This exam adds up to a total of 91 points. It will be scaled to 100 points for your final grade.

**Part I. Matching.**
1. For each term on the left, enter the letter of the matching definition from the right-hand column. **Use each item only once.** There is only one possible way to correctly match all the items using each one only once. (7 pts)

   i. Isomers **F**  
      a. A substance containing more than one element which can be broken into other substances by a chemical change.

   ii. Isotopes **F**  
      b. Organic compounds which only contain the elements carbon and hydrogen.

   iii. Hydrocarbons **B**  
      c. A substance which is uniform at any scale and which can be broken into other substances by a physical change.

   iv. Homogeneous mixture **C**  
      d. A type of compound that contains metals combined with nonmetals.

   v. Compound **A**  
      e. Compounds that have the same chemical formula but with the atoms arranged differently.

   vi. Inorganic substance **G**  
      f. Atoms of the same element that contain different numbers of neutrons.

   vii. Ionic substance **D**  
      g. A type of compound that is based or elements other than carbon and hydrogen.

**Part II. Multiple choice questions.** Circle the letter of the correct answer for each of the following questions. Do not skip any questions. If you don’t know the answer, you are better off guessing than leaving it blank. (4 pts each)

2. Which of the following substances is **not** an ionic compound?
   - a. LiCl
   - b. LiBr
   - c. NH₄Cl
   - d. (NH₄)₂SO₄
   - e. CoSO₄

3. Which of the following conversion factors is **correct**?
   a. 1 g = 1000 kg  
   b. 1 kg = 1 x 10⁻³ g  
   c. 1 cm = 1 x 10⁻³ m  
   d. 1 m = 0.01 cm  
   e. 1 mg = 0.01 g

4. Which of the following calculations should have 3 significant figures in the final answer?
   a. 2.356 + 3.868  
   b. 2.356 x 3.868  
   c. (2.356 - 2.350) / 1.000  
   d. (2.356 - 1.125) / 1.000  
   e. (2.356 - 1.125) / 1.000

5. Which one of the following substances is a transition metal?
   a. K  
   b. Ca  
   c. Cr  
   d. Ge  
   e. Kr
6. Which of the following describes a heterogeneous mixture?
   a. salt water (sodium chloride dissolved in water)
   b. mud (degraded plant and animal matter in water)
   c. lead pellets (small spheres of Pb)
   d. sugar (sucrose, C₁₂H₂₂O₁₁)
   e. vodka (ethanol, C₂H₅O, in water)

7. Which of the following terms does NOT correctly describe the element xenon (Xe)?
   a. noble gas
   b. group 8A element
   c. 5th period element
   d. nonmetal
   e. lanthanide

8. Which of the following is the correct formula for the nitrate ion?
   a. NO₃⁻
   b. NO₂⁻
   c. NO₂⁺
   d. NO₃⁺
   e. NO³⁻

9. Which of the following formulas represents butane?
   a. CH₄
   b. C₂H₆
   c. C₃H₈
   d. C₄H₁₀
   e. C₅H₁₂

10. Which of the following elements is a halogen?
    a. Na
    b. Ra
    c. Mn
    d. O
    e. Cl

11. Which of the following is the correct symbol for a ruthenium atom with 57 neutrons?
    a. ⁷⁷Ru
    b. ⁷⁸Ru
    c. ⁷⁹Ru
    d. ⁸⁰Ru
    e. ⁸₁Ru

12. What is the systematic name for the compound KClO₃?
    a. Potassium perchlorate
    b. potassium chloride
    c. calcium chloride
    d. potassium chloride oxide
    e. calcium monochloride oxide

13. What is the correct formula for the compound rubidium sulfate?
    a. RuSO₄
    b. Rb₂SO₄
    c. Rb₂SO₃
    d. Rb₂S
    e. Rb₂S

14. Rutherford's gold foil experiment was important because it showed that:
    a. Atoms contain neutral particles called neutrons in the nucleus.
    b. The smallest piece of an element is a particle called an atom.
    c. Atoms contain small, negatively charged particles called electrons.
    d. Atoms have a small central nucleus which contains all of the positive charge in the atom.
    e. The type of radiation known as beta particles is actually high energy electrons.
Part III. Longer answer questions. Answer the following questions in the space provided. Show all work for numerical problems, and report answers with the correct number of digits and units. Please circle your final answers. If you do not know an earlier answer that you need in order to do the later parts of a problem, make up an answer to use in the later parts, and clearly note on your test that this is what you’ve done.

15. A compound used to generate \( \text{O}_2 \) gas in the laboratory has a mass composition of 31.91% K, 28.93% Cl, with the remainder being oxygen.  

a. Determine the empirical formula of the compound. (6 pts)  
\[
\text{\% K} = \frac{31.91}{100} = 0.3191 \quad \text{\% Cl} = \frac{28.93}{100} = 0.2893 \quad \text{\% O} = 1 - 0.3191 - 0.2893 = 0.4\,\text{mol K} \\
\quad = 0.4162 \quad \text{mol Cl} = 0.4160 \quad \text{mol O} = 1.0002 \quad \text{= 1} \\
\]
\[
\frac{1}{35.452 \, \text{g mol}^{-1}} = 0.0284 \quad \text{g mol}^{-1} = 0.0284 \quad \text{g mol}^{-1} = 3.000 \\
\]
\( \text{empirical formula is: } [\text{KClO}_3] \)

b. The molar mass of the compound in part a is 122.55 g/mol. Determine the molecular formula of the compound. (3 pts)  
\[
\text{empirical formula mass} = 1(39.098) + 1(35.453) + 3(14.999) = 122.548 \, \text{g mol}^{-1} \\
\text{molar mass} = 122.548 \, \text{g mol}^{-1} \\
\text{molar mass} \times \text{empirical formula mass} \times 1 = 1050.30 \, \text{g mole}^{-1} \\
\text{molecular formula is: } [\text{KClO}_3] \\
\]

16. Epsom salts consist of magnesium sulfate heptahydrate (\( \text{MgSO}_4 \cdot 7\,\text{H}_2\text{O} \)). How many atoms of magnesium are in 2.00 g of Epsom salts? (6 pts)  
\[
\text{mass of Epsom salts} = 2.00 \, \text{g} \\
\text{molar mass of Epsom salts} = 246.471 \, \text{g mol}^{-1} \\
\text{molar mass of Mg} = 24.305 \, \text{g mol}^{-1} \\
\text{molar mass of \( \text{H}_2\text{O} \)} = 18.015 \, \text{g mol}^{-1} \\
\text{mass of Mg in 2.00 g of Epsom salts} = \frac{2.00 \times 24.305}{246.471} = 0.207 \, \text{g} \\
\text{number of \text{Mg} atoms in 2.00 g of Epsom salts} = \frac{0.207}{24.305} = 8.56 \times 10^{-3} \, \text{mol} \\
\]
\( \text{empirical formula mass} = 0.0831 \, \text{g} \)
17. Fill in the blanks.
a. One atom of molybdenum-95 contains \(42\) protons, \(53\) neutrons, and \(42\) electrons, and it has a mass number of \(95\). (3 pts)

b. Mo forms the Mo(II) cation. This cation has a charge of \(-2\) and it contains \(2\) electrons than a neutral molybdenum atom, giving it a total of \(42\) protons, \(53\) neutrons, and \(40\) electrons. (4 pts)

c. The element selenium forms ions with a charge of \(-2\). The formula for molybdenum(II) selenide is \(MoSe_2\). (4 pts)

18. The density of a sulfuric acid solution is 1.285 g/ml, and it is 38.08% sulfuric acid by mass (the rest is water). What volume of the acid solution (in mL) should you measure out if you need 5.50 \(\times\) 10\(^{-3}\) mg of sulfuric acid for a reaction? (6 pts)

\[
D_{\text{mol}} = \frac{1.285 \text{ g/mL}}{100 \text{ g/mol}} = 1.285 \text{ g/mol}
\]

\[
5.50 \times 10^{-3} \text{ g acid} \times \frac{1 \text{ mL acid}}{1.285 \text{ g acid}} = 4.28 \text{ mL acid needed}
\]

\[
5.50 \times 10^{-3} \text{ g acid} = 0.360 \text{ (mass soln. needed)}
\]

\[
\text{mass soln. needed} = 1.44 \text{ g}
\]

\[
D_{\text{mol}} = \frac{1.44 \text{ g soln.}}{1 \text{ mL soln.}} = \frac{1.285 \text{ g/mL}}{4 \text{ mL soln.}} = 3.28 \text{ g/L}
\]

19. **BONUS** (5 pts) At 25°C the density of liquid water is 0.997 g/cm\(^3\) and at -10°C the density of ice is 0.917 g/cm\(^3\). If a plastic soft drink bottle (volume = 250.0 mL) is filled with pure water at 25°C, capped, and then frozen at -10°C, what volume will the ice occupy? Assume that the plastic bottle is slightly stretchy so that it can expand or contract during the freezing process, if necessary.

\[
D_w = 0.997 \text{ g/cm}^3 \quad D_i = 0.917 \text{ g/cm}^3 \quad V = 250.0 \text{ mL} = 250.0 \text{ cm}^3
\]

Mass will not change when frozen, so calculate at 25°C and use this to calculate at -10°C.

\[
V = \frac{250.0 \text{ cm}^3 \times (0.997 \text{ g/cm}^3)}{1 \text{ cm}^3} = 249.25 \text{ g}
\]

\[
249.25 \text{ g} \times \frac{1 \text{ cm}^3}{0.917 \text{ g}} = 271.41 \text{ cm}^3 \text{ occupied by ice = 272 mL}
\]