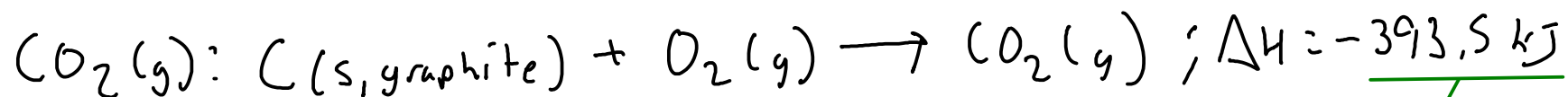
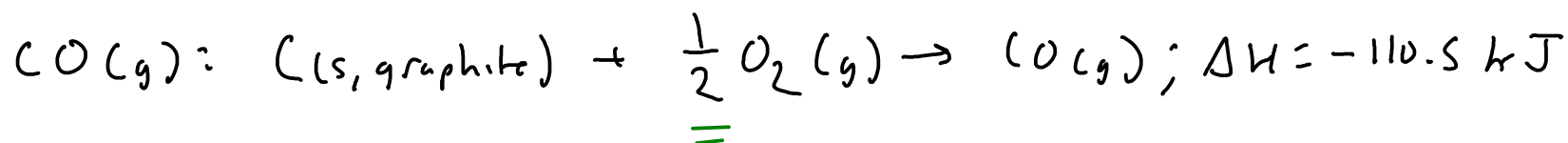


FORMATION REACTIONS

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



heat of formation of carbon dioxide ΔH_f° or ΔH_f
"enthalpy of formation"



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

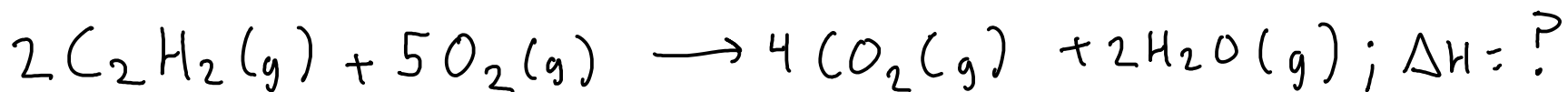
- The heat of formation for an element in its standard state at 25C and 1 atm is ZERO.

$$\Delta H_f^\circ, \text{O}_2(\text{g}) = 0 \text{ kJ/mol}$$

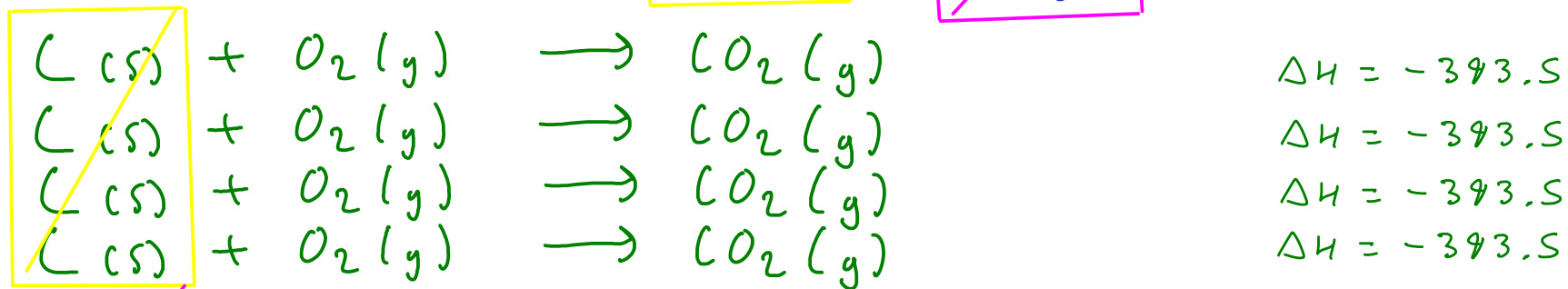
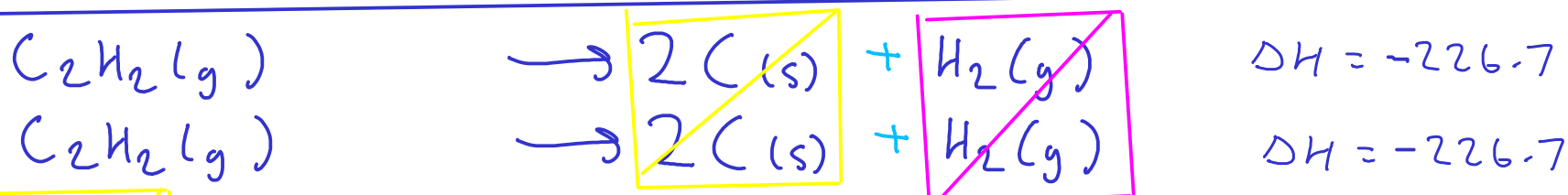
- What are formation reactions good for?

... finding enthalpies for more interesting reactions!

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



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



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

Hess' Law using enthalpy of formation:

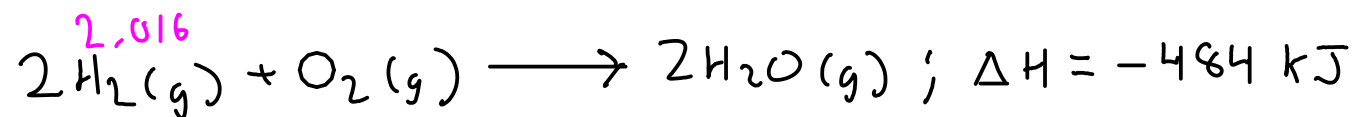
$$\Delta H = \sum \Delta H_{f, \text{products}} - \sum \Delta H_{f, \text{reactants}}$$
$$\Delta H = \left(\overset{\text{CO}_2}{4(-393.5)} + \overset{\text{H}_2\text{O}}{2(-241.8)} \right) - \left(\overset{\text{C}_2\text{H}_2}{2(226.7)} + \overset{\text{O}_2}{5(0)} \right)$$
$$= \boxed{-2511 \text{ kJ}}$$

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:



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

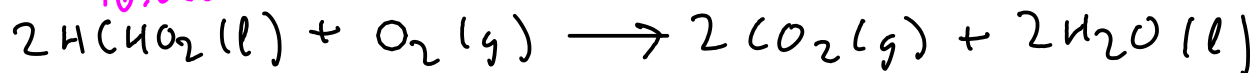
$$2.016 \text{ g H}_2 = 1 \text{ mol H}_2$$

$$\text{Kg} = 10^3 \text{ g}$$

$$2 \text{ mol H}_2 = -484 \text{ kJ}$$

$$1.00 \text{ kg H}_2 \times \frac{10^3 \text{ g}}{\text{Kg}} \times \frac{1 \text{ mol H}_2}{2.016 \text{ g H}_2} \times \frac{-484 \text{ kJ}}{2 \text{ mol H}_2} = \boxed{-120000 \text{ kJ per kg H}_2}$$

FW: 46.026



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?

$$\Delta H = \frac{Q_{\text{constant P}}}{\text{moles HCHO}_2}$$

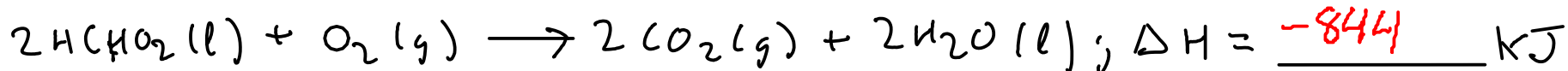
$$Q = -50.3 \text{ kJ}$$

Find mol HCHO₂: 46.026 g HCHO₂ = mol HCHO₂

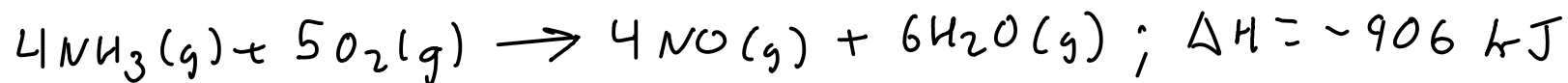
$$5.48 \text{ g HCHO}_2 \times \frac{\text{mol HCHO}_2}{46.026 \text{ g HCHO}_2} = 0.119063 \text{ mol HCHO}_2$$

$$\Delta H = \frac{Q_{\text{constant P}}}{\text{moles HCHO}_2} = \frac{-50.3 \text{ kJ}}{0.119063 \text{ mol HCHO}_2} = -422 \text{ kJ/mol HCHO}_2$$

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



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.



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

$$PV = nRT$$

$$P = 1.50 \text{ atm}$$

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

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

$$V = 150. \text{ L}$$

$$T = 25.0^\circ\text{C} = 298.2 \text{ K} \quad n = ???$$

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

$$4 \text{ mol NO} = -906 \text{ kJ}$$

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