



What would be the enthalpy change when 25 g of water are produced by the reaction?

1 - Convert 25 grams water to moles. Use FORMULA WEIGHT.

2 - Convert moles water to enthalpy change. Use THERMOCHEMICAL EQUATION.

$$\text{H}_2\text{O}: \text{H}: 2 \times 1.008$$

$$\text{O}: 1 \times 16.00$$

$$\underline{18.016 \text{ g H}_2\text{O} = \text{mol H}_2\text{O}}$$

$$3 \text{ mol H}_2\text{O} = -1800 \text{ kJ}$$

$$25 \text{ g H}_2\text{O} \times \frac{\text{mol H}_2\text{O}}{18.016 \text{ g H}_2\text{O}} \times \frac{-1800 \text{ kJ}}{3 \text{ mol H}_2\text{O}} = \boxed{-830 \text{ kJ}}$$

This is an EXOTHERMIC reaction. 830 kJ are transferred to the SURROUNDINGS.

The enthalpy change here is the same as Q, as long as we do a constant pressure process.

A few more terms related to enthalpy:

- Enthalpy of vaporization / heat of vaporization: The enthalpy change on vaporizing one mole of a substance. (from liquid to vapor)

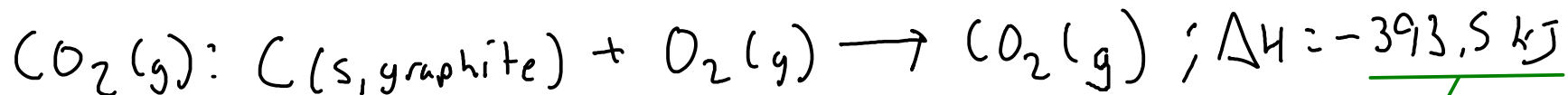
- Enthalpy of fusion / heat of fusion: The enthalpy change when a mole of liquid changes to the solid state.



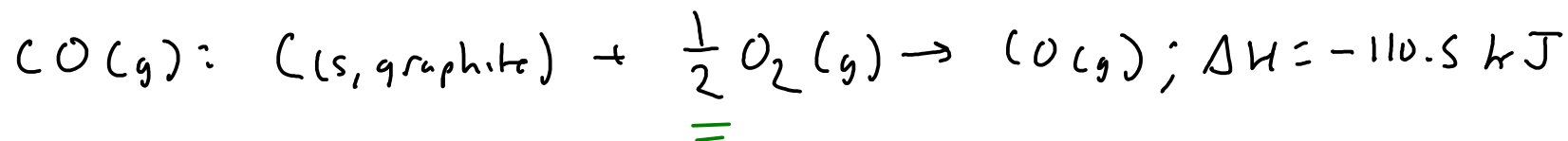
Phase changes require energy, too!

160 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!

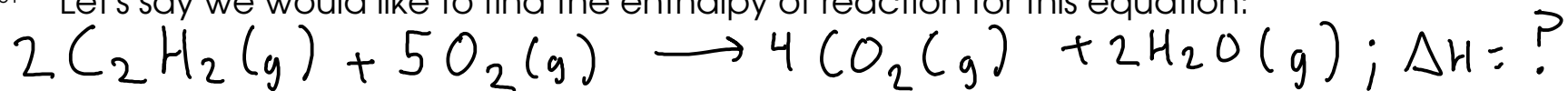
- The heat of formation for an element in its standard state at 25C and 1 atm is ZERO.

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

- What are formation reactions good for?

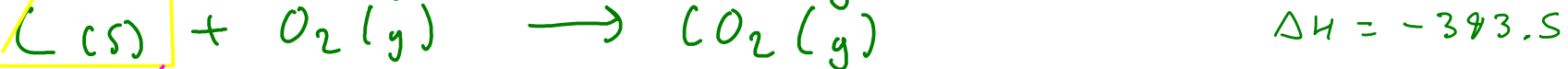
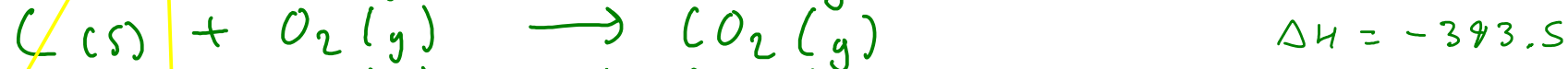
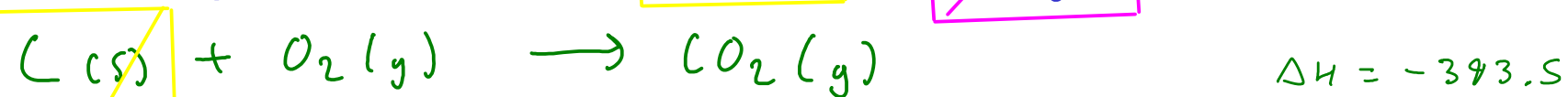
... finding enthalpies for more interesting reactions!

¹⁶¹ Let's say we would like to find the enthalpy of reaction for this equation:



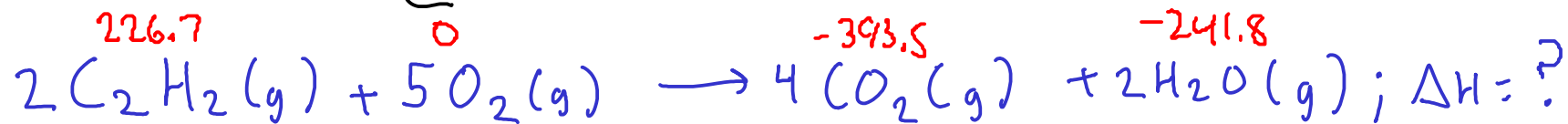
From
A-8,
text
↓

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



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

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



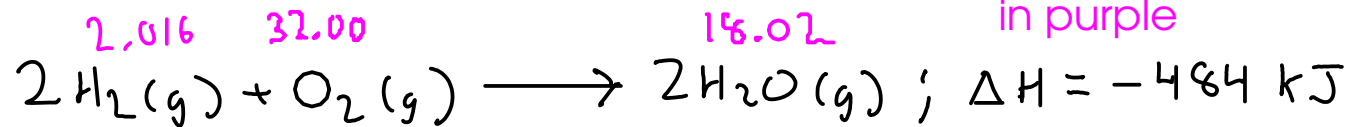
$$\Delta H = [4(-393.5) + 2(-241.8)] - [2(226.7) + 5(0)]$$

$$= -2811 \text{ kJ}$$

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!



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

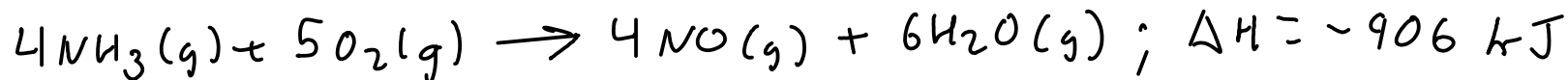
1 - Convert 1.00 kg hydrogen gas to moles. Use formula weight.

2 - Convert moles hydrogen gas to enthalpy change. Use thermochemical equation.

$$\textcircled{1} \quad 2.016 \text{ g H}_2 = 1 \text{ mol H}_2, \quad \text{kg} = 10^3 \text{ g}$$

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

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



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 NO to moles. Use IDEAL GAS EQUATION.

2 - Convert moles NO to enthalpy change. Use THERMOCHEMICAL EQUATION.

$$\textcircled{1} PV = nRT \quad | \quad P = 1.50 \text{ atm} \quad V = 150. \text{ L}$$

$$n = \frac{PV}{RT} \quad | \quad R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \quad T = 25.0^\circ\text{C} = 298.2 \text{ K}$$

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

$$\textcircled{2} 4 \text{ mol NO} = -906 \text{ kJ}$$

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

②