

An Ionic Compound

The enthalpy changes involved in the synthesis of magnesium oxide can be shown in a Born-Haber cycle as below.

Some of the enthalpy changes are given in the table:

$\Delta H_a = 247 \text{ kJ mol}^{-1}$		$\Delta H_e = 1460 \text{ kJ mol}^{-1}$
$\Delta H_b = 146 \text{ kJ mol}^{-1}$		$\Delta H_f = 775 \text{ kJ mol}^{-1}$
$\Delta H_c = 744 \text{ kJ mol}^{-1}$		$\Delta H_g = ?$
$\Delta H_d = -142 \text{ kJ mol}^{-1}$		$\Delta H_h = -602 \text{ kJ mol}^{-1}$

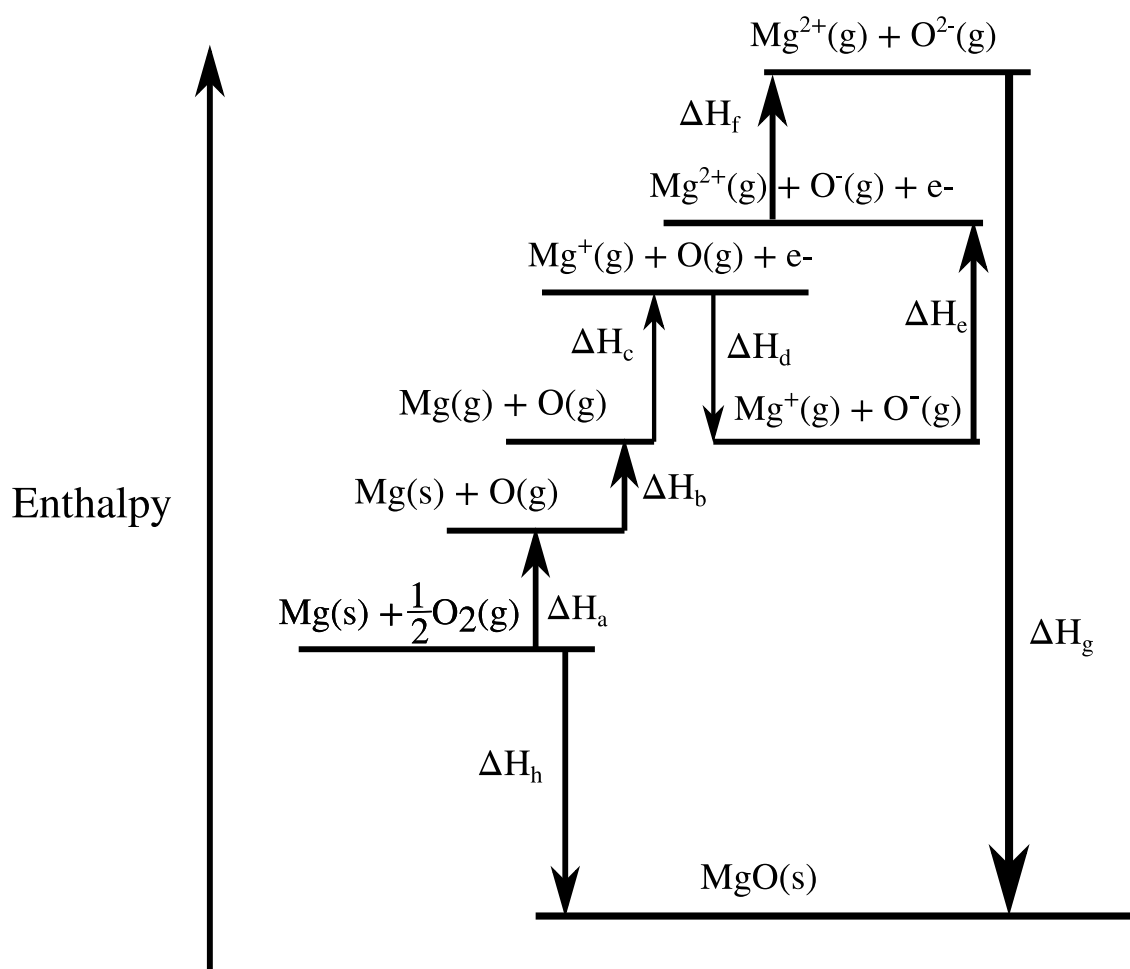


Figure 1: The Born-Haber cycle for the formation of MgO.

Part A Second ionisation enthalpy

Why is ΔH_e greater than ΔH_c ?

Part B Second electron affinity

Why is ΔH_d negative but ΔH_f positive?

Part C Lattice enthalpy, ΔH_g

Calculate the value of ΔH_g .

Part D Group trend in ionisation enthalpy

How would you expect the value of ΔH_c for the reaction of calcium with oxygen to compare to that given for magnesium and oxygen above?

- ☐ Higher
- ☐ The same
- ☐ Lower
-

Part E Group trend in electron affinity

How would you expect the value of ΔH_d for the reaction of calcium with oxygen to compare to that given for magnesium and oxygen above?

- ☐ Lower
- ☐ The same
- ☐ Higher
-

Part F Group trend in lattice enthalpy

How would you expect the magnitude (absolute value) of ΔH_{g} for the reaction of calcium with oxygen to compare to that given for magnesium and oxygen above?

- ☐ Larger
 - ☐ Smaller
 - ☐ The same
-

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Bonds in Carbon Dioxide

A Level



The enthalpies of atomisation of carbon and oxygen at 298 K are given below:

Element	Enthalpy of atomisation /kJ, mol ⁻¹
Carbon	+715
Oxygen	+248

If the enthalpy of combustion, $\Delta_c H^\ominus$, for carbon is -394 kJ mol^{-1} , work out the average C=O bond enthalpy in CO_2 (to 3 significant figures).

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Essential Pre-Uni Chemistry F4.1

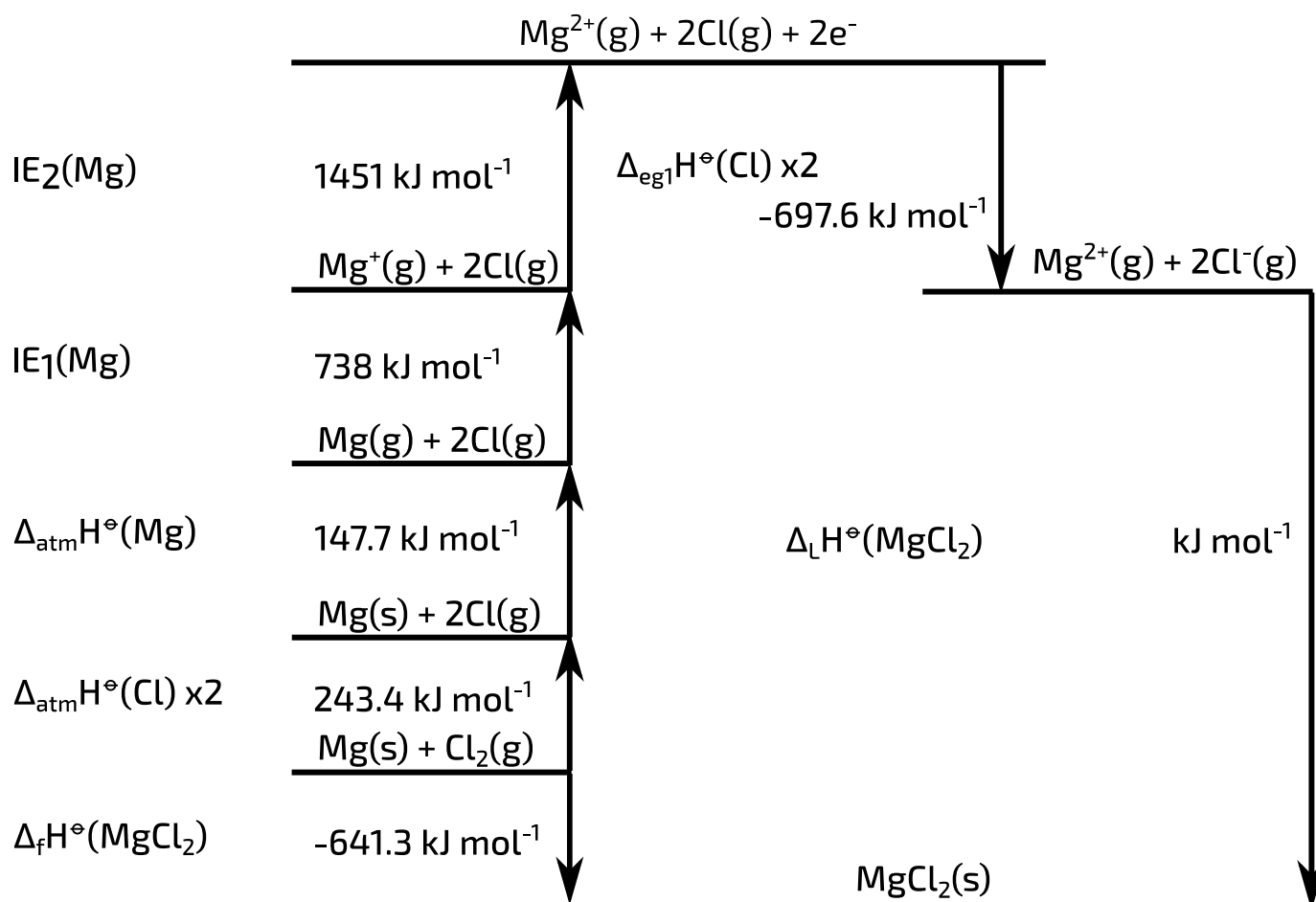


Figure 1: Born-Haber cycle

Calculate the lattice enthalpy of magnesium chloride. Give your answer to 4 significant figures.

Essential Pre-Uni Chemistry F4.2

A Level

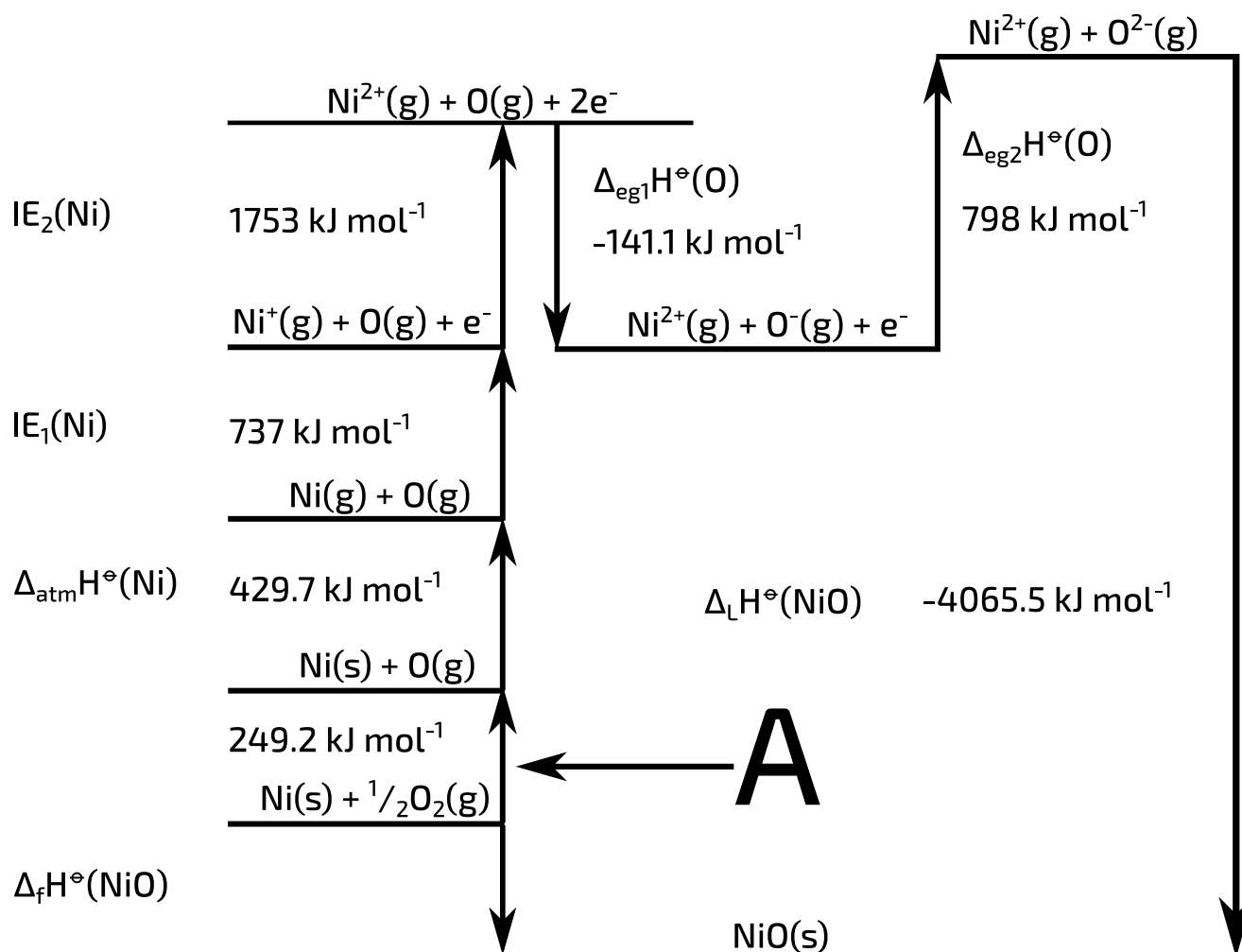


Figure 1: Born-Haber cycle for NiO

Part A Formation enthalpy of NiO

Use the Born-Haber cycle above to find the enthalpy of formation of nickel(II) oxide.

Part B Type of enthalpy change

The enthalpy change labelled A is the _____ enthalpy of oxygen.

- ☐ Atomisation
 - ☐ Formation
 - ☐ First electron gain
 - ☐ Separation
-

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Essential Pre-Uni Chemistry F4.3

All values are in kJ mol^{-1}

COMPOUND	LiBr	Na_2O	CaF_2	Cr_2O_3	Hg_2Cl_2
$\Delta_f H^\ominus$	-351.2	-414.2	-1219.6	-1139.7	-265.2
$\Delta_{\text{atm}} H^\ominus$ (metal)	159.4	107.3	178.2	(a)	61.3
$\Delta_{\text{atm}} H^\ominus$ (non-metal)	111.9	249.2	(b)	249.2	121.7
$\Delta_{\text{i.e.1}} H^\ominus$	520	(c)	590	653	1007
$\Delta_{\text{i.e.2}} H^\ominus$	7298	4563	1145	1592	1810
$\Delta_{\text{i.e.3}} H^\ominus$	11815	6913	4912	2987	3300
$\Delta_{\text{eg1}} H^\ominus$	-324.6	-141.1	-328	-141.1	(d)
$\Delta_{\text{eg2}} H^\ominus$	N/A	798	N/A	798	N/A
$\Delta_L H^\ominus$	(e)	-2526.9	-2634.8	-15115.2	-1947.6

$\Delta_f H^\ominus$ = standard enthalpy of formation

$\Delta_{\text{atm}} H^\ominus$ (metal) = standard enthalpy of atomisation of the metal

$\Delta_{\text{atm}} H^\ominus$ (non-metal) = standard enthalpy of atomisation of the non-metal

$\Delta_{\text{i.e.1}} H^\ominus$ = first ionisation energy of the metal

$\Delta_{\text{i.e.2}} H^\ominus$ = second ionisation energy of the metal

$\Delta_{\text{i.e.3}} H^\ominus$ = third ionisation energy of the metal

$\Delta_{\text{eg1}} H^\ominus$ = first standard electron gain enthalpy of the non-metal

$\Delta_{\text{eg2}} H^\ominus$ = second standard electron gain enthalpy of oxygen

$\Delta_L H^\ominus$ = standard lattice enthalpy

Note: you may be more familiar with the term "electron affinity" rather than "electron gain enthalpy". The two quantities are defined similarly, but have opposite sign.

Fill in the missing value in each column of the table, assuming that a Born-Haber cycle may be used to calculate the lattice enthalpy in the usual way. Give all your answers to 3 significant figures.

Part A $\Delta_{\text{atm}}H^\ominus$ for Cr_2O_3

$\Delta_{\text{atm}}H^\ominus$ for Cr_2O_3 in kJ mol^{-1}

Part B $\Delta_{\text{atm}}H^\ominus$ for CaF_2

$\Delta_{\text{atm}}H^\ominus$ for CaF_2 in kJ mol^{-1}

Part C $\Delta_{\text{i.e.1}}H^\ominus$ for Na_2O

$\Delta_{\text{i.e.1}}H^\ominus$ for Na_2O in kJ mol^{-1}

Part D $\Delta_{\text{eg1}}H^\ominus$ for Hg_2Cl_2

$\Delta_{\text{eg1}}H^\ominus$ for Hg_2Cl_2 in kJ mol^{-1}

Part E $\Delta_{\text{L}}H^\ominus$ for LiBr

$\Delta_{\text{L}}H^\ominus$ for LiBr in kJ mol^{-1}



Essential Pre-Uni Chemistry F4.6

A Level



The molar enthalpy change on decomposition of calcium carbonate into calcium oxide and carbon dioxide is 178 kJ mol^{-1} .

Given the lattice enthalpies of CaCO_3 ($-2799 \text{ kJ mol}^{-1}$) and CaO ($-3396 \text{ kJ mol}^{-1}$), find the enthalpy change when bonding an oxide ion to carbon dioxide in the gas phase.

Combustion and Formation

A Level



The following reaction scheme describes the Diels-Alder reaction between 1,3-butadiene and acrolein.

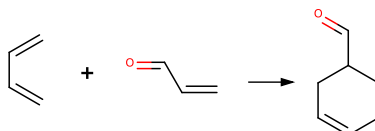


Figure 1: The equation for the Diels-Alder reaction.

Thermodynamic data about the reactants and products is given below.

Compound	Enthalpy of Combustion	Enthalpy of Formation
Butadiene	$\Delta_c H = -2540 \text{ kJ mol}^{-1}$	
Acrolein		$\Delta_f H = -68.1 \text{ kJ mol}^{-1}$
Reaction Product		$\Delta_f H = -161 \text{ kJ mol}^{-1}$
H_2O		$\Delta_f H = -286 \text{ kJ mol}^{-1}$
CO_2		$\Delta_f H = -394 \text{ kJ mol}^{-1}$

What is the enthalpy change for the Diels-Alder reaction?



Combustion Enthalpy

A Level



When molar quantities of carbon monoxide, hydrogen and methanol are burnt completely in oxygen, the following enthalpy changes of reaction are observed:

Reaction	Enthalpy Change
$\text{CO} + \frac{1}{2}\text{O}_2 \longrightarrow \text{CO}_2$	$\Delta_r H_1 = 283 \text{ kJ}$
$\text{H}_2 + \frac{1}{2}\text{O}_2 \longrightarrow \text{H}_2\text{O}$	$\Delta_r H_2 = 286 \text{ kJ}$
$\text{CH}_3\text{OH} + \frac{3}{2}\text{O}_2 \longrightarrow \text{CO}_2 + 2\text{H}_2\text{O}$	$\Delta_r H_3 = 713 \text{ kJ}$

Part A Reaction enthalpy

Calculate the enthalpy of reaction when methanol is synthesised from carbon monoxide and hydrogen.

Part B Combustion enthalpy

The following table gives average bond enthalpies, ΔH .

Bond	$\Delta H / \text{kJ mol}^{-1}$
C–H	413
C–C	347
O=O	495
O–H	467
C=O	799

Cyclohectane is a posited chemical that would have a structure similar to cyclohexane or another cycloalkane, except the ring part of the structure would be made up of 100 carbon atoms rather than 6.

Using the values above, estimate the enthalpy of combustion of cyclohectane (to 2 significant figures).

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Keep hydrated

A Level



The tables below contain information about enthalpy changes and some Group 2 elements.

Enthalpy Change	Process
ΔH_a	$M(s) \longrightarrow M(g)$
ΔH_l	$M(g) \longrightarrow M^{2+}(g)$
ΔH_h	$M^{2+}(g) \longrightarrow M^{2+}(aq)$
ΔH_{latt}	$M^{2+}(g) + X^{2-}(g) \longrightarrow MX(s)$

Element	ΔH_a /kJ, mol ⁻¹	ΔH_l /kJ, mol ⁻¹	ΔH_h /kJ, mol ⁻¹	$\Delta H_{latt}(MO)$ /kJ, mol ⁻¹	$\Delta H_{latt}(MCO_3)$ /kJ, mol ⁻¹	r /nm
Be	321	2660	-2455	-	-	0.031
Mg	150	2186	-1920	-3889	-3200	0.065
Ca	193	1740	-1650	-3513	-3021	0.099
Ba	176	1468	-1360	-3152	-2707	0.135

where r is the radius of the M^{2+} ion in nm.

Part A Magnesium enthalpy change

Calculate the enthalpy change of the process $M(s) \longrightarrow M^{2+}(aq)$ for Magnesium.

Part B Strength as reducing agents

Estimate the enthalpy change for the process $M(s) \longrightarrow M^{2+}(aq)$ in the other three elements and thus place the metals in order of their relative strength as reducing agents with reference to aqueous solutions.

- ☐ Ba > Ca > Mg > Be
- ☐ Be > Mg > Ba \approx Ca
- ☐ Ca \approx Ba > Mg > Be
- ☐ Be > Mg > Ca > Ba
- ☐ Ba > Ca \approx Be > Mg
- ☐ Be \approx Mg > Ca > Ba
-

Part C Decomposition of calcium carbonate

Assume that ΔH_r for the reaction below is 945 kJ mol^{-1} .



Calculate the value for the enthalpy change of the decomposition of calcium carbonate and give a reason why the thermal stability of the Group 2 carbonates increases in the order:

Mg < Ca < Ba

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Water Vaporisation

A Level



Bond enthalpies are always defined for gaseous substances. Some bond enthalpies are given below.

Bond	Average Bond Enthalpy /kJ, mol ⁻¹
O–H	467
O=O	495
H–H	432

Using these and the enthalpy of formation of liquid water, $\Delta_f H^\ominus (\text{H}_2\text{O}(\text{l})) = -286 \text{ kJ mol}^{-1}$, calculate the enthalpy of vaporisation of water.