

PROBLEM SET 5

1) a) Find the equilibrium constant at 298 K for the reaction



b) Find the total pressure if 0.001 mol of PCl_5 is placed in a vessel with a volume of 20 L at 298 K and allowed to equilibrate. Assume ideal gas behavior.

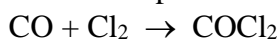
2) a) Find ΔH° , ΔG° and K_p at 298 K for $\text{I}_{2(g)} \rightarrow 2\text{I}_{(g)}$

b) Assume ΔH° constant find temperature at which $K_p=1$

c) Assume ΔH° constant find K_p at 1000 K.

d) Assume ΔC_p constant find K_p at 1000 K.

3) A certain gas mixture held at 395 K has the following initial pressures. $P(\text{Cl}_2) = 351.4$ torr, $P(\text{COCl}_2) = 0$. At equilibrium total pressure is 439.5 torr is held constant. Find K at 395 K for



4) For the ideal gas reaction $\text{PCl}_5 \rightarrow \text{PCl}_3 + \text{Cl}_{2(g)}$

State whether equilibrium shifts to the right or left when each of the following changes is made in an equilibrium mixture at 25 °C

a) T is decreased at constant P

b) V is decreased at constant T

c) Some PCl_5 is removed at constant T and V

d) $\text{He}_{(g)}$ is added at constant T and V

e) $\text{He}_{(g)}$ is added at constant T and P

5) For $2\text{CO}_{(g)} + \text{O}_{2(g)} \rightarrow 2\text{CO}_{2(g)}$ assume ideal gas behavior and $\Delta G^\circ_{298} = -514.382$ kJ/mol and ΔH°_T (kJ/mol) = $-565.968 + 0.0015(T-298) + 2.85 \cdot 10^{-6}(T^2-298^2) + 1448((1/T)-(1/298))$

Find an expression for $\ln K_p(T)$ and calculate K_p at 1000 K for this reaction.

6) Suppose 1.0 mol of CO_2 and 1.0 mol of COF_2 are placed in a very big vessel at 25°C and a catalyst for the gas phase reaction $2\text{COF}_2 \leftrightarrow \text{CO}_2 + \text{CF}_4$ is added. Find the equilibrium amounts. $\Delta G^\circ_{298} = -35$ kJ/mol

7) For the ideal gas reaction $\text{N}_2 + 3\text{H}_2 \leftrightarrow 2\text{NH}_3$ suppose 1 mol of N_2 and 3 mol of H_2 react at constant T and P, no other gases are present initially. Let x be the number of moles of N_2 that have reacted when equilibrium is reached. ($x = \epsilon_{\text{eq}}$)

Show that,

$$X = 1 - [1 - s/(s+4)]^{1/2}, \quad s = (27 K_p)^{1/2} P/P^*$$

8) Nitrogen trioxide dissociates according to the reaction



When one mole of $\text{N}_2\text{O}_{3(g)}$ is held at 25 °C and 1 bar total pressure until equilibrium is reached, the extent of reaction is 0.30. What is $\Delta_r G^\circ$ for this reaction at 25 °C?

9) Calculate the molar Gibbs energy of butane isomers for extents of reaction of 0.2, 0.4, 0.6 and 0.8 for the reaction **n-butane = isobutene** at 1000 K and 1 bar.

At 1000 K $\Delta_r G^\circ(\text{n-butane}) = 270$ kJ/mol, $\Delta_r G^\circ(\text{isobutene}) = 276.6$ kJ/mol

Make a plot and show that the minimum corresponds to the equilibrium extent of reaction.

10) At 250 °C, PCl_5 is 80 % dissociated at a pressure of 1.013 bar, and so $K=1.80$. What is the extent of reaction at equilibrium after sufficient nitrogen has been added at constant pressure to produce a nitrogen partial pressure of 0.9 bar? The total pressure is maintained at 1 bar.