
F^-(g)	–483		

Use the data to calculate

(a) the standard enthalpy change, in kJ mol^{-1}, for the following process.

$$Mg^{2+}(g) + 2Cl^-(g) \rightarrow Mg^{2+}(aq) + 2Cl^-(aq)$$

(1)

- ☒ **A** –1241
- ☒ **B** –1581
- ☒ **C** –2261
- ☒ **D** –2601

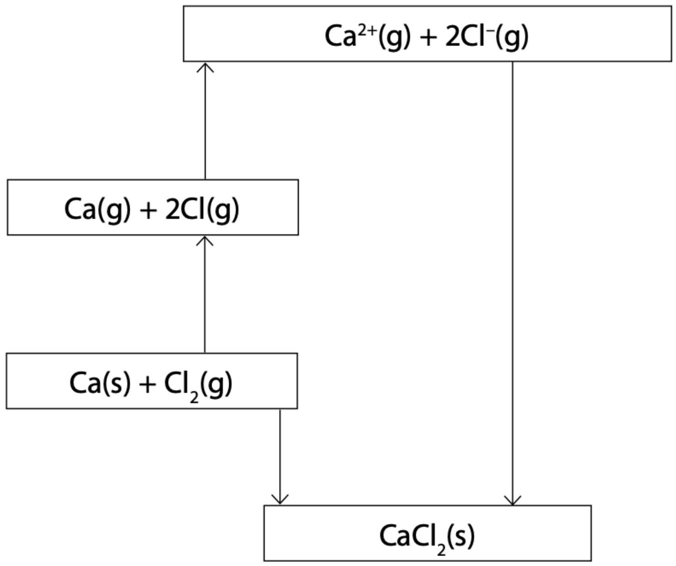
(b) the standard enthalpy change of solution, in kJ mol^{-1}, of caesium fluoride, CsF.

(1)

- ☒ **A** –12
- ☒ **B** +12
- ☒ **C** –1506
- ☒ **D** +1506

Q3.

The diagram shows a Born-Haber cycle for calcium chloride, $CaCl_2$.



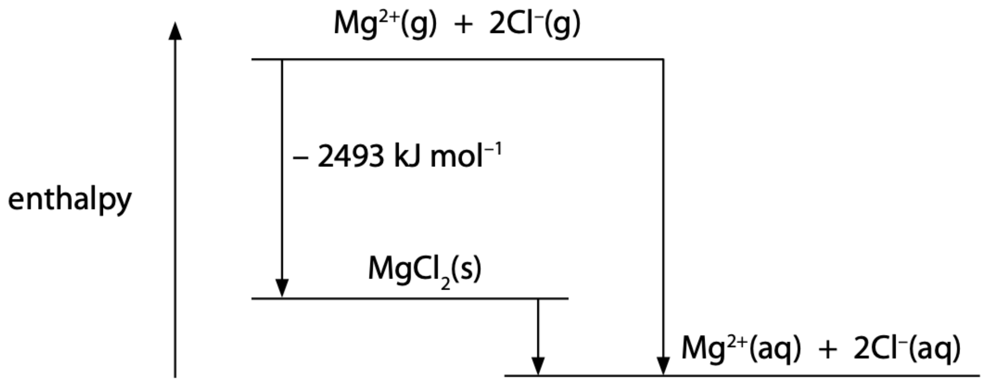
	kJ mol⁻¹
Enthalpy of formation of $CaCl_2$(s)	–796
Lattice energy of $CaCl_2$(s)	–2258
Enthalpy of atomisation of Ca(s) → Ca(g)	178
Enthalpy of atomisation of ½Cl_2(g) → Cl(g)	122
First ionisation energy of Ca(g)	590
Electron affinity of Cl(g)	–349

Calculate the second ionisation energy of calcium, in kJ mol^{-1}.

(2)

Q4.

Magnesium chloride is soluble in water. The enthalpy level diagram for the dissolving of magnesium chloride is



The enthalpy changes of hydration of the ions are:

Mg^{2+} -1920 kJ mol^{-1}

Cl^{-} -364 kJ mol^{-1}

Calculate the enthalpy change of solution, $\Delta H_{solution}$, of $MgCl_2$(s) in kJ mol^{-1}.

(2)

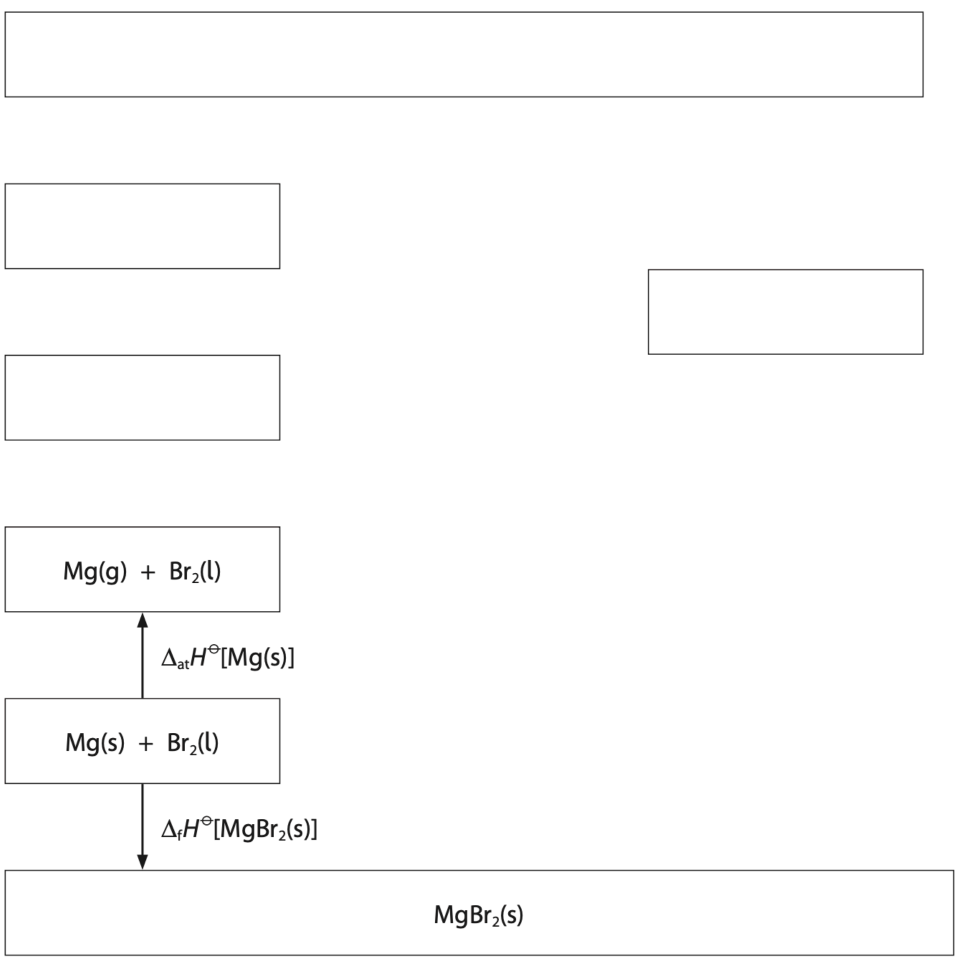
Q5.

The table shows the enthalpy changes needed to calculate the first electron affinity of bromine.

Enthalpy change	Value / kJ mol^{-1}
enthalpy change of atomisation of magnesium, $\Delta_{at}H^{\ominus}[Mg(s)]$	+148
1st ionisation energy of magnesium, 1st IE[Mg(g)]	+738
2nd ionisation energy of magnesium, 2nd IE[Mg^{+}(g)]	+1 451
enthalpy change of atomisation of bromine, $\Delta_{at}H^{\ominus}[\frac{1}{2}Br_2(l)]$	+112
lattice energy of magnesium bromide, LE[$MgBr_2$(s)]	−2 440
enthalpy change of formation of magnesium bromide, $\Delta_{f}H^{\ominus}[MgBr_2(s)]$	−524

(i) Complete the Born-Haber cycle for magnesium bromide with formulae, electrons and labelled arrows. The cycle is not drawn to scale.

(3)



(ii) Calculate the first electron affinity of bromine, in kJ mol^{-1}.

(2)

(c) (i) The first ionisation energy of sodium is 496 kJ mol^{-1}.

Explain why the first ionisation energy of magnesium is higher than that of sodium.

(3)

....

....

....

....

....

....

....

....

(ii) Write the equation, including state symbols, to show the **third** ionisation energy of magnesium.

(1)

Q6.

Calculate the enthalpy change of solution of magnesium hydroxide, using the following data.

Energy or enthalpy change	Value / kJ mol^{-1}
Lattice energy of $Mg(OH)_2(s)$	−2842
$\Delta_{hyd}H$ ($Mg^{2+}(aq)$)	−1920
$\Delta_{hyd}H$ ($OH^-(aq)$)	−460

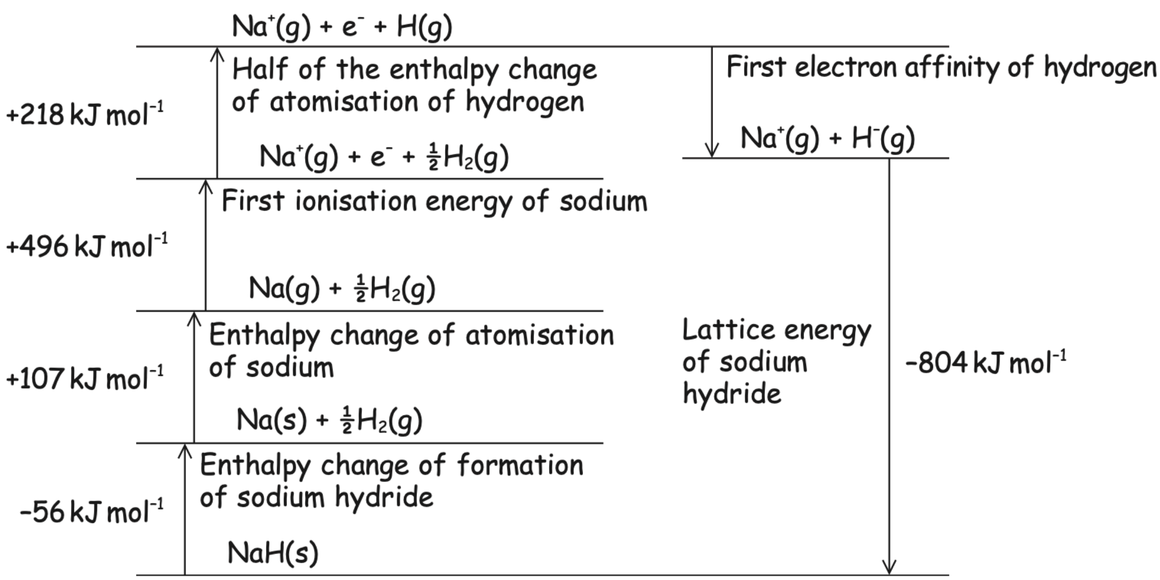
(2)

Q7.

Sodium hydride, NaH, can be used to generate hydrogen for fuel cells.

(a) In order to calculate the first electron affinity of hydrogen, a student was asked to draw a Born-Haber cycle for sodium hydride.

The cycle had **two** errors but the numerical data were correct.



(i) Identify and correct the **two** errors in this Born-Haber cycle.

(2)

....

....

....

....

(ii) Calculate the first electron affinity, in kJ mol^{-1}, of hydrogen, using the values given in the cycle.

(1)

Q1.

Question Number	Correct Answer	Reject	Mark
(a)	D		1

Question Number	Correct Answer	Reject	Mark
(b)	B		1

Q2.

Question Number	Correct Answer	Reject	Mark
(a)	D		1

Question Number	Correct Answer	Reject	Mark
(b)	A		1

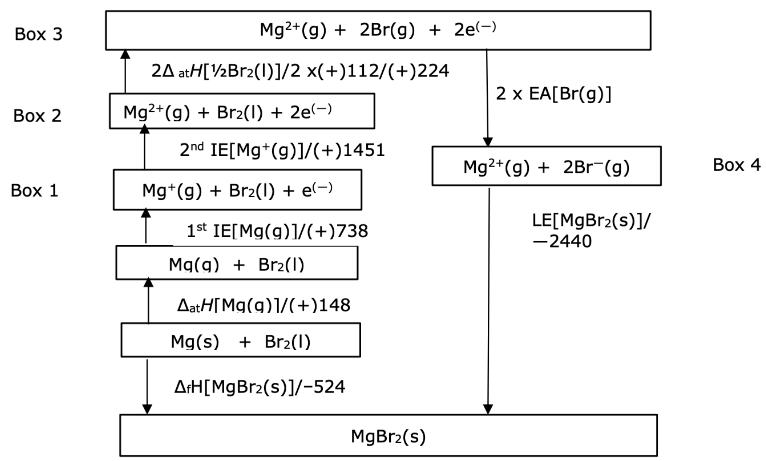
Q3.

(e)	• construction of balanced cycle (1) • substitution and evaluation of 2nd IE (1)	Example calculation $-2258 = -590 - 2^{nd}$ IE + 2 (349) − 178 − 2 (122) − 796 hence 2^{nd} IE = (+) 1148 ($kJ\ mol^{-1}$) correct answer, no working scores 2 marks	**2**

Q4.

(b)	• rearrangement of equation (1) • calculation of $\Delta H_{solution}$ (1)	Example of calculation $-2493 + \Delta H_{solution} = -1920 + (-2 \times 364)$ $\Delta H_{solution} = -155$ ($kJ\ mol^{-1}$) Correct sign must be given in final answer Correct answer and sign with no working scores 2 marks	**2**

Q5.

Question Number	Answer and Additional Guidance	Mark
(b)(i)	 • Correct arrows with 1^{st} **and** 2^{nd} IE of Mg labelled **and** correct Mg symbols with state symbols in boxes 1 and 2 or 2 and 3 **(1)** • 2 x $\Delta_{at}H^{\circ}[\frac{1}{2}Br_2(l)]$ / 2 x(+)112 / (+)224 **and** 2Br(g) in box 3 or 1 **and** 2 x EA[Br(g)] labelled **and** $2Br^-$(g) in box 4 **and** correct arrows **(1)** • LE[$MgBr_2$(s)] / −2440 labelled **and** arrow in correct direction **(1)** Allow any unambiguous labels for the arrows with words and/or numbers – state symbols not required Accept enthalpy change of atomisation of bromine before IEs of magnesium Ignore missing electrons / $2e^{(-)}$ in boxes 1, 2 and 3 Allow 1 state symbol missing but penalise 2 missing, or an incorrect state symbol in boxes once only	(3)

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	• correct expression for 2 x EA(Br) in numbers or symbols **(1)** • calculation of EA(Br) **(1)**	<u>Example of calculation</u> 2 x EA(Br) = − (2 x +112) − (+1451) − (+738) − (+148) + (−524) − (−2440) EA(Br) = $-\frac{645}{2}$ = −322.5 /−323 (kJ mol^{-1}) Correct answer with no working scores (2) Allow for 1 mark: (+)322.5 / (+)323 (wrong sign) −266.5 /−267 (2 missing from $\Delta_{at}H$ (Br)) −645 (2 missing from EA) −533 (both 2s missing for Br) Ignore units No TE on incorrect arrows in (b)(i)	(2)

Question Number	Answer	Additional Guidance	Mark
(c)(i)	An explanation that makes reference to the following points: • **Nuclear charge** magnesium (atom) / Mg has more protons than sodium (atom) / Na **or** magnesium / Mg has a greater (effective) nuclear charge (than sodium / Na) **(1)** • **Shielding** (outer) electron in magnesium (atom) / Mg in the same (quantum) shell / energy level / sub-shell / orbital as in a sodium atom / Na **or** shielding in magnesium atom / Mg similar to / same as that in sodium atom / Na **(1)** • **Attraction** so the force of attraction between the nucleus and the (outer) electron is greater in magnesium (atom) / Mg (than in sodium atom / Na) **(1)**	Penalise reference to ion once only Ignore reference to atomic radius Allow correct E.C of both atoms Allow same number of (quantum) shells / energy levels in Mg and Na Allow the (outer) electron in Mg is held more tightly to the nucleus (than in Na) **Note** An answer that describes the trend across a period, without one reference to either sodium or magnesium, scores maximum (2) marks	**(3)**

Question Number	Answer	Additional Guidance	Mark
(c)(ii)	• correct equation with state symbols	<u>Examples of equations</u> $Mg^{2+}(g) \rightarrow Mg^{3+}(g) + e^{(-)}$ $Mg^{2+}(g) - e^{(-)} \rightarrow Mg^{3+}(g)$ Ignore state symbol for the electron Do not allow ⇌	**(1)**

Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(iii)	• use of $\Delta_{sol}H = \Delta_{hyd}H[Mg^{2+}(aq)] + 2\Delta_{hyd}H[OH^{-}(aq)] - \Delta_{latt}H[Mg(OH)_2(s)]$ **(1)** • calculation of $\Delta_{sol}H$ **(1)**	<u>Example of calculation</u> $\Delta_{sol}H = -1920 + 2(-460) - (-2842)$ Allow this shown on a Hess cycle $\Delta_{sol}H = (+)2$ (kJ mol^{-1}) Allow 2000 J mol^{-1} Correct answer with no working scores 2	**(2)**

Q7.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	An answer that makes reference to the following points: • identification and correction of the first error **(1)** • identification and correction of the second error **(1)**	Allow corrections to be made on the diagram Error 1 – arrow for enthalpy change of formation should go down/be reversed Error 2 – the word 'half ' should be deleted from the enthalpy change of atomisation of hydrogen	**(2)**

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	• calculation of first electron affinity of hydrogen	<u>Example of calculation</u> 1^{st} EA= −(218+496+107)−56 +804 = −73 (kJ mol^{-1}) Allow a TE 1^{st} EA = +39(kJ mol^{-1}) if the first arrow reversed direction is not identified	**(1)**