FR Practice #1 (2011B #2, 9 points)

1. An 8.55 mol sample of methanol, CH_3OH, is placed in a 15.0 L evacuated rigid tank and heated to 327°C. At that temperature, all of the methanol is vaporized and some of the methanol decomposes to form carbon monoxide gas and hydrogen gas, as represented in the equation below.

$$CH_3OH(g) \rightleftharpoons CO(g) + H_2(g)$$

a. The reaction mixture contains 6.30 mol of CO(*g*) at equilibrium at 327°C.

i. Calculate the number of moles of $H_2(g)$ in the tank. (1 point)

ii. Calculate the number of grams of $CH_3OH(g)$ remaining in the tank. (1 point)

iii. Calculate the mole fraction of $H_2(g)$ in the tank. (2 points)

iv. Calculate the total pressure, in atm, in the tank at 327°C. (2 points)

b. Consider the three gases in the tank at 327°C: $CH_3OH(g)$, $CO(g)$, and $H_2(g)$.

i. How do the average kinetic energies of the molecules of the gases compare? Explain. (1 point)

ii. Which gas has the highest average molecular speed? Explain. (1 point)

c. The tank is cooled to 25°C, which is well below the boiling point of methanol. It is found that small amounts of $H_2(g)$ and $CO(g)$ have dissolved in the liquid CH_3OH. Which of the two gases would you expect to be more soluble in methanol at 25°C? Justify your answer. (1 point)

(a)(i) $6.30 \text{ mol CO} \times \frac{2 \text{ mol } H_2}{1 \text{ mol CO}} = \boxed{12.6 \text{ mol } H_2}$ (1 pt)

(ii) $6.30 \text{ mol CO} \times \frac{1 \text{ mol } CH_3OH}{1 \text{ mol CO}} = 6.30 \text{ mol } CH_3OH$ reacted

$8.55 \text{ mol } CH_3OH_i - 6.30 \text{ mol } CH_3OH_{reacted} = 2.25 \text{ mol } CH_3OH \times \frac{32.042 \text{ g } CH_3OH}{1 \text{ mol } CH_3OH}$

$= \boxed{72.1 \text{ g } CH_3OH}$ (1 pt)

(2 pt) (iii) $\frac{12.6 \text{ mol } H_2}{(2.25 \text{ mol} + 6.30 \text{ mol} + 12.6 \text{ mol})} = \frac{12.6}{21.15} = \boxed{0.596}$ (1 pt)

CH_3OH CO H_2 (1 pt)

(2 pt) (iv)

$P = \frac{nRT}{V} = \frac{(21.15 \text{ mol})(0.08206 \frac{L \cdot atm}{mol \cdot K})(600. K)}{15.0 \text{ L}} = \boxed{69.4 \text{ atm}}$ (1 pt)

(1 pt)

(b) (i) The average kinetic energies are the same b/c all three gases are at the same temperature. (1pt)

(ii) H_2 molecules have the highest average molecular speed, b/c $KE = \frac{1}{2}mv^2$ and thus at the same temperature molecules w/ the lowest mass have the highest average speed. (1pt)

(c) Non-polar H_2 molecules can only form weak dipole-induced dipole IMFs w/ CH_3OH. In contrast, polar CO molecules can form stronger dipole-dipole attractions w/ CH_3OH. Since CO forms stronger IMFs w/ CH_3OH than H_2, CO should be more soluble in CH_3OH than H_2. (1pt)