

$$Q - W_s = \Delta H + \Delta E_k + \Delta E_p$$

Q = Heat evolved or heat required (kJ for Q, kJ/time Q dot)

Ws = shaft work, mechanical work, turning a turbine, pumping a fluid

dH = Enthalpy accounts for all energy associated with phase change, temperature change, pressure change, and chemical reactions

dEk = change in kinetic energy, associated with motion, changes in velocity, acceleration, changes in pipe diameter, changes in linear velocity

dEp = change in potential energy, changes in height,

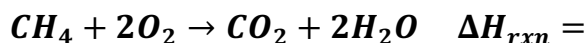
**When doing a theoretical process path that involves phase change, temperature change, and pressure change, what is the best order to go in?**

1. If you want to do a phase change, you HAVE TO go through standard conditions if you want to use Table B.1.

Standard heat of... vaporization, sublimation, fusion .. which are found in Table B.1 occur at 1 atm and the “normal temperature”. For example, the standard heat of vaporization for water occurs at 1 atm and the normal boiling point (100 C).

You will likely need to change T and P before you can change the phase.

**Can you do an example of Hess’s Law to calculate the heat of reaction?**



Formation of CH4:  $C + 2H_2 \rightarrow CH_4$  ,

$$\Delta H_{f, CH_4}^0 = X \text{ kJ/mol}$$

Formation of O2:  $O_2$ ,

$$\Delta H_{f, O_2}^0 = 0 \text{ kJ/mol}$$

Formation of CO2:  $C + O_2 \rightarrow CO_2$ ,

$$\Delta H_{f, CO_2}^0 = Y \text{ kJ/mol}$$

Formation of H<sub>2</sub>O:  $H_2 + \left(\frac{1}{2}\right) O_2 \rightarrow H_2O,$

$$\Delta H_f^0_{H_2O} = Z \text{ kJ/mol}$$

$$\Delta H_{rxn} = -\Delta H_f^0_{CH_4} - 2\Delta H_f^0_{O_2} + \Delta H_f^0_{CO_2} + 2\Delta H_f^0_{H_2O}$$

$$\Delta H_{rxn} = \sum_{products} v_i \Delta H_i - \sum_{reactants} v_i \Delta H_i$$

### What about the enthalpy change for a liquid?

For ideal gases, when there is a pressure change – the enthalpy is approximated as ZERO.

For solids and liquids, when there is a pressure change – the enthalpy takes this form

$$\Delta H = \Delta P \hat{V}$$

For solids and liquids, they are also INCOMPRESSIBLE, if you were to apply a pressure – the density doesn't change (i.e. molar volume ( $\hat{V}$ ) does not change). We rewrite this as

$$\Delta H = \hat{V} \Delta P$$