

Topic 15.1 Energy Cycles

Past Exam Questions (Paper 1, 2)

1. [1 mark]

Which ionic compound has the most endothermic lattice enthalpy?

- A. NaCl
- B. KCl
- C. NaF
- D. KF

2. [1 mark]

Which step(s) is/are endothermic in the Born-Haber cycle for the formation of LiCl?

- A. $\frac{1}{2}Cl_2(g) \rightarrow Cl(g)$ **and** $Li(s) \rightarrow Li(g)$
- B. $Cl(g) + e^- \rightarrow Cl^-(g)$ **and** $Li(g) \rightarrow Li^+(g) + e^-$
- C. $Li^+(g) + Cl^-(g) \rightarrow LiCl(s)$
- D. $\frac{1}{2}Cl_2(g) \rightarrow Cl(g)$ **and** $Cl(g) + e^- \rightarrow Cl^-(g)$

3. [1 mark]

Which is a correct definition of lattice enthalpy?

- A. It is the enthalpy change that occurs when an electron is removed from 1 mol of gaseous atoms.
- B. It is the enthalpy change that occurs when 1 mol of a compound is formed from its elements.
- C. It is the enthalpy change that occurs when 1 mol of solid crystal changes into a liquid.
- D. It is the enthalpy change that occurs when 1 mol of solid crystal is formed from its gaseous ions.

4. [1 mark]

Which row of the table correctly represents the equations for the lattice enthalpy of substance XY and the electron affinity of atom Y?

	Lattice enthalpy	Electron affinity
A.	$X^+(g) + Y^-(g) \rightarrow XY(g)$	$Y^-(g) + e^- \rightarrow Y^{2-}(g)$
B.	$X^+(g) + Y^-(g) \rightarrow XY(s)$	$Y(g) + e^- \rightarrow Y^-(g)$
C.	$X^+(g) + Y^-(g) \rightarrow XY(s)$	$Y(s) + e^- \rightarrow Y^-(s)$
D.	$X^+(g) + Y^-(g) \rightarrow XY(g)$	$Y(g) + e^- \rightarrow Y^-(g)$

5. [1 mark]

Which equation corresponds to the lattice enthalpy for silver iodide, AgI?

- A. $AgI(s) \rightarrow Ag(s) + I(g)$
- B. $AgI(s) \rightarrow Ag(s) + \frac{1}{2}I_2(g)$
- C. $AgI(s) \rightarrow Ag^+(aq) + I^-(aq)$
- D. $AgI(s) \rightarrow Ag^+(g) + I^-(g)$

6. [1 mark]

Which ionic compound has the greatest lattice enthalpy?

- A. MgO
- B. CaO
- C. NaF
- D. KF

7. [1 mark]

Which equation represents the electron affinity of chlorine?

- A. $Cl(g) + e^{-} \rightarrow Cl^{-}(g)$
- B. $Cl(g) + e^{-} \rightarrow Cl(g)$
- C. $Cl_2(g) + 2e^{-} \rightarrow 2Cl^{-}(g)$
- D. $Cl(g) \rightarrow Cl^{+}(g) + e^{-}$

8. [1 mark]

Which ionic compound has the most endothermic lattice enthalpy?

- A. Sodium chloride
- B. Sodium oxide
- C. Magnesium chloride
- D. Magnesium oxide

9. [1 mark]

Which combination of ions will give the greatest absolute lattice enthalpy?

- A. A small positive ion with a high charge and a small negative ion with a high charge
- B. A small positive ion with a low charge and a small negative ion with a low charge
- C. A large positive ion with a high charge and a large negative ion with a high charge
- D. A large positive ion with a low charge and a small negative ion with a low charge

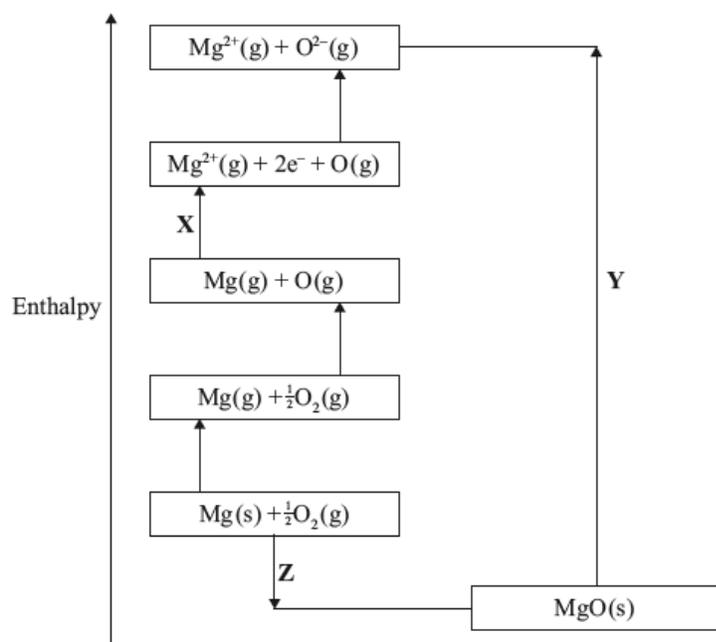
10. [1 mark]

Which compound has the most positive lattice enthalpy of dissociation?

- A. NaCl
- B. NaBr
- C. $MgCl_2$
- D. $MgBr_2$

11. [1 mark]

The Born-Haber cycle for the formation of magnesium oxide is shown below.



What is a correct description of the steps X, Y and Z in this cycle?

	Step X	Step Y	Step Z
A.	2nd ionization energy of Mg	enthalpy of formation of MgO	lattice enthalpy of MgO
B.	2nd ionization energy of Mg	lattice enthalpy of MgO	enthalpy of formation of MgO
C.	sum of the 1st and 2nd ionization energies of Mg	lattice enthalpy of MgO	enthalpy of formation of MgO
D.	sum of 1st and 2nd ionization energies of Mg	enthalpy of formation of MgO	lattice enthalpy of MgO

12. [1 mark]

What is the correct definition of lattice enthalpy?

- A. Enthalpy change when one mole of a solid ionic compound is separated into gaseous ions.
- B. Enthalpy change when one mole of a solid ionic compound is separated into its ions in their standard state.
- C. Enthalpy change when one mole of a solid ionic compound is formed from gaseous elements.
- D. Enthalpy change when one mole of a compound is formed from the elements in their standard states.

13. [1 mark]

Which equation represents the lattice enthalpy of calcium chloride?

- A. $\text{CaCl}(s) \rightarrow \text{Ca}^+(g) + \text{Cl}^-(g)$
- B. $\text{CaCl}_2(s) \rightarrow \text{Ca}^{2+}(g) + 2\text{Cl}^-(g)$
- C. $\text{CaCl}_2(g) \rightarrow \text{Ca}^{2+}(g) + 2\text{Cl}^-(g)$
- D. $\text{CaCl}_2(s) \rightarrow \text{Ca}^{2+}(aq) + 2\text{Cl}^-(aq)$

14. [1 mark]

Which equation represents the second electron affinity of oxygen?

- A. $\frac{1}{2}\text{O}_2(g) + 2e^- \rightarrow \text{O}^{2-}(g)$
- B. $\text{O}(g) + 2e^- \rightarrow \text{O}^{2-}(g)$
- C. $\text{O}_2(g) + 4e^- \rightarrow 2\text{O}^{2-}(g)$
- D. $\text{O}^-(g) + e^- \rightarrow \text{O}^{2-}(g)$

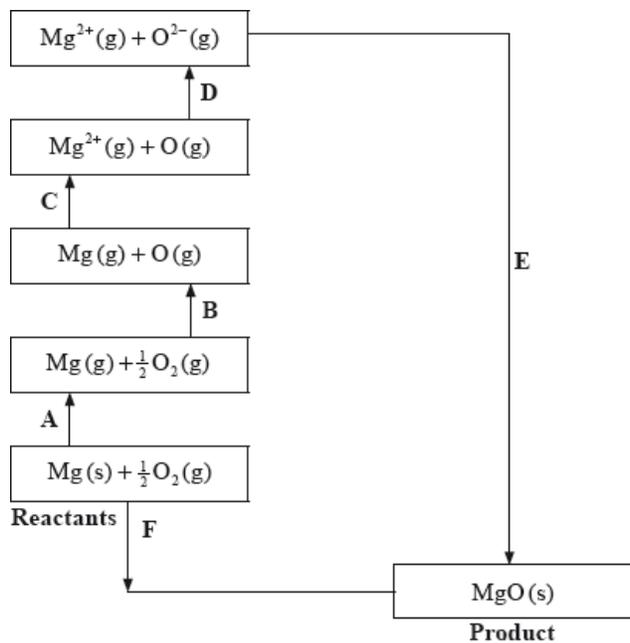
15. [1 mark]

What is the correct order for **increasing** lattice enthalpy?

- A. $\text{MgO} < \text{MgCl}_2 < \text{NaCl} < \text{CsCl}$
- B. $\text{CsCl} < \text{NaCl} < \text{MgCl}_2 < \text{MgO}$
- C. $\text{NaCl} < \text{CsCl} < \text{MgO} < \text{MgCl}_2$
- D. $\text{NaCl} < \text{CsCl} < \text{MgCl}_2 < \text{MgO}$

16a. [3 marks]

The Born-Haber cycle for MgO under standard conditions is shown below.



The values are shown in the table below.

Process	Enthalpy change / kJ mol^{-1}
A	+150
B	+248
C	+736 + (+1450)
D	-142 + (+844)
E	
F	-602

Identify the processes represented by **A**, **B** and **D** in the cycle.

16b. [2 marks]

Define the enthalpy change, **F**.

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16c. [2 marks]

Determine the value of the enthalpy change, **E**.

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16d. [4 marks]

Define the enthalpy change **C** for the first value. Explain why the second value is significantly larger than the first.

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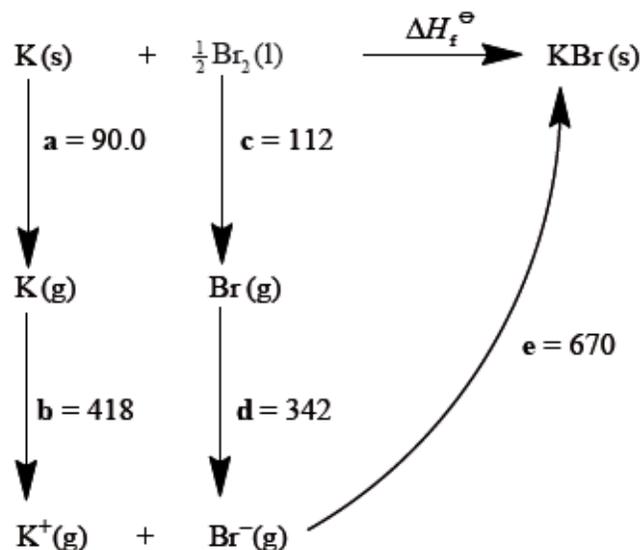
16e. [2 marks]

The inter-ionic distance between the ions in NaF is very similar to that between the ions in MgO. Suggest with a reason, which compound has the higher lattice enthalpy value.

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17a. [2 marks]

Consider the following Born-Haber cycle:



The magnitudes for each of the enthalpy changes (**a** to **e**) are given in kJ mol^{-1} but their signs (+ or -) have been omitted.

State the names for the enthalpy changes **c** and **d**.

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17b. [1 mark]

Deduce which **two** of the enthalpy changes **a** to **e** have negative signs.

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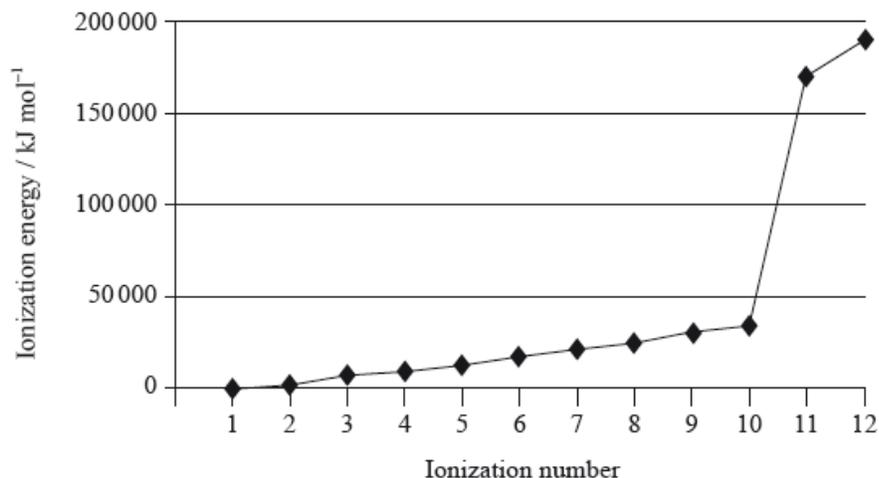
17c. [2 marks]

Explain why the quantitative value for the lattice enthalpy of calcium bromide is larger than the value for the lattice enthalpy of potassium bromide.

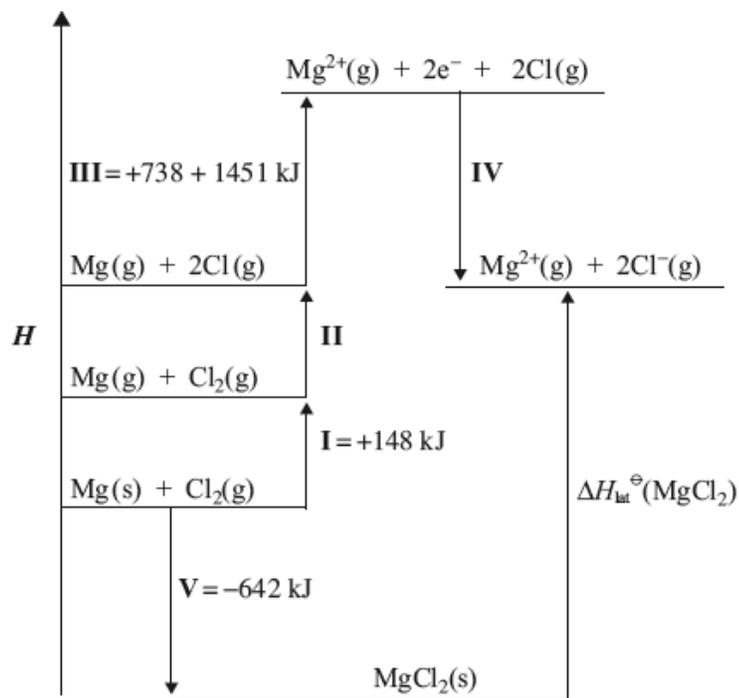
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18. [10 marks]

Magnesium is the eighth most abundant element in the earth's crust. The successive ionization energies of the element are shown below.



The lattice enthalpy of magnesium chloride can be calculated from the Born-Haber cycle shown below.



(i) Identify the enthalpy changes labelled by I and V in the cycle.

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(ii) Use the ionization energies given in the cycle above and further data from the Data Booklet to calculate a value for the lattice enthalpy of magnesium chloride.

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(iii) The theoretically calculated value for the lattice enthalpy of magnesium chloride is +2326 kJ. Explain the difference between the theoretically calculated value and the experimental value.

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(iv) The experimental lattice enthalpy of magnesium oxide is given in Table 13 of the Data Booklet. Explain why magnesium oxide has a higher lattice enthalpy than magnesium chloride.

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19a. [2 marks]

Lattice enthalpies can be determined experimentally using a Born–Haber cycle and theoretically using calculations based on electrostatic principles.

The experimental lattice enthalpies of the chlorides of lithium, LiCl, sodium, NaCl, potassium, KCl, and rubidium, RbCl, are given in Table 13 of the Data Booklet. Explain the trend in the values.

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19b. [2 marks]

Explain why magnesium chloride, $MgCl_2$, has a much greater lattice enthalpy than sodium chloride, NaCl.

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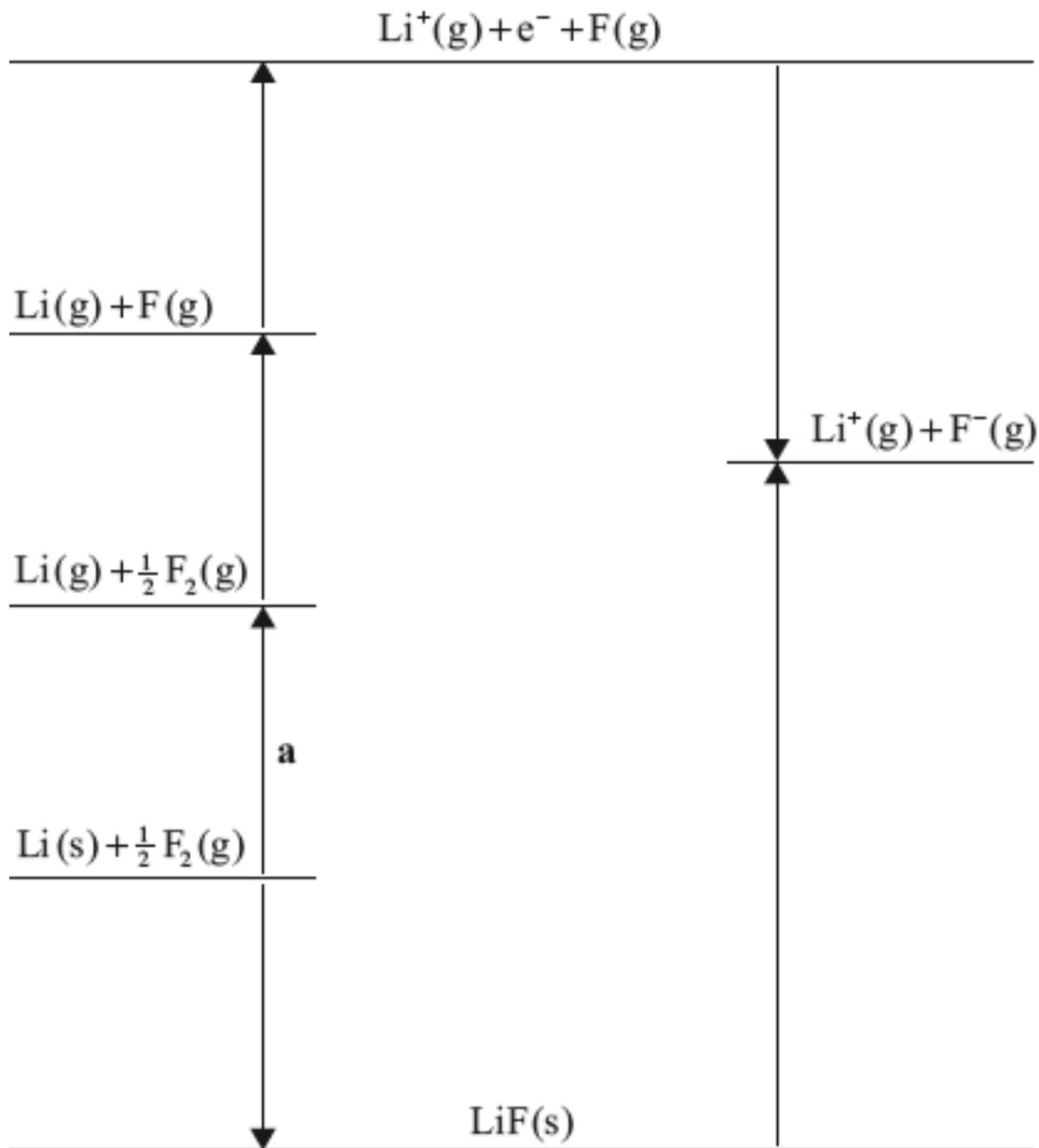
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19c. [3 marks]

(i) Identify the process labelled **a** on the Born-Haber cycle for the determination of the standard enthalpy of formation of lithium fluoride, LiF.



(ii) The enthalpy change for process **a** is $+ 159 \text{ kJ mol}^{-1}$. Calculate the standard enthalpy of formation of lithium fluoride, LiF, using this and other values from the Data Booklet.

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20a. [2 marks]

Magnesium, a reactive metal found in many common minerals, is also an essential nutrient for both plants and animals.

Define the term *first ionization energy*.

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20b. [4 marks]

Successive ionization energies of magnesium are given in the table below.

	First	Second	Third
Energy required / kJ mol⁻¹	738	1450	7730

(i) Explain why the second ionization energy is greater than the first ionization energy.

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(ii) Explain why the third ionization energy is much greater than the second ionization energy.

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20c. [3 marks]

Although magnesium is usually found as Mg^{2+} in its compounds, it is possible to use the Born-Haber cycle to investigate the possibility of Mg^+ being able to form stable compounds.

Use the ionization energy data from part (b), along with the other data provided below, to determine the enthalpy change of formation of $MgCl(s)$. Assume that, because Mg^+ would be similar in size to Na^+ , $MgCl$ would have a similar lattice enthalpy to $NaCl$.

Enthalpy of atomization of Mg + 146 kJ mol^{-1}

Bond enthalpy in Cl_2 + 243 kJ mol^{-1}

Electron affinity of Cl + 349 kJ mol^{-1}

Lattice enthalpy of $NaCl$ + 790 kJ mol^{-1}

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20d. [3 marks]

Consider the lattice enthalpies of MgF_2 , $MgCl_2$ and $CaCl_2$. List these from the most endothermic to the least endothermic and explain your order.

Most endothermic → *Least endothermic*

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