Name _____ Class _____ Date _____

3 BASIC CHEMISTRY
Activity 1. Atomic Theory of Matter

SUBSTANCES

It is obvious that the world is made of many different materials. A particular kind of material, with definite properties and chemical composition, is called a *substance*. A sample of any substance is made up of large numbers of particles of matter.

1. Name three common substances.

_____

ELEMENTS

By means of chemical changes, most substances can be broken down into other substances. However, there are certain substances that cannot be broken down into others by ordinary chemical reactions. These substances are called *elements*. Elements are composed of only one type of atom. All substances are either elements or compounds. Compounds are combinations of two or more elements.

1. After the name of each element, write its symbol.

hydrogen _____	sodium _____	chlorine _____
carbon _____	phosphorus _____	potassium _____
nitrogen _____	sulfur _____	calcium _____
oxygen _____	magnesium _____	iron _____

COMPOUNDS

Most elements will combine with other elements under the right conditions. When two or more elements combine chemically, they form a *compound*. In forming a compound, the elements combine in definite proportions. For example, table salt, a compound of sodium and chlorine, always contains one atom of sodium for each atom of chlorine. The properties of a compound are different from those of the elements that form it. For example, the properties of table salt are very different from those of sodium, which is a soft metal, and chlorine, which is yellowish-green gas.

Organic compounds are carbon compounds that occur naturally in the bodies of living organisms or in their products and remains. Organic compounds almost always contain hydrogen and usually contain oxygen and nitrogen, as well. They may contain other elements, also. Sugars, starches, proteins, fats, and oils are organic compounds. Compounds that are not organic are called *inorganic* compounds.

1. In a compound, two or more _____ are combined in

_____ _____.

2. List the names of five kinds of organic compounds.

_____

STRUCTURE OF ATOMS

The basic unit of structure of all elements is the *atom*. Atoms, in turn, consist of three types of particles: *protons*, which are positively charged; *electrons*, which are

negatively charged: and *neutrons*, which have no electric charge. Protons and neutrons are found in the dense central portion of the atom called the *nucleus*. Electrons are found in the space around the nucleus. Each atom normally has an equal number of electrons and protons, so that as a whole it is electrically neutral.

1. The nucleus of a certain atom has 17 protons and 18 neutrons. The atom has _____ electrons.
2. If the atom had 17 protons and 19 neutrons, the atom would have _____ electrons.
3. If the nucleus having 17 protons and 19 neutrons lost one proton and two neutrons, what change in the number of electrons would be needed to keep the atom electrically neutral?

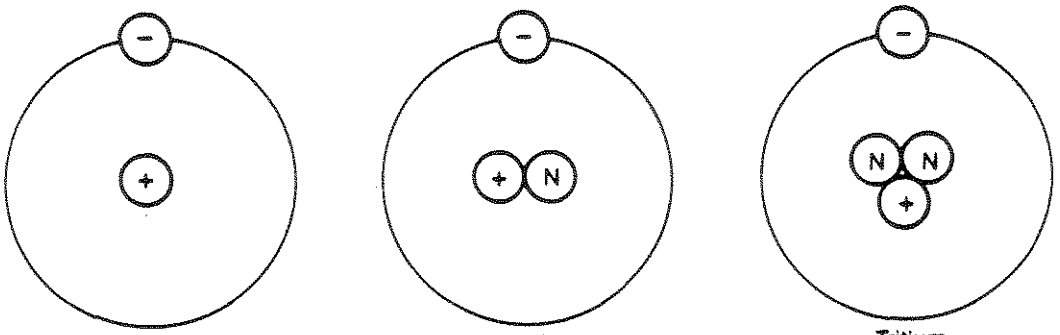
ATOMIC NUMBER, MASS NUMBER, AND ISOTOPES

Every atom of a given element has the same number of protons in its nucleus. This number is called the *atomic number* of the element. For example, every hydrogen atom has one proton. The atomic number of hydrogen is therefore 1. Every oxygen atom has eight protons. The atomic number of oxygen is 8. The identity of an element is determined by its atomic number (the number of protons in its atoms). Every atom with one proton is an atom of hydrogen. Every atom with eight protons is an atom of oxygen.

The *mass number* of an atom is the number of protons plus the number of neutrons in the nucleus of the atom. Most oxygen atoms, for example, have eight protons and eight neutrons. Their mass number is therefore 16.

The atomic number of an element does not vary. Its atoms all have the same number of protons. However, the number of neutrons in an atom of an element can vary. Therefore, atoms of the same element can have different mass numbers. These different varieties of the same element are called *isotopes*. For example, an atom of oxygen may have eight protons and nine neutrons. Its mass number is 17. To distinguish one isotope from another, we write the mass number along with the symbol of the element. For example, the oxygen isotope of mass number 16 is represented by ^{16}O or by O-16; the isotope of mass number 17 is shown as ^{17}O or O-17.

There are three known isotopes of hydrogen: ^{1}H, ^{2}H, and ^{3}H. They have been given the common names of protium, deuterium, and tritium, respectively. Their atomic structures are shown in the following diagram.



Ordinary Hydrogen
Mass number: 1

Deuterium
Mass number: 2

Tritium
Mass number: 3

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1. How many protons, electrons, and neutrons are there in a protium atom?

_____

2. The mass number of tritium is _____.

3. What is the difference, if any, in the number of (a) protons and (b) neutrons in tritium and deuterium?

_____

4. Give the atomic number and mass number of the following isotopes.

Isotope	Atomic number	Mass number
Chlorine (17+, 18N)		
Carbon (6+, 6N)		
Carbon (6+, 8N)		
Oxygen (8+, 10N)		

RADIOACTIVE ISOTOPES

The nuclei of many isotopes are unstable and undergo changes in which they give off radiation and/or charged particles. Such changes often end with the production of an isotope of another element. This process is called *radioactivity*, or *radioactive decay*. The rate at which a given radioactive isotope, or *radioisotope*, decays is always the same. This fact often allows us to calculate how long a certain decay process has been going on, and thus to determine the age of an object.

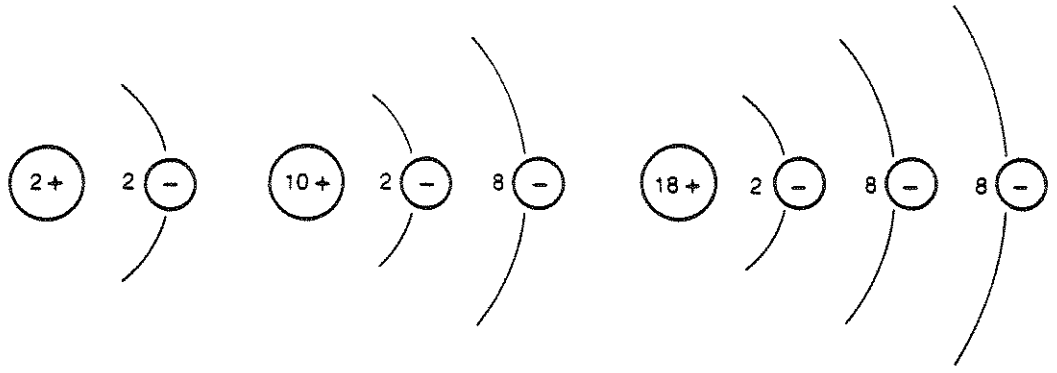
1. The breakdown of an unstable isotope to an isotope of another element is called _____, or _____ _____.

2. The atoms of some radioactive isotopes, or radioisotopes, are used in scientific studies. They are called _____.

ELECTRON STRUCTURE OF ATOMS

The electrons in an atom occupy certain regions around the nucleus called *energy levels*. For our purposes, we will use the following simplified model for electron arrangements. The first, or innermost, energy level can hold a maximum of two electrons. The second (next-to-innermost) energy level can hold a maximum of eight electrons. The third energy level can hold a maximum of eight electrons (since a ninth electron would occupy the fourth energy level). Thus, the diagrams on the next page represent atoms with filled outermost energy levels.

Atoms that have filled outermost energy level tend not to react chemically. Atoms that do not have a filled outermost energy level tend to react and combine chemically. They do this by shifting their outer electrons in such a way as to produce a filled outermost energy level. This may be accomplished by sharing the outer electrons with other atoms, by adding electrons from other atoms to the outermost energy level, or by donating outer electrons to other atoms.

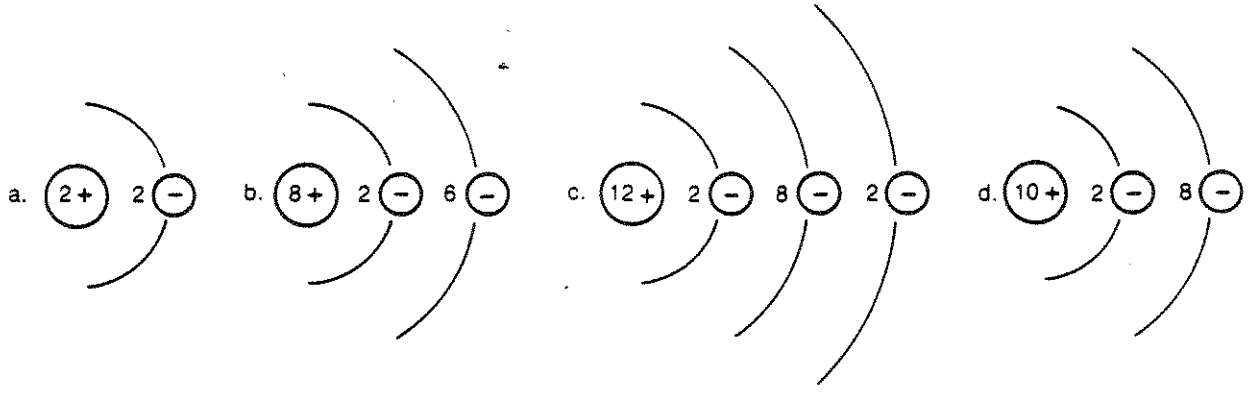


Helium
Atomic number: 2

Neon
Atomic number: 10

Argon
Atomic number: 18

1. Which of the following atoms have a filled outermost energy level? Which are the most likely to form compounds with atoms of other elements?



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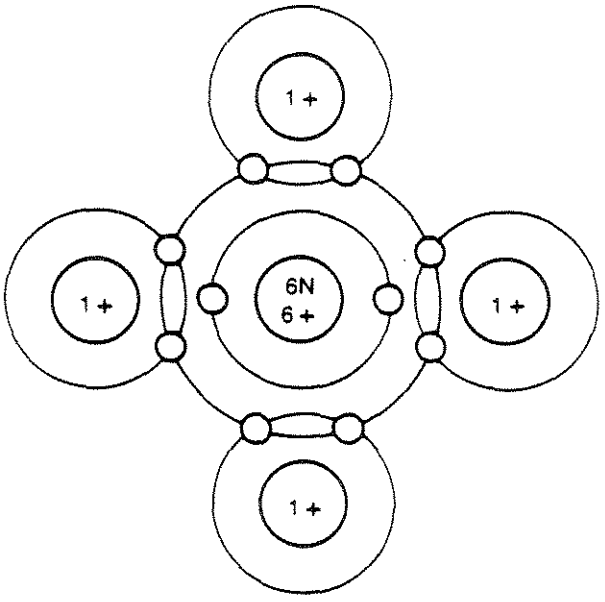
3 BASIC CHEMISTRY
Activity 2. Chemical Bonds and Chemical Reactions

COVALENT BONDING

Most of the bonds in organic compounds are covalent bonds. In covalent bonding, the outer energy level of each atom is filled by a sharing of electrons. A carbon atom has four electrons in its outer energy level. When carbon combines with other elements, each carbon atom fills its outer energy level by sharing its four electrons and four electrons from other atoms. The diagram shows how carbon combines with hydrogen to form methane, CH_4. A hydrogen atom has one electron in an energy level that is filled when it has two electrons. By sharing electrons with the carbon atom, each hydrogen atom obtains two electrons to fill its outer energy level, and the carbon atom obtains eight electrons to fill its outer energy level. Notice that each bond between the carbon atom and a hydrogen atom consists of a *pair* of shared electrons. In covalent bonding, the electrons are always shaired in pairs.

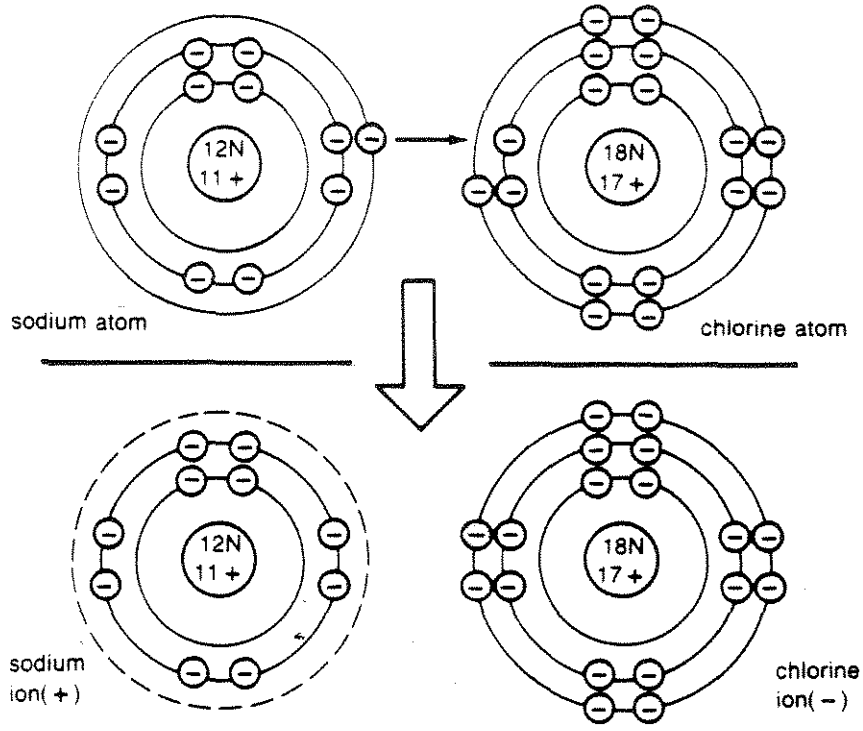


1. An oxygen atom has six outer electrons. It must share _____ pairs of electrons in covalent bonding.

IONIC BONDING

The atoms of a compound are joined together by *chemical bonds*. There are two basic types of bonds—*ionic* and *covalent*. In ionic bonding there is a transfer of electrons from one atom to another. That is, one atom gives up electrons and the other atom gains them. In this way both atoms obtain filled outer energy levels.

The diagram on the next page shows how sodium chloride (ordinary salt) is formed by ionic bonding of sodium and chlorine atoms. A sodium atom has one electron in its outer energy level and eight electrons in the next inner energy level. A chlorine atom has seven electrons in its outer energy level. An outer energy level is filled when it has eight electrons. When the single outer electron of a sodium atom is transferred to the outer energy level of a chlorine atom, the chlorine energy level becomes filled with eight electrons, and the sodium atom is left with a filled outer energy level of eight electrons. When the sodium atom gives up one electron with a negative charge, it is left with an excess positive charge of one unit. The chlorine atom now has one extra electron and therefore has an excess negative charge of one unit. An atom (or group of atoms) that has acquired an electric charge by losing or gaining one or more electrons is called an *ion*. Sodium chloride consists of positive sodium ions and negative chlorine ions. The attraction between these opposite charges is the chemical bond that holds the ions together in a crystal of the compound.



1. An oxygen atom has six electrons in its outer energy level. It needs _____ electrons to fill that energy level.
2. A calcium atom has two electrons in its outer energy level. When calcium forms an ionic bond with another element, the charge of its ion is _____.

WRITING CHEMICAL FORMULAS

Compounds are formed by combinations of atoms in definite ratios. Chemical formulas represent these combinations by means of symbols. In an *empirical formula*, the elements in the compound are represented by their symbols, and the simplest proportion of atoms in the compound in shown by subscript numbers. The empirical formula for sodium chloride is NaCl, showing that the sodium and chlorine atoms are combined in a one-to-one ratio. The formula for water is H_2O. The subscript numeral 2 after the H means that there are two hydrogen atoms for each oxygen atom in water. (A subscript 1 is never written.) A *molecular formula* shows the actual composition of a molecule of a compound. A *structural formula* shows how the atoms in a molecule are bonded to one another. A dash is used to represent one *pair* of shared electrons, or one covalent bond.

1. For each of the following formulas, state the number of atoms of each element represented in the formula.

   $NaOH$ _____

   CCl_4 _____

   $C_6H_{12}O_6$ _____

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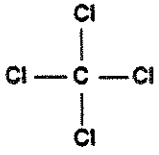
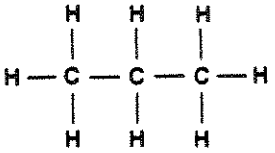
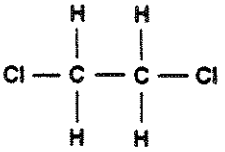
CHAPTER 3

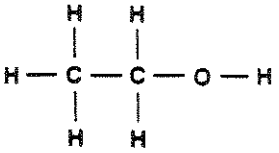
Activity 2. Chemical Bonds and Chemical Reactions

2. The structural formula for carbon dioxide is O = C = O.
   a. The empirical formula for carbon dioxide is _____.
   b. Each oxygen atom is sharing _____ pairs of electrons.
   c. The carbon atom is sharing _____ pairs of electrons.
3. Write the empirical formula for each of the compounds shown below.









_____ _____ _____ _____

4. Write the formula for the diatomic molecule formed by two atoms of each of the following elements.

   hydrogen _____ oxygen _____

   chlorine _____ nitrogen _____

CHEMICAL EQUATIONS

The chemical bonds holding atoms together in a compound can be broken. The atoms can then form new bonds with other atoms in new combinations. This is called a *chemical reaction*. Substances present at the beginning of the reaction are called *reactants*. Substances produced by the reaction are called *products*. With the use of symbols and formulas, a reaction can be represented by a *chemical equation*. Chemical equations are stated in a special way. In the following example, Reactant 1 and Reactant 2 react, producing Product 1 and Product 2.

Reactant 1 + Reactant 2 ⟶ Product 1 + Product 2

1. Complete and balance the following equations.

   _____ $Na + Cl_2 \longrightarrow$ _____

   _____ $H_2 + O_2 \longrightarrow$ _____

   $C_6H_{12}O_6 +$ _____ $O_2 \longrightarrow$ _____

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3 BASIC CHEMISTRY

Activity 3. Solutions and Suspensions; Acids, Bases, and Salts

MIXTURES

A *mixture* is a physical, rather than a chemical, association of substances. Each substance in a mixture retains its individual properties. No chemical bonds are formed between the substances making up a mixture. A mixture can be separated into its component substances by physical means. Different types of mixtures include solutions, suspensions, and colloids.

A *solution* is a homogeneous mixture of two or more substances. In a solution made by dissolving a small amount of one or more substances in a larger amount of liquid, the dissolved substance (or substances) is called the *solute*. The liquid in which it dissolves is called the *solvent*. Particles of solute will not settle out on standing. Solutions are transparent.

A *suspension* is a mixture in which particles larger than those in a solution are suspended in another medium. For example, particles of fine clay mixed in water form a suspension. Unlike a solution, the particles in a suspension may not be evenly distributed, and eventually they settle out. Also unlike solutions, suspensions are cloudy.

A *colloid*, or *colloidal suspension*, shares some characteristics of both solutions and suspensions. The particles in colloids are larger than those in solutions but smaller than those in suspensions. The particles in colloids do not settle out, but are kept suspended by impacts with the molecules of the dispersing medium.

1. State whether each of the following materials is generally a solution, a suspension, or a colloid.

   Salt in water _____

   Mayonnaise _____

   Soil in water _____

   Hydrochloric acid in water _____

   Milk _____

   Sodium hydroxide in water _____

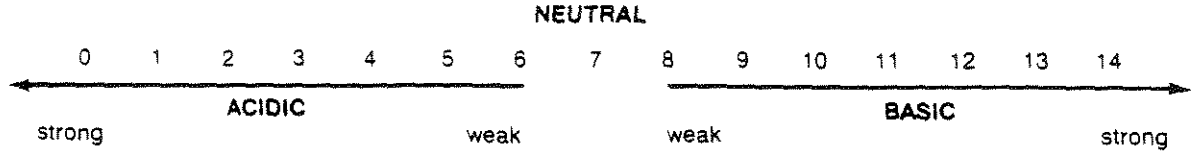
ACIDS, BASES, AND pH

Acids and bases are common and important types of compounds. Water solutions of acids contain an excess of hydrogen ions (H^+), while water solutions of bases contain an excess of hydroxyl ions (OH^-). The presence of excess hydrogen ions gives all acids certain properties in common, while the presence of excess hydroxyl ions gives all bases certain properties in common.

The acidic or basic property of a solution is measured by pH, which is determined by the hydrogen ion concentration of the solution. The pH scale runs from about 0 to about 14, with the strongest acids having the lowest pH and the strongest bases having the highest pH. A pH of 7 indicates a neutral solution, in which the number of hydrogen ions is equal to the number of hydroxyl ions. Pure water has a pH of 7. A solution with a pH of 6 is slightly acidic, and one with a pH of 8 is slightly basic

Name _____ Class _____ Date _____

CHAPTER 3 **Activity 3. Solutions and Suspensions; Acids, Bases, and Salts**



1. Identify each of the following as acidic, basic, or neutral. Indicate the relative strength or weakness of each acid and base.

   Sodium hydroxide (pH = 13) _____

   Concentrated sulfuric acid (pH = 1) _____

   Sodium bicarbonate (pH = 8.2) _____

   Concentrated hydrochloric acid (pH = 1.1) _____

   Water (pH = 7) _____

   Sodium carbonate (pH = 11.4) _____

NEUTRALIZATION

Neutralization occurs when an acid is mixed with a base in the correct amounts, producing a neutral solution. The hydrogen ions of the acid react with the hydroxyl ions from the base to form water.

$$H^- + OH^- \longrightarrow H_2O$$

If the amounts of acid and base are correct, all the H^- ions react with all the OH^- ions. Another product, called a *salt*, is formed in this reaction. The negative ion of the acid reacts with the positive ion from the base, producing the new compound.

$$HCl + NaOH \longrightarrow H_2O + NaCl$$

1. Complete the following neutralization reactions.

   H_2SO_4 + _____ KOH $\longrightarrow$ _____

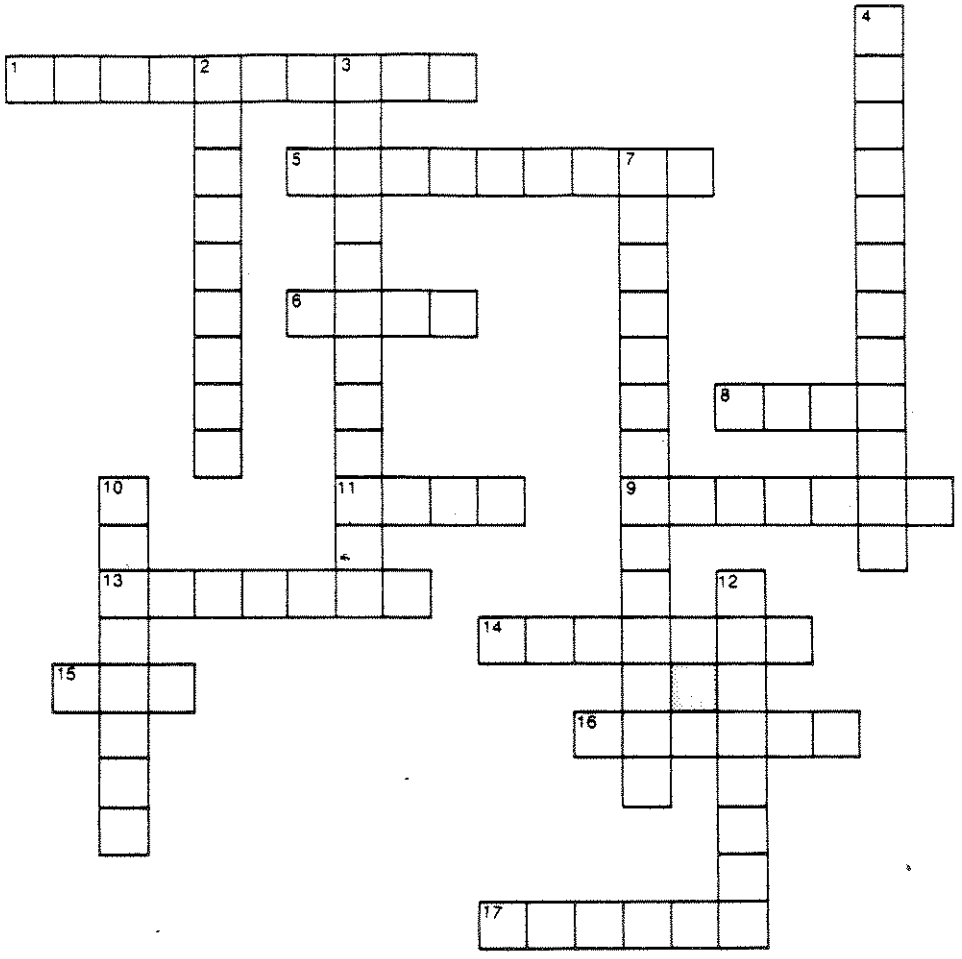
   HNO_3 + NaOH $\longrightarrow$ _____

2. Why is pure water neutral, despite the fact that some of the water molecules dissociate into ions?

_____

_____

Chapter 3. Vocabulary Puzzle



Across

1. Total number of protons and neutrons in an atom.
5. Force of attraction between ions in a chemical compound.
6. A compound that produces an excess of hydrogen ions in water.
8. A compound produced by a neutralization reaction.
9. Atoms that differ only by the number of neutrons in their nuclei.
11. A compound that produces an excess of hydroxyl ions in water.
13. A combination of substances that are not chemically bonded.
14. An electrically neutral subatomic particle.
15. An atom with an electric charge.
16. A substance dissolved in a solvent.
17. A positively charged particle found in the nucleus of every atom.

Down

2. A substance that changes color when the pH changes.
3. The number of protons in the nucleus of an atom.
4. A radioactive isotope.
7. The reaction of an acid and a base.
10. Two or more kinds of atoms combined in definite proportions.
12. A homogeneous mixture.

3. Using key choices, select the appropriate responses to the following descriptive statements. Insert the appropriate letter or term in the answer blanks.

KEY CHOICES:

A. Atom	**D.** Energy	**G.** Molecule	**I.** Protons
B. Electrons	**E.** Ion	**H.** Neutrons	**J.** Valence
C. Element	**F.** Matter		

_____ **1.** An electrically charged atom

_____ **2.** Anything that takes up space and has mass (weight)

_____ **3.** A unique, or basic, substance that cannot be decomposed or broken down by ordinary chemical means

_____ **4.** Negatively charged particles, forming part of an atom

_____ **5.** Subatomic particles that determine an atom's chemical behavior, or bonding ability

_____ **6.** The ability to do work

_____ **7.** Building block, or smallest particle, of an elemental substance

_____ **8.** Smallest particle of a substance formed when atoms combine chemically

_____ **9.** Positively charged particles, forming part of an atom

_____ **10.** Name given to the electron shell of an atom that contains the most reactive electrons

_____ **11.** _____ **12.** Subatomic particles responsible for most of an atom's mass

4. Insert the *chemical symbol* (the chemist's shorthand) in the answer blanks for each of the following elements.

_____ **1.** Oxygen

_____ **2.** Carbon

_____ **3.** Potassium

_____ **4.** Iodine

_____ **5.** Hydrogen

_____ **6.** Nitrogen

_____ **7.** Calcium

_____ **8.** Sodium

_____ **9.** Phosphorus

_____ **10.** Magnesium

_____ **11.** Chlorine

_____ **12.** Iron

5. Match the terms in Column B to the chemical equations listed in Column A. Enter the correct letter or term in the answer blanks.

	Column A	Column B
_____	**1.** $A + B \rightarrow AB$	**A.** Decomposition
_____	**2.** $AB + CD \rightarrow AD + CB$	**B.** Exchange
_____	**3.** $XY \rightarrow X + Y$	**C.** Synthesis

6. Figure 2-1 is a diagram of an atom. First select different colors for each of the structures listed below. Color in the coding circles and corresponding structures on the figure and complete this exercise by responding to the questions that follow, referring to the atom in this figure. Insert your answers in the spaces provided.

◯ Nucleus

Electrons

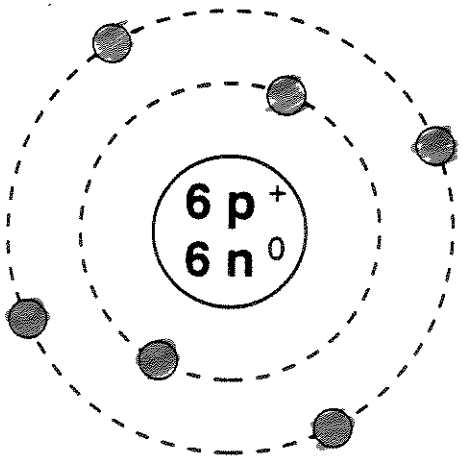


Figure 2-1

1. What is the atomic number of this atom? _____
2. What is its atomic mass? _____
3. What atom is this? _____
4. If this atom had one additional neutron but the other subatomic particles remained the same as shown, this slightly different atom (of the same element) would be called a(n) _____
5. Is this atom chemically active or inert? _____
6. How many electrons would be needed to fill its outer (valence) shell? _____

11. Respond to the following instructions relating to the equation:

$$H_2CO_3 \rightarrow H^+ + HCO_3^-$$

1. In the space provided, list the chemical formula(s) of compounds. _____

2. In the space provided, list the chemical formula(s) of ions. _____

3. Circle the product(s) of the reaction.

4. Modify the equation by adding a colored arrow in the proper place to indicate that the reaction is reversible.

Organic Chemistry

12. Use an *X* to designate which of the following are organic compounds.

_____ Nucleic acids	_____ Fats	_____ Proteins
_____ Oxygen	_____ KCl	_____ Glucose

13. Match the terms in Column B to the descriptions provided in Column A. Enter the correct letter(s) or term(s) in the answer blanks.

	Column A	Column B
_____	**1.** Building blocks of carbohydrates	**A.** Amino acids
_____	**2.** and **3.** Building blocks of fats	**B.** Carbohydrates
_____	**4.** Building blocks of proteins	**C.** Fats (lipids)
_____	**5.** Building blocks of nucleic acids	**D.** Fatty acids
_____	**6.** Cellular cytoplasm is primarily built from this substance	**E.** Glycerol
_____	**7.** The most important fuel source for body cells	**F.** Glycogen
_____	**8.** Not soluble in water	**G.** Nucleotides
_____	**9.** Contains C, H, and O in the ratio CH_2O	**H.** Monosaccharides
_____	**10.** Contain C, H, and O, but have relatively small amounts of oxygen	**I.** Proteins
_____	**11.** _____	**12.** Building blocks that contain N in addition to C, H, and O (two answer

14. Using key choices, correctly select *all* terms that correspond to the following descriptions. Insert the correct letter(s) or their corresponding term(s) in the answer blanks.

KEY CHOICES:

A. Cholesterol	**D.** Enzyme	**G.** Hormones	**J.** Maltose
B. Collagen	**E.** Glycogen	**H.** Keratin	**K.** RNA
C. DNA	**F.** Hemoglobin	**I.** Lactose	**L.** Starch

_____ **1.** Example(s) of fibrous (structural) proteins

_____ **2.** Example(s) of globular (functional) proteins

_____ **3.** Biologic catalyst

_____ **4.** Plant storage carbohydrate

_____ **5.** Animal storage carbohydrate

_____ **6.** The "stuff" of the genes

_____ **7.** A steroid

_____ **8.** Double sugars, or disaccharides

15. Five simplified diagrams of biologic molecules are depicted in Figure 2-3. First, identify the molecules and insert the correct name in the answer blanks on the figure. Then select a different color for each molecule listed below and use it to color the coding circles and the corresponding molecule on the illustration.

◯ Fat ◯ Nucleotide ◯ Monosaccharide

◯ Functional protein ◯ Polysaccharide

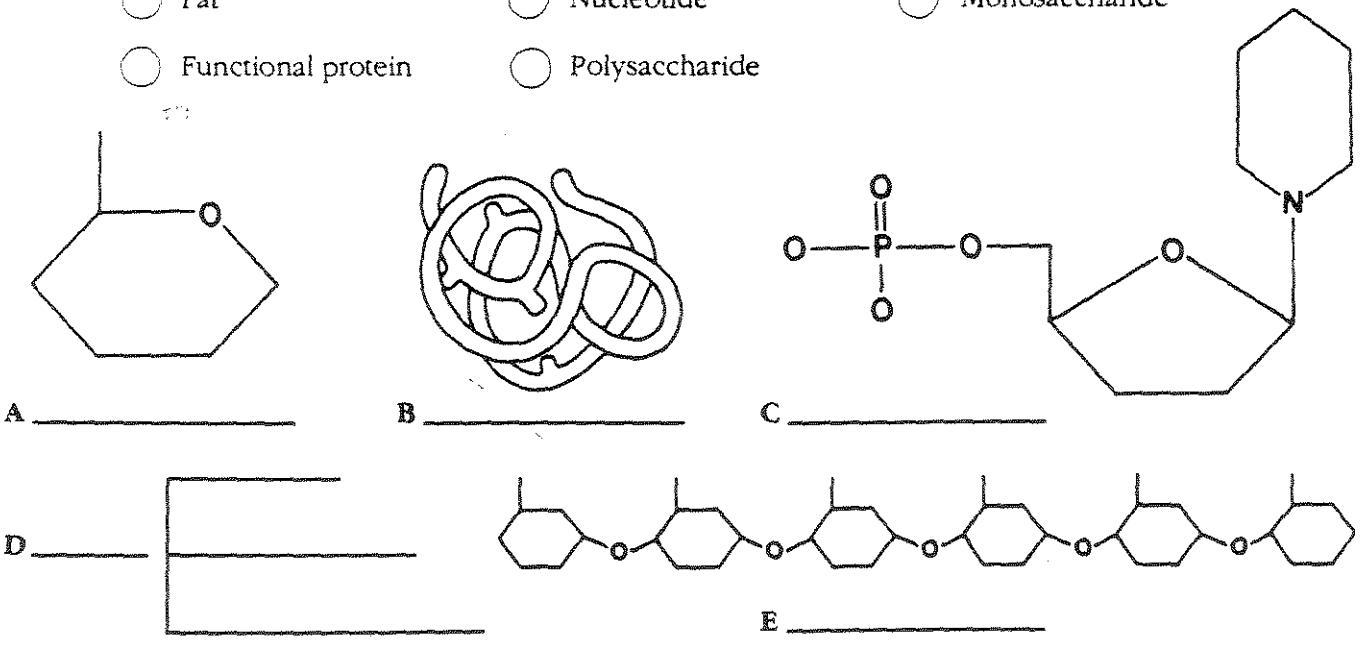
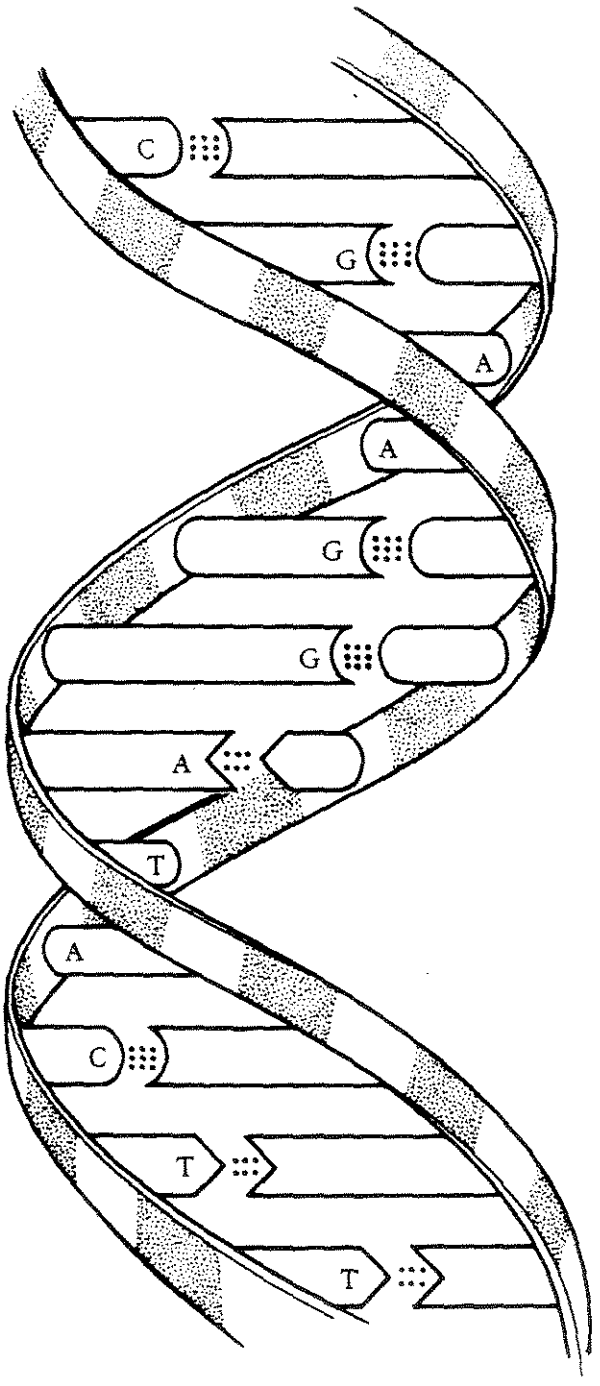


Figure 2-3



DNA

Figure 2-4: Two DNA strands (coiled)

1. Name the bonds that help to hold the two DNA strands together. _____
2. Name the three-dimensional shape of the DNA molecule. _____
3. How many base-pairs are present in this segment of a DNA model? _____
4. What is the term that means "base-pairing"? _____