Chapter 1—Matter and Measurements

Overview Chapter 1 sets the stage for a view of our surroundings as chemical in nature. Chemical symbols are introduced early, as are the concepts of formulas and energy. Interesting examples relate the study of chemistry to environmental problems.

Introduction for Instructors

- Students will need to learn new uses and meanings for words.
- Although little math is used in Chapter 1, it rears its head later, and students have difficulty making practical use of the extensive amount of algebra they already know. Simple illustrations and problems will help them immensely.
- Chemistry is not only a new science for most students, it's a new language.
- Students forget lists and definitions rapidly. Concrete examples (especially references to environmental problems, medicine or health), stories and jokes help reinforce vocabulary and concepts. Many students will consult the Internet for additional information.

Chapter Goals

- To understand:
  - What matter is
  - How matter is classified
  - What are the properties of matter and what units are used in measurement
  - What common tools are used to make measurements in science
- To understand:
  - How chemical elements are represented
  - How to name chemical elements
  - How the periodic table is used to classify elements
  - How SI units are used to simplify measurements and calculations
  - How to use the factor-label method
- To understand the properties of matter
- To understand how large and small numbers are represented
- To understand some methods for solving problems
- To be able to define and use the concepts of specific heat, density and specific gravity

Lecture Outline

1.1 Chemistry: The Central Science

- Chemistry is the science central to all others.
- Many fields of study overlap, so some fields such as chemistry and biology or physics combine concepts.
- Chemistry is the study of matter and changes in composition of matter.
- A physical change is a change in form but not in composition.
- A chemical change alters the chemical composition of a substance.

Hands-On Chemistry 1.1

- Burning of potassium in water is an example of a chemical change.

1.2 States of Matter

- Matter has mass and volume.
- Chemical properties describe what matter is made of.
- Matter has both physical and chemical properties.
  - Matter can be grouped into metals, nonmetals and semimetals
- Matter exists in three states: solids, liquids, gases
- The states of matter can be changed by physical means.

1.3 Classification of Matter

- Matter can be classified as a pure substance or a mixture.
  - Pure substances may be elements or compounds.
  - Pure substances that cannot be broken down to simpler substances are called elements.
  - Pure substances that can be broken down by chemical means to other pure substances are called compounds.
- Mixtures may be homogenous (alike throughout) or heterogeneous (having nonuniform composition).
- A physical change is a change in state such as freezing or boiling. The composition of the matter doesn't change during a physical change.

Chemistry in Action—
Aspirin: A Case Study

- Hippocrates, a Greek physician, found that the bark and leaves of willow trees alleviated pain.
- The active principle was later found to be salicin, a derivative of salicylic acid.
- Further research allowed production of acetylsalicylic acid, a potent painkiller.

1.4 Chemical Elements and Symbols

- One hundred and eighteen chemical elements are now known.
- Elements are represented by chemical symbols.
- Symbols are made up of one or two letters.
- The first letter is always capitalized; the second is never capitalized, even if written small.

1.5 Chemical Reactions: Examples of Chemical Change

- Chemical reactions result in changes in the composition of substances.
- Chemical reactions are represented by chemical equations.

1.6 Physical Quantities: Units and Scientific Notation

- The amounts of matter under discussion are described in physical quantities having units.
- For scientific purposes, quantities of matter are usually described in SI units.

Chemistry in Action—
Mercury and Mercury Poisoning

- Mercury, the only liquid element at room temperature, has been known since ancient times.
- Some mercury compounds are relatively safe to handle, but some are very toxic.
- Very small amounts of mercury in the environment may be concentrated by some organisms and may reach toxic levels in the food chain.

1.7 Measuring Mass, Length, and Volume

- Grams, liters, and meters are the basis of measurements of mass, volume, and length.
- Smaller amounts are usually designated by the prefixes *centi* and *milli*.

Hands-On Chemistry 1.2

- The mass of an object provides us with important information about its composition.

1.8 Measurement and Significant Figures

- When making calculations, scientists assume the answer to be no more accurate than the least number of significant figures in the least accurate piece of information.
- The use of a calculator allows computation to many places more than are usually significant.
- Scientific calculations are simplified when numbers are provided in scientific notation.
- Any number can be expressed as a digit multiplied by 10 raised to some power.
  - To express a number in scientific notation, move the decimal point to the right side of the first digit. For each place the decimal point is moved to the right, raise the power of 10 by one power. For every place the decimal point is moved to the left, raise the power of 10 by one negative number. For example, 500 becomes 5×10^2, and 0.00072 becomes 7.2×10^{-4}.

1.9 Rounding Off Numbers

- An answer may not have more significant figures than the least significant data.
- Perform all the calculations; then round the answer to the least number of significant figures.

1.10 Problem Solving: Unit Conversion and Estimating Answers

- Calculation of answers to complex problems is simplified by multiplying and dividing units along with the numerical values. If the answer appears in the correct units, the calculation is probably correct.
- Another key to finding the correct answer is to look at the setup for the problem and estimate the answer, arriving at a "ballpark" figure.

1.11 Temperature, Heat, and Energy

- Energy is defined as the capacity or ability to do work.
- Temperature is a measure of the intensity of heat, one form of energy.
  - Temperature is measured in degrees Fahrenheit, Celsius, or kelvin.
- The specific heat is the amount of heat needed to raise the temperature of 1g °C.

Chemistry in Action—
Temperature-Sensitive Materials

- Temperature-sensitive indicators are widely used in health and industry.
- Many toys, foods, and items of wearing apparel now carry temperature-sensitive tags.
- Some shape-memory alloys such as those used in arterial stents or orthodontic wires can be inserted into place and then heated to assume their original shapes.

1.12 Density and Specific Gravity

- Density is defined as the ratio of the mass of an object to its volume.
- Specific gravity is defined as the ratio of the mass of an object to the mass of an equal volume of water.

Chemistry in Action—

Obesity and Body Fat

- The body mass index is a quick measure of obesity. BMI = weight/height^2.
- It has long been known that obesity is related to increased mortality. Less well-known is research showing that weight loss can translate into increased longevity.

Lecture Demonstrations

- Intro to Chemistry: Note anecdotes about chemistry. Bring in a biochemistry or organic textbook to show the interrelations of several branches of chemistry. Sadly, students retain very little of the material they learn. They will remember more and retain information longer if practical applications and anecdotes are used to illustrate concepts. Demonstrations help to illustrate and cement some abstract concepts. Don't overdo it, but try to use a demo a day to provide a break from lecture. Don't be afraid to appear silly. Some of the best instructors break the rules in order to get a point across.
- For the introduction to matter and energy, use available objects such as books and desks. Note that each student produces about as much heat as a 60 Watt light bulb. If a gas jet is handy, open it briefly and discuss whether the invisible stream of methane is matter. Consider its physical and chemical properties. Carefully ignite the gas and let it burn for a short time.
- Use calcium acetate handwarmers to illustrate physical change as well as an exothermic reaction. These contain a supersaturated solution of calcium or sodium acetate and act when a small disk in the bag is pressed. The disk provides surfaces which initiate crystallization, with concomitant release of heat. Bags can be boiled and reused. (Place the used bag in boiling water for a few minutes.) These handwarmers are often sold at sporting goods stores along with hunting or fishing supplies. One brand is EZ Heat, supplied by Prism Technologies of San Antonio, Texas. Cost: about $4.00, but reusable.
- The analogy of anvils in the discussion of matter, mass, and weight is useful. Ask students to suggest other analogies, such as locomotives, trucks, or football linemen.
- Burn a sheet of paper to demonstrate chemical change. Note that substances having new chemical properties were formed.
- For examples of mixtures, consider samples of soil and air. How about iced tea, with or without cubes and lemon?
- For the discussion of chemical composition, have a balloon of hydrogen gas on a string. Ignite it, using a wood splint on the end of a meter stick. **(Warn students to cover their ears.)** Later, illustrate chemical reactions by using the same demonstration, and if the lecture hall is large enough, try a mix of one part oxygen and two parts hydrogen for a spectacular boom!
- Show states of matter with ice, water, and steam. Use a carbon dioxide fire extinguisher to show that high pressure liquids sometimes form solids when the pressure is released.
- Be certain that you have a carbon dioxide extinguisher. Shoot it onto
- the back of a well-insulated student. Ask students which molecules will come out first, those with high energy or low. The average velocity of a carbon dioxide molecule in the tank is about 600 mph. Spray the carbon dioxide into the air over the students (not onto them). Some CO_2 snow may fall. Ask them to catch it and watch it sublime. Have a student feel the tank. Feel the tank. Is it hot or cold? Why?

- For another example of a chemical reaction, try burning a piece of paper or magnesium ribbon. Note that materials of new composition (MgO and Mg_3N_2) are formed.
- Illustrate conductivity, luster, ductility, and malleability of metals by using practical examples.
- When discussing applications of mercury, bring in a small bottle of mercury and a mercury thermometer. Refer to *Chemical & Engineering News*, June 16, 1997 for an article on the death of Dr. Karen E. Wetterhahn due to absorption of dimethylmercury through latex gloves. Note that the study and practice of chemistry are relatively safe *because* we take precautions.
- If available, use a magnetoelectric generator such as those in old-time crank telephones (available at second-hand stores or supply houses such as Central Scientific) to demonstrate The amount of energy needed to light a small electric bulb. Unscrew the bulb and note the ease of cranking. This is an excellent example of the necessity of energy to do work.
- Try boiling water in a paper sack.
- Pass steam through a metal tube placed in a flame or on a burner. The steam can be heated enough to ignite paper or matches.
- Point out that a piece of ice (such as an iceberg) floating in water does not cause a change in water level upon melting.

Teaching Tips

1.2 Students often can't visualize the placement of molecules. Have them draw a beaker containing 10 molecules of solid, another having 10 molecules of liquid, and one containing 10 molecules of gas. (Some of the molecules will be above the beaker.)

1.5 It may help to discuss some of the history of elements and relate their symbols to the language used by their discoverers.

1.5 It might be interesting to students to compare the number of elements known in 1900 with the number now, or the elements mentioned in the Bible. Students might enjoy speculating as to whether more elements will be discovered and whether they might be useful.

Chemistry in Action—Mercury

In 1950, students often coated dimes or pennies with mercury. Students are often confused about the danger of mercury. Liquid mercury isn't very hazardous if contact is limited, but mercury compounds can be toxic and mercury vapor can be absorbed from our respiratory system. Over time, microorganisms may convert elemental or inorganic mercury into toxic organomercurial compounds. At one time, royal palaces in Spain are reported to have had reflecting pools of mercury. Mercury amalgams used in dentistry are probably harmless.

1.8 It may be helpful to emphasize prefixes such as *milli-*, *deci-*, *kilo-*, and *micro-*.

1.9 Students will appreciate practical examples of the importance of significant figures.

1.10 Students may benefit from a review of the use of basic algebra to solve problems using scientific notation.

1.11 In order to simplify calculations, many instructors provide data so that students can arrive at answers having three significant figures.

1.12 Many students are likely to appreciate the beauty of dimensional analysis.

1.12 Being able to estimate a ballpark figure may be very helpful to students who apply their science to practical situations.

1.13 Ballpark estimates are likely to prove very helpful in determining the validity of temperature conversions.

1.13 It may be helpful for students to remember that some points on the three temperature scales correspond. The freezing point of water is 0 degrees on the Celsius scale, 32 degrees on the Fahrenheit scale, and 273.15 on the kelvin scale. The boiling point of water is 100 °C, 212 °F, and 373.15 K.

1.13 It may also help students to know that some scientists still refer to degrees K as "absolute" temperature.

1.13 Some students may be interested to know that in the heating and air-conditioning trades, the specific heat of water is given in British thermal units. One BTU is the amount of heat needed to raise the temperature of a pound of water 1 °F.

1.14 It may be helpful to provide the formula for density: d = m/v

1.14 It may be convenient for students to remember that the density of water is 1 g/cm^3 (1g/mL).

1.14 Students may benefit by remembering that the density value has units, while specific gravity has none, and that if SI units are used, the numerical values of density and specific gravity are the same.

Group Problems

1.113 (a) 445 euros **(b)** 320 pounds **(c)** 32440 rupees **(d)** 645 Canadian dollars
Note: Answers will vary depending on current rates.

1.114 $C_2H_3Cl_3O_2$—four different elements; carbon—two, hydrogen—three, chlorine—three, oxygen—two

1.115 whiskey: about 40%, 0.94 sp. gravity; wine: about 12.5–14.5% by volume, 0.99 sp. gravity; beer: from 4–10 % by volume, 1.02 sp. gravity

1.116 1.26×10^{11} L; production of fertilizers