CHM 110 – Heat – Practice Problems

Solve the problems.

1) Find the mass of propane (C_3H_8, FW = 44.09 g/mol) required to heat 1.00 gal (3.78 L) of water from 25.0 °C to 100.0 °C. Then, find the mass of propane required to vaporize the water at 100.0 °C. Assume the density of water at 25.0 °C is 1.00 g/ml.

$$\mathbf{C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(\mathit{l}); \quad \Delta H = -2220\ kJ}$$
$$\mathbf{H_2O(\mathit{l}) \rightarrow H_2O(g); \quad \Delta H = 44.0\ kJ}$$

<u>Complete solution</u>

This problem is essentially a stoichiometry problem involving heat. First, we calculate the energy requirement for heating the water to 100.0 °C using the formula for specific heat.

$$Q = m \times C \times \Delta T = (3780\,g) \times (4.184\,\frac{J}{g \cdot {}^{o}C}) \times (100.0\,{}^{o}C - 25.0\,{}^{o}C)$$

Q = 1186000 J = 1186 kJ

Now, calculate the mass of propane required to heat the water. Keep in mind that the process is <u>exo</u>thermic from the point of view of the propane!

$$-1186\,kJ \times \frac{1\,mol\,C_3H_8}{-2220\,kJ} \times \frac{44.09\,g\,C_3H_8}{mol\,C_3H_8} = 23.55\,g\,C_3H_8$$

*So, **23.6 g of C_3H_8** are required to heat the water to 100.0 °C.*

Next, we calculate the amount of heat required to boil (vaporize) the same quantity of water.

$$3780\,g\,H_2O \times \frac{mol\,H_2O}{18.02\,g\,H_2O} \times \frac{44.0\,kJ}{mol\,H_2O} = 9230\,kJ$$

Finally, we calculate the amount of propane required to provide this heat - just like we did previously. This process is <u>exo</u>thermic from the point of view of the propane!

$$-9230\,kJ \times \frac{1\,mol\,C_3H_8}{-2220\,kJ} \times \frac{44.09\,g\,C_3H_8}{mol\,C_3H_8} = 183.3\,g\,C_3H_8$$

***183 g of C_3H_8** of propane are required to vaporize the water.*

2) Sodium bicarbonate thermally decomposes to form sodium carbonate, water, and carbon dioxide.

$$\mathbf{2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g)}$$

Calculate the enthalpy change of the decomposition of 42.5 g of solid $NaHCO_3$.

Complete solution

First, find the enthalpy of the reaction as written. Using data tables, look up the heat of formation of each reactant and product, then use Hess's Law to find the enthalpy change of the reaction.

Substance	ΔH_f **(kJ/mol)**
$Na_2CO_3(s)$	-1130.8
$H_2O(g)$	-241.8
$CO_2(g)$	-393.5
$NaHCO_3(s)$	-950.8

$$\Delta H = (1\times -1130.8 + 1\times -241.8 + 1\times -393.5) - (2\times -950.8) = 135.5\ \text{kJ}$$

$$2NaHCO_3(s) \dashrightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g);\quad \Delta H = 135.5\ \text{kJ}$$

Now, solve the problem by converting the mass of sodium bicarbonate to moles, then to enthalpy using the thermochemical equation.

$$42.5\ \text{g NaHCO}_3 \times \frac{\text{mol NaHCO}_3}{84.01\ \text{g NaHCO}_3} \times \frac{135.5\ \text{kJ}}{2\ \text{mol NaHCO}_3} = 34.3\ \text{kJ}$$

ΔH = ***34.3 kJ*** *for the decomposition of 42.5 grams of sodium bicarbonate. The process is endothermic.*

3) Calculate the enthalpy change for the combustion of 175 L of H_2S gas at 25 ºC and 1.00 atm pressure. The thermochemical equation for the process is given below.

$$\mathbf{2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g)\ ; \quad \Delta H = -1036\,kJ}$$

<u>Complete solution</u>

To solve this problem, you will first have to calculate the number of moles of H_2S burned using the ideal gas equation. Then, you will need to find the enthalpy change using the thermochemical equation.

Find the number of moles. Remember to convert temperature to Kelvins.

$$T = 25 + 273 = 298\ K$$

$$n = \frac{P \times V}{R \times T}$$

$$n = \frac{(1.00\,atm) \times (175\,L)}{(0.08208 \frac{L \cdot atm}{mol \cdot K}) \times (298\,K)} = 7.156\,mol\,H_2S$$

Find the enthalpy change.

$$\Delta H = 7.156\,mol\,H_2S \times \frac{-1036\,kJ}{2\,mol\,H_2S} = \mathbf{-3710\,kJ}$$