Midterm Exam – AP Chemistry

1. The first step in the production of high purity silicon for semiconductors is represented by this equation.

$$\mathbf{SiO_2(s) + 2C(s) \rightarrow Si(s) + 2CO(g) \qquad \Delta H° = +689.9\ kJ}$$

   a. Calculate $\Delta H_f°$ for SiO_2. Given: $\Delta H_f°$ for CO = -110.5 kJ/mol
   b. Find ΔS_{rxn} for the production of pure silicon. Given: S° for C = 5.7 $JK^{-1}mol^{-1}$, for CO is 197.6$JK^{-1}mol^{-1}$, for Si = 18.8 $JK^{-1}mol^{-1}$, and for SiO_2 = 41.8 $JK^{-1}mol^{-1}$
   c. Determine ΔG° for the reaction at 25°C.
   d. Find the minimum temperature in °C at which this reaction is spontaneous. Assume that ΔH° and ΔS° do not vary with temperature

2. A certain element, **X**, forms the fluorides **X**F_3 and **X**F_5. Element **X** also reacts with sodium to form Na_3**X**.
   a. Give the symbol of an element that behaves in this way.
   b. For both **X**F_3 and **X**F_5:
      i. write Lewis electron dot structures.
      ii. describe the electron pair and molecular geometries.
      iii. give the hybridization of the **X** atom.
   c. The bonds in **X**F_5 are not all the same length. Identify the longer bonds and account for this behavior.
   d. Another element, **Y**, in the same family as **X**, forms **Y**F_3 but not **Y**F_5. Identify element **Y** and account for its inability to form **Y**F_5.

3. Account for each observation with appropriate atomic and molecular properties.
   a. Carbon dioxide has a higher vapor pressure than sulfur dioxide at the same temperature.
   b. Hydrogen chloride has a lower normal boiling point than either hydrogen fluoride or hydrogen bromide.
   c. Calcium oxide has a much higher melting point (2580°C) than potassium fluoride (858°C).
   d. Tin (II) chloride is an ionic compound (mp = 240°C) while tin (IV) chloride is a covalent compound (bp = 114°C)
   e. Magnesium exists as +2 ions rather than +1 ions in all of its compounds despite the fact that the second ionization energy of a magnesium atom is more than twice as great as the first ionization energy.
   f. Titanium forms ions with different charges (+2, +3, and +4). The first two of these ions are colored while the last is colorless.

4. 0.1152 g of a compound containing carbon, hydrogen, nitrogen, and oxygen are burned in excess oxygen. The gases produced are treated further to convert nitrogen-containing products into N_2. The resulting mixture of CO_2, H_2O and N_2 and excess O_2 is passed through a $CaCl_2$ drying tube, which gains 0.09912 g. The gas stream is bubbled through water where the CO_2 forms H_2CO_3. Titration of this solution to the second endpoint with 0.3283 M NaOH requires 28.81 mL. The excess O_2 is removed by reaction with copper metal and the N_2 is collected in a 225.0 mL measuring bulb where it exerts a pressure of 65.12 mmHg at 25°C. In a separate experiment, the molar mass of this compound is found to be approximately 150 g/mol.
   a. Calculate the number of moles of
      i. H_2O
      ii. CO_2
      iii. N_2
   b. Determine the mass in the original compound of
      i. C
      ii. H
      iii. N
      iv. O
   c. Find the empirical formula of the compound.
   d. Find the molecular formula.

5. Answer the following problems about gases.
   a. The average atomic mass of naturally occurring neon is 20.18 amu. There are two common isotopes of naturally occurring neon as indicated in the table below.

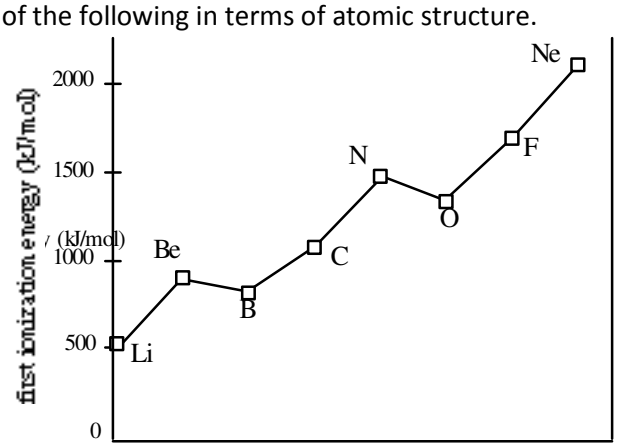
Isotope	Mass (amu)
Ne-20	19.99
Ne-22	21.99

      i. Using the information above, calculate the percent abundance of each isotope.
      ii. Calculate the number of Ne-22 atoms in a 12.55 g sample of naturally occurring neon.
   b. A major line in the emission spectrum of neon corresponds to a frequency of $4.34 \times 10^{14}\ s^{-1}$. Calculate the wavelength, in nanometers, of light that corresponds to this line.
   c. In the upper atmosphere, ozone molecules decomposed as they absorb ultraviolet (UV) radiation, as shown by the equation below. Ozone serves to block harmful ultraviolet radiation that comes from the Sun.

$$\mathbf{O_3(g) \xrightarrow{UV} O_2(g) + O(g)}$$

   A molecule of $O_3(g)$ absorbs a photon with a frequency of $1.00 \times 10^{15}\ s^{-1}$.
      i. How much energy, in joules, does the $O_3(g)$ molecule absorb per photon?
      ii. The minimum energy needed to break an oxygen-oxygen bond in ozone is 387 kJ/mol. Does a photon with a frequency of $1.00 \times 10^{15}\ s^{-1}$ have enough energy to break this bond? Support your answer with a calculation.

6. The diagram shows the first ionization energies for the elements from Li to Ne. Briefly (in one to three sentences) explain each of the following in terms of atomic structure.



   a. In general, there is an increase in the first ionization energy from Li to Ne.
   b. The first ionization energy of B is lower than that of Be.
   c. The first ionization energy of O is lower than that of N.
   d. Predict how the first ionization energy of Na compares to those of Li and of Ne. Explain.

7. Molecular geometries of carbon/oxygen compounds and polyatomic ions.
   a. Draw the Lewis electron-dot structures for CO_3^{2-}, CO_2, and CO, including resonance structures where appropriate.
   b. Which of the three species has the shortest C-O bond length? Explain the reason for your answer.
   c. Predict the molecular shapes for the three species. Explain how you arrived at your predictions.

8. The melting points of alkali metals decrease from Li to Cs. In contrast, the melting points of the halogens increase from F_2 to I_2.
   a. Using bonding principles, account for the decrease in the melting points of the alkali metals.
   b. Using bonding principles, account for the increase in the melting points of the halogens.
   c. What is the expected trend in the melting points of the compounds LiF, NaCl, KBr, and CsI? Explain this trend using bonding principles.

9. Answer the following questions regarding light and its interactions with molecules, atoms, and ions.
    a. The longest wavelength of light with enough energy to break the Cl-Cl bond in Cl_2 is 495 nm.
        i. Calculate the frequency, in s^{-1}, of the light.
        ii. Calculate the energy, in J, of a photon of the light.
        iii. Calculate the minimum energy, in kJ/mol, of the Cl-Cl bond.
    b. A certain line in the spectrum of atomic hydrogen is associated with the electronic transition of the H atom from the sixth energy level to the second energy level.
        i. Indicate whether the H atom emits energy or whether it absorbs energy during the transition. Justify your answer.
        ii. Calculate the wavelength, in nm, of the radiation associated with the spectral line.
        iii. Account for the observation that the amount of energy associated with the same electronic transition (n = 6 to n = 2) in the He^+ ion is greater than that associated with the corresponding transition in the H atom.

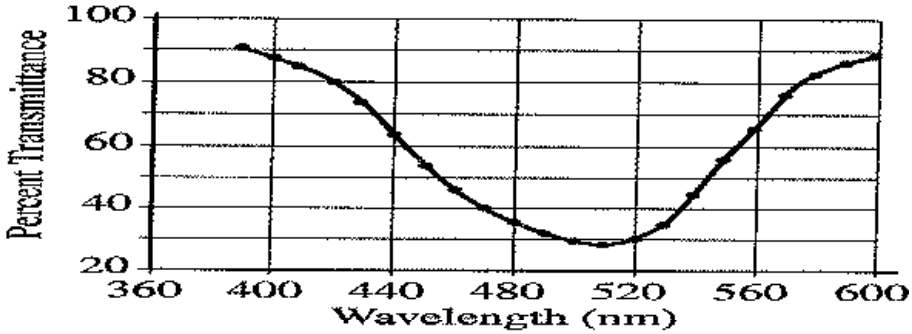
10. In a laboratory determination of the atomic weight of tin, a sample of tin is weighed in a crucible. Nitric acid is added, and the reaction proceeds to give a hydrate tin (IV) oxide plus NO_2 and H_2O. The hydrated tin (IV) oxide is then heated strong and reacts as follows: $\mathbf{SnO_2 \cdot xH_2O(s) \rightarrow SnO_2(s) + xH_2O(g)}$
    The SnO_2 is finally cooled and weighed in the crucible. Explain the effect on the calculated atomic weight of tin that would result from each of the following experimental errors:
    a. Considerable spattering occurs when the nitric acid is added to the tin.
    b. The hydrated tin (IV) oxide is not heated sufficiently to change it completely to tin oxide.

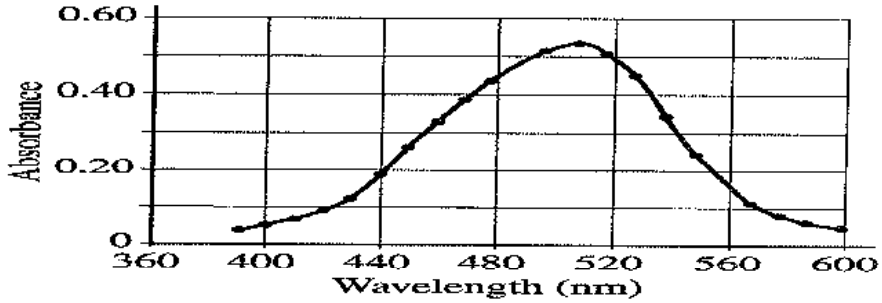
11. Suppose that a stable element with atomic number 119, symbol Q, has been discovered.
    a. Write the ground-state electron configuration for Q.
    b. Would Q be a metal or a nonmetal? Explain in terms of electron configuration.
    c. On the basis of periodic trends, would Q have the largest atomic radius in its group or would it have the smallest? Explain in terms of electronic structure.
    d. What would be the most likely charge of the Q ion in stable ionic compounds?
    e. Write a balanced equation that would represent the reaction of Q with water.
    f. Assume that Q reacts to form a carbonate compound.
        i. Write the formula for the compound formed between Q and the carbonate ion.
        ii. Predict whether or not the compound would be soluble in water. Explain your reasoning.

12. For each of the following reactions, write a balanced equation for the reaction. Coefficients should be in terms of lowest whole numbers. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solutions as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction.
    a. Solid potassium chlorate is strongly heated.
    b. Zinc metal is placed in a solution of copper (II) sulfate.
    c. A solution of nickel (II) bromide is added to a solution of potassium hydroxide.
    d. A 0.1 M nitrous acid solution is added to the same volume of a 0.1 M sodium hydroxide solution.
    e. Solid zinc carbonate is added to 1.0 M sulfuric acid.
    f. Excess carbon dioxide is bubbled through a solution of calcium hydroxide.
    g. Hydrogen sulfide gas is bubbled through a solution of lead (II) nitrate.
    h. Powder magnesium oxide is added to a container of carbon dioxide gas.

13. A student is instructed to determine the concentration of a solution of $CoCl_2$ based on absorption of light (spectrometric/colorimetric method). The student is provided with a 0.10 M solution of $CoCl_2$ with which to prepare standard solutions with concentrations of 0.020 M, 0.040 M, 0.060 M, and 0.080 M.
    a. Describe the procedure for diluting the 0.10 M solutions to a concentration of 0.020 M using distilled water, a 100 mL volumetric flask, and a pipet or buret. Include specific amounts where appropriate.

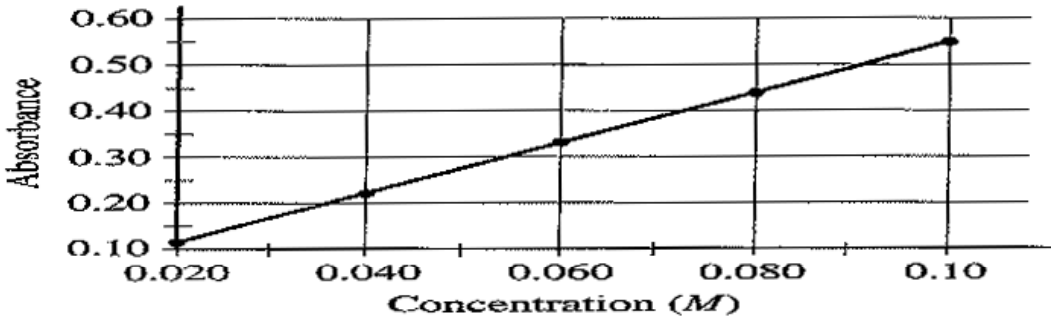
The student takes the 0.10 M solution and determines the percent transmittance and the absorbance at various wavelengths. The two graphs below represent the data.





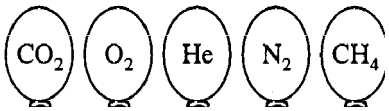
b. Identify the optimum wavelength for the analysis.

The student measures the absorbance of the 0.020 M, 0.040 M, 0.060 M, 0.080 M, and 0.10 M solutions. The data are plotted below.



c. The absorbance of the unknown solution is 0.275. What is the concentration of the solution?
d. Beer's Law is an expression that includes three factors that determine the amount of light that passes through a solution. Identify two of these factors.
e. The student handles the sample container that holds the unknown solution and leaves fingerprints in the path of the light beam. How will this affect the calculated concentration of the unknown? Explain your answer.
f. Why is this method of determining the concentration of $CoCl_2$ solution appropriate, whereas using the same method for measuring the concentration of NaCl solution would not be appropriate?

14. Represented to the right are five identical balloons each filled to the same volume at 25°C and 1.0 atmosphere pressure with the pure gases indicated.



a. Which balloon contains the greatest mass of gas? Explain.
b. Compare the average kinetic energies of the gas molecules in the balloons. Explain.
c. Which balloon contains the gas that would be expected to deviate most from the behavior of an ideal gas?
d. Twelve hours after being filled, all the balloons have decreased in size. Predict which balloon will be the smallest. Explain your reasoning.