

Chemistry 2000 Spring 2006 Test 2

Time: 50 minutes

Total marks: 49

Aids allowed: Calculator

Instructions: Answer all questions in the booklets provided. You can answer the questions in any order, but make sure that your answers are clearly marked with the question number.

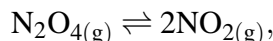
Useful data

$$\begin{aligned}c^\circ &= 1 \text{ mol/L} \\P^\circ &= 1 \text{ bar} \\ \text{At } 25^\circ\text{C}, K_w &= 10^{-14}.\end{aligned}$$

1. Suppose that you are titrating a solution of the weak base methylamine (CH_3NH_2) with hydrochloric acid. The pK_b of methylamine is 3.38. Would you expect the pH at the equivalence point to be above or below 7? Explain briefly. [3 marks]

Bonus: Draw a Lewis diagram of methylamine. Explain why it can act as a Lewis base.

2. For the reaction



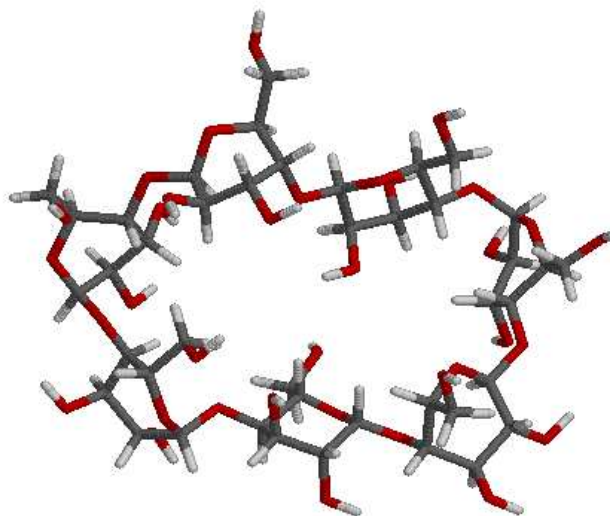
$K = 0.660$ at 319 K. Some NO_2 and N_2O_4 are introduced into a sealed container at the following pressures: $P_{\text{NO}_2} = 0.4 \text{ bar}$ and $P_{\text{N}_2\text{O}_4} = 0.5 \text{ bar}$. Is the reaction in equilibrium? If not, in what direction will the reaction proceed? [4 marks]

3. The K_{sp} of nickel (II) hydroxide is 6×10^{-18} at 25°C .
 - (a) Without doing any calculations, would the solubility of this compound be larger in a pH 4 or a pH 10 buffer? Explain briefly. [5 marks]
 - (b) Calculate the solubility of this compound in a pH 7 buffer. [7 marks]
4. Hydroselenic acid (H_2Se) has K_a 's of 1.3×10^{-4} and 1×10^{-11} at 25°C . What is the pH of a 0.12 mol/L solution of hydroselenic acid in water? [10 marks]

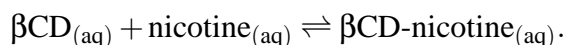
Bonus: When I originally set this question, I had picked an H_2Se concentration of $1.2 \times 10^{-4} \text{ mol/L}$, and then realized that this made the problem much harder. Why?

5. You have been asked to prepare about 500 mL of a pH 9 buffer. Your laboratory reagent shelf includes both ammonium chloride (53.49 g/mol) and 1.5 M ammonia solution. The pK_a of the ammonium ion is 9.3. How would you prepare this buffer? [10 marks]

6. As you no doubt know, smokers can be helped to quit by providing them with nicotine by alternative means. One popular class of products are nicotine-containing chewing gums. Unfortunately, while this is an excellent way to deliver nicotine to the body, nicotine tastes absolutely awful. Many popular nicotine gums also contain the sugar β -cyclodextrin (β CD), which has the following structure:



As you can see, there is a big hole in the middle of this molecule into which other molecules can bind. This is what happens to nicotine in the presence of β CD:



This keeps the nicotine away from the taste buds. The equilibrium constant for this reaction in water at 37°C is 194.¹ If 0.5 mg of nicotine (molar mass 162.23 g/mol) is dissolved in 1 mL of saliva with 50 mg β CD (molar mass 1134.98 g/mol), what percentage of the nicotine is free in solution? [10 marks]

Hint: Start by calculating the concentrations of the three chemical species in solution.

¹J. Szejtli and L. Szenté, *Eur. J. Pharmaceutics Biopharmaceutics* **61**, 115 (2005). This review article has the rather amusing title “Elimination of bitter, disgusting tastes of drugs and foods by cyclodextrins”.