

# CHAPTER 1

## CHEMISTRY: MATTER AND MEASUREMENT

### Chapter Learning Goals

- Section 1.1** Describe the processes involved in the scientific method.
- Section 1.2** Identify the symbol and name of elements from the periodic table.
- Section 1.3** Identify the group number and period to which an element belongs.  
Identify the regions of the periodic table.
- Section 1.4** Identify properties as *extensive* or *intensive* and as *chemical* or *physical*.
- Section 1.5** List the seven basic SI units of measure, and give the numerical equivalent of the common metric prefixes used with these units.  
Express numbers in scientific notation (textbook Appendix A).
- Section 1.6** Interconvert metric and English masses.
- Section 1.7** Interconvert metric and English lengths.
- Section 1.8** Interconvert Fahrenheit, Celsius, and Kelvin temperatures.
- Section 1.9** Interconvert metric and English volumes.
- Section 1.10** Calculate densities from measured masses and volumes.  
Use density to interconvert mass and volume.
- Section 1.11** Distinguish between accuracy and precision.  
Determine the number of significant digits and uncertainty in a measured quantity.
- Section 1.12** State the result of a calculation involving measured quantities to the correct number of significant digits.
- Section 1.13** Use dimensional analysis to solve metric-English conversion problems.

## **Lecture Outline**

### **1.1. Approaching Chemistry: Experimentation**

- A. Chemistry is an experimental science.
- B. Scientific Method – systematic approach to research
  - 1. Observation
  - 2. Experimentation
  - 3. Hypothesis – interpretation explaining results of many experiments
  - 4. Theory – consistent explanation of known observations; logical interpretations of experimental results

### **1.2. Chemistry and the Elements**

- A. Element – the smallest fundamental substance that retains the properties of that substance. Elements *can* be broken into simpler substances (protons, neutrons, electrons, etc.), but the energy required is greater than available under ordinary chemical conditions.
  - 1. Chemical symbol – represents a specific element
    - a. Capitalize first letter
    - b. Lower case used for second letter if present
- B. Periodic table – tabular organization of all 114 elements

### **1.3. Elements and the Periodic Table**

- A. Periodic table – grid of the elements arranged in 7 horizontal rows and 18 vertical columns
- B. Periods – seven horizontal rows in the periodic table
- C. Groups – 18 vertical columns in the periodic table. Because elements in the same group tend to exhibit similar chemical behavior, a group is also called a *family*.
  - 1. Groups numbered 1A → 8A and 1B → 8B (or 1 → 18)
  - 2. Actually have 32 groups – lanthanides (14 elements after lanthanum) and actinides (14 elements after actinium) not included in the group numbers
- D. Elements in a given group have similar chemical properties.
- E. The periodic table of the elements is the most important organizing principle of chemistry.
  - 1. Regular progression in size of the seven periods – reflects a similar regularity in atomic structure
  - 2. Main Group (or Representative) Elements – Groups 1A-8A; (two larger groups on the left and six larger groups on the right of the table)
  - 3. Transition Metal Elements – Groups 1B-8B; (10 smaller groups in the middle of the table)
  - 4. Inner Transition Metal (or Rare Earth) Elements (14 groups shown separately at the bottom of the table)

### **1.4. Some Chemical Properties of the Elements**

- A. Property – any characteristic used to describe or identify matter
  - 1. Physical properties – characteristics not involving chemical change of the sample
  - 2. Chemical properties – properties that do change chemical makeup of the sample
  - 3. Intensive properties – sample size-independent properties
  - 4. Extensive properties – sample size-dependent properties
- B. Elements within a group have similar chemical properties.
  - 1. Group 1A – Alkali metals
    - a. Lustrous, silvery metals
    - b. React rapidly with water to form highly alkaline products
  - 2. Group 2A – Alkaline earth metals:
    - a. Lustrous, silvery metals
    - b. Less reactive than alkali metals
  - 3. Group 7A – Halogens
    - a. Corrosive, nonmetallic elements
    - b. Salt formers.
    - c. Example: Iodine is a silvery-gray solid that sublimates to a purple gas.
  - 4. Group 8A – Noble gases: gases with low reactivity

C. Exceptions:

1. While elements within the same group tend to have similar chemical properties, due to its small size the first member of each main group exhibits a chemistry that differs most from the other members of the group.
2. Hydrogen is a unique element. Although listed under group 1A, hydrogen is not a metal under ordinary conditions. In its ionic chemistry, hydrogen sometimes behaves as though it belongs in group 7A. In covalent compounds, hydrogen behaves as though it belongs between boron and carbon.

D. Three major classes of elements

1. Metals

- a. Largest category of elements
- b. Found on the left side of the periodic table (left of the heavy zigzag line)
  - i. Solids (except mercury)
  - ii. Malleable
  - iii. Ductile – can be drawn into thin wires without breaking
  - iv. Conduct heat and electricity

2. Nonmetals

- a. Relatively small number
- b. Found on the right side of the periodic table (right of the heavy zigzag line).
  - i. Gases, liquids, or solids
  - ii. Brightly colored
  - iii. Brittle solids
  - iv. Poor conductors of heat and electricity

3. Semimetals (metalloids)

- a. Elements adjacent to the zigzag boundary between metals and nonmetals.
- b. Properties fall between metals and nonmetals
  - i. Brittle
  - ii. Poor conductors of heat and electricity

**1.5. Experimentation and Measurement**

- A. International System (SI) of Units – seven base units (and units derived from them) that suffice for all scientific measurements (textbook Table 1.3)
- B. All systems of measurement are based on arbitrary standards. The SI system is as arbitrary as the English system, but the relationship of one unit to another is more systematic and easier to remember in the metric system.
- C. Common prefixes used to modify SI units. For very large or very small quantities, commonly used prefixes represent amounts that vary by three powers of 10, for example, milli, micro, nano, and pico ( $10^{-3}$ ,  $10^{-6}$ ,  $10^{-9}$ , and  $10^{-12}$ , respectively).
  1. mega (M); factor =  $10^6$
  2. kilo (k); factor =  $10^3$
  3. deci (d); factor =  $10^{-1}$
  4. centi (c); factor =  $10^{-2}$
  5. milli (m); factor =  $10^{-3}$
  6. micro ( $\mu$ ); factor =  $10^{-6}$
  7. nano (n); factor =  $10^{-9}$
- D. Scientific notation – exponential format for very large or very small numbers (textbook Appendix A)
- E. All measurements of physical quantities contain a
  1. number.
  2. unit label.

**1.6. Measuring Mass**

- A. Mass (SI unit = kg) – amount of matter in an object
- B. Matter – anything physically real
- C. Weight – pull of gravity on an object

- D. Mass of an object
1. Measured on a balance
  2. A comparison of the weight of the object to the weight of a reference standard of known mass

### 1.7 Measuring Length

- A. Meter
1. Standard SI unit of length
  2. Distance traveled by light in a vacuum in  $1/299,792,458$ th of a second

### 1.8. Measuring Temperature

- A. Common unit – Celsius degree ( $^{\circ}\text{C}$ ).
- B. Scientific unit – Kelvin.
- C. Celsius and Kelvin scales –100 degrees between the freezing point and boiling point of water
- Temperature in K = temperature in  $^{\circ}\text{C}$  + 273.15
- Temperature in  $^{\circ}\text{C}$  = temperature in K – 273.15
- D. Fahrenheit scale –180° between the freezing point and boiling point of water
1. 180°F encompasses the same range as 100°C.

$$1\ ^{\circ}\text{C} \times \frac{180\ ^{\circ}\text{C}}{100\ ^{\circ}\text{F}} = \frac{9}{5} \times\ ^{\circ}\text{F}$$

- E. Conversion from Celsius to Fahrenheit
1. Size correction
  2. Followed by zero-point correction
- F. Conversion from Fahrenheit to Celsius
1. Zero-point correction
  2. Followed by a size correction

$$^{\circ}\text{F} = \left( \frac{9\ ^{\circ}\text{F}}{5\ ^{\circ}\text{C}} \times\ ^{\circ}\text{C} \right) + 32\ ^{\circ}\text{F}$$

$$^{\circ}\text{C} = \frac{5\ ^{\circ}\text{C}}{9\ ^{\circ}\text{F}} \times ( ^{\circ}\text{F} - 32\ ^{\circ}\text{F} )$$

### 1.9. Derived Units: Measuring Volume

- A. Derived quantities – quantities expressed in terms of one or more of the seven base units (See textbook Table 1.5.)
- B. Volume – amount of space occupied by an object
1. Measured in SI units by the cubic meter ( $\text{m}^3$ )
  2. Commonly used measurements:
    - a. Cubic decimeter ( $\text{dm}^3$ ) = metric liter (L)
    - b. Cubic centimeter ( $\text{cm}^3$ ) = metric milliliter (mL)
  3. Computation - Both the measured number and unit are raised to the appropriate power when dealing with areas and volumes. For example,  $(3\ \text{cm})^3 = 3^3\ \text{cm}^3 = 27\ \text{cm}^3$ , not  $3\ \text{cm}^3$  or 27 cm.

### 1.10. Derived Units: Measuring Density

- A. Density – intensive property relating mass to volume
1. Expressed in units of  $\text{g}/\text{cm}^3$  or  $\text{g}/\text{mL}$
  2. Temperature dependent property
  3. Useful property – allows conversion of a liquid’s volume to mass.
- B. Density is not to be confused with mass. A kg of feathers weighs the same as a kg of gold, but gold occupies less space because it has a greater density.
- C. In relation to density, it is often useful to use water as standard when relating the density of a solid to the density of a liquid. However, water is unique in that ice floats atop liquid water.

### 1.11. Accuracy, Precision, and Significant Figures in Measurement

- A. Accuracy – how close a measurement is to the true value
- B. Precision – how well a number of independent measurements agree with one another
  - 1. To indicate the precision of a measurement use all the digits known with certainty, plus one additional estimated digit. Uncertainty arises from the last estimated digit.
  - 2. Number of digits in the measurement = number of significant figures
- C. Determining the number of significant figures – see rules in textbook
  - 1. Significant figures are a shortcut to expressing the limitations of laboratory measurements.
  - 2. Only measured quantities may contain a measured error, which limits the number of significant figures. In addition to counted objects (7 days = 1 week), numbers related by definition (1 in = 2.54 cm) are exact numbers with an infinite number of significant figures.
- D. Using scientific notation – helpful in determining number of significant figures
- E. Exact numbers – infinite number of significant figures

### 1.12. Rounding Numbers

- A. In carrying out a multiplication or division, the answer can't have more significant figures than either of the original numbers.
- B. In carrying out an addition or subtraction, the answer can't have more digits to the right of the decimal point than either of the original numbers.
- C. The answer given to a series of calculations involving measured quantities is limited by the least precise measurement.
- D. Rules for rounding off numbers
  - 1. See text
  - 2. Doing calculations
    - a. Use all figures, significant or not
    - b. Avoid round-off errors by always using one more significant figure for constants or molar masses than required by measured data and rounding off only the final answer.

### 1.13. Calculations: Converting from One Unit to Another

- A. Dimensional analysis method
  - 1. Quantity described in one unit converted into an equivalent quantity described in a different unit
  - 2. Conversion factor used to express relationship between units  
  
Starting quantity  $\times$  conversion factor = equivalent quantity
  - 3. Units
    - a. Treated like numbers
    - b. Can be multiplied and divided
  - 4. Equation
    - a. Set up so that all unwanted units cancel
    - b. Leave only desired units
    - c. Correct answer obtained only if equation set up so unwanted units cancel
  - 5. Method:
    - a. Start with given information, including units
    - b. Identify information needed, including units
    - c. Find relationship between known information and unknown answer
    - d. Plan a strategy to get from known information to unknown answer
    - e. Solve
      - i. Use conversion factor that allows units in given information to cancel
      - ii. Continue conversion factor use to cancel the previous unit until desired unit remains
    - f. Consider whether answer obtained is reasonable (Refer to Ballpark Check in textbook.)
  - 6. Number of significant figures in answer determined from given information