Friday Worksheet **Name: ……………….**

Chemical equilibrium worksheet 3

1) Hydrogen and oxygen gases are placed in a sealed vessel and allowed to react according to the equation below.

$$2H_{2(g)} + O_{2(g)} \rightleftarrows 2H_2O_{(g)} \quad \Delta H = -572 \text{ kJ mol}^{-}$$

The reaction is allowed to reach equilibrium at which point one of the following changes takes place.

a) Discuss how each change will impact on the equilibrium position and offer an explanation

   a. A catalyst is added.
   No change. The catalyst does not impact on the equilibrium position. Catalysts speed up the forward and backward reactions equally.

   b. The volume of the vessel is doubled.
   The equilibrium shifts to left. Increasing he volume will cause a decrease in pressure and hence the reaction will drive to the left to increase the number of particles.

   c. Temperature of the vessel is increased.
   Since it is an exothermic reaction a temperature increase will drive the equilibrium to the left reducing the yield.

   d. Helium is added to double the pressure of the vessel.
   Helium does not appear in the equilibrium expression for this reaction and hence will have no impct on the equilibrium position.

   e. Solid iron is added which reacts with the oxygen gas.
   The equilibrium will shift to the left, partially replacing the oxygen gas.

b) What are the ideal conditions for maximum yield. Low temperature and high pressure

c) How are the conditions for maximum yield at odds with the rate at which the reaction reaches equilibrium? Low temperature may increase the yield but gives a low rate of reaction.
Compromises have to be made between yield and rate. What are they? A reasonable temperature range is selected and a catalyst is used to increase the rate of reaction. High pressure will also drive the equilibrium to the right and cause a greater yield.

2) Nitrogen gas reacts with hydrogen gas to form ammonia according to the following equation.

$$N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g)$$

The equilibrium constant for the above reaction at a given temperature is $8.32 \times 10^{-3}\ M^{-2}$ Hydrogen and nitrogen gases were mixed together in a sealed 4 litre vessel and allowed to react. At equilibrium the concentration of ammonia is 0.234 mol/litre and the concentration of nitrogen is 0.843 mol/litre. What is the amount of hydrogen present, in grams, in the reaction vessel at this temperature?

$$\frac{[NH_3]^2}{[H_2]^3\ [N_2]} = 8.32 \times 10^{-3}$$

$$\Rightarrow \quad \frac{[0.234\ ]^2}{[H_2]^3\ [0.843]} = 8.32 \times 10^{-3}$$

$$\Rightarrow \quad \frac{0.234^2}{8.32 \times 10^{-3} \times 0.843} = [H_2]^3$$

$$\Rightarrow \quad 7.81 = [H_2]^3$$

$$\Rightarrow \quad 1.98 = [H_2]$$

$$\Rightarrow \quad n = C \times V = 1.98 \times 4.00 = 7.92 \text{ mol}$$

$$\Rightarrow \quad \text{mass} = n \times Fm = 7.92 \text{ mol} \times 2.00 = 15.8 \text{ grams}$$

3) In an experiment, 2.00 mol of pure phosgene, $COCl_2$, is placed in a 2.00 L flask where the following reaction takes place.

$COCl_2(g) \Leftrightarrow CO(g) + Cl_2(g)$ $K_e = 2.1 \times 10^{-8}$ M

a) It can be assumed that, at equilibrium, the amount of unreacted $COCl_2$ is approximately equal to 2.0 mol. On the basis of the data provided, explain why this assumption is justified.

The equilibrium constant at 2.1×10^{-8} is very small indicating that the reaction hardly proceeds in the forward reaction at the given temperature.

b) What is the mass of Cl_2 gas present in the reaction vessel at this temperature?

$$\frac{[CO]\,[Cl_2]}{[COCl_2]} = 2.1 \times 10^{-8}\ M$$

Since the mol of CO and Cl_2 produced are equal according to the stoichiometric ratio of the balanced equation and negligible $COCL_2$ reacts we can write the following expression.

$$\frac{[Cl_2]^2}{[1.00]} = 2.1 \times 10^{-8}\ M$$

$$[Cl_2] = 1.44 \times 10^{-4}\ M$$

$$n_{chlorine} = C \times V = 1.44 \times 10^{-4}\ M \times 2.00 \text{ litres}$$

$$\text{mass}_{\text{ chlorine}} = 71.0 \times 2.88 \times 10^{-4}\ M$$

$$\text{mass}_{\text{ chlorine}} = 0.0204 \text{ grams}$$