Standard Enthalpies of Formation and Calculating Enthalpy of Reaction (ΔH^0_{rxn})

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Standard Enthalpy of Formation (ΔH_f^0)

- Standard Enthalpies of formation (ΔH_f^0) are defined as the enthalpy change for the formation of one mole of a given compound from its constituent elements in their standard states.

Standard Enthalpy of Formation (ΔH_f^0)

- Examples:

$\frac{1}{2}N_2(g) + O_2(g) \rightarrow NO_2(g)$ $\quad \Delta H_f^0 = 33.18\ {}^{kJ}/_{mol}$

$Ca(s) + \frac{1}{2}O_2(g) \rightarrow CaO(s)$ $\quad \Delta H_f^0 = -634.9\ {}^{kJ}/_{mol}$

$C_{(graphite)} + 2Br_2(l) \rightarrow CBr_4(s)$ $\quad \Delta H_f^0 = 29.4\ {}^{kJ}/_{mol}$

Standard Enthalpy of Formation (ΔH_f^0)

- Standard Enthalpies of formation (ΔH_f^0) are tabulated at 298 K (usually) and 1 atm.

They are compiled in huge tables of thermodynamic quantities.

Examples of Standard Enthalpies of Formation (ΔH_f^0) in a Table

- An example is given below.

Substance	$\Delta H_f°$ (kJ/mol)	$\Delta G_f°$ (kJ/mol)	$S°$ (J/mol K)
Aluminum:			
Al(s)	0.0	0.0	28.3
Al(g)	330.0	289.4	164.6
$AlCl_3(s)$	−704.2	−628.8	109.3
$Al_2O_3(s)$	−1675.7	−1582.3	50.9

Here is the column that provides ΔH_f^0 values (in kJ/mol).

Standard Enthalpies of Formation (ΔH_f^0) for Elements in their Standard States

- Standard Enthalpies of formation (ΔH_f^0) for pure elements in their standard states are **assigned zero**. ($\Delta H_f^0 = 0$)

Examples:

$\Delta H_f^0(\mathrm{O_2(g)}) = 0$ $\quad$ $\Delta H_f^0(\mathrm{Al(s)}) = 0$

$\Delta H_f^0(\mathrm{Fe(s)}) = 0$ $\quad$ $\Delta H_f^0(\mathrm{C(s, graphite)}) = 0$

Calculating ΔH^0_{rxn} (ΔH_{rxn}) Using Std Enthalpies of Formation (ΔH_f^0)

- We can calculate ΔH^0_{rxn} (i.e., ΔH_{rxn}) from these tabulated enthalpies of formation (ΔH_f^0)

For the reaction

$$aA + bB \rightarrow cC + dD$$

$$\Delta H^0_{rxn} = c\left(\Delta H^0_f(C)\right) + d\left(\Delta H^0_f(D)\right) - \left[a\left(\Delta H^0_f(A)\right) + b\left(\Delta H^0_f(B)\right)\right]$$

Calculating ΔH^0_{rxn} (ΔH_{rxn}) Using Std Enthalpies of Formation (ΔH_f^0)

Another way to write the equation:

For the reaction $aA + bB \rightarrow cC + dD$

$$\Delta H^0_{rxn} = \sum n_p \Delta H^0_f(\text{products}) - \sum n_r \Delta H^0_f(\text{reactants})$$

$$\Delta H^0_{rxn} = c\left(\Delta H^0_f(C)\right) + d\left(\Delta H^0_f(D)\right) - \left[a\left(\Delta H^0_f(A)\right) + b\left(\Delta H^0_f(B)\right)\right]$$

Example: Calculate ΔH^0_{rxn} (ΔH_{rxn}) Using Std Enthalpies of Formation (ΔH_f^0)

- For the reaction $N_2O_4(g) \rightarrow 2NO_2(g)$

The following data was found in the table:

$\Delta H_f^0(N_2O_4(g)) = 9.16\ kJ/mol$

$\Delta H_f^0(NO_2(g)) = 33.18\ kJ/mol$

Calculate ΔH^0_{rxn} using these values for the given reaction.

Example: Calculate ΔH^0_{rxn} (ΔH_{rxn}) Using Std Enthalpies of Formation (ΔH_f^0)

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The following data was found in the table:

$\Delta H_f^0(N_2O_4(g)) = 9.16\ kJ/mol$

$\Delta H_f^0(NO_2(g)) = 33.18\ kJ/mol$

Use the equation:

$$\Delta H^0_{rxn} = \sum n_p\, \Delta H^0_f(\text{products}) - \sum n_r\, \Delta H^0_f(\text{reactants})$$

Example: Calculate ΔH^0_{rxn} (ΔH_{rxn}) Using Std Enthalpies of Formation (ΔH_f^0)

For the reaction $N_2O_4(g) \rightarrow 2NO_2(g)$

The following data was found in the table:

$\Delta H_f^0(\mathrm{N_2O_4(g)}) = 9.16\ \mathrm{kJ/mol}$

$\Delta H_f^0(\mathrm{NO_2(g)}) = 33.18\ kJ/mol$

Fill in the appropriate quantities:

$$\Delta \mathbf{H^0_{rxn}} = \mathbf{2}\left(\Delta \boldsymbol{H_f^0}(\mathbf{NO_2(g)})\right) - \left[\mathbf{1}\left(\Delta \boldsymbol{H_f^0}(\boldsymbol{N_2O_4}(\mathbf{g}))\right)\right]$$

$$\Delta \mathbf{H^0_{rxn}} = \mathbf{2(33.18)} - \mathbf{[1(9.16\ )]} = \mathbf{57.2\ kJ/mol}$$

Endo or exothermic?

More examples coming soon…

What You Should Be Able to Do (so far)

- Describe what standard enthalpies of formation (ΔH_f^0) are and how they are acquired.

Describe how standard enthalpies of formation (ΔH_f^0) can be used to calculate the standard enthalpy of reaction ($\Delta \mathbf{H_{rxn}^0}$) .

Be able to use standard enthalpies of formation (ΔH_f^0) to calculate the std enthalpy of reaction ($\Delta \mathbf{H_{rxn}^0}$), often called ($\Delta \mathbf{H_{rxn}}$).

Determine whether enthalpy of reaction ($\Delta \mathbf{H_{rxn}^0}$) is exo- or endothermic from the sign of ΔH.