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

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

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

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

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

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

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

Hess' Law using enthalpy of formation:

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

$$\Delta H = \left(4(-393.5) + 2(-241.8)\right) - \left(2(226.7) + 5(0)\right)$$

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

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

* 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!

Example problems:

FORMULA WEIGHTS in g/mol in purple

$$\underset{2.016}{2H_2(g)} + \underset{32.00}{O_2(g)} \longrightarrow \underset{18.02}{2H_2O(g)} \; ; \; \Delta H = -484 \text{ kJ}$$

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

---

1 - Convert 1.0 kg of hydrogen gas to moles using formula weight.
2 - Convert moles hydrogen gas to enthaply change using thermochemical equation

---

$2.016 \text{ g } H_2 = \text{mol } H_2$ | $\text{Kg} = 10^3 \text{ g}$ | $2 \text{ mol } H_2 = -484 \text{ kJ}$

$$1.0 \text{ kg } H_2 \times \frac{10^3 \text{ g}}{\text{Kg}} \times \frac{\text{mol } H_2}{2.016 \text{ g } H_2} \times \frac{-484 \text{ kJ}}{2 \text{ mol } H_2} = \boxed{-120000 \text{ kJ per kg } H_2}$$

FW: 46.026 32.00 44.01 18.02

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

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?

$Q = -50.3\ kJ$; $\Delta H = \dfrac{Q_{constant\ pressure}}{mol\ HCHO_2}$

Find moles formic acid:

$$5.48\ g\ HCHO_2 \times \frac{mol\ HCHO_2}{46.026\ g\ HCHO_2} = 0.11906\ mol\ HCHO_2$$

$$\Delta H = \frac{-50.3\ kJ}{0.11906\ mol\ HCHO_2} = \boxed{-422\ kJ/mol\ HCHO_2}$$

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

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

We calculated the enthalpy change for a mole of formic acid being burned, and the equation has two moles being burned. Double the enthalpy change for two moles.

$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$; $\Delta H = -906$ 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 150 L of NO to moles using ideal gas equation
2 - Convert moles NO to enthalpy change using thermochemical equation

---

$PV = nRT$ | $P = 1.50$ atm $\quad R = 0.08206 \frac{L\text{-atm}}{mol\text{-}K}$

$n = \frac{PV}{RT}$ | $V = 150.$ L

$T = 25.0^\circ C = 298.2$ K

① $n_{NO} = \frac{(1.50\text{ atm})(150.\text{ L})}{\left(0.08206 \frac{L\text{-atm}}{mol\text{-}K}\right)(298.2\text{ K})} = 9.194822849$ mol NO

---

4 mol NO = −906 kJ

$9.194822849 \text{ mol NO} \times \frac{-906 \text{ kJ}}{4 \text{ mol NO}} = \boxed{-2080 \text{ kJ}}$

34.086 g/mol

Heat of formation / enthalpy of formation!

$2H_2S(g)$	$+ 3O_2(g)$	$\rightarrow 2H_2O(\ell)$	$+ 2SO_2(g)$	
−20.50	0	−285.8	−296.8	ΔH_f°, kJ/mol

(Appendix C)

What is the enthalpy change at standard conditions when 25.0 grams of hydrogen sulfide gas is reacted?

1 - Calculate the enthalpy change for the reaction as written using HEATS OF FORMATION and Hess's Law

2 - Convert 25.0 g of hydrogen sulfide to moles using formula weight

3 - Convert moles hydrogen sulfide to enthalpy change using thermochemical equation.

① $\Delta H = \sum \Delta H_{f,\text{products}}^\circ - \sum \Delta H_{f,\text{reactants}}^\circ$

$= [2(-285.8) + 2(-296.8)] - [2(-20.50) + 3(0)]$

$= -1124.2\ \text{kJ}$

Thermochemical equation:

$2H_2S(g) + 3O_2(g) \rightarrow 2H_2O(\ell) + 2SO_2(g)\ ;\ \Delta H = -1124.2\ \text{kJ}$

$34.086\ \text{g}\ H_2S = \text{mol}\ H_2S \quad | \quad 2\ \text{mol}\ H_2S = -1124.2\ \text{kJ}$

$$25.0\ \text{g}\ H_2S \times \frac{\text{mol}\ H_2S}{34.086\ \text{g}\ H_2S} \times \frac{-1124.2\ \text{kJ}}{2\ \text{mol}\ H_2S} = \boxed{-412\ \text{kJ}}$$

② ③