

Reactivity 1.2 HL

Answers

IB CHEMISTRY HL

25 Mn Manganese 54.938045	16 S Sulfur 32.065	J	6 C Carbon 12.0107	2 He Helium 4.002602	25 Mn Manganese 54.938045
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Reactivity 1.2.3 and 1.2.4

Understandings:

- Standard enthalpy changes of combustion, ΔH_c , and enthalpy of formation, ΔH_f , data are used in thermodynamic calculations (1.2.3).
- An application of Hess's law uses enthalpy of formation data or enthalpy of combustion data to calculate the enthalpy change (1.2.4).

Learning outcomes:

- Deduce equations and solutions to problems involving these terms (1.2.3).
- Calculate enthalpy changes of a reaction using ΔH_f data or ΔH_c data (1.2.4).
- $\Delta H^{\ominus} = \sum \Delta H_c^{\ominus} \text{ reactants} - \sum \Delta H_c^{\ominus} \text{ products}$
- $\Delta H^{\ominus} = \sum \Delta H_f^{\ominus} \text{ products} - \sum \Delta H_f^{\ominus} \text{ reactants}$

Additional notes:

- Enthalpy of combustion and formation data are given in the data booklet.
- The above equations are given in the data booklet.

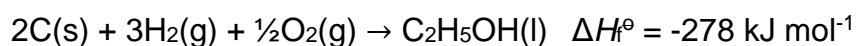
Linking questions:

- Structure 2.2 Would you expect allotropes of an element, such as diamond and graphite, to have different ΔH values?

Standard enthalpy change of formation (ΔH_f^\ominus)

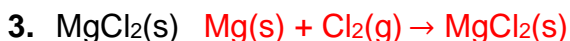
- The standard enthalpy change of formation (ΔH_f^\ominus) is the enthalpy change when one mole of a substance is formed from its elements in their standard states under standard conditions.
- Standard state is the normal, most pure stable state of a substance measured at a pressure of 100 kPa.

Examples:



- Note that fractional coefficients are used because the equation is written for the formation of one mole of product.

Exercise: Write equations for the formation of one mole of the following compounds.



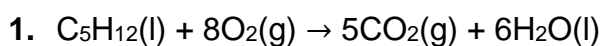
Calculating ΔH for a reaction using ΔH_f^\ominus values

$$\Delta H^\ominus = \sum \Delta H_f^\ominus_{\text{products}} - \sum \Delta H_f^\ominus_{\text{reactants}}$$

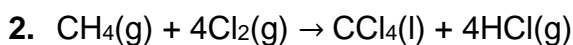
- ΔH_f^\ominus values can be found in table 12 of the data booklet.
- Elements have a standard enthalpy change of formation of zero.

Exercise: Calculate the enthalpy change for each of the reactions below, given the data in the table.

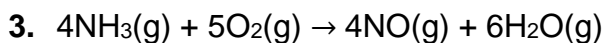
	ΔH_f^\ominus (kJ mol ⁻¹)
CO ₂ (g)	-394
CH ₄ (g)	-74.9
H ₂ O(g)	-241.8
H ₂ O(l)	-285.8
HCl(g)	-92.3
C ₅ H ₁₂ (l)	-173
CCl ₄ (l)	-95.7
NH ₃ (g)	-45.9
NO(g)	+90.3



$$\Delta H = [(5 \times -394) + (6 \times -286)] - (-173) = -3513 \text{ kJ mol}^{-1}$$



$$\Delta H = [(4 \times -92.3) + (-95.7)] - [(-74.9)] = -390 \text{ kJ mol}^{-1}$$

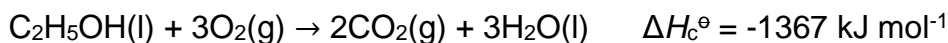


$$\Delta H = [(6 \times -241.8) + (4 \times +90.3)] - [(4 \times -45.9)] = -906 \text{ kJ mol}^{-1}$$

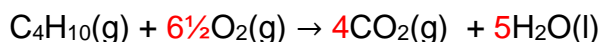
Standard enthalpy change of combustion (ΔH_c^\ominus)

- The standard enthalpy change of combustion (ΔH_c^\ominus) is the enthalpy change when one mole of a substance is burned completely in oxygen under standard conditions.

Example:



- Note that the equation is balanced for one mole of reactant and the oxygen is assumed to be the excess reactant.
- Write an equation for the complete combustion of one mole of butane, C₄H₁₀.

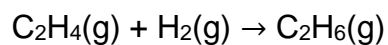


Calculating ΔH using ΔH_c^\ominus values

- The equation used to calculate the ΔH of a reaction using ΔH_c^\ominus values is given below.

$$\Delta H^\ominus = \sum \Delta H_c^\ominus_{\text{reactants}} - \sum \Delta H_c^\ominus_{\text{products}}$$

Example: Determine the ΔH of the following reaction using the values given in the table.



	ΔH_c^\ominus
C_2H_4	-1411
H_2	-286
C_2H_6	-1561

$$\Delta H^\ominus = (-1411 + -286) - (-1561)$$

$$\Delta H^\ominus = -136 \text{ kJ mol}^{-1}$$

Reactivity 1.2.5

Understandings:

- A Born–Haber cycle is an application of Hess's law, used to show energy changes in the formation of an ionic compound.

Learning outcomes:

- Interpret and determine values from a Born–Haber cycle for compounds composed of univalent and divalent ions.

Additional notes:

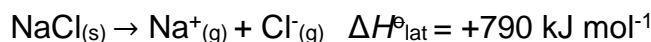
- The cycle includes: ionization energies, enthalpy of atomization (using sublimation and/or bond enthalpies), electron affinities, lattice enthalpy, enthalpy of formation.
- The construction of a complete Born–Haber cycle will not be assessed.

Linking questions:

- Structure 2.1 What are the factors that influence the strength of lattice enthalpy in an ionic compound?

Lattice enthalpy ($\Delta H_{\text{lat}}^{\ominus}$)

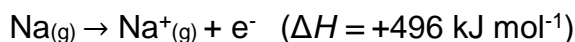
- Lattice enthalpy ($\Delta H_{\text{lat}}^{\ominus}$) is the enthalpy change when one mole of solid ionic compound is separated into its gaseous ions under standard conditions.



- Note that $\Delta H_{\text{lat}}^{\ominus}$ is endothermic and has a positive ΔH .
- A Born-Haber cycle is an enthalpy cycle that can be used to calculate the lattice enthalpy or enthalpy of formation of an ionic compound.
- Enthalpy of atomisation ($\Delta H_{\text{atom}}^{\ominus}$)** – the enthalpy change when one mole of gaseous atoms is formed from an element in its standard state (endothermic).



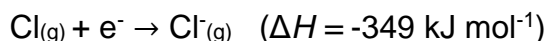
- First ionisation energy ($\Delta H_{\text{i}}^{\ominus}$)** – the minimum energy required to remove one mole of electrons from one mole of gaseous atoms (endothermic)



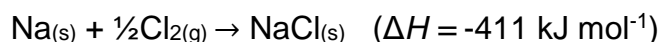
- Bond dissociation enthalpy (E)** – the enthalpy change when one mole of bonds is broken in the gaseous state (endothermic).



- First electron affinity ($\Delta H_{\text{e}^{\ominus}}$)** – the enthalpy change when one mole of electrons are added to one mole of gaseous atoms (exothermic).

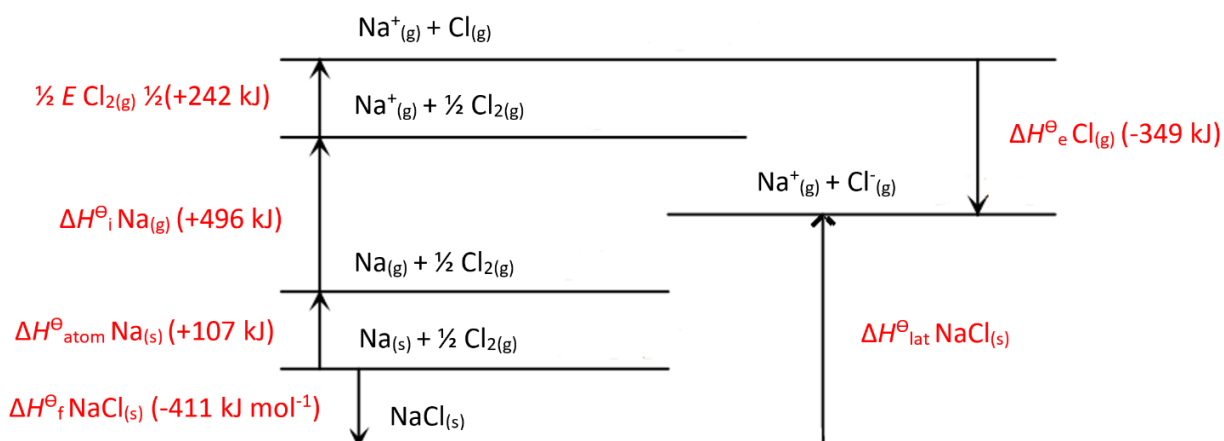


- Standard enthalpy change of formation ($\Delta H_{\text{f}}^{\ominus}$)** – the enthalpy change when one mole of a compound is formed from its elements in their standard states under standard conditions.



Exercises:

- Using the values given above, construct a Born-Haber cycle using the template below and calculate the $\Delta H^\ominus_{\text{lat}}$ for NaCl.



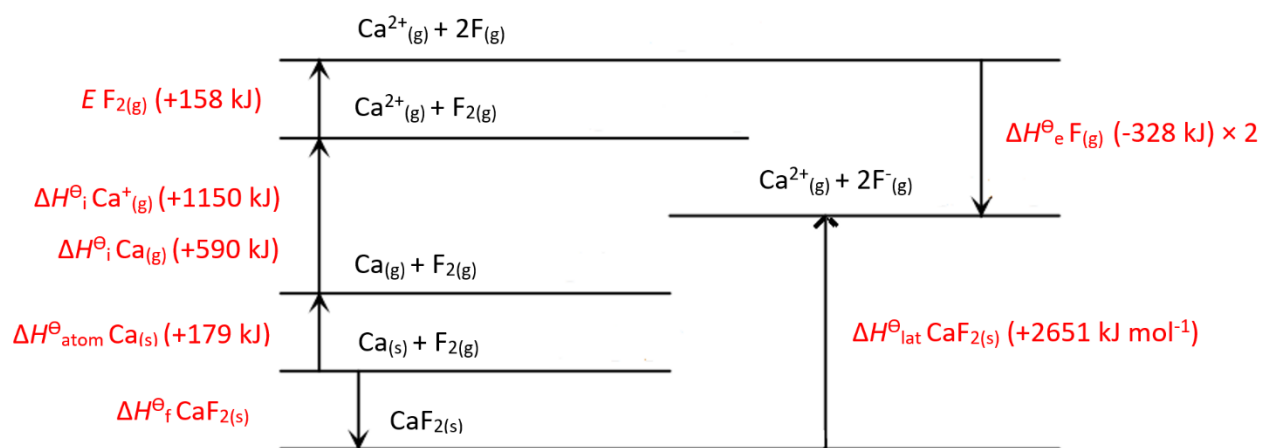
$$\Delta H^\ominus_{\text{lat}} = \Delta H^\ominus_{\text{atom}} \text{Na(s)} + \Delta H^\ominus_{\text{i}} \text{Na(g)} + \frac{1}{2} E \text{Cl}_{2(\text{g})} + \Delta H^\ominus_{\text{e}} \text{Cl(g)} - \Delta H^\ominus_{\text{f}} \text{NaCl}$$

$$\Delta H^\ominus_{\text{lat}} = (+107) + (+496) + (+121) + (-349) - (-411)$$

$$\Delta H^\ominus_{\text{lat}} = +786 \text{ kJ mol}^{-1}$$

- Using the values given in the table below, construct a Born-Haber cycle and calculate the $\Delta H^\ominus_{\text{f}}$ for CaF_2

$\Delta H_{\text{atom}} \text{Ca(s)}$ (enthalpy of atomization)	+179 kJ mol ⁻¹
$E \text{F}_{2(\text{g})}$ (bond dissociation enthalpy)	+158 kJ mol ⁻¹
$\Delta H^\ominus_{\text{i}} \text{Ca(g)}$ (1 st ionisation energy)	+590 kJ mol ⁻¹
$\Delta H^\ominus_{\text{i}} \text{Ca}^+(\text{g})$ (2 nd ionisation energy)	+1150 kJ mol ⁻¹
$\Delta H^\ominus_{\text{e}} \text{F(g)}$ (first electron affinity)	-328 kJ mol ⁻¹
$\Delta H_{\text{lat}} \text{CaF}_{2(\text{s})}$ (lattice enthalpy)	+2651 kJ mol ⁻¹



$$\Delta H^\ominus_{\text{f}} = \Delta H^\ominus_{\text{atom}} \text{Ca}(\text{s}) + \Delta H^\ominus_{\text{i}} \text{Ca}(\text{g}) + \Delta H^\ominus_{\text{i}} \text{Ca}^+(\text{g}) + E \text{F}_2(\text{g}) + 2(\Delta H^\ominus_{\text{e}} \text{F}(\text{g})) - \Delta H^\ominus_{\text{lat}} \text{CaF}_2(\text{s})$$

$$\Delta H^\ominus_{\text{f}} = (+179) + (+590) + (+1150) + (+158) + 2(-328) - (+2651)$$

$$\Delta H^\ominus_{\text{f}} = -1230 \text{ kJ mol}^{-1}$$