General Chemistry

1. A sample of PCl_5 weighing 2.69 g was placed in a 1.00-L flask and completely vaporized at a temperature of 250 °C. The total pressure observed at this temperature was 1.00 atm. The possibility exists that some of the PCl_5 may have dissociated according to

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

   What must be the final partial pressure of PCl_5, PCl_3 and Cl_2 under these experimental conditions? [6%]

2. Indicate which of the following statements regarding the kinetic theory of gasses are correct. For those that are false, formulate a correct version of the statement. [8%]
   (a) The average kinetic energy of a collection of gas molecules at a given temperature is proportional to $M^{1/2}$ (M = molar mass of the gas).
   (b) The gas molecules are assumed to exert no forces on each other.
   (c) All the molecules of a gas at a given temperature have the same kinetic energy.
   (d) The volume of the gas molecules is negligible in comparison to the total volume in which the gas is contained.

3. (a) Under what experimental conditions do gases usually behave nonideally? [2%]
   (b) What two properties or characteristics of gas molecules cause them to behave nonideally? [2%]

4. When 3.24 g of mercuric nitrate, $Hg(NO_3)_2$, are dissolved in 1000 g of water, the freezing point of the solution is found to be -0.0558 °C. When 10.85 g of mercuric chloride, $HgCl_2$, are dissolved in 1000 g of water, the freezing point of the solution is -0.0744 °C. The molal freezing-point depression constant for water is 1.86. Is either of these salts dissociated into ions in aqueous solutions? The atomic weight of Hg is 200.59. [5%]

5. Consider a solution saturated with $Ag_2SO_4(s)$ according to the equilibrium

$$Ag_2SO_4(s) \rightleftharpoons 2Ag^+(aq) + SO_4^{2-}(aq)$$

   How would the amount of solid $AgSO_4$ in equilibrium be affected by each of the following ? [4%]
   (a) Addition of more water
   (b) Addition of $AgNO_3(s)$
   (c) Addition of $NaNO_3(s)$
   (d) Addition of NaCl(s)　　(Hint: note that some AgCl may precipitate.)

6. Write down a closed-octet Lewis electron-dot diagram for each of the following. An acceptable diagram has the lowest-possible formal charges with closed octets. If resonance is involved, show one diagram and indicate how the other resonant forms would be diagrammed. The central atom is underlined in polyatomic molecules. [6%]
   (a) $\underline{Si}H_4$　　(b) $\underline{N}O_2^-$

7. Complete and balance the following reactions for the basic aqueous solution. [4%]
   (a) $Al + NO_3^- + OH^- \rightarrow Al(OH)_4^- + NH_3$
   (b) $Ag_2S(s) + CN^- + O_2(g) \rightarrow Ag(CN)_2^- + S(s)$
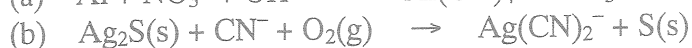
8. The slow oxidation of Fe^{2+} by dissolved O_2 has been found to follow the rate law

$$-\frac{d[Fe^{2+}]}{dt} = k[Fe^{2+}]^2 P(O_2)$$

   At 35 $^\circ$C and in 0.5 M $HClO_4$, $k = 3.7 \times 10^{-3}$ L mol^{-1} atm^{-1} h^{-1}. Assume a constant $P(O_2) = 0.2$ atm, calculate the half-life in days of a 0.10 M Fe^{2+} solution in 0.5 M $HClO_4$ that is exposed to air. [6%]

9. Explain why the effective nuclear charge experienced by a $3s$ electron in iron is greater than that for a $3d$ electron. [3%]

10. Write the electron configuration for (a) Ca (atomic number = 20) and (b) Ge (atomic number = 32) using the appropriate noble-gas inner core for abbreviation. [4%]

General Physics

11. Find the moments of inertia for the following objects with respect to an axis of rotation that passes its center.
    (1) A solid sphere of density ρ and radius R. [6%]
    (2) A thin spherical shell of radius R. [3%]

12. By writing down the corresponding governing equations, show that an analogy may be drawn between an electric circuit composed of a resistor, an inductor, and a capacitor in series and a mechanical system of a point mass connected to an elastic spring and a dashpot in series. [9%]

13. Explain the terms "transverse wave" and "longitudinal wave". Draw corresponding diagrams showing the motions of atoms in a crystal that are consistent with transverse and longitudinal sound waves, respectively. [12%]

14. Explain the terms "linear polarization" and "circular polarization" of light. How may these be achieved experimentally? [12%]

15. Explain the term "birefringence". [8%]