5.2 Hess's Law

Enthalpy cycles = Hess's Law
- enthalpy change for any chemical reaction is independent of route, provided starting conditions + final reactants + products are same
  - allows for indirect measurement for rxns unable to do.

using Law of Conservation of Energy
enthalpy cycles = 0

elements combined to make ethanol
$\Delta H_1 = -277\ kJmol^{-1}$

$$2C_{(graphite)} + 3H_{2(g)} + 3\tfrac{1}{2}O_{2(g)} \longrightarrow C_2H_5OH_{(l)} + 3O_{2(g)}$$

$\Delta H_3 = -1644$
elements burned separately

$\Delta H_2 = -1367$
ethanol burned

$$2CO_{2(g)} + 3H_2O_{(l)}$$

★ follow the arrows $0 = \Delta H_1 + \Delta H_2 - \Delta H_3$

LoC Energy

arrow in opposite direction

$\therefore \Delta H_1 + \Delta H_2 = \Delta H_3$

$-277 + -1367 = -1644$

$2C + 3H_2 + 3\tfrac{1}{2}O_2$

$\downarrow \Delta H_1$

$\downarrow \Delta H_3$

$C_2H_5OH + 3O_2$

$\downarrow \Delta H_2$

$2CO_2 + 3H_2O$

★ helps determine stability

example : $\Delta H_1 \quad \boxed{S} + {}^{2}\cancel{1}\tfrac{1}{2} O_2 \rightarrow SO_3 \quad \Delta H^\circ = -395\ kJ$

$\Delta H_2 \quad \cancel{\boxed{SO_2} + \tfrac{1}{2} O_2 \rightarrow SO_3 \quad \Delta H^\circ = -98\ kJ}$

reverse to put into products

$SO_3 \rightarrow SO_2 + \tfrac{1}{2} O_2 \quad \Delta H^\circ = +98\ kJ$

$\Delta H_3 \quad \boxed{S} + O_2 \rightarrow \boxed{SO_2} \quad \Delta H^\circ = \boxed{-297\ kJ}$

$-395 + 98 =$

standard enthalpy changes of a reaction (ΔH°)

- measured under std conditions
  - $T = 298K\ (25^\circ C)$
  - $P = 1.00 \times 10^5\ Pa\ (100\ kPa)$

ΔH_f° = std enthalpy change of formation

- Occurs when 1 mol of substance is formed from its elements in their std states (pureform of substance under std conditions)
- Measurements taken under std conditions
  - Measure of stability
  - Used to calculate changes for all rxns

Thermochemical equation

- elements → compound $\quad \Delta H_f^\circ$: section 12

$2\ C_{(graphite)} + 3 H_{2(g)} + \tfrac{1}{2} O_{2(g)} \rightarrow 1\ C_2H_5OH_{(l)} \quad \Delta H_f^\circ = -278\ kJ\,mol^{-1}$

* Balance for 1 mol of substance

Using ΔH_f°

$$
\begin{tikzcd}[column sep=large]
\text{(real) reactants} \arrow[rr, "\Delta H^\circ_{rxn}"] & & \text{(real) products} \\
& \text{elements (indirect)} \arrow[ul, "\Sigma \Delta H_f^\circ (\text{reactants})"] \arrow[ur, "\Sigma \Delta H_f^\circ (\text{products})"'] &
\end{tikzcd}
$$

$$\therefore \ \Delta H^\circ_{rxn} = \Sigma \Delta H_f^\circ (\text{products}) - \Sigma \Delta H_f^\circ (\text{reactants})$$

example: calculate ΔH°_{rxn} for:

$$\underline{\quad}\, C_3H_8 + \underline{5}\, O_2 \rightarrow \underline{3}\, CO_2 + \underline{4}\, H_2O$$

	$\underline{\Delta H_f^\circ}$
C_3H_8	-105
CO_2	-394
H_2O	-286

★ ΔH_f° of an element in its most stable form = 0

1. $\underline{\quad}\, C_3H_8 + \underline{5}\, O_2 \rightarrow \underline{3}\, CO_2 + \underline{4}\, H_2O$

   $-105 \quad 5(\varnothing) \quad 3(-394) \quad 4(-286)$

2. $\Delta H^\circ_{rxn} = \Sigma \Delta H_f^\circ (p) - \Sigma \Delta H_f^\circ (r)$

   $= [3(-394) + 4(-286)] - (-105)$

   $= -2221 \text{ KJ mol}^{-1}$