# CHAPTER 2

## CHEMISTRY OF MATTER

- ***THE PHYSICAL SETTING: KEY IDEA 3***
  ***Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.***
- ***THE PHYSICAL SETTING: KEY IDEA 4***
  ***Energy exists in many forms and when these forms change, energy is conserved.***

### Elements

Matter is made of elements. For example, air contains nitrogen and oxygen. **Elements** cannot be chemically broken down into simpler substances. There are more than one hundred known elements. Most elements are solids at room temperature. Elements combine in many ways to produce compounds that make up all living and nonliving substances. Few elements are found in their pure form.

#### Review Questions

1. Matter can be made of combinations of different _____.
2. There are more than _____ known elements.
3. Most elements are _____ at room temperature.
4. Elements can not be physically or _____ broken down into simpler substances.

### Atoms

**Atoms** are the smallest part of an element. Atoms are too small to be seen with a light microscope. Scientists have learned about atoms from experiments. Scientists use models as visual representations of what they are studying.

Atoms are always in motion. The higher the temperature, the more the atoms vibrate or move. The core or center of the atom is called the nucleus. The nucleus contains protons and neutrons. Protons have a positive charge. Neutrons have no charge. Surrounding the nucleus are electrons. Electrons are very small, and have a negative charge.

Atoms of one element are different from the atoms of another element. Atoms of different elements have a different number of protons. The number of protons is the atomic number. There must be an equal number of protons and electrons to keep the charge of the whole atom at zero. In an atom, the positive charges equal the negative charges. Atomic mass is expressed in atomic mass units.

## Review Questions

5. The smallest part of an element is a(n) _____.
6. An atom with 5 protons will have 5 _____.
7. Complete the chart.

| Particle | Charge | Location in atom |
|---|---|---|
| electron | a. | b. |
| c. | neutral | d. |
| e. | f. | in the nucleus |

## The Periodic Table

The Periodic Table is a model used to classify the different elements. Symbols of one, two or three letters are used to represent the names of the elements. Only the first letter of the symbol is capitalized.

Elements are arranged in order of increasing atomic number. All the elements in the same columns or groups have similar properties. Example: Li, Na, and K are all solids. The last column of elements, such as He, Ne, Ar, and Kr, are the **noble gases**. These elements are inert, they do not usually react with any other elements.

The zigzag line on the table separates two types of elements. Elements to the left are metals. **Metals** have luster (shiny) and are solid, malleable (can be hammered into a shape), ductile, and are good conductors of heat and electricity. **Non-metals** are on the right side of the line. They are dull, brittle, and are poor conductors of heat and electricity. Most of the elements that are along the line are metalloids. **Metalloids** have some properties of metals and non-metals. Most elements are metals.

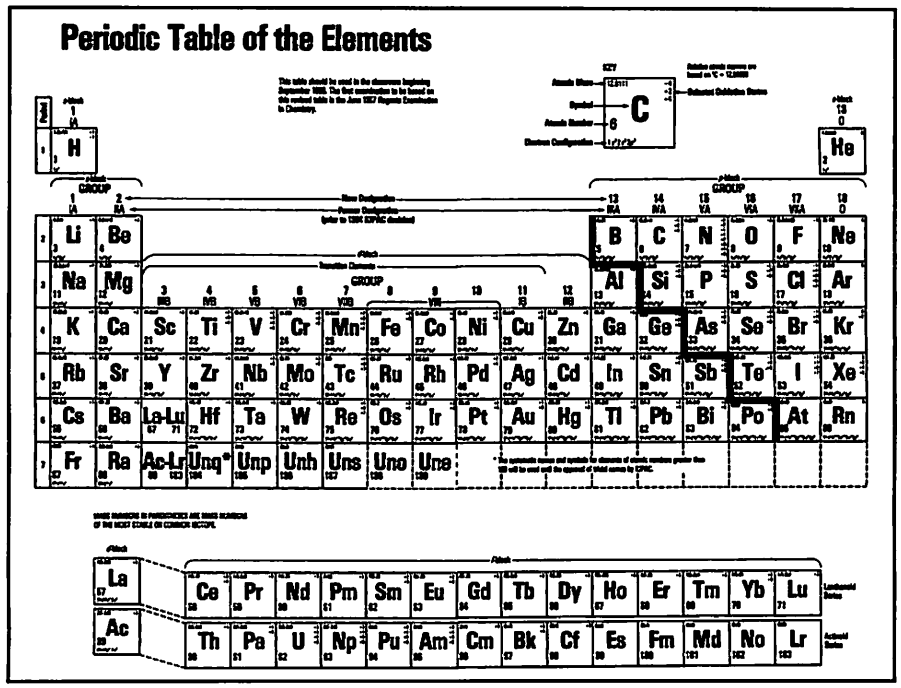



FIGURE 1

## Review Questions

8. The first letter of the symbol of an element is a _____ letter.
9. Elements are arranged in order of _____ atomic number.
10. Elements in the same group have similar _____.
11. _____ are malleable, have luster, and are good conductors.
12. Non-metals are _____ conductors of heat.
13. The elements that do not react with other elements are the _____.

### Matter

**Matter** is made of atoms. Matter has mass and takes up space (volume). Matter is not energy. Energy has no mass and does not take up space. Energy is used to change matter. For example, heat energy can change solid water (ice) to liquid water. Matter is identified by its properties or characteristics. **Physical properties** such as size, color, shape, and melting point can be observed. **Chemical properties** describe how the matter reacts with other matter. For example, iron will form rust when exposed to air.

## Review Questions

14. Matter is anything that has _____ and _____.
15. Is it matter (**M**) or energy (**E**)?
    - **a.** sunlight _____
    - **b.** air _____
    - **c.** electricity _____
    - **d.** sand _____
16. Is it a chemical property (**C**) or a physical property (**P**) ?
    - **a.** 23.9 grams _____
    - **b.** irregular shape _____
    - **c.** combines with oxygen _____
    - **d.** boils at 100°C _____

## Phases (states) of Matter

There are three **phases of matter**: solid, liquid, and gas. In each phase the position and motion of the particles are different.

| Phase | Position of particles | Motion of particles | Examples |
|---|---|---|---|
| Solid (s) | close together in fixed positions, definite volume and shape | can only vibrate | wood, rock, ice |
| Liquid (l) | loosely packed, can change position by sliding past each other, definite volume, no definite shape | more motion than a solid | milk, water |
| Gas (g) | very far apart, spread out, fills container no definite volume or shape | move freely, in constant motion | air, oxygen, helium |

Matter can change phase (state) depending on the motion of its particles. The phase of matter depends on the attractive force between the particles. If heat energy is added to a solid, the particles will move apart and it will change to a liquid. This is called **melting**. If heat is removed from a liquid, it will become a solid as the particles move closer together. This is called **freezing**.

When heat is added to a liquid, it will change to a gas as the particles faster and further apart. This occurs during **boiling** or **evaporation.** If heat is removed from a gas, it will become a liquid as the particles move closer together and slower. This is called **condensation**.

### Review Questions

**17.** A _____ has no definite shape or volume.

**18.** A _____ has a definite volume but no definite shape.

**19.** The size of the container will determine the volume of _____.

**20.** Particles in a _____ have the least motion or kinetic energy.

**21.** The change from solid to liquid is called _____.

**22.** If heat energy is added to a liquid it can become a _____.

**23.** Condensation is the change from _____ to _____.

## Density

Density is a physical property of matter. Every substance has a measurable density. Aluminum has a density of 2.7g/cm$^3$. Gold has a density of 19.3 g/cm$^3$. Density can be used to identify matter. **Density** is the concentration of mass in an object. It is the amount of matter in a given amount of space. If two objects have the same volume, but one has more mass, then the one with more mass is more dense.

Density is calculated by dividing the mass of an object by its volume. Mass is measured in grams with a triple beam balance. Volume is measured in milliliters (mL) with a graduated cylinder or in cubic centimeters (cm$^3$) with a ruler.

$$D = \frac{M}{V}$$

The density of a substance can change. As the temperature of matter increases, its density decreases (hot air rises). As pressure increases, density increases (matter is compressed). Gases are the least dense state of matter, solids (except for ice) are the densest.

**Buoyancy** is the tendency of an object to float or sink. An object will float if it is less dense than the substance it is placed in. For example, cork floats in water but lead sinks. Cork is less dense than water. Lead is more dense than the water or cork.

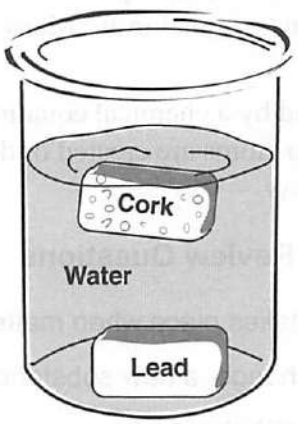



FIGURE 2. COMPARING DENSITY

### Review Questions

**24.** Density is the amount of _____ in a unit of volume.

**25.** A substance with a mass of 12.0 grams and a volume of 4.0 cm$^3$ will have a density of _____.

**26.** Density is a _____ property of matter.

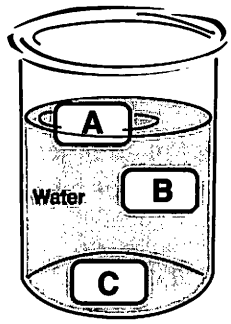
**27.** As temperature increases, density will _____.

**28.** As pressure increases, density will _____.

**29.** A _____ is the least dense phase of matter.

30. Buoyancy is the tendency of an object to _____ because of its density.

31. The least dense object in the container shown below is (A) (B) (C).




## Physical and Chemical Changes

A **physical change** occurs when matter changes form but its chemical composition and properties stay the same. Sawing wood into pieces or boiling water only changes the physical appearance of the matter.

During a **chemical change**, atoms and/or molecules interact to form new substances with different physical and chemical properties. When iron is exposed to air, rust is formed which has different physical and chemical properties than the original iron. Many chemical changes are started with the addition of energy.

Chemical changes can be represented by a chemical equation. The total mass of the reactants will be equal to the mass of the products. No atoms are created or destroyed, they only change form. This is called the *Law of Conservation of Mass.*

### Review Questions

32. A _____ change takes place when matter only changes its appearance.

33. During a _____ change, a new substance is formed.

34. Is it a physical (**P**) or a chemical (**C**) change?

    **a.** burning wood _____

    **b.** sawing wood _____

    **c.** melting ice _____

    **d.** making yogurt _____

## Chemistry of Matter

Two or more elements can chemically combine to form a **compound**. The properties of a compound are different from the elements that make up the compound. A compound is the result of a chemical change or reaction. Most matter on Earth is made of compounds. The smallest part of a compound is a **molecule**. Compounds can be broken down into the component elements by a chemical process .

An example of a compound is calcium carbonate, $CaCO_3$, which is found in chalk. This formula, $CaCO_3$, indicates that each molecule of calcium carbonate is made of one calcium atom, one carbon atom, and three oxygen atoms. The number that follows the element symbol is the number of atoms of that element in the compound. If no number is shown, the number of atoms is one.

**Mixtures** are two or more substances physically combined, but not chemically changed. The substances in a mixture keep their own properties. Mixtures can be separated by simple physical means. A filter can be used to separate sand and water. A magnet can separate iron from sand.

**Solutions,** such as air and salt water, are mixtures in which one substance is evenly mixed with another. When a substance dissolves, it goes into solution. There are two parts of a solution. The part that dissolves is the **solute**. The part into which the solute dissolves is the **solvent**. In salt water, salt is the solute and water is the solvent. A substance that dissolves in another is soluble. **Solubility**, or the ability to dissolve, can be affected by temperature, pressure, and amount of solute. To speed up the rate of dissolving, a solution can be stirred, heated, or the solute can be broken into smaller pieces.

### Review Questions

**35.** A _____ is a substance made up of two or more elements chemically combined.

**36.** The smallest part of a compound is a _____.

**37.** In the chemical compound : **$BaCO_3$**

**a.** How many different elements are there? _____

**b.** How many atoms of carbon (**C**) are there? _____

**38.** A _____ can be physically separated.

**39.** The part of the solution which dissolves is the _____.

**40.** Water is a good _____.

**41.** If the solvent is cold, the solute will dissolve _____.

## pH

A solution can be classified as acidic, basic, or neutral. The strength of acids and bases is measured on a pH scale. This scale is a series of numbers from one to fourteen. A neutral solution has a pH of 7. Acids have a pH below 7. Bases (alkaline) have a pH above 7. An indicator, such as litmus paper, is used to test the pH. Red litmus paper will turn blue in bases, and blue litmus turns red in acids.

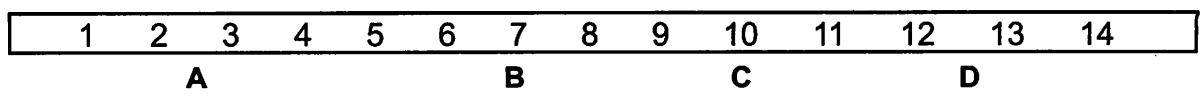
### Review Questions

**42.** pH can be tested using _____ paper.

**43.** A pH of 4 means that the solution is _____.

**44.** Is the lettered position acidic, basic, or neutral ?

**A.** _____ **B.** _____ **C.** _____ **D.** _____



## VOCABULARY

atom

boiling point

buoyancy

chemical change

chemical property

compound

condensation

density

element

evaporate

freezing point

matter

metal

metalloid

mixture

molecule

noble gas

non-metal

phase (state) of matter

physical change

physical property

solubility

solute

solution

solvent