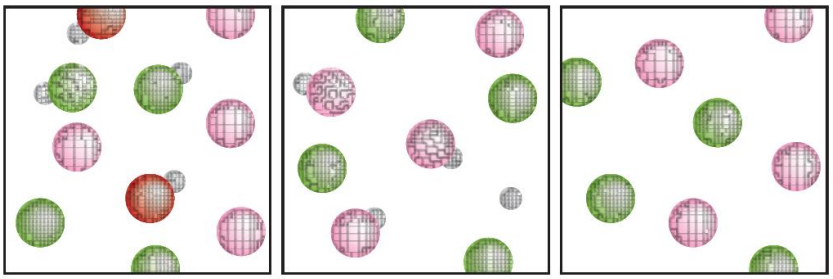
2023 Fall Chemistry 2

Assignment 2 (Atkins, Focus 6)

(Total 200 pt; Due 2023/11/1 Class)

1. The images below represent the solutes in the solutions of three salts (water molecules are not shown, hydrogen atoms and hydronium ions are represented by small gray spheres, hydroxide ions by red and gray spheres, cations by pink spheres, and anions by green spheres). (a) Which salt has a cation that is the conjugate acid of a weak base? (b) Which salt has an anion that is the conjugate base of a weak acid? (c) Which salt has an anion that is the conjugate base of a strong acid? Explain each of your answers. [15 pt]



(1) (2) (3)

2. Many reactions that take place in water have analogous reactions in liquid ammonia (normal boiling point, −33 °C). (a) Write the chemical equation for the autoprotolysis of NH_3. (b) Write the formulas of the acid and base species that result from the autoprotolysis of liquid ammonia. (c) The autoprotolysis constant, K_{am}, of liquid ammonia has the value 1×10^{-33} at −35 °C. What is the value of pK_{am} at that temperature? (d) What is the molar concentration of NH_4^+ 1 ions in liquid ammonia? (e) Evaluate pNH_4 and pNH_2, which are the analogs of pH and pOH, in liquid ammonia at −35 °C. (f) Derive the relation between pNH_4, pNH_2, and pK_{am}. [30 pt]

3. The Topic 6C discusses the relationship between molecular structure and the strengths of acids. The same ideas can be applied to bases. (a) Explain the relative strengths of the Brønsted bases OH^-, NH_2^-, and CH_3^- (see Table 6C.3). (b) Explain why NH_3 is a weak base in water, but PH_3 forms essentially neutral solutions. (c) If you were ranking the species in (a) or (b) as Lewis bases, would your rankings be the same or different? Explain your reasoning. [15 pt]

4. You require 0.150 L of a buffer solution with pH = 3.00. On the shelf is a bottle of trichloracetic acid/sodium trichloracetate buffer with pH = 2.95. The label also says [trichloracetate ion] = 0.200 mol• L^{-1}. What mass of which substance (trichloracetic acid or sodium trichloracetate) should you add to 0.150 L of the buffer to obtain the desired pH? [10 pt]

5. A sample of 0.150 M Na_2CO_3(aq) of volume 25.0 mL is titrated with 0.100 m HCl(aq). What is the pH of the solution at each stoichiometric point in the titration? [10 pt]

6. Consider the equilibria

   $ZnS(s) \leftrightarrow Zn^{2+}(aq) + S^{2-}(aq)$

$S^{2-}(aq) + H_2O(l) \leftrightarrow HS^-(aq) + OH^-(aq)$
$HS^-(aq) + H_2O(l) \leftrightarrow H_2S(aq) + OH^-(aq)$

(a) Write the chemical equation for the overall equilibrium and determine the corresponding equilibrium constant. (b) Evaluate the solubility of ZnS in a saturated H_2S solution, 0.1 M $H_2S(aq)$, adjusted to pH = 7.0. (c) Evaluate the solubility of ZnS in a saturated H_2S solution, 0.1 M $H_2S(aq)$, adjusted to pH = 10.0. [15 pt]

7. The pH of the blood is maintained by a buffering system consisting primarily of hydrogen carbonate ion (HCO_3^-) and H_3O^+ in equilibrium with water and CO_2:
$H_3O^+(aq) + HCO_3^-(aq) \leftrightarrow 2H_2O(l) + CO_2(g)$
During exercise, CO_2 is produced at a rapid rate in muscle tissue. (a) How does exercise affect the pH of blood? (b) Hyperventilation (rapid and deep breathing) can occur during intense exertion. How does hyperventilation affect the pH of the blood? (c) The normal first-aid treatment for hyperventilation is to have the patient breathe into a paper bag. Explain briefly why this treatment works and tell what effect the paper-bag treatment has on the pH of the blood. See Box 6G.1. [15 pt]

8. State how the oxidizing strength of each of the following oxidizing agents would be affected by raising the pH (stronger, weaker, or no change): (a) Br_2; (b) MnO_4^-; (c) NO_3^-; (d) ClO_4^-; (e) Cu^{2+}. Justify your answers. [25 pt]

9. Using data in Appendix 2B, calculate the standard potential for the half-reaction $Ti^{4+}(aq) + 4e^- \rightarrow Ti(s)$. [15 pt]

10. Cyclohexane Suppose that 35.0 mL of 0.012 M $Cu^+(aq)$ is titrated with 0.010 M KBr(aq) at 25 °C. A copper electrode is immersed in this solution, and its potential is measured relative to a standard hydrogen electrode. What volume of the KBr solution must be added to reach the stoichiometric point, and what will the potential be at that point? K_{sp} (CuBr) = 5.2×10^{-9}. [15 pt]

11. (a) What is the standard cell potential ($E_{cell}°$) for the reaction below at 298 K? (b) What is the standard cell potential for the reaction at 335 K? (c) What is the cell potential for the reaction at 335 K when $[Zn^{2+}] = 2.0 \times 10^{-4}$ mol• L^{-1} and $[Pb^{2+}] = 1.0$ mol• L^{-1} (See Exercise 6.59.)
$Pb^{2+}(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + Pb(s)$. [15 pt]

12. The entropy change of a cell reaction can be determined from the change of the cell potential with temperature. (a) Show that $\Delta S° = nF(E_{cell,2}° - E_{cell,1}°)/(T_2 - T_1)$. Assume that $\Delta S°$ and $\Delta H°$ are constant over the temperature range considered. (b) Calculate $\Delta S°$ and $\Delta H°$ for the cell reaction $Hg_2Cl_2(s) + H_2(g) \rightarrow 2Hg(l) + 2H^+(aq) + 2Cl^-(aq)$, given that $E°$ = +0.2699 V at 293 K and +0.2669 V at 303 K. [20 pt]