FORMATION REACTIONS

- A reaction that forms exactly one mole of the specified substance from its elements at their STANDARD STATE at 25C and 1 atm pressure.

$CO_2(g)$: $C(s, graphite) + O_2(g) \longrightarrow CO_2(g)$; $\Delta H = -393.5$ kJ

heat of formation of carbon dioxide ΔH_f° or ΔH_f

"enthalpy of formation"

$CO(g)$: $C(s, graphite) + \frac{1}{2} O_2(g) \rightarrow CO(g)$; $\Delta H = -110.5$ kJ

you may see fractional coefficients in these formation reactions, because you MUST form exactly one mole of the product!

- The heat of formation for an element in its standard state at 25C and 1 atm is ZERO.

$\Delta H^\circ_{f, O_2(g)} = 0$ kJ/mol

- What are formation reactions good for?

... finding enthalpies for more interesting reactions!

Let's say we would like to find the enthalpy of reaction for this equation:

$$2C_2H_2(g) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(g);\ \Delta H = ?$$

Hess' Law: If you add two reactions to get a new reaction, their enthalpies also add.

C_2H_2: $2C(s) + H_2(g) \longrightarrow C_2H_2(g)$ $\Delta H = 226.7$

CO_2: $C(s) + O_2(g) \longrightarrow CO_2(g)$ $\Delta H = -393.5$

H_2O: $H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(g)$ $\Delta H = -241.8$

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$$2C_2H_2(g) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(l)$$

$$\Delta H = 2(-226.7) + 4(-393.5) + 2(-241.8) = \boxed{-2511\ kJ}$$

Hess' Law using enthalpy of formation:

$$\Delta H = \sum \Delta H_{f,\,products} - \sum \Delta H_{f,\,reactants}$$

$$\Delta H = \left(4(-393.5)_{CO_2} + 2(-241.8)_{H_2O} \right) - \left(2(226.7)_{C_2H_2} + 5(0)_{O_2} \right)$$

$$= \boxed{-2511\ kJ}$$

* Remember:

- Multiply each enthalpy by its stoichiometric coefficient from the reaction
- Enthalpy of formation of an element at its standard state is zero
- Watch phase labels. You will usually find SEVERAL enthalpies of formation for a given substance in different phases!
- For ionic substances in solution, remember that they exist as free ions, so look up the aqueous IONS!

See Appendix C in the textbook for enthalpy of formation data: p A-8 to A-11

Example problems:

$$\overset{2.016}{2H_2(g)} + O_2(g) \longrightarrow 2H_2O(g)\ ;\ \Delta H = -484\ kJ$$

Calculate the enthalpy change for the combustion of 1.00 kg of hydrogen gas.

1 - Convert 1 kg of hydrogen gas to moles using the formula weight of hydrogen gas

2 - Convert moles hydrogen gas to enthalpy change using thermochemical equation

$2.016\ g\ H_2 = mol\ H_2$	$kg = 10^3\ g$	$2\ mol\ H_2 = -484\ kJ$

$$1.00\ kg\ H_2 \times \frac{10^3\ g}{kg} \times \frac{mol\ H_2}{2.016\ g\ H_2} \times \frac{-484\ kJ}{2\ mol\ H_2} = \boxed{-12\bar{0}000\ kJ \text{ per kg } H_2}$$

FW: 46.026

$$2\,HCHO_2(l) + O_2(g) \longrightarrow 2\,CO_2(g) + 2\,H_2O(l)$$

If 50.3 kJ of heat was released when 5.48 g of formic acid are burned at constant pressure, then what is the enthalpy change of this reaction per mole of formic acid?

$$\Delta H = \frac{Q_{constant\ P}}{moles\ HCHO_2} = ?$$

$$Q = -50.3\ kJ$$

Find mol $HCHO_2$: $46.026\ g\ HCHO_2 = mol\ HCHO_2$

$$5.48\ g\ HCHO_2 \times \frac{mol\ HCHO_2}{46.026\ g\ HCHO_2} = 0.119063\ mol\ HCHO_2$$

$$\Delta H = \frac{Q_{constant\ P}}{moles\ HCHO_2} = \frac{-50.3\ kJ}{0.119063\ mol\ HCHO_2} = \boxed{-422\ kJ/mol\ HCHO_2}$$

Based on the calculation above, can we complete this thermochemical equation?

$$2\,HCHO_2(l) + O_2(g) \longrightarrow 2\,CO_2(g) + 2\,H_2O(l);\ \Delta H = \underline{-844}\ kJ$$

We calculated the heat per ONE MOLE of formic acid, while this equation is written on the basis of TWO MOLES of formic acid being burned.

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)\ ;\ \Delta H = -906\ kJ$$

What is the enthalpy change when 150. L of nitrogen monoxide are formed by this reaction at 25.0 C and 1.50 atm pressure?

1 - Convert volume of NO to moles using the ideal gas equation
2 - Convert moles NO to enthalpy change using thermochemical equation

$$PV = nRT$$

$$\frac{PV}{RT} = n$$

$P = 1.50\ atm$

$V = 150.\ L$

$T = 25.0°C = 298.2\ K$

$R = 0.08206\ \frac{L \cdot atm}{mol \cdot K}$

$n = ???$

$$① \ n_{NO} = \frac{(1.50\ atm)(150.\ L)}{\left(0.08206\ \frac{L\cdot atm}{mol \cdot K}\right)(298.2\ K)} = 9.19482\ mol\ NO$$

$4\ mol\ NO = -906\ kJ$

$$9.19482\ mol\ NO \times \frac{-906\ kJ}{4\ mol\ NO} = \boxed{-2080\ kJ = \Delta H}$$