Exercise 1: Equilibrium

Equilibrium calculations

1. 5.0 moles of ammonia are introduced into a 5.0 liter reactor vessel in which it partially dissociates at high temperatures: 
   \[
   2 \text{NH}_3 (g) \rightarrow 3 \text{H}_2 (g) + \text{N}_2 (g). 
   \]
   At equilibrium at 700°C, 1.0 moles of ammonia remains. Calculate \(K_c\) for the reaction.

2. Gaseous phosphorus pentachloride decomposes according to:
   \[
   \text{PCl}_5 (g) \rightarrow \text{PCl}_3 (g) + \text{Cl}_2 (g) 
   \]
   \(K_c\) for the reaction is \(1.00 \times 10^{-3}\) mol/L. Suppose 2.00 moles of phosphorus pentachloride in a 2.00 liter vessel is allowed to come to equilibrium. Calculate the equilibrium concentrations of all species.
3. For the reaction $\text{N}_2\text{O}_4 \rightarrow 2 \text{NO}_2$, $\Delta H_{\text{rxn}} = +58 \text{ kJ/mole}$. **Write** the equilibrium expression and, using that, predict the results (in terms of the direction the reaction will go) of the following changes to an equilibrium mixture of the reaction.

a) Addition of NO$_2$ (g)

b) Addition of He (g) (not a catalyst, nor does it react)

c) Decreasing the container volume

d) Increasing the temperature

e) Addition of a Ni (s) catalyst

4. An example of thermodynamics and kinetics from biochemistry: F$_{\text{ab}}$ is the variable part of the antibody molecule and it binds to a substrate, called a hapten. At 25°C, the dissociation constant of an F$_{\text{ab}}$–hapten complex is $3.0 \times 10^{-7}$.

The rate constant of the release of the hapten from the complex is $120 \text{ s}^{-1}$. What is the **rate constant** for the capture of the hapten molecule by F$_{\text{ab}}$?