Equilibria, Energetics and Elements
Lattice Enthalpy

1. (a) (i) Ca^+ is smaller than Ca/ proton : electron ratio in Ca^+ > Ca **(1)**
greater attraction from nucleus **(1)** 2

(ii) "oxide" ion, O^- and electron are both negative **(1)**
hence energy is required to overcome repulsion **(1)** 2

(b) completes Born-Haber cycle showing 1st IE↑ 2nd IE↑ 1st EA ↓ 2nd EA↑
and LE↓**(1)(1)(1)** (lose 1 mark for each error/omission)
LE = –**(1)**3451 kJ mol^{-1} **(1)** 5

(c) differences in size of lattice enthalpies linked to ionic sizes/attraction using **more/less exothermic** rather than bigger or smaller. **(1)**
Mg^{2+} is smaller/Mg^{2+} has greater charge density**(1)**
hence has stronger attraction for O^{2-} **(1)** 3

[12]

2. **Definition – maximum 3 marks**

$Mg^{2+}(g) + 2Cl^-(g) \rightarrow MgCl_2(s)$ **(1)**
The enthalpy change that accompanies the formation of one mole of a solid (compound) **(1)**;
from its constituent gaseous ions **(1)**

__Allow__ marks from an equation
__Allow__ energy released / energy change
__Not__ energy required
__Allow__ ionic compound / salt

Born-Haber cycle – maximum 5 marks

Correct formulae on cycle **(1)**
Correct state symbols **(1)**
Use of 2 moles of Cl(g) ie 246 **(1)**
Use of 2 moles of $Cl^-(g)$ 1.e. 698 **(1)**
–2526 kJ mol^{-1} **(1)**

Every formula must have the correct state symbol at least once
__Allow__ -2403 / -2875 (2)
__Allow__ -2752 __(1)__
Unit __required__

Comparison – maximum 3 marks

Any three from

Na^+ has a larger radius than Mg^{2+} / ora **(1)**

Br^- has a larger radius than Cl^- / ora **(1)**

Na^+ has a lower charge than Mg^{2+} / ora **(1)**

Strongest attraction is between Mg^{2+} and Cl^- / $MgCl_2$ has the strongest attraction between its ions / ora **(1)**

Penalise the use of incorrect particle only once within the answer.
Penalise it the first time an incorrect particle is mentioned

Or

Na^+ has a lower charge density than Mg^{2+} / ora **(1)**

Br^- has a lower charge density than Cl^- / ora **(1)**

Strongest attraction between ions which have the highest charge density / $MgCl_2$ has the strongest attraction between its ions / ora **(1)**

And QWC

One mark for correct spelling, punctuation and grammar in at least two sentences **(1)** 12

[12]

3. (a) (i) Ionisation energy refers to removing electrons that are attracted to the nucleus / energy needed to overcome the force of attraction between outer electrons and nucleus **(1)** 1

(ii) Electron affinity involves an electron (being gained) experiencing attraction to the nucleus **(1)** 1

(b) (i) Correct state symbols **(1)**;

***Allow** 1 error or omission in state symbols.*
Providing formula has correct state symbols once in cycle this is sufficient

Correct formula **(1)**;

Correct cycle with labelling or energy values **(1)** 3

(ii) = +178 + 249 + 798 + (–141) + 1150 + 590 + (–3459) **(1)**

= –635 kJ mol^{-1} **(1)** 2

Final answer must have correct units
+635 kJ mol^{-1} scores 0

(iii) Ionic radius of iron(II) less (than that of calcium ion) / charge density of Fe^{2+} greater (than that of Ca^{2+}) /. ora **(1)** 1

[8]

4. (a) Atomisation of Na = (+)218 / 2 × (+) 109 **(1)**;
Ionisation of Na = (+)990 / 2 × (+)495 **(1)**;
Any other two correct enthalpy changes **(1)**;
Last two correct enthalpy change **(1)** 4

(b) –791 + 141 – 247 – 990 – 218 – 416 **(1)**;
–2521 **(1)** 2

Allow *ecf from part (a) e.g. –2026 if only 1 mole of Na → Na^+*
–2412 if only 1 mole of
Na (s) → Na (g)
–1917 if only 1 mole of Na throughout
Allow *full marks for –2521 with no working out*

(c) Calcium chloride **(1)**
If wrong salt chosen maximum of 2 marks (the comparison of the ions)

And

Br^- has larger ionic radius than Cl^- / Br^- has lower charge density than Cl^- / ora **(1)**;
Not Br has larger radius

K^+ has a lower charge than Ca^{2+} / K^+ has lower charge density than Ca^{2+} / K^+ has a larger ionic radius than Ca^{2+} / ora **(1)**;
Not *K has lower charge*
Not *K^+ has larger atomic radius*

Strongest attraction between ions (when smallest radius and highest charge) / strongest attraction between ions (with the highest charge density) / ora **(1)** 4
Penalise *use of atoms rather than ions just once in this question*

[10]

5. (a) (i) Electron affinity -696 (1 mark);
Atomisation of Cl_2 +244 (1 mark);
From top to bottom
2^{nd} IE +1150,
1^{st} IE +590,
atomisation of Ca +178
formation -796 (1 mark) 3

Allow *244, 1150, 590 and 176 i.e. without plus sign*

(ii) -796 - 178 - 590 - 1150 - 244 + 696 **(1)**;

But

-2262 (with no working) (2) 2

Allow *ecf from the wrong figures on the Born-Haber cycle*
1 error ***max one mark***
2 errors ***0 mark***

(iii) Magnesium fluoride more exothermic than calcium chloride / ora
Answer must refer to the correct particle.

because

Ionic radius of Mg^{2+} is less than that of Ca^{2+} / charge density of magnesium ion is greater than that of calcium ion / ora **(1)**;
Ionic radius of F- is less than that of Cl^- / charge density of fluoride ion is greater than that of chloride ion / ora **(1)**;

Not *Mg or magnesium has a smaller radius or fluorine has a smaller radius*

Stronger (electrostatic) attraction between cation and anion in MgF_2 than in $CaCl_2$ / stronger ionic bonds in MgF_2 **(1)** 3

Allow *magnesium or fluorine has a smaller ionic radius*

(b) **Any two from**
For second ionisation energy the electron lost is closer to the nucleus / AW **(1)**;
For second ionisation energy the electron is lost from a particle that is already positive **(1)**;
For second ionisation energy there is one more proton than electron **(1)**
So outer electron more firmly attracted to the nucleus **(1)** 2

Allow *ora*

[10]