EXAM III – Oct. 31, 2019

Answers to Calculation-Based Problems

2. (36 pts) The U.S. produces approximately 2.6 billion gallons of methanol (CH_3OH) each year. It is used in fuels, as a solvent for perfumes and dyes, and in the preparation of a wide range of other chemicals – formaldehyde, plastics, paints, explosives, etc. A common preparation method involves reacting carbon monoxide and hydrogen gas as shown below:

$$CO\ (g)\ +\ 2\ H_2\ (g)\ \rightarrow\ CH_3OH\ (g)$$

The following questions are related to this reaction (or these substances). **Note that your answer to each part is independent of the others.**

d. (10 pts) Using the thermodynamic data provided (p. 5), please **calculate $\Delta H°$** for this reaction in **kJ per mole of CH_3OH** formed. Is the reaction **endothermic or exothermic**?

Answer: $\Delta H° = -90.5$ kJ (exothermic)

e. (10 pts) Suppose that an engineer in a chemical plant performs this reaction in a 1500.0-liter stainless steel vat at 25.0 °C and determines the pressure of methanol to be 25.4 atm. **How many moles** of CH_3OH were formed?

Answer: $n = 1.56 \times 10^3$ moles

3. (24 pts) The questions below relate to the following reaction:

$$P_4O_{10}\ (s)\ +\ 6\ PCl_5\ (g)\ \rightarrow\ 10\ Cl_3PO\ (g) \qquad \mathbf{\Delta H_{rxn} = ???}$$

a. Please use the thermodynamic data below to **determine ΔH_{rxn}** for this process.

$$P_4\ (s)\ +\ 6\ Cl_2\ (g)\ \rightarrow\ 4\ PCl_3\ (g) \qquad \Delta H = -1225.6\ kJ$$

$$P_4\ (s)\ +\ 5\ O_2\ (g)\ \rightarrow\ P_4O_{10}\ (s) \qquad \Delta H = -2967.3\ kJ$$

$$PCl_3\ (g)\ +\ Cl_2\ (g)\ \rightarrow\ PCl_5\ (g) \qquad \Delta H = -84.2\ kJ$$

$$PCl_3\ (g)\ +\ ½\ O_2\ (g)\ \rightarrow\ Cl_3PO\ (g) \qquad \Delta H = -285.7\ kJ$$

Answer: $\Delta H = -610.1$ kJ

b. How much heat is absorbed or released when 50.0 g of PCl_5 reacts completely?

Answer: -24.4 kJ released

4. (22 pts) The over-the-counter remedy called “milk of magnesia” contains magnesium hydroxide, which neutralizes hydrochloric acid in the stomach. Suppose that you carry out the following reaction in a coffee-cup calorimeter to determine the heat flow involved:

$$2\ HCl\ (aq)\ +\ Mg(OH)_2\ (aq)\ \rightarrow\ MgCl_2\ (aq)\ +\ 2\ H_2O\ (l)$$

You add 250.0 mL of 4.00 M HCl to enough $Mg(OH)_2$ to make 500.0 total grams of solution. Initially, you measure a temperature of 23.6 °C; after reaction is complete, the temperature is 50.3 °C. Calculate ΔH_{rxn} in kJ per mole of $MgCl_2$ formed. The specific heat of solution 4.18 J/g °C. [**Hint:** Start by calculating the heat of reaction.]

Answer: ΔH = -112 kJ/mol