Units 1-5: Chemistry Basics, Measurement, Atomic Structure, Periodic Table, Bonding
Grade 9 Chemistry - Advanced Workbook

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Contents

Unit 1: Chemistry and its Importance Workbook

Multiple Choice Questions

1. Chemistry is best defined as the study of:

   (A) Living organisms and their interactions.

   (B) Matter and its properties, composition, structure, and transformations.

   (C) The physical laws governing motion, energy, and forces.

   (D) Rocks, minerals, and the Earth's structure.

   Answer: (B) **Explanation:** Chemistry specifically deals with matter, its characteristics, how it's put together, and how it changes, including the energy involved in those changes. (A) is Biology, (C) is Physics, (D) is Geology.

2. Which of the following is NOT considered a primary branch or discipline of modern chemistry?

   (A) Physical Chemistry

   (B) Organic Chemistry

   (C) Astrology

   (D) Analytical Chemistry

   Answer: (C) **Explanation:** Astrology is a pseudoscience concerning celestial objects and human affairs, not a branch of chemistry. Physical, Organic, Inorganic, Analytical, and Biochemistry are the main branches.

3. The study of carbon-containing compounds is primarily the domain of:

   (A) Inorganic Chemistry

   (B) Physical Chemistry

   (C) Biochemistry

   (D) Organic Chemistry

   Answer: (D) **Explanation:** Organic chemistry is specifically defined as the study of compounds containing carbon, which form the basis of life and many synthetic materials.

4. A chemist investigating the rate at which a reaction occurs and the energy changes involved is likely working in the field of:

   (A) Analytical Chemistry

   (B) Physical Chemistry

   (C) Organic Chemistry

   (D) Biochemistry

Answer: (B) **Explanation:** Physical chemistry applies principles of physics (like kinetics and thermodynamics) to study chemical systems, including reaction rates and energy transfers.

5. The development of chemical fertilizers like ammonium sulphate primarily benefits which sector?

   (A) Medicine

   (B) Building Construction

   (C) Agriculture

   (D) Transportation

   Answer: (C) **Explanation:** Fertilizers provide essential nutrients (like nitrogen from ammonium sulphate) to soil, significantly increasing crop yields in agriculture.

6. The study of chemical processes occurring within living organisms is called:

   (A) Geochemistry

   (B) Biochemistry

   (C) Inorganic Chemistry

   (D) Medicinal Chemistry

   Answer: (B) **Explanation:** Biochemistry focuses specifically on the chemistry of life processes within cells and organisms.

7. Which common chemical industry in Ethiopia is primarily associated with the production of Trona (sodium sesquicarbonate)?

   (A) Ziway Caustic Soda factory

   (B) Abijata Soda Ash Factory

   (C) Adola Magnesium Oxide Factory

   (D) Repi Soap & Detergent P.L.C

   Answer: (B) **Explanation:** The Abijata Soda Ash Factory, located near Lake Abijata (Bulbula), naturally harvests Trona, a source of soda ash (Na_2CO_3).

8. Chemistry is often called the 'central science' because:

   (A) It is the oldest scientific discipline.

   (B) It is the most difficult scientific discipline.

   (C) It connects and overlaps with many other scientific fields like biology, physics, and geology.

   (D) All scientists must first study chemistry.

Answer: (C) **Explanation:** Chemistry deals with matter and its transformations, which are fundamental concepts underlying processes studied in biology (life processes), physics (energy, forces), geology (rocks, minerals), medicine, etc., linking these fields together.

True/False Questions

9. Chemistry only deals with substances created in laboratories, not natural materials. **Answer:** False **Explanation:** Chemistry studies both natural substances (water, air, minerals, biological molecules) and synthetic substances created in labs.

10. The transformation of wood into ash when burned is an example of a chemical change studied by chemistry. **Answer:** True **Explanation:** Burning (combustion) is a chemical reaction where wood reacts with oxygen, transforming into new substances (ash, carbon dioxide, water vapor) and releasing energy, all of which fall under the scope of chemistry.

11. Biochemistry is primarily concerned with the chemical composition of rocks and minerals. **Answer:** False **Explanation:** Biochemistry studies the chemical processes within living organisms. Geochemistry studies the chemistry of rocks and minerals.

12. Analytical chemistry focuses on developing new chemical compounds. **Answer:** False **Explanation:** Analytical chemistry focuses on identifying the components (qualitative analysis) and determining the amounts (quantitative analysis) of substances in a sample. Developing new compounds is more related to organic or inorganic synthesis.

13. The production of plastics and polymers falls under the scope of chemistry. **Answer:** True **Explanation:** Polymers are large molecules synthesized through chemical reactions, often studied within organic and polymer chemistry. Plastics are common examples of synthetic polymers.

14. All chemical processes involve a change in energy (either released or absorbed). **Answer:** True **Explanation:** Chemical reactions involve the breaking and forming of chemical bonds, which always corresponds to a change in potential energy, manifested as heat released (exothermic) or absorbed (endothermic).

15. The properties of a substance are independent of its composition and structure. **Answer:** False **Explanation:** The unique properties of a substance (like melting point, density, reactivity) are directly determined by its specific composition (types of atoms) and structure (how atoms are arranged and bonded).

Short Answer Questions

16. Define chemistry in your own words. **Answer:** Chemistry is the scientific study of matter, its properties, how it is composed and structured, how it changes (transforms), and the energy associated with these changes.

17. List the five main disciplines (branches) of chemistry mentioned in the text. **Answer:** Physical chemistry, Organic chemistry, Inorganic chemistry, Analytical chemistry, Biochemistry.

18. Explain the difference between the composition and structure of a substance. Give an example. **Answer: Composition** refers to the types and relative amounts of elements that make up a substance (e.g., water is composed of hydrogen and oxygen atoms in a 2:1 ratio). **Structure** refers to the arrangement of these atoms or molecules in space (e.g., the water molecule has a bent structure).

19. Give two examples of how chemistry is applied in medicine. **Answer:** (Any two valid examples) 1. Development and synthesis of life-saving drugs (e.g., antibiotics like penicillin, cancer therapies like cisplatin, antivirals like AZT). 2. Development of diagnostic tools and medical materials (e.g., materials for artificial organs, imaging agents). 3. Understanding biochemical processes related to diseases.

20. Give two examples of how chemistry is applied in agriculture. **Answer:** (Any two valid examples) 1. Production of chemical fertilizers (e.g., urea, ammonium sulphate) to increase crop yields. 2. Manufacture of pesticides (fungicides, herbicides, insecticides) to protect crops from damage. 3. Development of soil testing methods to determine nutrient needs. 4. Manufacturing plastic pipes for irrigation.

21. What is the difference between a substance and matter? **Answer: Matter** is anything that occupies space and has mass. **Substance** is a specific type of matter that has uniform and definite composition and properties (e.g., pure water is a substance, while pond water is matter but a mixture).

22. Name three common chemical products manufactured in Ethiopia, according to Table 1.1 or the text. **Answer:** (Any three from the list, e.g.) Soap and detergent, Paints, Aluminum sulphate, Sodium hydroxide (caustic soda), Plastic products, Cement, Sugar.

23. Why is chemistry considered essential for meeting basic human needs? **Answer:** Chemistry is fundamental to producing or understanding things essential for survival and well-being, including food (agriculture, preservation), clothing (fibers, dyes), shelter (building materials), health (medicines, sanitation), energy, clean air, and clean water.

Conceptual Problems

24. Explain the relationship between chemistry and physics using an example. **Answer:** Chemistry and Physics overlap significantly as both deal with matter and energy. Physical chemistry is a major branch applying physics principles (like thermodynamics, quantum mechanics, kinetics) to understand chemical systems. Example: Studying the rate of a chemical reaction involves understanding molecular motion and energy transfer (physics concepts) applied to chemical species (chemistry). Atomic structure understanding relies heavily on physics principles.

25. Describe how the 'property' of table salt (NaCl) allows us to distinguish it from sugar ($C_{12}H_{22}O_{11}$). **Answer:** Table salt and sugar can be distinguished by several properties rooted in their different chemical compositions and structures. Key distinguishing properties include: Taste (salt is salty, sugar is sweet), Solubility (both dissolve in water, but perhaps differently in other solvents), Melting Point (salt has a very high melting point 800°C, sugar melts and decomposes at much lower temperatures 186°C), Electrical Conductivity (molten or dissolved salt conducts electricity, sugar does not).

26. The text mentions chemistry can result in dangerous substances. Give one example mentioned or a common example, and explain its negative effect. **Answer:** Example: Fluorochlorohydrocarbons (CFCs) - were used as refrigerants and propellants. Negative effect: They deplete the ozone layer in the upper atmosphere, which protects life on Earth from harmful ultraviolet radiation. Another example: Oxides of nitrogen and sulphur (from burning fossil fuels) cause acid rain, damaging ecosystems and structures.

27. If a new material is discovered, what branch of chemistry would be primarily responsible for determining what elements it contains and in what quantities? **Answer:** Analytical Chemistry. **Explanation:** Analytical chemistry focuses specifically on separating, identifying (qualitative analysis), and quantifying (quantitative analysis) the chemical components of materials.

28. How does understanding the 'structure' of a school building (arrangement of roof, walls, doors etc.) help in understanding its function, similar to how understanding chemical structure helps understand properties? **Answer:** Knowing the structure of a school building—where classrooms, labs, offices, and exits are located—helps understand how people move within it, how different activities are organized, and how safe it might be. Similarly, knowing the arrangement of atoms and bonds (structure) in a chemical substance helps predict and explain its properties, such as its shape, polarity, reactivity, melting point, and how it will interact with other substances.

29. Why is understanding the 'transformation' of substances (chemical reactions) central to chemistry? **Answer:** Transformations (chemical reactions) are how new substances with new properties are formed from existing ones. Understanding these processes

allows chemists to explain natural phenomena (like digestion, rusting), synthesize new materials (medicines, plastics), produce energy, and control chemical processes for specific outcomes. It's the core of how matter changes.

30. Consider the common chemical industries listed for Ethiopia (cement, sugar, textiles, etc.). Briefly explain how chemistry is essential for ONE of these industries. **Answer:** Example: Cement Industry. Chemistry is crucial for understanding the raw materials (like limestone, clay, silica), controlling the high-temperature reactions in the kiln that transform these materials into clinker (involving chemical decomposition and formation of new calcium silicate compounds), and analysing the final product's composition and properties (like setting time and strength).

Unit 2: Measurements and Scientific Methods Workbook

Multiple Choice Questions

1. Which of the following is NOT one of the seven SI base units?

   (A) Kilogram (kg)

   (B) Meter (m)

   (C) Liter (L)

   (D) Second (s)

   Answer: (C) **Explanation:** The Liter (L) is a common unit for volume but it is a derived unit ($1L = 1dm^3 = 0.001m^3$). The seven SI base units are meter, kilogram, second, Kelvin, Ampere, mole, and candela.

2. The SI prefix 'kilo' (k) represents a factor of:

   (A) 10^{-3}

   (B) 10^{3}

   (C) 10^{-6}

   (D) 10^{6}

   Answer: (B) **Explanation:** 'kilo' means one thousand, which is 10^3. For example, 1 kilometer (km) = 1000 meters.

3. Density is defined as mass per unit volume. What type of quantity is density?

   (A) Fundamental Quantity

   (B) Derived Quantity

   (C) Scalar Quantity with fundamental units

   (D) Vector Quantity

   Answer: (B) **Explanation:** Density is calculated from two fundamental quantities (mass and length, as volume is length cubed). Therefore, it is a derived quantity with derived units (e.g., kg/m^3 or g/cm^3).

4. How many significant figures are in the measurement 0.0580 m^3?

   (A) 2

   (B) 3

   (C) 4

   (D) 5

Answer: (B) **Explanation:** Leading zeros (0.0) are not significant. Non-zero digits (5, 8) are significant. Trailing zeros after a decimal point (the final 0) are significant. Thus, 5, 8, and 0 are significant, making 3 significant figures.

5. When adding 11,254.1 g and 0.1983 g, the result reported with the correct number of significant figures is:

   (A) 11,254.2983 g

   (B) 11,254.298 g

   (C) 11,254.3 g

   (D) 11,254 g

   Answer: (C) **Explanation:** In addition/subtraction, the result is limited by the number with the fewest decimal places. 11,254.1 has one decimal place, while 0.1983 has four. The sum (11,254.2983) must be rounded to one decimal place, resulting in 11,254.3 g.

6. The closeness of a measurement to its true value is called:

   (A) Precision

   (B) Accuracy

   (C) Uncertainty

   (D) Resolution

   Answer: (B) **Explanation:** Accuracy refers to how close a measured value is to the actual or accepted true value. Precision refers to the closeness of repeated measurements to each other.

7. Which piece of laboratory glassware is designed to measure and deliver a precise volume of liquid?

   (A) Beaker

   (B) Erlenmeyer flask

   (C) Volumetric pipet

   (D) Graduated cylinder

   Answer: (C) **Explanation:** A volumetric pipet is calibrated to deliver a single, highly accurate volume (e.g., 25.00 mL). Graduated cylinders measure variable volumes but with less precision than pipets or volumetric flasks. Beakers and Erlenmeyer flasks are mainly for holding/mixing liquids and have very approximate volume markings.

8. The scientific method typically begins with:

   (A) Experimentation

(B) Forming a hypothesis

(C) Observation and formulating a question

(D) Drawing a conclusion

Answer: (C) **Explanation:** The scientific process usually starts with observing a phenomenon in the natural world and asking a question about it.

True/False Questions

9. The SI unit for volume is the Liter (L). **Answer:** False **Explanation:** The SI base unit for length is the meter (m). The SI derived unit for volume is the cubic meter (m^3). The Liter (L) is a common non-SI unit equivalent to dm^3.

10. A measurement of 64 mm ± 3 mm means the true value lies between 61 mm and 67 mm. **Answer:** True **Explanation:** The ± value represents the uncertainty. The range is found by subtracting and adding the uncertainty to the measured value (64-3 = 61; 64+3 = 67).

11. Random errors in measurement can be completely eliminated by careful technique. **Answer:** False **Explanation:** Random errors arise from unpredictable fluctuations and the limits of instrument precision. They can be reduced by repeated measurements and averaging, but never completely eliminated. Systematic errors, in principle, can be eliminated if identified.

12. In the number 3000 mL, there are four significant figures. **Answer:** False **Explanation:** Trailing zeros in a number without an explicit decimal point are ambiguous. It could have 1, 2, 3, or 4 significant figures. Scientific notation (e.g., 3.000×10^3 mL for 4 sig figs) is needed for clarity. Unless specified otherwise, it's often assumed to have only one (the digit 3).

13. The primary purpose of using scientific notation is to make numbers look more complicated. **Answer:** False **Explanation:** Scientific notation is used to conveniently express very large or very small numbers and to clearly indicate the number of significant figures.

14. Kelvin (K) is the SI base unit for temperature. **Answer:** True **Explanation:** Kelvin is one of the seven fundamental units in the SI system, representing thermodynamic temperature.

15. It is acceptable to return unused chemicals to their original container to avoid waste. **Answer:** False **Explanation:** This is a crucial safety rule. Returning chemicals risks contaminating the stock container. Excess chemicals should be disposed of according to proper procedures.

Short Answer Questions

16. List the seven fundamental SI quantities and their corresponding base units. **Answer:** Length (meter, m), Mass (kilogram, kg), Time (second, s), Temperature (Kelvin, K), Electric Current (Ampere, A), Amount of Substance (mole, mol), Luminous Intensity (candela, cd).

17. Explain the difference between precision and accuracy in scientific measurements. **Answer: Accuracy** refers to how close a measurement is to the true or accepted value. **Precision** refers to how close multiple measurements of the same quantity are to each other (reproducibility). A measurement can be precise but inaccurate, or accurate but imprecise.

18. Write the number 0.000 000 523 in proper scientific notation. **Answer:** 5.23×10^{-7} **Explanation:** Move the decimal point 7 places to the right to get 5.23 (a number between 1 and 10). Since we moved it right, the exponent is negative.

19. Write the number 602,000,000,000,000,000,000,000 in proper scientific notation with three significant figures. **Answer:** 6.02×10^{23} **Explanation:** Move the decimal point 23 places to the left to get 6.02. Since we moved left, the exponent is positive. The digits 6, 0, 2 are significant.

20. What are the four main steps of the scientific method, as shown in Figure 2.6? **Answer:** 1. Observation and formulation of a question. 2. Data collection and hypothesis formulation. 3. Testing the hypothesis (experimentation). 4. Analysis and conclusion.

21. Why is it important to wear safety goggles in a chemistry laboratory? **Answer:** To protect the eyes from chemical splashes, fumes, vapors, or flying debris (e.g., broken glass) that could cause irritation, burns, or permanent damage including blindness.

22. Name two common traditional (non-standard) units of measurement used locally and state what quantity they measure. **Answer:** (Examples vary locally) Could include: *Sini* (small cup, often for coffee, measures volume), *Kunta* (bundle, measures quantity e.g., firewood), Arm's length/cubit (length), *Birle* (jug, volume), Tin can (volume).

23. Convert 2.5 Liters (L) into cubic centimeters (cm^3). **Answer:** 2500 cm^3 **Explanation:** 1 L = 1 dm^3 and 1 dm = 10 cm. Therefore, 1 L = $(10\ cm)^3$ = 1000 cm^3. So, 2.5 L * (1000 cm^3/L) = 2500 cm^3. Alternatively, 1 L = 1000 mL and 1 mL = 1 cm^3, so 2.5 L = 2500 mL = 2500 cm^3.

Calculation and Problem Solving

24. A block of wood measures 5.0 cm x 4.0 cm x 10.0 cm and has a mass of 160 g. Calculate the density of the wood in g/cm^3. Report your answer with the correct number of significant figures. **Answer:** 0.80 g/cm^3 **Explanation:** Volume V = length x width x height = 5.0 cm * 4.0 cm * 10.0 cm = 200 cm^3 (Note: 4.0 cm limits volume to 2 sig figs). Density d = mass / volume = 160 g / 200 cm^3 = 0.8 g/cm^3. However, the inputs 5.0, 4.0, 10.0 have 2, 2, and 3 sig figs respectively. Mass 160g is ambiguous (could be 2 or 3). If we assume 160 has 3 sig figs (160.), then V is limiting factor (2 sig figs). Result should have 2 sig figs: 0.80 g/cm^3. If 160 has 2 sig figs (1.6×10^2), result is still 0.80 g/cm^3.

25. Convert 55 kilometers per hour (km/h) to meters per second (m/s). **Answer:** 15 m/s (approx) **Explanation:** Use conversion factors: 1 km = 1000 m and 1 hr = 3600 s. $55\frac{\text{km}}{\text{hr}} \times \frac{1000\text{ m}}{1\text{ km}} \times \frac{1\text{ hr}}{3600\text{ s}} = \frac{55\times1000}{3600}\frac{\text{m}}{\text{s}} \approx 15.28$ m/s. Rounding to 2 significant figures (from 55 km/h) gives 15 m/s.

26. A student measures the length of a table three times and gets 155.2 cm, 155.8 cm, and 155.5 cm. The true length is known to be 155.4 cm. Are the student's measurements precise? Are they accurate? Explain. **Answer:** Precise: Yes. Accurate: Yes. **Explanation:** The measurements are close to each other (range 155.2 to 155.8 cm), indicating high **precision**. The average measurement is (155.2 + 155.8 + 155.5) / 3 = 155.5 cm. This average is very close to the true value of 155.4 cm, indicating high **accuracy**.

27. Express the following calculation result with the correct number of significant figures: (2.64 $\times$ 10^3 cm) + (3.27 $\times$ 10^2 cm). **Answer:** 2.97 $\times$ 10^3 cm **Explanation:** First, express numbers with the same power of 10: 2.64 $\times$ 10^3 cm + 0.327 $\times$ 10^3 cm. Now add, keeping track of decimal places relative to the power of 10: (2.64 + 0.327) $\times$10^3 cm = 2.967 $\times$10^3 cm. The first number (2.64) has two decimal places relative to the power of 10, limiting the result. Round 2.967 to two decimal places: 2.97 $\times$ 10^3 cm.

28. Calculate the percent uncertainty for a measurement of 23.25 g made on a top-loading balance with an absolute uncertainty of $\pm$0.05 g. **Answer:** $\pm$0.2**Explanation:** Percent uncertainty = (absolute uncertainty / measured value) x 100

29. Convert 75 °F to degrees Celsius (°C) and Kelvin (K). **Answer:** 24 °C, 297 K (approx) **Explanation:** $T_C = \frac{5}{9}(T_F - 32) = \frac{5}{9}(75 - 32) = \frac{5}{9}(43) \approx 23.89°C$. Rounding to 2 significant figures (from 75) gives 24 °C. $T_K = T_C + 273.15 \approx 23.89 + 273.15 = 297.04K$. Rounding based on the precision of the Celsius conversion gives approx 297 K.

30. A flask weighs 52.13 g empty. When filled with water (density = 1.00 g/cm^3), it weighs 76.84 g. When filled with an unknown liquid, it weighs 71.55 g. What is the density of the unknown liquid? **Answer:** 0.786 g/cm^3 **Explanation:** Mass of water = 76.84 g - 52.13 g = 24.71 g. Volume of water (and flask) = Mass / Density = 24.71 g / 1.00

g/cm³ = 24.71 cm³. Mass of unknown liquid = 71.55 g - 52.13 g = 19.42 g. Density of unknown liquid = Mass / Volume = 19.42 g / 24.71 cm³ 0.7859 g/cm³. Rounding to 4 significant figures (limited by masses) gives 0.7859 g/cm³. (Or 3 sig figs 0.786 if density water treated as 3 sig figs). Textbook style usually keeps precision, so 0.7859 g/cm³ is likely preferred, but 0.786 g/cm³ reflects typical sig fig rules applied early. Let's use 3 sig figs based on 1.00 density. → 0.786 g/cm³.

Unit 3: Structure of the Atom Workbook

Multiple Choice Questions

1. The concept that matter consists of indivisible particles called atoms was first proposed by:

   (A) John Dalton

   (B) J.J. Thomson

   (C) Ancient Greek philosophers (like Democritus)

   (D) Ernest Rutherford

   Answer: (C) **Explanation:** While Dalton formalized the atomic theory based on evidence, the philosophical idea of 'atomos' (indivisible particles) originated with ancient Greek thinkers like Leucippus and Democritus.

2. Which postulate of Dalton's Atomic Theory is now known to be incorrect due to the existence of isotopes?

   (A) Elements are made of atoms.

   (B) Atoms can neither be created nor destroyed.

   (C) All atoms of the same element are identical and have the same mass and size.

   (D) Atoms combine in small whole numbers to form compounds.

   Answer: (C) **Explanation:** Isotopes are atoms of the same element (same number of protons) but with different numbers of neutrons, meaning they have different masses. Therefore, not all atoms of the same element are identical in mass.

3. The discovery of the electron is primarily credited to:

   (A) Ernest Rutherford (Gold Foil Experiment)

   (B) J.J. Thomson (Cathode Ray Tube Experiments)

   (C) James Chadwick (Discovery of Neutron)

   (D) Robert Millikan (Oil Drop Experiment)

   Answer: (B) **Explanation:** J.J. Thomson's experiments with cathode ray tubes demonstrated the existence of negatively charged particles (electrons) and determined their charge-to-mass ratio.

4. The 'plum pudding' model of the atom proposed that:

   (A) Atoms are mostly empty space with a dense nucleus.

   (B) Electrons orbit the nucleus like planets.

   (C) Electrons are embedded in a uniform sphere of positive charge.

   (D) Atoms are indivisible solid spheres.

Answer: (C) **Explanation:** Thomson's plum pudding model envisioned the atom as a positively charged 'pudding' with negatively charged electrons ('plums') scattered throughout.

5. Rutherford's gold foil experiment provided evidence for:

   (A) The existence of electrons.

   (B) The quantization of electron energy levels.

   (C) The existence of neutrons.

   (D) The existence of a small, dense, positively charged nucleus.

   Answer: (D) **Explanation:** The deflection of some alpha particles at large angles, and the reflection of a few straight back, indicated that the atom's positive charge and mass were concentrated in a tiny central nucleus, with most of the atom being empty space.

6. Which subatomic particle has a positive charge and a mass of approximately 1 atomic mass unit (amu)?

   (A) Electron

   (B) Proton

   (C) Neutron

   (D) Nucleus

   Answer: (B) **Explanation:** Protons carry a +1 relative charge and have a mass very close to 1 amu.

7. Which subatomic particle has no charge and a mass of approximately 1 amu?

   (A) Electron

   (B) Proton

   (C) Neutron

   (D) Positron

   Answer: (C) **Explanation:** Neutrons are neutral (no charge) and have a mass slightly greater than, but approximately equal to, 1 amu.

8. The atomic number (Z) of an element represents the number of:

   (A) Neutrons in the nucleus.

   (B) Protons in the nucleus.

   (C) Electrons in a neutral atom.

   (D) Both (B) and (C).

Answer: (D) **Explanation:** The atomic number (Z) fundamentally defines the element by the number of protons in its nucleus. In a neutral atom, the number of electrons must equal the number of protons to balance the charge.

9. The mass number (A) of an atom represents the total number of:

   (A) Protons only.

   (B) Neutrons only.

   (C) Protons and electrons.

   (D) Protons and neutrons.

   Answer: (D) **Explanation:** The mass number (A) is the sum of the number of protons (Z) and the number of neutrons (N) in the nucleus (A = Z + N). These are the particles contributing significantly to the atom's mass.

10. Isotopes of an element differ in their number of:

    (A) Protons

    (B) Electrons

    (C) Neutrons

    (D) Atomic number

    Answer: (C) **Explanation:** Isotopes are atoms of the same element (same Z, same number of protons) but have different numbers of neutrons, resulting in different mass numbers (A).

True/False Questions

11. Cathode rays are streams of positively charged particles. **Answer:** False **Explanation:** Cathode rays are streams of negatively charged electrons, deflected towards the positive plate in an electric field. Anode rays (canal rays) are positively charged.

12. The nucleus of an atom contains protons and electrons. **Answer:** False **Explanation:** The nucleus contains protons and neutrons. Electrons orbit the nucleus.

13. According to Bohr's model, electrons can orbit the nucleus at any distance. **Answer:** False **Explanation:** Bohr's model proposed that electrons exist only in specific, quantized energy levels or orbits at fixed distances from the nucleus.

14. The mass of an electron is significantly greater than the mass of a proton. **Answer:** False **Explanation:** The mass of an electron is about 1/1836th (or roughly 1/2000th) the mass of a proton or neutron. Protons and neutrons account for almost all the atom's mass.

15. The number of electrons in the outermost shell determines the chemical properties of an element. **Answer:** True **Explanation:** These outermost electrons are called valence electrons, and they are the ones involved in chemical bonding and reactions, thus dictating chemical behavior.

16. The symbol $^{14}_{6}C$ represents an isotope of carbon with 6 protons and 14 neutrons. **Answer:** False **Explanation:** The subscript (6) is the atomic number (protons). The superscript (14) is the mass number (protons + neutrons). Number of neutrons = Mass Number - Atomic Number = 14 - 6 = 8 neutrons.

17. Most of the volume of an atom is occupied by the nucleus. **Answer:** False **Explanation:** Rutherford's experiment showed the nucleus is extremely small and dense compared to the overall size of the atom. Most of the volume is the space occupied by the electron cloud.

Short Answer Questions

18. State the three main subatomic particles and their relative charges. **Answer:** Proton (+1), Neutron (0), Electron (-1).

19. What was the main conclusion drawn from Rutherford's gold foil experiment regarding atomic structure? **Answer:** The atom consists of a tiny, dense, positively charged nucleus at the center, with electrons occupying the mostly empty space surrounding it.

20. Define isotope and give an example using chlorine (Atomic number 17), which has isotopes with mass numbers 35 and 37. **Answer:** Isotopes are atoms of the same element (same atomic number/number of protons) that have different numbers of neutrons, and therefore different mass numbers. Example: Chlorine-35 ($^{35}_{17}Cl$) has 17 protons and 18 neutrons (35-17=18). Chlorine-37 ($^{37}_{17}Cl$) has 17 protons and 20 neutrons (37-17=20).

21. Briefly describe the concept of main energy levels (shells) in Bohr's atomic model. **Answer:** Bohr proposed that electrons orbit the nucleus only in specific, allowed circular paths called energy levels or shells (labeled K, L, M, N... or n=1, 2, 3, 4...). Each shell corresponds to a fixed amount of energy. Electrons do not radiate energy while in a stationary orbit but can jump between levels by absorbing or emitting specific amounts of energy.

22. What are valence electrons and why are they important in chemistry? **Answer:** Valence electrons are the electrons in the outermost energy level (shell) of an atom. They are important because they are the electrons primarily involved in forming chemical bonds and determining the chemical reactivity and properties of an element.

23. Explain the difference between atomic number (Z) and mass number (A). **Answer:** Atomic Number (Z) is the number of protons in the nucleus of an atom; it defines the element. Mass Number (A) is the total number of protons and neutrons in the nucleus; it approximates the atomic mass in amu.

24. Why is an atom electrically neutral? **Answer:** A neutral atom contains an equal number of positively charged protons in its nucleus and negatively charged electrons orbiting the nucleus. The equal and opposite charges cancel each other out, resulting in a net charge of zero.

Calculation and Problem Solving

25. An atom has 15 protons and 16 neutrons.
    a) What is its atomic number?
    b) What is its mass number?
    c) How many electrons does it have if it is neutral?
    d) What element is it? **Answer:** a) Z = 15. b) A = 15 + 16 = 31. c) 15 electrons. d) Phosphorus (P). **Explanation:** a) Atomic number (Z) = number of protons = 15. b) Mass number (A) = protons + neutrons = 15 + 16 = 31. c) In a neutral atom, electrons = protons = 15. d) The element with Z=15 is Phosphorus.

26. Complete the following table:

Symbol	Atomic No. (Z)	Mass No. (A)	Protons	Neutrons	Electrons
$^{39}_{19}$K	19	39	?	?	?
?	26	56	?	?	26
$^{238}_{92}$U	?	?	92	?	92

Answer:

Symbol	Atomic No. (Z)	Mass No. (A)	Protons	Neutrons	Electrons
$^{39}_{19}$K	19	39	**19**	**20**	**19**
$^{\mathbf{56}}_{\mathbf{26}}$**Fe**	26	56	**26**	**30**	26
$^{238}_{92}$U	**92**	**238**	92	**146**	92

Explanation: Protons = Z. Neutrons = A - Z. Electrons = Protons (for neutral atom). Element symbol determined by Z.

27. Magnesium (Mg) has three naturally occurring isotopes: ^{24}Mg (mass 23.985 amu, abundance 78.99**Answer:** 24.31 amu **Explanation:** Average Atomic Mass = $\sum$(%abundance$_i$ × mass$_i$)/100. Avg Mass = [(78.99 * 23.985) + (10.00 * 24.986) + (11.01 * 25.983)] / 100 Avg Mass = [1894.575 + 249.86 + 286.073] / 100 Avg Mass = 2430.508 / 100 = 24.30508 amu. Rounding to match precision of percentages (2 decimal places) gives 24.31 amu.

28. Write the complete nuclear symbol for an atom that contains 82 protons, 126 neutrons, and 82 electrons. What element is this? **Answer:** $^{208}_{82}$Pb (Lead) **Explanation:**

Atomic number Z = protons = 82. Mass number A = protons + neutrons = 82 + 126 = 208. The element with Z=82 is Lead (Pb). Electrons = protons, so it is neutral.

29. Draw the Bohr model diagram (showing electron shells K, L, M...) for a neutral Argon (Ar) atom. Argon has atomic number 18. **Answer:** (Diagram description) Nucleus in center. K shell (n=1) with 2 electrons. L shell (n=2) with 8 electrons. M shell (n=3) with 8 electrons. **Explanation:** Argon Z=18, so 18 protons and 18 electrons. Electron configuration: K shell holds max 2 ($2n^2 = 2(1)^2 = 2$). L shell holds max 8 ($2(2)^2 = 8$). M shell holds remaining $18 - 2 - 8 = 8$ electrons. Config (2, 8, 8).

30. Calculate the number of neutrons in the following isotopes: a) Carbon-14 (^{14}C) b) Uranium-235 (^{235}U) **Answer:** a) 8 neutrons b) 143 neutrons **Explanation:** Neutrons = Mass Number (A) - Atomic Number (Z). a) For C, Z=6. Neutrons = 14 - 6 = 8. b) For U, Z=92. Neutrons = 235 - 92 = 143.

Unit 4: Periodic Classification of Elements Workbook

Multiple Choice Questions

1. Mendeleev arranged the elements in his periodic table primarily based on increasing:

   (A) Atomic number

   (B) Atomic weight (mass)

   (C) Number of neutrons

   (D) Number of valence electrons

   Answer: (B) **Explanation:** Mendeleev's Periodic Law states that properties are periodic functions of atomic weight. The modern table is based on atomic number.

2. The Modern Periodic Law states that the properties of elements are periodic functions of their:

   (A) Atomic mass

   (B) Mass number

   (C) Atomic number

   (D) Number of neutrons

   Answer: (C) **Explanation:** Henry Moseley established that atomic number (number of protons) is the fundamental property determining element properties and position.

3. Elements in the same vertical column (group) of the periodic table generally have similar:

   (A) Atomic masses

   (B) Numbers of electron shells

   (C) Chemical properties

   (D) Atomic radii

   Answer: (C) **Explanation:** Elements in the same group have the same number of valence electrons, leading to similar chemical behavior and reactivity.

4. Which block of the periodic table contains the Alkali Metals (Group 1) and Alkaline Earth Metals (Group 2)?

   (A) s-block

   (B) p-block

   (C) d-block

   (D) f-block

Answer: (A) **Explanation:** In s-block elements, the last electron enters an s-orbital. This corresponds to Groups 1 (IA) and 2 (IIA).

5. The Halogens belong to which group in the periodic table?

   (A) Group 1 (IA)
   (B) Group 2 (IIA)
   (C) Group 17 (VIIA)
   (D) Group 18 (VIIIA)

   Answer: (C) **Explanation:** Group 17 (or VIIA) elements (F, Cl, Br, I, At) are known as the Halogens.

6. How does atomic radius generally change across a period from left to right?

   (A) Increases
   (B) Decreases
   (C) Stays the same
   (D) Increases then decreases

   Answer: (B) **Explanation:** Across a period, the number of protons (nuclear charge) increases, pulling the electron shells closer to the nucleus, thus decreasing the atomic radius.

7. Which of the following elements has the highest first ionization energy (IE_1)?

   (A) Sodium (Na)
   (B) Magnesium (Mg)
   (C) Chlorine (Cl)
   (D) Argon (Ar)

   Answer: (D) **Explanation:** Ionization energy generally increases across a period. Noble gases (like Argon, Ar) have the highest IE_1 in their respective periods due to their stable, filled valence shells, making it very difficult to remove an electron.

8. Which of the following elements has the highest electronegativity?

   (A) Lithium (Li)
   (B) Carbon (C)
   (C) Oxygen (O)
   (D) Fluorine (F)

   Answer: (D) **Explanation:** Electronegativity increases across a period and decreases down a group. Fluorine (F) is the most electronegative element on the Pauling scale (value 4.0).

True/False Questions

9. Elements in the same period have the same number of valence electrons. **Answer:** False **Explanation:** Elements in the same period have the same number of occupied electron shells (principal energy levels). Elements in the same group have the same number of valence electrons.

10. The Law of Octaves proposed by Newlands held true for all known elements at the time. **Answer:** False **Explanation:** Newlands' Law of Octaves worked reasonably well for lighter elements but failed for elements beyond Calcium and did not account for undiscovered noble gases.

11. Transition metals are located in the p-block of the periodic table. **Answer:** False **Explanation:** Transition metals (Groups 3-12) are located in the d-block, where the (n-1)d subshell is being filled. The p-block contains Groups 13-18.

12. Ionization energy generally decreases down a group. **Answer:** True **Explanation:** Down a group, the outermost electron is in a shell farther from the nucleus and experiences more shielding from inner electrons, making it easier to remove (lower IE).

13. Electron affinity measures the energy required to remove an electron from an atom. **Answer:** False **Explanation:** Electron affinity measures the energy change when an electron is *added* to a neutral atom. Ionization energy measures the energy required to *remove* an electron.

14. Metals tend to have lower electronegativity values than nonmetals. **Answer:** True **Explanation:** Metals tend to lose electrons (are electropositive) and thus have a weaker attraction for bonding electrons (lower electronegativity) compared to nonmetals, which tend to gain or strongly attract electrons (higher electronegativity).

15. The atomic radius of Potassium (K) is larger than the atomic radius of Sodium (Na). **Answer:** True **Explanation:** Potassium is below Sodium in Group 1. Atomic radius increases down a group because the valence electrons are in higher principal energy levels, farther from the nucleus.

Short Answer Questions

16. State the Modern Periodic Law. Who is credited with its discovery? **Answer:** The physical and chemical properties of the elements are periodic functions of their atomic number. Credit: Henry Moseley.

17. Explain the difference between a group and a period on the periodic table. **Answer:** A **group** is a vertical column. Elements in a group have the same number of valence electrons and similar chemical properties. A **period** is a horizontal row. Elements in a period have the same highest occupied principal energy level (shell number). Properties change predictably across a period.

18. What is meant by the term 'periodicity' in the context of the periodic table? **Answer:** Periodicity refers to the repeating pattern or recurring trends in the properties of elements when they are arranged in order of increasing atomic number.

19. Name the specific group names for Group 1 (IA), Group 2 (IIA), Group 17 (VIIA), and Group 18 (VIIIA). **Answer:** Group 1: Alkali Metals. Group 2: Alkaline Earth Metals. Group 17: Halogens. Group 18: Noble Gases.

20. What determines which block (s, p, d, or f) an element belongs to? **Answer:** The block is determined by the subshell (s, p, d, or f) that receives the last (highest energy or differentiating) electron according to the Aufbau principle.

21. Explain the concept of effective nuclear charge (Z_{eff}). How does it generally trend across a period? **Answer:** Effective nuclear charge is the net positive charge experienced by an outer electron, considering the shielding effect of inner electrons which reduce the full attraction of the nucleus. Z_{eff} generally increases across a period because the nuclear charge (Z) increases while the number of inner shielding electrons remains the same.

22. Why does ionization energy generally decrease down a group? **Answer:** Down a group, the outermost electron is in a higher principal energy level, meaning it is farther from the nucleus and experiences increased shielding from the additional inner electron shells. These factors reduce the electrostatic attraction between the nucleus and the valence electron, making it easier to remove (lower IE).

23. Explain the general trend for electron affinity across a period (left to right) and provide the reason. **Answer:** Electron affinity generally becomes more negative (higher affinity) across a period. Reason: The increasing effective nuclear charge (Z_{eff}) attracts an incoming electron more strongly.

Problem Solving and Application

24. An element has the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^4$. Identify its period, group number (using A/B notation and 1-18 notation), and block. Is it a metal, nonmetal, or metalloid? **Answer:** Period 3, Group 16 (VIA), p-block, Nonmetal (Sulfur). **Explanation:** Highest principal energy level (n) is 3, so it's in Period 3. Valence electrons are in $3s^2 3p^4$, totaling 2+4=6 valence electrons. For p-block, Group number (A) =

valence electrons, so Group VIA. In 1-18 notation, Group 16. Since the last electron enters the p-subshell, it's p-block. Sulfur (element with this config) is a nonmetal.

25. Arrange the following elements in order of increasing atomic radius: O, S, Se. Explain your reasoning. **Answer:** O ¡ S ¡ Se **Explanation:** O, S, and Se are all in Group 16 (VIA). Atomic radius increases down a group because electrons occupy progressively higher energy levels (shells) farther from the nucleus.

26. Arrange the following elements in order of increasing first ionization energy (IE_1): Na, Mg, Al, Si. Explain any irregularities. **Answer:** Na ¡ Al ¡ Mg ¡ Si **Explanation:** General trend across Period 3 is increasing IE_1. However, there's an irregularity: Mg (Group 2, $3s^2$) has a higher IE_1 than Al (Group 13, $3s^2 3p^1$). Removing an electron from Mg disrupts a stable, filled 3s subshell, requiring more energy than removing the single, relatively higher-energy 3p electron from Al. Na (Group 1) has the lowest IE_1, and Si (Group 14) follows the general trend after Mg/Al.

27. Arrange the following elements in order of increasing electronegativity: K, Ca, As, Br. Explain your reasoning. **Answer:** K ¡ Ca ¡ As ¡ Br **Explanation:** These elements are all in Period 4. Electronegativity generally increases across a period from left to right as effective nuclear charge increases, strengthening the atom's pull on bonding electrons. K (Group 1) ¡ Ca (Group 2) ¡ As (Group 15) ¡ Br (Group 17).

28. Predict the period and group (1-18 notation) for the element with atomic number Z = 35. What is the name of this element and its group family name? **Answer:** Period 4, Group 17. Element: Bromine (Br). Group Family Name: Halogens. **Explanation:** Z=35 configuration: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^5$. Highest n=4, so Period 4. It's p-block. Valence electrons $4s^2 4p^5 = 7$ valence electrons. Group = 10 + valence electrons (for p-block) = 10+7=17. Group 17 is the Halogens. Element 35 is Bromine.

29. Which element is expected to have a larger atomic radius, Li or Be? Why? **Answer:** Li **Explanation:** Li and Be are in the same period (Period 2). Atomic radius decreases across a period. Be (Z=4) has a higher effective nuclear charge than Li (Z=3), pulling its electrons closer.

30. Why does Chlorine (Cl) have a more negative electron affinity than Sulfur (S)? **Answer:** Both are in Period 3. Chlorine (Group 17) is further right than Sulfur (Group 16). Across a period, effective nuclear charge increases. Chlorine's higher Z_{eff} attracts an incoming electron more strongly than Sulfur's, leading to a greater release of energy (more negative EA). Chlorine is closer to achieving a stable octet.

Unit 5: Chemical Bonding Workbook

Multiple Choice Questions

1. Which type of bond involves the complete transfer of electrons from one atom to another?

   (A) Covalent Bond

   (B) Ionic Bond

   (C) Metallic Bond

   (D) Coordinate Covalent Bond

   Answer: (B) **Explanation:** Ionic bonding is characterized by the electrostatic attraction between oppositely charged ions formed by the transfer of electrons, typically from a metal to a nonmetal.

2. Which of the following pairs of elements is most likely to form an ionic bond?

   (A) Carbon and Oxygen (C O)

   (B) Hydrogen and Hydrogen (H H)

   (C) Potassium and Fluorine (K F)

   (D) Nitrogen and Nitrogen (N N)

   Answer: (C) **Explanation:** Potassium (K) is an alkali metal (low EN) and Fluorine (F) is a halogen (highest EN). The large difference in electronegativity favors electron transfer and ionic bond formation. The other pairs involve nonmetals with smaller EN differences (forming covalent bonds).

3. According to the Octet Rule, atoms tend to gain, lose, or share electrons to achieve the electron configuration of a:

   (A) Halogen

   (B) Alkali Metal

   (C) Transition Metal

   (D) Noble Gas

   Answer: (D) **Explanation:** The Octet Rule states that atoms strive for a stable configuration with eight valence electrons, like that of the noble gases (except for He, which has a stable duet).

4. A positively charged ion formed by losing electrons is called a(n):

   (A) Anion

   (B) Cation

   (C) Isotope

(D) Molecule

Answer: (B) **Explanation:** Cations are positive ions formed when an atom loses one or more electrons. Anions are negative ions formed by gaining electrons.

5. Which type of bond involves the sharing of electron pairs between two nonmetal atoms?

   (A) Ionic Bond

   (B) Metallic Bond

   (C) Covalent Bond

   (D) Hydrogen Bond

   Answer: (C) **Explanation:** Covalent bonding occurs when nonmetal atoms share valence electrons to achieve stable electron configurations.

6. How many electron pairs are shared in a double covalent bond?

   (A) 1 pair (2 electrons)

   (B) 2 pairs (4 electrons)

   (C) 3 pairs (6 electrons)

   (D) 4 pairs (8 electrons)

   Answer: (B) **Explanation:** A double bond involves the sharing of two pairs of electrons between two atoms, represented by two dashes (=).

7. In the Lewis structure for water (H_2O), how many lone pairs of electrons are on the central oxygen atom?

   (A) 0

   (B) 1

   (C) 2

   (D) 3

   Answer: (C) **Explanation:** Oxygen has 6 valence electrons. It forms single bonds with two hydrogen atoms (using 2 electrons). The remaining 4 valence electrons exist as two lone pairs on the oxygen atom.

8. A covalent bond in which electrons are shared unequally is called a:

   (A) Nonpolar covalent bond

   (B) Polar covalent bond

   (C) Ionic bond

   (D) Metallic bond

Answer: (B) **Explanation:** Unequal sharing occurs when the bonded atoms have different electronegativities, creating partial positive ($\delta+$) and partial negative ($\delta-$) charges, resulting in a polar covalent bond.

9. Which of the following molecules is expected to be nonpolar?

   (A) HCl (Hydrogen Chloride)

   (B) H_2O (Water)

   (C) NH_3 (Ammonia)

   (D) CH_4 (Methane)

   Answer: (D) **Explanation:** Methane (CH_4) has polar C-H bonds, but its symmetrical tetrahedral geometry causes the bond dipoles to cancel out, making the overall molecule nonpolar. HCl, H_2O, and NH_3 have polar bonds and asymmetrical shapes, making them polar molecules.

10. The "electron sea model" is used to describe which type of bonding?

    (A) Ionic Bonding

    (B) Covalent Bonding

    (C) Metallic Bonding

    (D) Hydrogen Bonding

    Answer: (C) **Explanation:** Metallic bonding is described as an array of positive metal ions immersed in a "sea" of mobile, delocalized valence electrons.

True/False Questions

11. Ionic compounds typically form discrete molecular units. **Answer:** False **Explanation:** Ionic compounds form extensive, repeating crystal lattices of cations and anions, not discrete molecules.

12. Covalent compounds generally have higher melting and boiling points than ionic compounds. **Answer:** False **Explanation:** Ionic compounds generally have much higher melting and boiling points because strong electrostatic forces in the ionic lattice must be overcome. Covalent compounds (molecular) usually have weaker intermolecular forces, requiring less energy to melt or boil.

13. Metals are good conductors of electricity because their electrons are tightly held by individual atoms. **Answer:** False **Explanation:** Metals conduct electricity well because their valence electrons are delocalized and mobile within the "electron sea," allowing them to move easily and carry charge.

14. In a coordinate covalent bond, both atoms contribute one electron each to the shared pair. **Answer:** False **Explanation:** In a coordinate covalent (dative) bond, one atom (the donor) provides *both* electrons for the shared pair, which are accepted into an empty orbital of the other atom (the acceptor).

15. Ionic compounds conduct electricity when solid, but not when molten or dissolved. **Answer:** False **Explanation:** Ionic compounds do NOT conduct electricity in the solid state because ions are fixed. They DO conduct when molten or dissolved because the ions become free to move and carry charge.

16. A molecule with polar bonds is always a polar molecule. **Answer:** False **Explanation:** A molecule can have polar bonds, but if its geometry is symmetrical (like CO_2 or CCl_4), the bond dipoles can cancel each other out, resulting in a nonpolar molecule overall.

17. The Octet Rule applies without exception to all elements in the periodic table. **Answer:** False **Explanation:** Exceptions include Hydrogen/Helium (duet rule), elements like Be/B (can be stable with fewer than 8), and elements in Period 3 and beyond (can have expanded octets with more than 8).

Short Answer Questions

18. Explain the main difference between how ionic and covalent bonds are formed. **Answer:** Ionic bonds form through the complete *transfer* of electrons from a metal to a nonmetal, creating oppositely charged ions that attract electrostatically. Covalent bonds form through the *sharing* of electron pairs between nonmetal atoms.

19. Draw the Lewis dot symbol for a neutral atom of Sulfur (S, Group 16). How many covalent bonds would Sulfur typically form to achieve an octet? **Answer:** Lewis Symbol: ⋮S̈· (Symbol S with 6 dots around it: 2 pairs, 2 singles). Sulfur typically forms **two** covalent bonds (by sharing its two unpaired electrons) to achieve an octet (e.g., in H_2S). It can also form expanded octets.

20. What is a crystal lattice in the context of ionic compounds? **Answer:** A crystal lattice is the regular, repeating, three-dimensional arrangement of cations and anions in an ionic solid, structured to maximize electrostatic attractions and minimize repulsions.

21. Define electronegativity and explain how its difference between two atoms determines the type of covalent bond (polar or nonpolar). **Answer:** Electronegativity is the measure of an atom's ability to attract shared electrons in a chemical bond. If the difference in electronegativity (ΔEN) between two bonded atoms is very small (approx ¡ 0.5), the electrons are shared almost equally, forming a nonpolar covalent bond. If

the ΔEN is significant (approx 0.5 - 2.0), the electrons are shared unequally, forming a polar covalent bond.

22. Why are metals generally malleable and ductile, while ionic crystals are brittle? **Answer:** In metals, the delocalized electron sea allows layers of positive ions to slide past each other under stress without breaking the metallic bond. In ionic crystals, shifting layers brings ions of like charge close together, causing strong repulsion that shatters the crystal (brittleness).

23. Give an example of a molecule containing a coordinate covalent bond and identify the donor and acceptor atoms. **Answer:** Example: Ammonium ion (NH_4^+). Donor: Nitrogen (N) in ammonia (NH_3), which provides its lone pair. Acceptor: Hydrogen ion (H^+), which has an empty 1s orbital.

24. Explain the "like dissolves like" rule for solubility, relating it to ionic and covalent compounds. **Answer:** This rule states that polar substances tend to dissolve in polar solvents, and nonpolar substances tend to dissolve in nonpolar solvents. Polar water molecules can surround and dissolve many ionic compounds (which are highly polar) and polar covalent compounds. Nonpolar covalent compounds dissolve well in nonpolar solvents like hexane because the intermolecular forces are similar.

Structure Drawing and Problem Solving

25. Draw the Lewis structure for Carbon Dioxide (CO_2). Is the molecule polar or nonpolar? Explain. **Answer:** Lewis Structure: $\ddot{O} = C = \ddot{O}$ (Each O has 2 lone pairs). Molecule is **nonpolar**. **Explanation:** Each C=O bond is polar (O is more electronegative than C). However, the molecule has a linear geometry, so the two equal bond dipoles point in opposite directions and cancel each other out, resulting in a nonpolar molecule overall.

26. Draw the Lewis structure for Ammonia (NH_3). Is the molecule polar or nonpolar? Explain. **Answer:** Lewis Structure: H - $\ddot{N}$ - H with another H bonded below N (N has one lone pair). Molecule is **polar**. **Explanation:** The N-H bonds are polar (N is more electronegative). The molecule has a trigonal pyramidal geometry due to the lone pair on N. This asymmetrical shape prevents the bond dipoles from canceling, resulting in a net dipole moment and a polar molecule.

27. Predict the type of bond (ionic, polar covalent, or nonpolar covalent) formed between the following pairs of atoms using electronegativity differences (Use approximate EN values: Na=0.9, Cl=3.0, C=2.5, H=2.1, O=3.5):
a) Na and Cl
b) C and H
c) H and O **Answer:** a) Ionic b) Nonpolar Covalent c) Polar Covalent **Explanation:** a) ΔEN(Na-Cl) $= 3.0 - 0.9 = 2.1$. Since $\Delta EN > 2.0$, the bond is ionic. b)

ΔEN(C-H) = 2.5 − 2.1 = 0.4. Since $\Delta EN < 0.5$, the bond is considered nonpolar covalent. c) ΔEN(H-O) = 3.5 − 2.1 = 1.4. Since $0.5 < \Delta EN < 2.0$, the bond is polar covalent.

28. Write the chemical formula for the ionic compound formed between Magnesium (Mg, Group 2) and Nitrogen (N, Group 15). **Answer:** Mg_3N_2 **Explanation:** Mg (Group 2) forms a +2 ion (Mg^{2+}). N (Group 15) typically forms a -3 ion (N^{3-}) to achieve an octet. To balance the charges, three Mg ions (total charge +6) are needed for every two N ions (total charge -6). Formula: Mg_3N_2.

29. Draw the Lewis structure for the polyatomic ion Phosphate (PO_4^{3-}). (Hint: P is central, satisfies octet usually but can expand; O atoms are terminal). **Answer:** [P single bonded to 4 O atoms. P has 0 lone pairs. Three O atoms have 3 lone pairs and a -1 formal charge each. One O atom forms a double bond with P and has 2 lone pairs. Overall charge 3-. Resonance structures exist.] *Simplified octet-rule compliant structure often drawn first:* [P single bonded to 4 O atoms. P has 0 lone pairs. Each O has 3 lone pairs. P has formal charge +1, each O has -1. Overall 3- charge.] (More complex structures involving double bonds are often preferred based on formal charge minimization, but simple octet structure acceptable at G9 level). **Explanation:** P (Group 15) = 5 valence e-. O (Group 16) = 6 valence e- each. Charge = 3-. Total valence e- = 5 + (4 * 6) + 3 = 5 + 24 + 3 = 32 electrons. Central P bonded to 4 O atoms (uses 8 e-). Remaining 32 - 8 = 24 e-. Distribute 24 e- as lone pairs on 4 O atoms (6 per O). Each O has octet. P has octet (4 single bonds). Structure $[P(\text{single O})_4]^{3-}$, each O with 3 lone pairs.

30. Explain why Tungsten (W), a metal, has an extremely high melting point (approx 3422 °C) compared to Sodium (Na), another metal (MP approx 98 °C). **Answer:** Tungsten is a transition metal with potentially more electrons (including d-electrons) contributing to the delocalized electron sea compared to Sodium (an alkali metal with only one valence electron). This denser electron sea and potentially higher charge on the Tungsten ion cores lead to much stronger metallic bonding, requiring significantly more energy (higher temperature) to overcome for melting.

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