8.4 BORN-HABER CYCLE

Objectives:

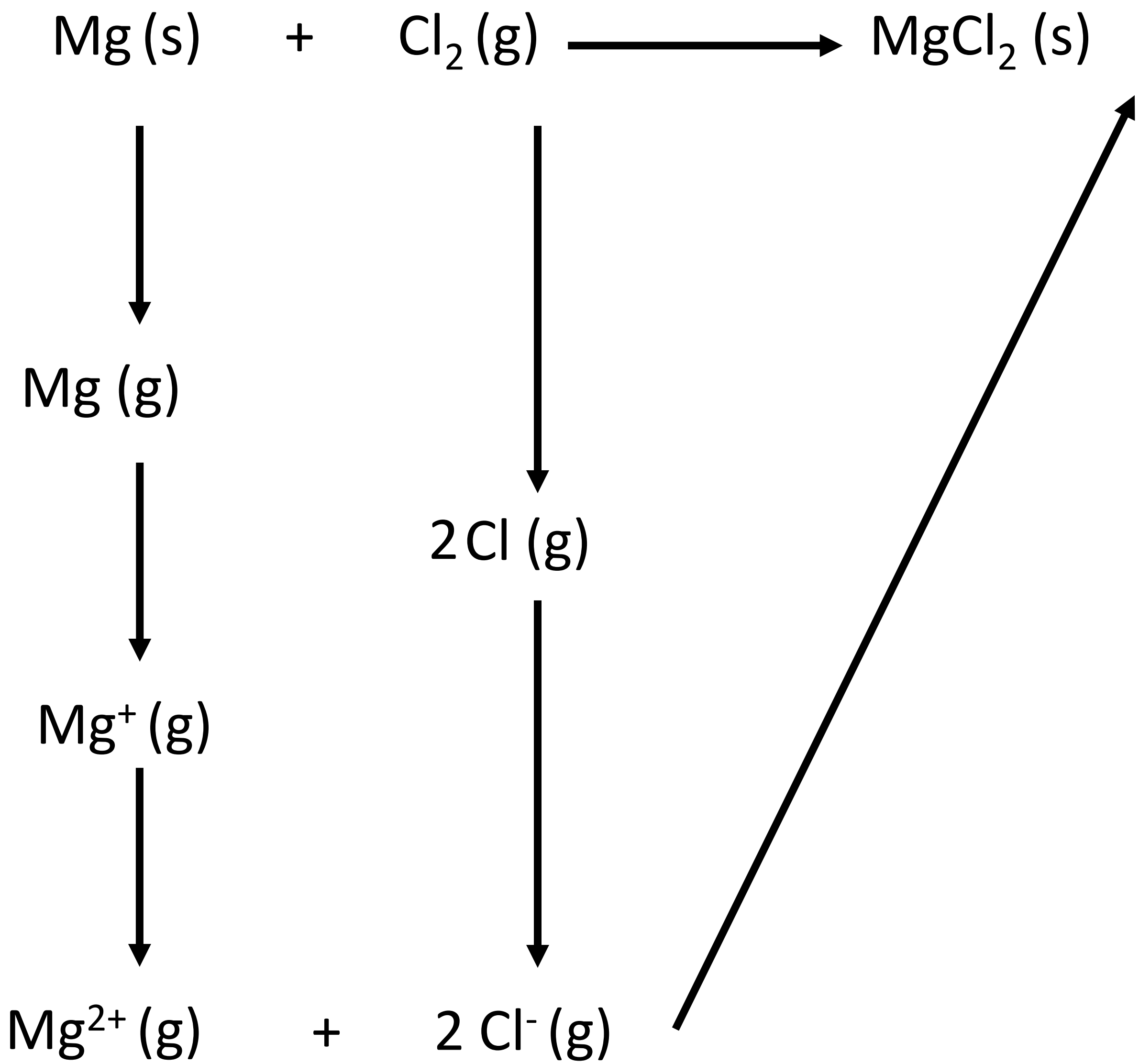
- Construct Born-Haber cycle for an ionic crystal
- Calculate unknown enthalpy using Born-Haber cycle

BORN-HABER CYCLE

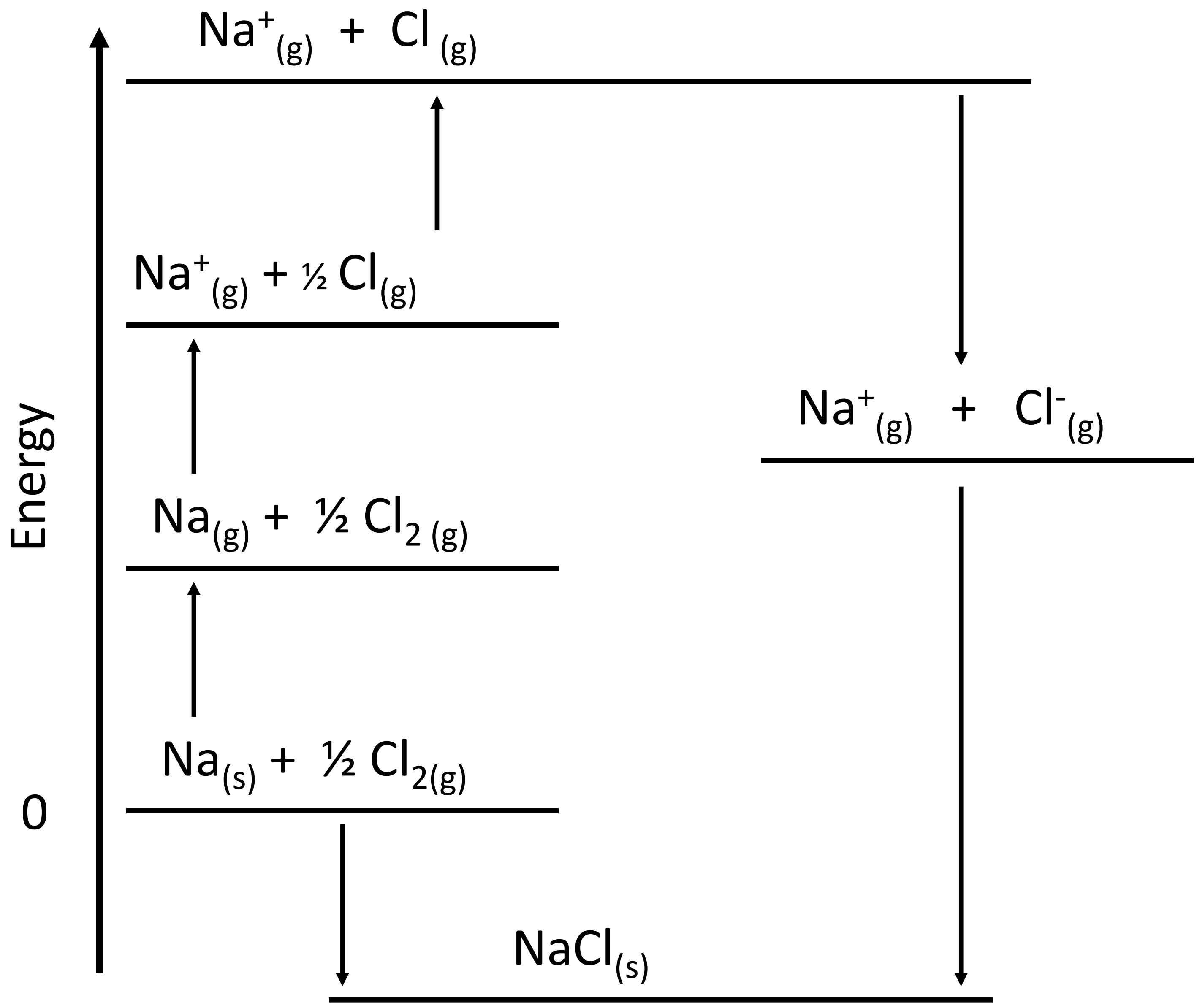
- A cycle of reactions (consisting 6 basic steps) used for calculating the lattice energies of ionic crystalline solids.
- The reaction enthalpies involved are:

1) enthalpy of atomisation of metal
2) enthalpy of atomisation of non-metal
3) ionisation energy of metal
4) electron affinity of non-metal
5) enthalpy of formation of ionic solid
6) lattice energy of ionic solid

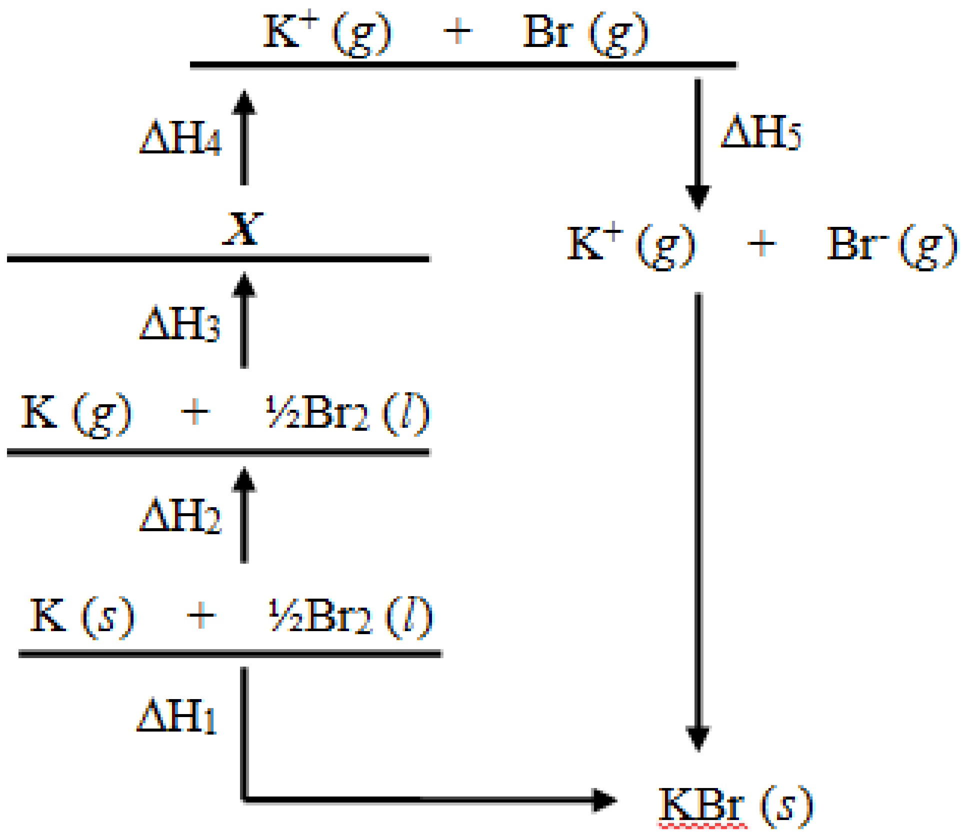
Example of Born-Haber 1



Example of Born-Haber 2



Example of Born-Haber 3



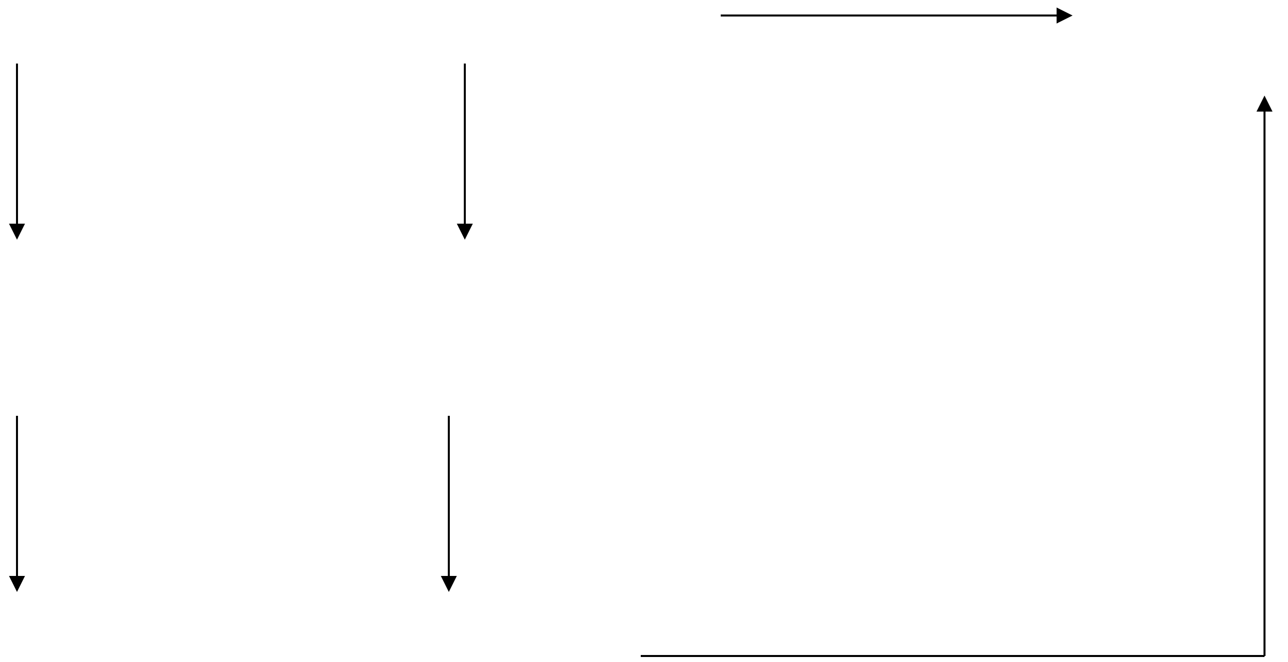
APPLICATION OF THE BORN – HABER CYCLE

By using the following data construct a Born-Haber Cycle for NaCl. Then calculate its lattice energy.

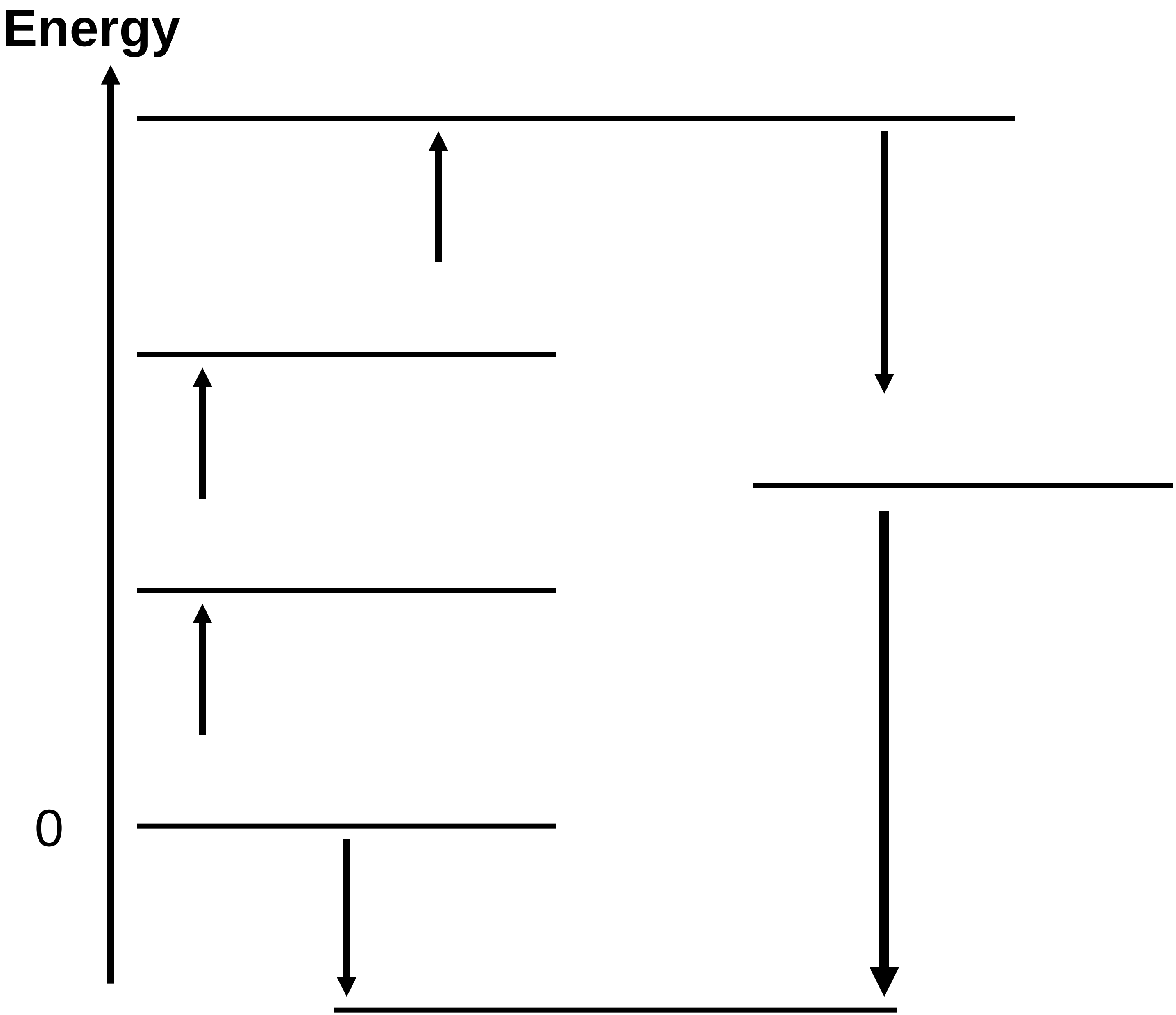
6 main enthalpies	Thermochemical equation
Enthalpy of formation of NaCl = - 411.3 kJ mol^{-1}	
Enthalpy of atomization of Na = + 107.8 kJ mol^{-1}	
First ionization energy of Na = + 495.4 kJ mol^{-1}	
Enthalpy of atomization of Cl = + 121.3 kJ mol^{-1}	
Electron affinity of Cl = - 348.8 kJ mol^{-1}	
Lattice energy of NaCl = ? kJ mol^{-1}	

BORN-HABER CYCLE

Solution:



BORN-HABER CYCLE – 2nd method



Exercise 1

Construct a Born-Haber cycle to calculate the lattice energy of pottasium bromide based on the following data below.

Standard enthalpy of formation of pottasium bromide	**= – 392 kJ mol^{-1}**
Enthalpy of sublimation of K	**= + 90 kJ mol^{-1}**
Ionization energy of K	**= + 420 kJ mol^{-1}**
Enthalpy of atomization of Br_2	**= +112 kJ mol^{-1}**
Electron affinity of Br	**= -342 kJ mol^{-1}**

Solution:

Exercise 2

Using the data provided, construct a Born-Haber cycle for magnesium chloride, and from it determined the electron affinity of chlorine.

Enthalpy of atomisation of chlorine	= + 122 kJ mol^{-1}
Enthalpy of atomisation of magnesium	= + 148 kJ mol^{-1}
First ionisation energy of magnesium	= + 738 kJ mol^{-1}
Second ionisation energy of magnesium	= + 1451 kJ mol^{-1}
Lattice enthalpy of magnesium chloride	= – 2526 kJ mol^{-1}
Enthalpy of formation of magnesium chloride	= – 641 kJ mol^{-1}

Solution:

From Hess's Law :

Exercise 3

Using the data provided, construct a Born-Haber cycle for magnesium oxide, and from it determined the enthalpy of formation of magnesium oxide.

$\Delta H_{atm\ (O)}$	= + 249 kJ mol^{-1}
$\Delta H_{atm\ (Mg)}$	= + 148 kJ mol^{-1}
$\Delta H_{1st\ IE\ (Mg)}$	= + 738 kJ mol^{-1}
$\Delta H_{2nd\ (Mg)}$	= + 1451 kJ mol^{-1}
$\Delta H_{1st\ EA\ (O)}$	= – 141 kJ mol^{-1}
$\Delta H_{2nd\ EA\ (O)}$	= + 798 kJ mol^{-1}
$\Delta H_{LE\ (MgO)}$	= – 3791 kJ mol^{-1}

Solution:

Ans: ΔH_f° = -548 kJ mol^{-1}

Check Point

1. (a) Construct a Born-Haber cycle for calcium fluoride, CaF_2.

   (b) Use the cycle to calculate the lattice energy of $CaF_2(s)$.

   The following data are given:

   enthalpy of atomisation of calcium = +178 kJ mol^{-1}

   electron affinity of fluorine atom = -328 kJ mol^{-1}

   enthalpy change of formation of CaF_2 = -1220 kJ mol^{-1}

   Bond energy of F – F = +158 kJ

   First ionisation energy of Ca = +590 kJ mol^{-1}

   Second ionisation energy of Ca = +1150 kJ mol^{-1}

(-2640 kJmol^{-1})

Check Point

2. Calculate the enthalpy changes for formation of these compounds; magnesium(I) chloride,MgCl; magnesium(II) chloride, $MgCl_2$; and magnesium(III) chloride, $MgCl_3$ from the data below.

	kJ
$Mg(s) \rightarrow Mg(g)$	146
$Mg(g) \rightarrow Mg^{+}(g)$	736
$Mg(g) \rightarrow Mg^{2+}(g)$	2184
$Mg(g) \rightarrow Mg^{3+}(g)$	9924
$Cl_2(g) \rightarrow 2Cl(g)$	242
$Cl(g) + e \rightarrow Cl^{-}(g)$	-364
Lattice energy MgCl(s)	-753
Lattice energy $MgCl_2(s)$	-2500
Lattice energy $MgCl_3(s)$	-5500

Answer:

ΔH^{θ}_{f}

MgCl = -114

$MgCl_2$ = -656

$MgCl_3$ = + 3841

Stability:

$MgCl_2 > MgCl > MgCl_3$

Write order of increasing stability for these chlorides.

Check Point

3. a) Define lattice energy

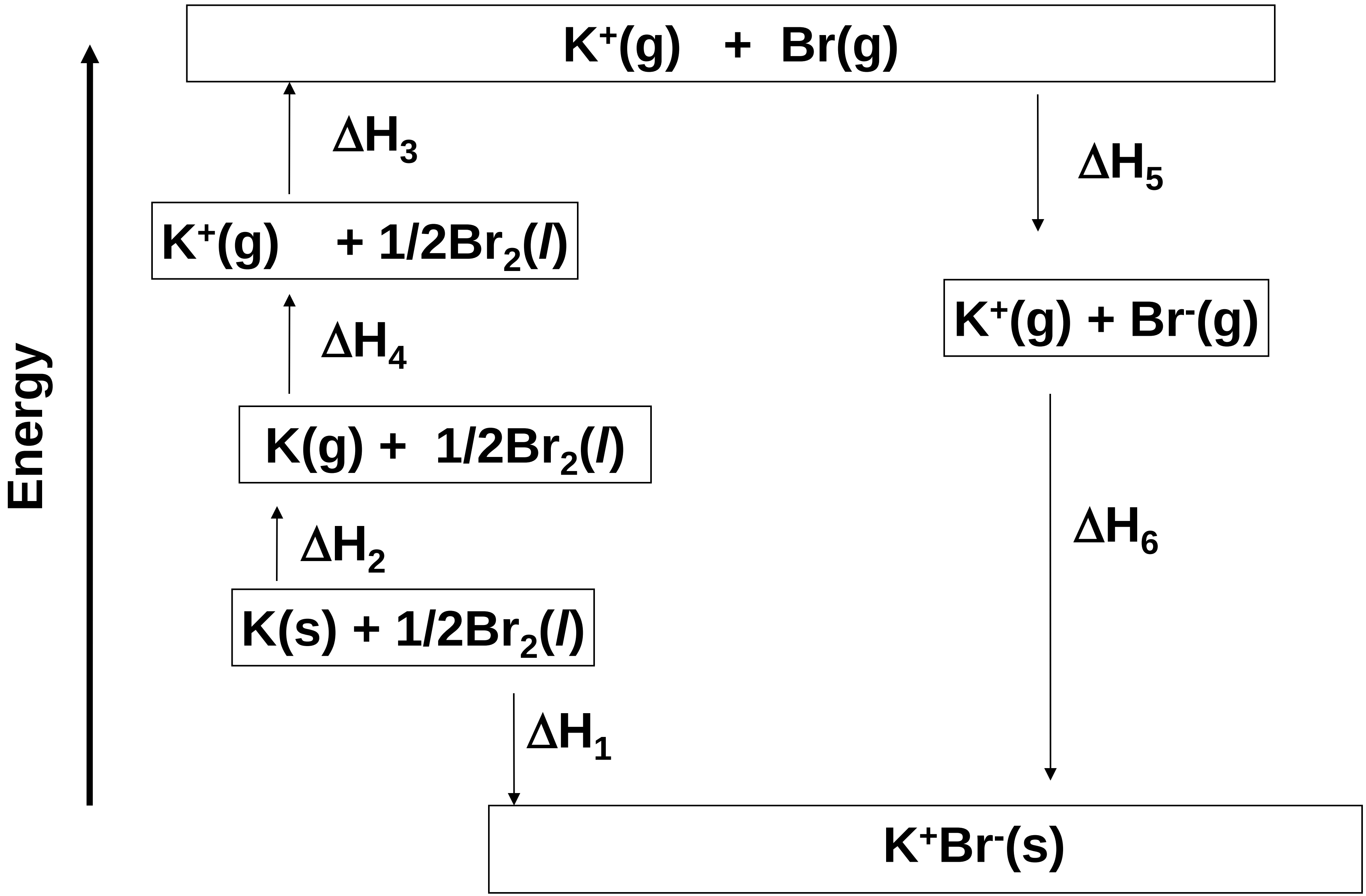
   b) Give factors that affect the magnitude of lattice energy of an ionic compound

   c) Draw the Born-Haber cycle for a formation of magnesium bromide and name the enthalpy changes involved.

   d) Suggest whether the magnitude of lattice energy for magnesium chloride is greater or lower than magnesium bromide? Explain your answer.

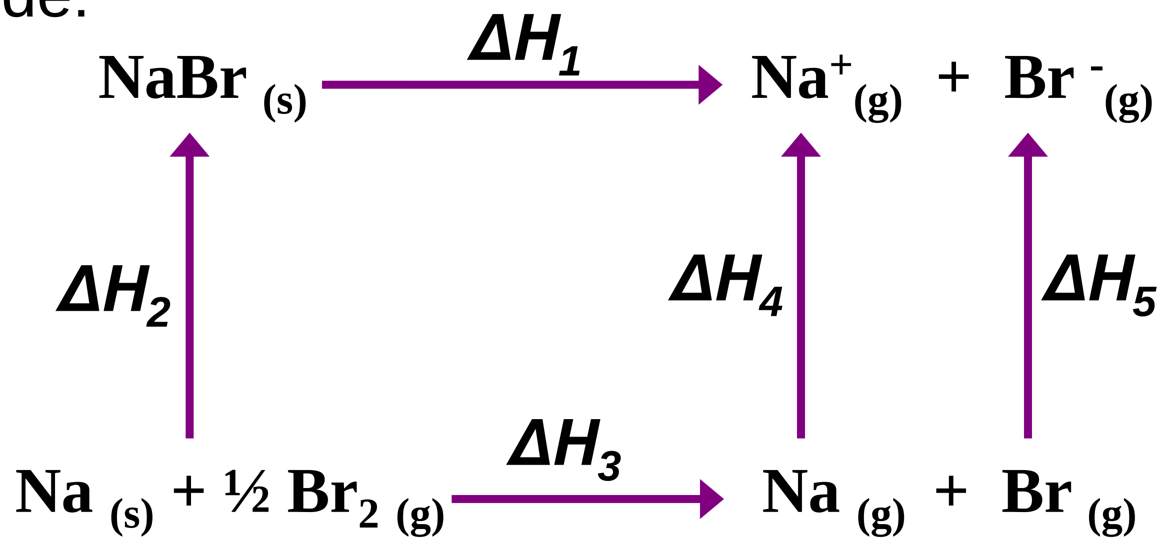
Check Point

4. Name the enthalpy changes (ΔH_1-ΔH_6) shown below in a Born-Haber cycle for formation of potassium bromide.



Check Point

5) The diagram below shows a Born-Haber cycle for sodium bromide:



Determine the ionisation energy for sodium. Use the given enthalpies below:

ΔH_1 = +736 kJ mol^{-1}, ΔH_2 = -376 kJ mol^{-1},

ΔH_3 = +205 kJ mol^{-1}, ΔH_5 = -335 kJ mol^{-1}

Check Point

6) Given the data below:

ΔH^o_f of RbCl = -431 kJ mol^{-1}

$\Delta H_{sublimation}$ Rb = +86 kJ mol^{-1}

ΔH_{BE} Cl_2 = +244 kJ mol^{-1}

IE for Rb = +408 kJ mol^{-1}

Lattice Energy for RbCl = -675 kJ mol^{-1}

Sketch the *Born-Haber cycle diagram and use it to calculate the electron affinity for the chlorine atom.*

The end….