Chemistry 2000 Spring 2001 Section B Assignment 1 Solutions

1.

$$\begin{aligned}
n_{\mathrm{KMnO_4}} &= \frac{8.0\,\mathrm{g}}{158.032\,\mathrm{g/mol}} = 0.051\,\mathrm{mol}.\\
m_{\mathrm{H_2O}} &= (250\,\mathrm{mL})(0.99823\,\mathrm{g/mL}) = 250\,\mathrm{g}.\\
\therefore n_{\mathrm{H_2O}} &= \frac{250\,\mathrm{g}}{18.015\,\mathrm{g/mol}} = 13.9\,\mathrm{mol}.\\
\therefore X_{\mathrm{K^+}} &= \frac{n_{\mathrm{K^+}}}{n_{\mathrm{H_2O}} + n_{\mathrm{K^+}} + n_{\mathrm{MnO_4^-}}} = \frac{0.051\,\mathrm{mol}}{13.9 + 0.051 + 0.051\,\mathrm{mol}} = 0.0036.
\end{aligned}$$

2. (a) Suppose that we take 1 L of this solution. This liter of solution contains 1.697 mol of acetone and weighs 0.9849 kg (from the concentration and density, respectively). The acetone weighs

$$m_{\mathrm{acetone}} = (1.697\,\mathrm{mol})(58.079\,\mathrm{g/mol}) = 98.56\,\mathrm{g}.$$

The water contained in our liter of solution therefore weighs

$$m_{\mathrm{water}} = 984.9 - 98.56\,\mathrm{g} = 886.3\,\mathrm{g}.$$

The molality is therefore

$$\tilde{c} = \frac{1.697\,\mathrm{mol}}{0.8863\,\mathrm{kg}} = 1.915\,\mathrm{mol/kg}.$$

(b) Consider again our liter of solution. We know how many moles of acetone it contains. The number of moles of water can be determined from the mass:

$$\begin{aligned}
n_{\mathrm{water}} &= \frac{886.3\,\mathrm{g}}{18.015\,\mathrm{g/mol}} = 49.20\,\mathrm{mol}.\\
\therefore X_{\mathrm{acetone}} &= \frac{1.697\,\mathrm{mol}}{1.697 + 49.20\,\mathrm{mol}} = 0.03334.
\end{aligned}$$

3. (a)

$$\frac{\Delta[\mathrm{A}]}{\Delta t} = \frac{0.382 - 0.400\,\mathrm{mol/L}}{0.32\,\mathrm{s}} = -0.056\,\mathrm{mol\,L^{-1}s^{-1}}.$$

(b)

$$\frac{\Delta[\mathrm{B}]}{\Delta t} = -2\frac{\Delta[\mathrm{A}]}{\Delta t} = 0.113\,\mathrm{mol\,L^{-1}s^{-1}}.$$

Notes: I am using Δ's instead of d's because these are average rates. However, it would not be wrong to use derivative notation. It's a matter of taste, and I'm not completely consistent about it myself. Also note that I got the answer to this question using more digits than are shown in my answer to question 3a. This is the correct procedure, even if the two numbers are then not quite in the stoichiometric ratio of 2:1. This is fine since the last significant figure shown in any calculation is supposed to be somewhat uncertain. (That's why we stop at that digit rather than some other.)

4. The rate law is assumed to be of a simple form, e.g. $dx/dt = kx^n$. If we increase x by a factor of 3, dx/dt increases by a factor of $9 = 3^2$. Therefore, the order of the reaction with respect to the reactant (n) is 2.

5. (a) Experiments 1, 2 and 3 were performed at identical nitrogen monoxide concentrations. The concentration of ozone was doubled from experiment 1 to experiment 2 and the rate increased by a factor of 2. Comparing experiments 1 and 3, the ratio of the ozone concentrations is 3 and the ratio of the rates is also 3. The rate is therefore proportional to the ozone concentration.

   Experiments 3, 4 and 5 were performed at identical ozone concentrations. The NO concentration was doubled in experiment 4 compared to experiment 3 and the rate doubled. Comparing experiments 3 and 5, we see that both the NO concentrations and rates are in ratios of 1:3. Thus, the rate is also proportional to the NO concentration.

   The rate law is therefore

$$\frac{d[\mathrm{NO_2}]}{dt} = k[\mathrm{NO}][\mathrm{O_3}].$$

   (b) I'll use data from experiment 1, but we could in principle use any of the data points:

$$\begin{aligned} k &= \frac{d[\mathrm{NO_2}]/dt}{[\mathrm{NO}][\mathrm{O_3}]} \\ &= \frac{66.0\times 10^{-6}\,\mathrm{mol\,L^{-1}s^{-1}}}{(1.00\times 10^{-6}\,\mathrm{mol/L})(3.00\times 10^{-6}\,\mathrm{mol/L})} \\ &= 2.20\times 10^{7}\,\mathrm{L\,mol^{-1}s^{-1}}. \end{aligned}$$

   Note that I got rid of the SI prefixes on the quantities appearing in this calculation to avoid getting an answer in awkward units ($22.0\,\mathrm{L}\,(\mu\mathrm{mol})^{-1}\mathrm{s}^{-1}$ or $22.0\,\mathrm{L}/\mu\mathrm{M}$). Strange units like these are sometimes useful, but it is generally considered bad style to have a prefix in the denominator of units in the SI system. The prefixes should really only be used as prefixes, i.e. at the beginning of a unit, whether it is a simple unit (g, mol, L, etc.) or a compound unit (such as $\mu\mathrm{mol\,L^{-1}s^{-1}}$).

(c)

$$\begin{aligned}
\frac{d[\mathrm{NO_2}]}{dt} &= k[\mathrm{NO}][\mathrm{O_3}] \\
&= (2.20\times 10^{7}\,\mathrm{L\,mol^{-1}s^{-1}})(1.30\times 10^{-6}\,\mathrm{mol/L})(5.00\times 10^{-6}\,\mathrm{mol/L}) \\
&= 143\,\mu\mathrm{mol\,L^{-1}s^{-1}}.
\end{aligned}$$