GREETINGS JUNIORS!

Welcome to your first year at the Governor's School! I look forward to meeting everyone when the new school year begins. To start preparing everyone for what will be a rigorous college level chemistry curriculum, I have prepared a summer assignment that focuses on the skills that are essential for success in a college-level general chemistry course. You will not need a textbook for any of these problems. With resources readily available at your home, local library, and the internet, I am confident that you will be able to complete this assignment and prepare for the upcoming school year.

Additionally, you will need the following supplies for chemistry class:

- A scientific calculator (please familiarize yourself with the calculator you will be bringing to class)
- Pens/pencils
- Paper
- A binder to keep notes and other class handouts in

You will find that much of the material in this assignment is already familiar to you. If you encounter something in this assignment that is unfamiliar to you, do not worry! We will be going over everything in this packet during the first few weeks of your first semester at the Governor's School. I highly encourage you to take your time with this summer assignment and to complete all sections by the first week of school. If you consistently work on this assignment, you can potentially complete the entire packet in approximately five days.

Have a great summer, and I look forward to meeting everyone in at the start of the school year!

Dr. Alexis Patanarut ("Dr. P")
patanaa@pwcs.edu

DAY 1 TOPICS
Chemistry Theory and Concepts, Significant Figures, and Dimensional Analysis

Instructions. Work on the following problems as a review/refresher activity of concepts specified for Day 1 of this assignment. You may show your work on separate sheets of paper. You may use any resources you have, including study guides, textbooks, and the internet.

PASSAGE 1: Chemical Principles and Classification

A coastal research team is studying the chemical processes affecting seawater and surrounding ecosystems. During their investigation, they observe that seawater contains dissolved salts, gases, and organic materials distributed uniformly at the macroscopic level. However, sediment collected from the ocean floor contains visibly distinct components such as sand, organic debris, and mineral fragments. The researchers note that the composition of seawater remains relatively constant over time, even though individual components may be added or removed through natural processes such as evaporation and precipitation. They cite the principle that matter is neither created nor destroyed in chemical reactions when explaining how dissolved salts remain in balance.

In a separate experiment, the team investigates copper oxides formed under different oxygen conditions. They find that one sample contains a higher ratio of copper to oxygen compared to another. This observation supports the idea that elements can combine in multiple fixed ratios to form different compounds. The team also examines various processes occurring in the marine environment. Some changes, such as the freezing of seawater and mechanical erosion of rocks, do not alter chemical composition. Others, such as the corrosion of metal structures and the metabolic digestion of organic matter by marine organisms, involve chemical transformations. Finally, the researchers classify substances found in their samples. Pure copper is identified as a substance composed of only one type of atom, whereas copper oxide consists of chemically bonded elements. Seawater is characterized as a homogeneous mixture, while ocean sediment is heterogeneous.

Questions (Based on passage 1)

1. Which of the following statements in the passage is best classified as a scientific LAW?
    a. Seawater contains dissolved salts and gases
    b. Matter is neither created nor destroyed in reactions
    c. Copper oxides form under different conditions
    d. Ocean sediments contain multiple components

2. The observation that copper forms multiple oxides supports which principle?
    a. Law of conservation of mass
    b. Law of multiple proportions
    c. Atomic theory
    d. Law of definite composition

3. Which of the following processes described in the passage is a PHYSICAL change?
    a. Corrosion of metal structures
    b. Digestion of organic matter
    c. Freezing of seawater
    d. Formation of copper oxide

4. Seawater is best classified as which of the following?
    a. Element
    b. Compound
    c. Homogenous mixture
    d. Heterogenous mixture

5. Which of the following terms best describes copper metal in the passage?
    a. Compound
    b. Mixture
    c. Element
    d. Solution

6. Which statement about properties is correct based on general chemical principles?
    a. Density depends on the amount of substance
    b. Volume is an intensive property
    c. Energy is an extensive property
    d. Temperature depends on sample size

7. The difference between an element and a compound is that:
    a. Compounds are always homogeneous
    b. Elements contain only one type of atom
    c. Compounds cannot be separated chemically
    d. Elements contain multiple bonded atoms

8. Which of the following is an example of a chemical process mentioned or implied in the passage?
    a. Crushing sediment
    b. Freezing seawater
    c. Corrosion of metals
    d. Sorting sand particles

9. The uniform composition of seawater suggests it is most like a:
    a. Colloid
    b. Heterogeneous mixture
    c. True solution
    d. Suspension

10. Which statement is NOT always true?
    a. Compounds have fixed ratios of elements
    b. Empirical formulas are always identical to molecular formulas
    c. Matter is conserved in reactions
    d. Elements combine in whole-number ratios

🧪 PASSAGE 2: Quantitative Skills in Chemistry

A materials science laboratory is analyzing a cylindrical silicon rod used in semiconductor manufacturing. The rod has a length of 21.3 cm and a mass of 5.00 kg. Silicon has a known density of 2.33 g/cm^3. To evaluate laboratory precision, researchers emphasize the importance of significant figures when reporting measurements and calculations. They note that trailing zeros after a decimal point often indicate measured precision, while leading zeros do not. The scientists also perform unit conversions using dimensional analysis. For example, distances are converted between metric and imperial units, and large or small quantities are expressed in scientific notation to simplify calculations.

In one experiment, atmospheric conditions are monitored. The pressure is recorded as 6.75 atm and later converted into other units such as millimeters of mercury and pascals. Temperature measurements are also converted from Celsius to Kelvin and Fahrenheit to ensure consistency across datasets. Finally, the team evaluates measurement types. Some properties, such as volume and total energy, depend on the size of the sample, while others, such as density and temperature, remain constant regardless of sample size.

Questions (Based on passage 2)

1. What is the volume of the silicon rod?
   a. 2.15×10^3 cm^3
   b. 2.15×10^2 cm^3
   c. 4.65×10^3 cm^3
   d. 1.17×10^3 cm^3

2. Based on the cylinder equation, the diameter of the rod is closest to:
   a. 2 cm
   b. 5 cm
   c. 11 cm
   d. 20 cm

3. Which measurement contains 4 significant figures?
   a. 0.001
   b. 100
   c. 0.0101
   d. 6.022×10^{23}

4. Which value is written correctly in scientific notation?
   a. $0.0000721 = 7.21 \times 10^{-6}$
   b. $350{,}000{,}000 = 3.5 \times 10^7$
   c. $765{,}400{,}000{,}000 = 7.654 \times 10^{11}$
   d. $0.0000000809 = 8.09 \times 10^{-10}$

5. A pressure of 6.75 atm is approximately equal to:
   a. 5,130 mm Hg
   b. 4,050 mm Hg
   c. 5,700 mm Hg
   d. 6,750 mm Hg

6. Which of the following is an extensive property?
   a. Density
   b. Temperature
   c. Volume
   d. Pressure

7. What is 55°C in Kelvin?
   a. 228 K
   b. 273 K
   c. 328 K
   d. 350 K

8. Which of the following best explains why scientific notation is useful?
   a. It increases measurement accuracy
   b. It simplifies handling very large or small numbers
   c. It eliminates unit conversions
   d. It reduces experimental error

9. The value 0.030100 kJ contains how many significant figures?
    a. 3
    b. 4
    c. 5
    d. 6

10. Which of the following best describes dimensional analysis?
    a. Estimating values without calculation
    b. Using units as conversion factors to solve problems
    c. Ignoring units in calculations
    d. Rounding numbers to correct precision

DAY 2 TOPICS
Chemistry Equations, Formulas, and Nomenclature

Instructions. Work on the following problems as a review/refresher activity of concepts specified for Day 2 of this assignment. You may show your work on separate sheets of paper. You may use any resources you have, including study guides, textbooks, and the internet.

PASSAGE 3: Chemical Nomenclature and Classification

A pharmaceutical company is developing new compounds for use in imaging agents. During synthesis, chemists must carefully distinguish between elements, ions, and compounds, as well as correctly name and classify substances. In one experiment, sodium metal reacts with chlorine gas to form a crystalline solid composed of oppositely charged ions. The scientists note that chlorine gas (Cl_2) consists of neutral atoms bonded together, whereas chloride ions (Cl^-) form when chlorine gains an electron. Similarly, a sodium atom becomes a sodium ion when it loses an electron, forming Na^+.

The chemists also prepare several ionic compounds, including calcium sulfate, ammonium phosphate, and zinc sulfide. These substances differ from molecular compounds such as carbon dioxide (CO_2) and methane (CH_4), which are formed by covalent bonding between nonmetals. During analysis, compounds are classified based on their composition and bonding. Ionic compounds typically consist of metals and nonmetals, while molecular compounds involve only nonmetals. Some substances, such as elemental fluorine (F_2) and oxygen (O_2), exist naturally as diatomic molecules.

The researchers also consider acids, bases, and salts in solution chemistry. Acids are defined as proton donors, bases as proton acceptors, and salts as ionic compounds formed from acid–base reactions. Understanding these distinctions allows chemists to predict chemical behavior and reactivity.

Questions (Based on passage 3)

1. Which statement best explains the difference between chlorine and chloride?
    a. Chlorine is ionic, while chloride is covalent
    b. Chlorine is neutral, while chloride carries a negative charge
    c. Chlorine contains protons, chloride does not
    d. Chlorine is a compound, chloride is an element

2. Sodium becomes a cation because it:
   a. Gains electrons
   b. Gains protons
   c. Loses electrons
   d. Loses neutrons

3. Which of the following is most likely the formula for calcium sulfate?
   a. $CaSO_3$
   b. $CaSO_4$
   c. Ca_2S
   d. CaS_2

4. Which compound listed in the passage is a molecular compound?
   a. Zinc sulfide
   b. Sodium chloride
   c. Carbon dioxide
   d. Calcium sulfate

5. Which of the following is classified as a diatomic element?
   a. CO_2
   b. NaCl
   c. O_2
   d. CH_4

6. Which compound is ionic?
   a. CH_4
   b. CO_2
   c. ZnS
   d. CCl_4

7. A substance that donates H^+ in solution is a:
   a. Base
   b. Salt
   c. Acid
   d. Metal

8. Which of the following best describes ammonium phosphate?
   a. Molecular compound
   b. Ionic compound with a polyatomic ion
   c. Diatomic element
   d. Metallic solid

9. Which classification best fits NaCl?
   a. Element
   b. Molecular compound
   c. Ionic compound
   d. Mixture

10. Which set correctly pairs symbol and name?
    a. Na – Nitrogen
    b. Fe – Fluorine
    c. Au – Gold
    d. K – Krypton

PASSAGE 4: Chemical Equations and Quantitative Chemistry

A chemical manufacturing plant produces ammonia (NH_3) using nitrogen and hydrogen gases in a process that requires precise balancing of chemical equations and careful stoichiometric calculations. Engineers must also analyze reaction yields and determine empirical and molecular formulas of compounds formed during production. In one reaction, nitrogen gas reacts with hydrogen gas to form ammonia. In another process, calcium carbide reacts with water

to produce acetylene gas (C_2H_2) and calcium hydroxide. These reactions must be balanced to conserve mass and ensure correct proportions of reactants.

The plant also performs combustion reactions, such as the burning of ethane (C_2H_6), which produces carbon dioxide and water. Data from combustion analysis are used to determine empirical formulas of unknown compounds by measuring the amounts of CO_2 and H_2O formed. In a quality control test, a compound containing iron and sulfur is analyzed and found to be 53.73% Fe and 46.27% S by mass. Engineers use this information to determine the empirical formula. Additionally, the plant calculates the number of molecules produced in reactions based on mole relationships. For instance, knowing that one mole contains 6.022×10^{23} particles allows conversion between moles and molecules.

Questions (Based on passage 4)

1. What is the correctly balanced equation for ammonia formation?
    a. $N_2 + H_2 \rightarrow NH_3$
    b. $N_2 + 2H_2 \rightarrow NH_3$
    c. $N_2 + 3H_2 \rightarrow 2NH_3$
    d. $2N_2 + H_2 \rightarrow 2NH_3$

2. Which law requires chemical equations to be balanced?
    a. Law of multiple proportions
    b. Law of conservation of mass
    c. Avogadro's law
    d. Boyle's law

3. What is the empirical formula of a compound that is 53.73% Fe and 46.27% S?
    a. FeS
    b. Fe_2S_3
    c. Fe_3S_2
    d. FeS_2

4. How many molecules are in 4.56 mol of N_2?
    a. 2.75×10^{23}
    b. 4.56×10^{23}
    c. 2.75×10^{24}
    d. 6.02×10^{23}

5. Which reaction type is ethane burning in oxygen?
    a. Synthesis
    b. Decomposition
    c. Combustion
    d. Single replacement

6. Which product is formed when calcium carbide reacts with water?
    a. Methane
    b. Acetylene
    c. Carbon dioxide
    d. Ethane

7. What is the molar mass of NH_3 (approximate)?
    a. 14 g/mol
    b. 17 g/mol
    c. 18 g/mol
    d. 20 g/mol

8. Which substance is used to determine empirical formulas in combustion analysis?
    a. Oxygen only
    b. Water and carbon dioxide produced
    c. Nitrogen gas
    d. Catalyst mass

9. The empirical formula CH_2 with molar mass 84 g/mol has molecular formula:
    a. CH_2
    b. C_2H_4
    c. C_6H_{12}
    d. C_4H_8

10. Which principle allows conversion from moles to molecules?
    a. Ideal gas law
    b. Avogadro's number
    c. Dalton's law
    d. Hess's law

DAY 3 TOPICS
Stoichiometry and Word Problems

Instructions. Work on the following problems as a review/refresher activity of concepts specified for Day 3 of this assignment. You may show your work on separate sheets of paper. You may use any resources you have, including study guides, textbooks, and the internet.

🧪 PASSAGE 5: Limiting Reactants in Industrial Chemistry

A chemical plant produces water through the reaction of hydrogen gas and oxygen gas:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

In one trial, engineers introduce 10.0 g of hydrogen gas and 64.0 g of oxygen gas into a reaction vessel. The goal is to maximize water production while minimizing leftover reactants. The engineers note that reactions proceed according to mole ratios, not mass ratios. Therefore, identifying the limiting reactant requires converting masses into moles. Once the limiting reactant is determined, the theoretical yield of water can be calculated. After the reaction is complete, they measure the amount of excess reactant remaining and compare it to predictions. This helps optimize resource use in large-scale production.

Questions (Based on passage 5)

1. How many moles of H_2 are initially present?
    a. 2.48 mol
    b. 4.95 mol
    c. 5.00 mol
    d. 9.90 mol

2. How many moles of O_2 are initially present?
    a. 1.00 mol
    b. 2.00 mol
    c. 3.00 mol
    d. 4.00 mol

3. Which reactant is limiting?
    a. Hydrogen
    b. Oxygen
    c. Neither
    d. Cannot be determined

4. What is the maximum number of moles of H_2O that can be produced?
    a. 2.00 mol
    b. 4.00 mol
    c. 5.00 mol
    d. 6.00 mol

5. What is the theoretical yield of water (in grams)?
    a. 36 g
    b. 72 g
    c. 90 g
    d. 108 g

6. After the reaction, which substance remains in excess?
    a. H_2
    b. O_2
    c. H_2O
    d. None

7. The concept used to determine the limiting reactant relies on:
    a. Mass ratios
    b. Volume ratios
    c. Mole ratios
    d. Density relationships

8. If the reaction produced less water than expected, the percent yield would be:
    a. 0%
    b. <100%
    c. 100%
    d. > 100%

🧪 PASSAGE 6: Stoichiometry and Reaction Yield in Pharmaceuticals

A pharmaceutical lab synthesizes a compound using the reaction:

$$2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$$

This reaction is similar to one used in automobile airbags, where nitrogen gas is rapidly generated. In a controlled experiment, 65.0 g of sodium azide (NaN_3) is heated to completion. The chemists measure the amount of nitrogen gas produced and compare it to the expected theoretical yield. They also use Avogadro's number to convert between moles and molecules, which is essential for understanding gas production at the molecular level.

Questions (Based on passage 6)

1. How many moles of NaN_3 are used in the reaction?
    a. 0.50 mol
    b. 1.00 mol
    c. 2.00 mol
    d. 4.00 mol

2. Based on the balanced equation, how many moles of N_2 are produced per mole of NaN_3?
    a. 1
    c. 2

b. 1.5 d. 3

3. How many moles of N_2 are produced in this reaction?
   a. 1.0 mol c. 2.0 mol
   b. 1.5 mol d. 3.0 mol

4. How many molecules of N_2 are produced?
   a. 6.02×10^{23} c. 1.20×10^{24}
   b. 9.03×10^{23} d. 1.80×10^{24}

5. What mass of nitrogen gas (N_2) is produced?
   a. 14 g c. 42 g
   b. 28 g d. 84 g

6. If actual yield is 35.0 g of N_2, what is the percent yield?
   a. 50% c. 83%
   b. 75% d. 125%

7. The reaction described is best classified as:
   a. Synthesis c. Decomposition
   b. Combustion d. Single replacement

8. Which quantity is conserved in this reaction?
   a. Volume only c. Mass
   b. Number of molecules only d. Moles of each substance

DAY 4 TOPICS
Word Problems and Reading Comprehension

Instructions. Please analyze the following word problems and provide the answers to the following questions. You do not have to solve them, but if you would like to provide the answer to each problem as an additional challenge, you may include your answer to each problem too.

🧪 Word Problem 1: Competing Reactions and Yield Analysis

A chemical plant attempts to produce sulfur trioxide (SO_3) through the oxidation of sulfur dioxide:

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

However, a side reaction also occurs:

$$SO_2(g) + \frac{1}{2}O_2(g) \rightarrow SO_3(g)$$

In a reactor, 128.0 g of SO_2 and 64.0 g of O_2 are introduced. Due to incomplete efficiency, only 82.5% of the limiting reactant participates in the desired reaction, while the rest forms SO_3 via the side reaction pathway. At the end of the reaction, the total mass of SO_3 collected is measured.

Questions

1. What is the value you are being asked to find? Please justify your answer using information (such as key words, sentence structures, etc.) provided in the text of the word problem.

2. What are your knowns?

3. What additional information do you think you might need to solve the problem? Where might you find this additional information?

4. What strategy are you going to use to solve this problem? Use a step-by-step numbered list.

🧪 Challenging Problem 2: Multi-Step Yield + Empirical Formula Connection

A hydrocarbon compound (C_xH_y) undergoes combustion:

$$C_xH_y + O_2 \rightarrow CO_2 + H_2O$$

In an experiment:

- 5.60 g of the hydrocarbon is burned
- 17.6 g of CO_2 and 7.20 g of H_2O are produced
- The reaction proceeds with **91.0% yield**

Later, the compound is independently found to have a molar mass of **56 g/mol**

Questions

1. What is the value you are being asked to find? Please justify your answer using information (such as key words, sentence structures, etc.) provided in the text of the word problem.

2. What are your knowns?

3. What additional information do you think you might need to solve the problem? Where might you find this additional information?

4. What strategy are you going to use to solve this problem? Use a step-by-step numbered list.