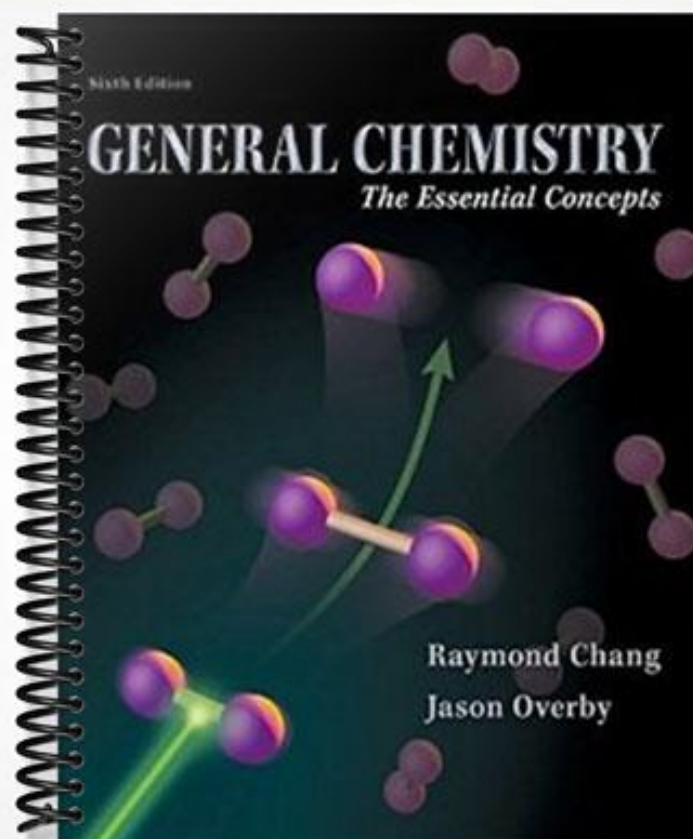


SOLUTIONS MANUAL



Chapter 2

Atoms, Molecules, and Ions

This chapter develops the concepts of atoms, molecules, and ions - the building blocks of all materials. Upon completion of Chapter 2, students should be able to:

- 1) List the hypotheses of Dalton's atomic theory.
- 2) Distinguish between the law of definite proportions and the law of multiple proportions.
- 3) Explain how Dalton's fourth hypothesis is another way of stating the law of conservation of mass.
- 4) Describe how electrons were discovered and how Millikan's oil drop experiment determined the charge of the electron.
- 5) Predict the path of alpha particles, beta particles, and gamma rays as they pass between two oppositely charged electrical plates.
- 6) Describe how Rutherford's experiment concluded that atoms are mostly empty space with very small central cores, known as nuclei.
- 7) Predict the path of protons, electrons, and neutrons as they pass between oppositely charged electrical plates.
- 8) Indicate the number of electrons, protons, and neutrons in atoms and ions.
- 9) Give examples of isotopes.
- 10) Write the names for the three isotopes of hydrogen.
- 11) Identify whether an element is a metal, nonmetal, or metalloid.
- 12) Classify elements as alkali metals, alkaline earth metals, or noble gases.
- 13) List several examples of diatomic molecules.
- 14) Classify ions in terms of monatomic ions, polyatomic ions, cations, and anions.
- 15) Describe the differences between molecular and empirical formulas.
- 16) Give examples of correct formulas for ionic compounds.
- 17) Name common ionic compounds, molecular compounds, binary acids, oxoacids, bases, and hydrates given their respective chemical formulas.
- 18) Predict the chemical formulas of common ionic compounds, molecular compounds, binary acids, oxoacids, bases, and hydrates given their respective names.

Section 2.1 The Atomic Theory

John Dalton's atomic theory is the basis for the modern era of chemistry. Atomic theory can be summarized in the following way:

- 1) Elements are composed of extremely small particles called atoms.
- 2) All atoms of a given element are identical, having the same size, mass, and chemical properties. The atoms of one element are different from atoms of all other elements. (Lego blocks can be used as an example).
- 3) Compounds are composed of atoms of more than one element. In any compound, the ratio of the numbers of atoms of any two elements present is either an integer or a simple fraction.

- 4) A chemical reaction involves only the separation, combination, or rearrangement of atoms. This is another way of stating the law of conservation of mass, which is that matter can be neither created nor destroyed.

As a result of Dalton's third point, Joseph Proust formulated the law of definite proportions, which states that different samples of the same compound always contain its constituent elements in the same proportion by mass. For example, all methane, CH_4 , samples have a carbon to hydrogen ratio of 3/1 by mass. The law of multiple proportions states that if two elements can combine to form more than one compound, the masses of one element that combines with a fixed mass of the other element are in ratios of small whole numbers. As an example, chlorine will combine with phosphorous to form PCl_3 and PCl_5 . The law of multiple proportions suggests that for a given mass of phosphorous (for example, 30.97 g, the mass of one mole of P), the ratio of masses of chlorine that will combine with given mass amount of phosphorous should be in the ratio of small whole numbers. For PCl_3 the mass of chlorine that will combine with 30.97 grams of phosphorous is 106.35 grams. The mass of chlorine that combines with 30.97 g of phosphorous in PCl_5 is 177.25 g. The ratio of these two masses of chlorine is 0.6 or 3/5. The prior example demonstrates the concept of the law of multiple proportions.

Section 2.2 The Structure of the Atom

The three particles that are fundamental to the composition of atoms are the electron, proton, and neutron. Even though the electron has a mass that is approximately 1/1840 the mass of a proton or neutron, we know that the electron plays an extremely important role in the chemistry of everyday reactions. It is interesting to note that radioactive materials were the sources for the discovery of these particles. J. J. Thompson used the cathode ray tube and R. A. Millikan used the oil-drop experiment to characterize the electron. Ernest Rutherford's famous gold-foil experiment established the existence of a nucleus and James Chadwick found the neutron.

Animations: Cathode ray tube on page 44; Millikan oil drop experiment on page 45; Alpha, Beta, and Gamma Rays on page 46; α -Particle Scattering on page 47.

Section 2.3 Atomic Number, Mass Number, and Isotopes

It is important that students understand that the number of protons in a nucleus determines which element is being studied. The number of protons is known as the atomic number and is symbolized by Z . Differing number of neutrons in the nucleus results in mass numbers (symbolized by A) that vary which results in isotopes. Hydrogen is the only element whose different isotopes have specific names. They are hydrogen, deuterium, and tritium. The mass effects of using H (mass = 1 amu), D (mass = 2 amu) and T (mass = 3 amu) have significant influence on some reactions. On the other hand, ${}_{92}^{235}\text{U}$ and ${}_{92}^{238}\text{U}$ would have insignificant mass effects. Your author uses ${}^A_Z\text{X}$ to describe specific isotopes of a given element. Where A is mass number Z is atomic number and X is an element.

Section 2.4 The Periodic Table

While students should have good general knowledge of the periodic table, they should refresh their memory of it. In addition, they should learn the common names of alkali metals (Group 1A), alkaline earth metals (Group 2A), halogens (Group 7A), and noble gases (no longer called inert gases, in Group 8A). Another group that is useful to recognize is the three metals: copper (Cu), silver (Ag), and gold (Au), which make up the “coinage metals”. This group will be important when we discuss exceptions to the electron configurations of these elements in a later chapter.

Section 2.5 Molecules and Ions

Of all the elements, the six noble gases are the only gases that exist in nature as single, or monatomic, gases. Most matter is composed of molecules or ions formed by atoms.

A molecule is an aggregate of at least two atoms in a definite arrangement held together by chemical forces, or chemical bonds.

Other elements contain two (diatomic) or more (polyatomic) molecules. There are many diatomic molecules. Examples of diatomic molecules include N_2 , O_2 , F_2 , Cl_2 , Br_2 , and I_2 . The vast majority of molecules contain more than two atoms classified as polyatomic molecules. Ozone, O_3 , is a well-known example. It should be pointed out that polyatomic molecules are not required to have only two elements as shown in the examples of water and ammonia. Ethanol, C_2H_6O , is another example of a polyatomic molecule.

An ion is an atom or a group of atoms that has a net positive or negative charge.

In the example of sodium atoms and sodium ions, it should be pointed out that the net charge of +1 (11 protons - 10 electrons) is the charge on the sodium ion. Similarly, the charge on the chloride ion is -1. Ions can be monatomic or polyatomic. Note that we used monatomic, diatomic, and polyatomic to describe neutral atoms and molecules. Since the term polyatomic ion includes the diatomic term, OH^- and HPO_4^{2-} would both be classified as polyatomic ions.

Section 2.6 Chemical Formulas

Chemicals can be written in several short-hand notations. For example, ethylene can be written as C_2H_4 (its chemical formula) or CH_2 (its empirical formula, which will be used more extensively in the next chapter) or H_2CCH_2 (its structural formula) to provide more information. We use the chemical formula when we write chemical reactions.

Section 2.7 Naming Compounds

It is imperative that students learn the correct names of common compounds. If they cannot “speak” the language of chemistry, they will not be able to communicate effectively when we get into chemical reactions. If they learn the correct methods of naming compounds early,

they will have one less barrier to overcome when we study such topics as balancing equations, combustion reactions, etc.

The trend is to de-emphasize the — ic (more positive charges) and — ous (fewer positive charges) suffixes. The favored system in use is the Stock system, which designates different cations with Roman numerals. Roman numeral I indicates one positive charge; II means two positive charges, and so on.

Table 2.3 can be challenging for students. A tip for learning the table is to indicate that the charges on alkali metal ions (Group 1A) can only be +1 and that the charges on alkaline earth metal ions (Group 2A) can only be +2. Another important point to note is that the prefixes in Table 2.4 are used for molecular compounds and not ionic compounds. An exception to that is the naming of oxyanions such as dihydrogen phosphate, H_2PO_4^- .

Another concept students may find difficult to understand is that HCl, as a gas, is molecular but HCl dissolved in water forms ions. Therefore, HCl has two different names depending upon its state. A question that will challenge even your best students is to ask them to give the formula for hydrosulfuric acid. Most students will respond with H_2SO_4 . However, if you then ask them what sulfuric acid is, they will realize that H_2SO_4 is not the correct answer for the name of H_2S .

Figure 2.14 is useful in learning oxoacids and their corresponding oxyanions. After students have been introduced to hypochlorous, chlorous, chloric, and perchloric acids, a challenging question is to ask them to describe components of HIO.

Naming hydrates is challenging. Explain that we can use numbers as subscript only in a chemical formula. However, since hydrates are two individual compounds, we use a dot followed by the number to indicate the number of water molecules in between a compound and water molecule/s. Since water is molecular, we use prefixes as shown in table 2.4.

Electronic Homework Problems

To assign electronic homework, go to: www.aris.mhhe.com Choose *General Chemistry*, 6th edition by Chang/Overby.