### **Chapter 1**

**FUNDAMENTAL CONCEPTS OF CHEMISTRY**

### This chapter contains important material that sets the tone for all that follows. Mastering the molecular view of matter, devising strategies for solving problems and reviewing fundamental ideas of compounds, stoichiometry, reaction yields and the limiting reactant are central to student success in general chemistry.

**Section 1.1**

**Atoms, Molecules, and Compounds**

### **Learning Objective:** become familiar with atoms, molecules and chemical formulas, as well as the molecular view.

This section relates the macroscopic and microscopic views of matter. Atoms and molecules are introduced, as well as symbols of elements and chemical formulas. The molecular view is emphasized.

**Section 1.2**

**Measurements in Chemistry**

### **Learning Objective:** recognize the SI units commonly used in chemistry, and perform some common unit conversions

Here we lay the groundwork for understanding measurement of physical properties important to chemistry. Magnitude and units of measurement are discussed. Unit conversions are presented. Precision and accuracy are discussed in the context of expressing measurements to the correct number of significant figures. Focus 1-1, “Tools for Discovery: Atomic Level Microscopy,” presents images acquired by scanning tunnelling and atomic force microscopy.

**Section 1.3**

**Chemical Problem Solving**

**Learning Objective:** analyze and solve problems in a consistent, organized fashion

This important section describes a seven-step general algorithm for students to apply whenever they encounter a problem whose solution is not immediately evident. The first illustration of this algorithm uses an application of density. Students are shown how problems that appear to be complex can be analyzed and solved in a simple stepwise fashion.

**Section 1.4**

**Counting Atoms: The Mole**

**Learning Objective:** solve mass-number-molecular weight type problems

This section formally introduces the mole and Avogadro’s number. Isotopic molar masses and natural abundances are used to calculate elemental molar mass. Mass-mole-atom conversions illustrate that chemical calculations are built around the mole.

**Section 1.5**

**Amounts of Compounds**

**Learning Objective:** perform mole-mass-number conversions

A continuation on the theme that nearly all chemical calculations are centered around the mole. Molar masses of elements are used to calculate molar masses of compounds. Example problems illustrate the importance of writing correct chemical formulas in order to calculate the molar mass of a molecular or ionic compound.

**Section 1.6**

**Aqueous Solutions**

**Learning Objective:** calculate concentrations of solutions and diluted solutions

This section covers solution terminology and describes the nature of aqueous solutions. Molecular and ionic solutes are discussed. Calculations involving molarity, preparation of solutions, and dilution are presented. Strategies for problem-solving are provided along with flowcharts.

**Section 1.7**

**Writing Chemical Equations**

**Learning Objective:** balance chemical reactions

Here we describe procedures for balancing chemical reactions by inspection. The text emphasizes that a balanced equation expresses conservation of the elements, and that such an equation can be interpreted on a molecular level or on a mole basis.

**Section 1.8**

**The Stoichiometry of Chemical Reactions**

**Learning Objective:** calculate the amount of a product from the amounts of the reactants and a balanced chemical reaction

Section 1.8 describes procedures for calculating amounts of different reagents. Students should first review relationships among atoms, moles, and masses of individual substances. Flowcharts are used to reiterate the importance of working with moles and to show visually the logic of the calculation sequence.

**Section 1.9**

**Yields of Chemical Reactions**

**Learning Objective:** calculate reaction yields

Procedures for calculating theoretical and percent yields are described in this section. Percent yields less than 100% may result from competing reactions consuming starting materials, loss during purification processes, or from reactions stopping before reaching completion. Some reactions do not go to completion because they reach dynamic equilibrium. Chemical equilibrium is treated in detail in Chapters 14, 15, and 16. Focus 1-2, “Chemistry and Life: Feeding the World,” describes the production of fertilizers by the chemical industry and illustrates why industry values the attainment of high yields.

**Section 1.10**

**The Limiting Reactant**

**Learning Objective:** solve limiting-reagent-type problems

This final section begins with an analogy of a bicycle shop limited by the number of wheels available to build bicycles. This analogy illustrates the simple principle underlying the limiting reagent: when a starting material runs out, production stops. Tables of amounts are used as a tool to organize stoichiometric data for limiting reagent calculations.**LECTURE OUTLINE - Chapter 1**

**FUNDAMENTAL CONCEPTS OF CHEMISTRY**

I. Atoms, molecules, and compounds

A. Properties of matter

1. Macroscopic view

2. Microscopic view

B. Atoms

1. Fundamental unit of a chemical substance

2. Smallest possible particle of a substance

C. Molecules

1. Combination of two or more atoms

2. Simplest molecules are diatomic

3. Atoms held together by attractive forces

D. Chemical formulas

1. Show symbols of elements chemically combined

2. Subscripts denote the number of atoms of each element in a molecule

II. Measurements in chemistry

A. Physical properties

1. Length

2. Area

3. Volume

4. Mass

a. Quantity of matter

b. Measured by weighing

5. Time

6. Temperature

a. Property of an object that determines direction of heat flow

b. Heat flows from higher temperature to lower temperature

B. Magnitude

1. Scientific notation

2. Scientific prefixes for magnitude

*Table 1-1* “Frequently Used Scientific Prefixes for Magnitude”

a. Tera, T (1012)

b. Giga, G (109)

c. mega, M (106)

d. kilo, k (103)

e. centi, c (10-2)

f. milli, m (10--3)

g. micro, μ (10-6)

h. nano, n (10-9)

i. pico, p (10-12)

j. femto, f (10-15)

k. atto, a (10-18)

C. Units of measurement

1. SI base units

*Table 1-2* “Base SI Units”

a. Kilogram (kg)

b. Meter (m)

c. Second (s)

d. Kelvin (K)

e. Mole (mol)

f. Ampere (A)

g. Candela (cd)

2. Unit conversions

D. Precision

1. Exactness of a measurement

2. Plus/minus notation used to indicate limits

E. Accuracy

1. How close a measurement is to the true value

2. More difficult to determine than precision

F. Significant figures

1. Digits in a numerical value starting with the first digit that is not zero

2. Trailing zeros are not significant unless a decimal point is shown

iii. Length

III. Chemical problem solving

A. Read the problem carefully

B. Identify what is asked for

C. Visualize the problem

D. Identify the problem solving process

E. Organize data

F. Manipulate equations

G. Substitute values and calculate

H. Check and evaluate answers

IV. Counting atoms: the mole

A. Number of atoms in exactly 12 grams of carbon-12

B. Avogadro’s number (*N*A) = 6.022 x 1023

C. Molar mass (*M*)

1. Mass of one mole of a substance

2. Elemental molar mass = ∑ (fractional abundance) (isotopic molar mass)

V. Amounts of compounds

A. Line structures

B. Molar masses of chemical compounds

1. Sum of the molar masses of the elements in a compound, taking into account the number of moles of each element present

2. Expressed in units of g/mole

C. Mass-mole-number conversions

1. Mass-mole-number conversions for atoms

2. Mass-mole-number conversions for compounds

VI. Aqueous solutions

A. Solution components

1. Solute

2. Solvent

B. Molarity

1. Number of moles solute per litre solution

2. Solutes

a. Molecular solutes

b. Ionic solutes

3. Dilution

a. Number of moles of solute does not change during dilution

b. Volume of solution increases

c. Concentration of solute decreases

VII. Writing chemical equations

A. Balanced equations

1. Reactants

a. Reagents consumed in a chemical reaction

b. Appear to the left of the arrow in a chemical equation

2. Products

a. Reagents produced in a chemical reaction

b. Appear to the right of the arrow in a chemical equation

3. Arrows indicate direction of change from reactants to products

4. Stoichiometric coefficients

* 1. Smallest integers that give a balanced equation in which amounts of all elements are conserved

i. Can be interpreted on a molecular level

ii. Can be interpreted on a mole level

* 1. Charge is conserved

B. Equations can be balanced by inspection

VIII. Stoichiometry of chemical reactions

A. Stoichiometric relationships are given by coefficients

1. Mole amounts of reactants are related

2. Mole amounts of products are related

3. Mole amounts of reactants and products are related

B. Mass-mole relationships

1. Mass divided by molar mass gives the number of moles

2. Mole-mole ratios are given by coefficients

C. Mass-mass relationships

1. Mass divided by its molar mass gives the number of moles

2. Mole-mole ratios are determined by coefficients in a balanced equation

3. Number of moles of a substance multiplied by its molar mass gives the mass of a substance

IX. Yields of chemical reactions

A. Theoretical yield is the amount of product predicted by stoichiometry

B. Actual yield is the amount of product actually obtained

C. Percent yield is the percentage of the theoretical amount that is actually obtained

X. Limiting reactants

A. Limit the amount of product that can be made

B. Solving quantitative limiting reactant problems

1. Organize data

2. Identify the limiting reactant

a. Write the balanced equation

b. Calculate the number of moles of each reactant

c. Divide the number of moles of each reactant by its stoichiometric coefficient

d. Reactant with the smallest value (step c) is limiting

3. Calculate product yields

4. Calculate amounts of reactants in excess

a. Calculate amounts of reactants consumed

b. Subtract amounts consumed from initial amounts

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**Suggestions for relating “Fundamental Concepts of Chemistry” to real-life experiences**

Relate atoms and molecules to letters of the alphabet and words. Symbols of elements can be correlated to letters. The first stage of learning to read and write is learning the alphabet, just as symbols and names of elements must be learned early on when studying chemistry. Words are formed by combining letters. Different letter combinations produce different words – it and at are different words. HF and HCl are different compounds. The number of each letter present forms different words. Toot is not the same word as tot. HOOH (H2O2) is not the same compound as HOH (H2O). The order of the letters in words is important. Bat is not the same word as tab. CH3COCH3 is not the same compound as CH3CH2OH.

Measurements in chemistry can be related to everyday measurements such as measurements of time, distance, speed, volume, and temperature using measuring devices such as stop watches, rulers, speedometers, measuring cups, and thermometers. Precision and accuracy can be discussed in the context of patterns of arrows striking a target as shown in Figure 1-8.

The meaning of the term mole can be related to the meaning of the word dozen. Molar mass can be related to the mass of one dozen objects. The mass of one mole of copper is different from the mass of one mole of helium. The mass of one dozen bowling balls is different from the mass of one dozen golf balls.

Molar masses of chemical compounds can be related to the mass of one dozen bicycles. Chemical compounds have “parts” (atoms or ions) just as bicycles have parts. The mass of 1 mole of HNO2 is determined by adding the mass of 1 mole of H to the mass of 1 mole of N and the mass of 2 moles of O, just as the mass of 1 dozen bicycles can be found by adding the mass of 1 dozen frames to the mass of 1 dozen chains and the mass of 2 dozen wheels.

Aqueous solutions and concentrations can be related to bottles of food coloring (stock solutions). Solutions of different concentration can be prepared by diluting the stock solution. This concept can to be related to adding a drop of food coloring to a small glass of water (making a concentrated solution) versus adding a drop of food coloring to a large bucket of water (a dilute solution).

Relate writing chemical equations to recipes, for example, baking a cake. Butter, eggs, sugar, flour, and vanilla are the reactants. The product is a pound cake. The chemical change (as indicated by the arrow in a balanced equation) takes place while the mixed ingredients are baking in the oven. The amounts of ingredients correspond to the coefficients in a balanced equation, i.e., 2 sticks butter, 5 eggs, 500 mL flour, 500 mL sugar, 5 mL vanilla extract makes 1 pound cake. Recipes can be scaled up or down, just as chemical reactions can be. The recipe (balanced equation) remains the same.

Stoichiometry can be related to an assembly, for example, setting up one dozen card tables for a card tournament. Four dozen chairs relates to one dozen tables and two dozen decks of cards, analogous to mole-mole relationships among reactants in balanced equations. Four dozen chairs are required for one dozen set-ups, analogous to mole-to-mole relationships among reactants and products in chemical equations.

Yields of chemical reactions can be related to the amount of something produced, such as the number of striped vests produced from balls of yarn. For example, 1.5 kg of white yarn, 250 g of red yarn, 250 g of blue yarn, and 250 g of green yarn should make four vests, the theoretical yield. Three vests were actually made from the yarn giving a 75% yield. The lower than 100% yield was due to a competing side reaction – a kitten got into the act!

Limiting reactant problems can be related to serving food items, such as a hot fudge sundae. The “reactants” are vanilla ice cream and hot fudge. Each sundae requires one scoop of ice cream and 30 mL of hot fudge. When one of the ingredients is used up, no more sundaes can be made. If there are three scoops of ice cream, and 120 mL of hot fudge available, the limiting reactant is the ice cream and the hot fudge is in excess. Only three sundaes can be made. 90 mL of hot fudge will be used, leaving 30 mL in excess.

**CHAPTER 1 CONCEPT MAP**

precision

accuracy

have

consist of

Measurements

numbers

units

scientific notation

can be expressed in

prefixes for magnitude

can be modified with

significant digits

as expressed by

include

kilo

centi

milli

micro

nano

mega

correlate to

are greater than

less than 100

percent yield

actual yields of products

theoretical yields of products

are used to predict

remaining when a reaction is over are

totally consumed are

excess reactants

limiting reactants

Reactants

are written as

Chemical reactions

are chosen to comply with conservation of

include

coefficients

balanced equations

molar mass

Avogadro’s number

solute

solution

solvent

molarity

components are

concentration can be expressed as

6.022 x 1023

one mole

equals

represents

is the mass of

elements

charge