Problem of the Day 25   CHEM 1252

1. Humans and other animals need nitrogen atoms for proteins, nucleic acids, vitamins, and hormones. The air we breath is about 80% N_2, but we are not capable of "fixing" this nitrogen i.e. converting molecular nitrogen into atomic nitrogen. Instead, we get our nitrogen by eating plants and other animals. One source of nitrogen for plants is the fertilizer ammonia, NH_3. One way to produce ammonia is by reacting molecular nitrogen and molecular hydrogen.

$$N_2(g) + 3\ H_2(g) \longrightarrow 2\ NH_3(g) \qquad H^o = -92.2\ \text{kJ/mol}$$

This reaction seems an obvious way to make NH_3, but when you take N_2 and H_2 and heat them together only a small amount of NH_3 forms. A German scientist, Fritz Haber, solved this problem of the low production of ammonia. The solution involves an appreciation of the dynamic nature of chemical equilibrium and some ingenious ways of shifting the equilibrium. This process is known as the Haber process.

(a) The Haber process was the first example of the use of **Le Chatelier's principle** to optimize the yield of an industrial chemical. List three different ways of increasing the yield of ammonia. You need to be explicit about how the change in reaction conditions leads to the increase.

Method 1

5

Method 2

5

Method 3

5

(b) Write the equilibrium constant for the reaction shown above in terms of pressures.

K_p =

5

(c) K_p for the Haber process is 4.31 x 10^{-4} at 200°C. In a certain experiment, 0.862 atm of N_2 and 0.373 atm of H_2 were allowed to react in a constant volume reaction vessel at 200°C. Calculate the partial pressures of all species when equilibrium is reached. Please make sure you follow the directions!

Step 1: Fill in this table with appropriate pressures and/or variables

	$N_2(g)$	+ $3\ H_2(g)$	$\longrightarrow$	$2\ NH_3(g)$
initial	1	1		1
change	1	1		1
equil.	1	1		1

Step 2: Using your results from Step 1, write the equilibrium expression (in terms of x) here.

K_p =

5

If you have done Step 2 correctly, you will notice that you have a fairly complicated mathematical expression. Since the value of the equilibrium constant is extremely small, let's assume that the value of x will be negligible **compared to the initial pressures**.

Step 3: Rewrite the equilibrium expression after making the assumption discussed above.

K_p=

4

Step 4: Calculate the partial pressures of N_2, H_2, and NH_3 at equilibrium.

	P_{final}(atm)
N_2	
H_2	
NH_3	

12

Step 5: Check the assumption made above using the "5% rule".

Is the assumption valid?

YES NO

6