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MATTER AND ELEMENTS

Although chemistry is a subject that some people try to avoid, we can't get very far in our study of biology before we need to consider a few of the basic principles of chemistry. After all, living things are made of matter, and matter follows the laws of chemistry. Even the activities we regard as unique to living things are the result of chemical reactions.

Color the headings Earth and States of Matter. Color titles A, B, and C and the solid, the liquid, and the gas in the illustration of the earth and the cross section of the landscape. Do not use red, white, or yellow, which need to be reserved for the lower part of the plate. Note that clouds are used to represent gas, though in reality clouds are actually composed of invisible water vapor (gas) and visible water droplets (liquid).

The stuff that makes up the earth and everything else in the universe is called matter. Matter exists in three principal states: *solid, liquid,* and *gas.* The land of the earth is largely solid; the oceans, lakes, and rivers are largely liquid; the atmosphere is largely gas but contains some microscopic droplets of liquid and particles of solid suspended in it. If the pressure or temperature within a substance is changed enough, the substance can change from one state to another. When we get water cold enough, for example, it turns into a solid, which we call ice. If we add heat energy to it, it becomes a liquid. If more heat is added to it, it becomes water vapor, a gas. Substances we think of as solid simply require temperatures much higher than we normally experience in order to change their states. (A fourth state of matter, called plasma, exists only at the extremely high temperatures found in stars.)

Color the "magnified" view of the particles of a solid, liquid, and gas in the circles below the landscape.

Matter is composed of incredibly tiny particles called atoms and molecules. Even the highest-powered microscopes will not allow us to see these particles as they are shown in the "magnified" view of this plate, but scientists have a great deal of indirect evidence that they exist and behave in the ways that we will discuss here. These particles are believed to be in constant motion, except at absolute zero (−273°C or −459.4°F), a temperature that has never quite been reached but at which all motion of particles should theoretically stop. In a solid, the particles are strongly attached to one another, and their only motion is vibration. A solid, therefore, has a fixed volume (if the temperature doesn't change) and a fixed shape. As we add heat energy, the particles vibrate faster and harder and finally vibrate so hard that they break loose from one another and enter the liquid state, where they are free to flow over one another. A liquid, then, has a fixed volume but takes the shape of whatever container it is in. As more heat energy is added, the particles move faster and faster until they break entirely away from one another and form a gas. In the gas state the particles are very far apart, and the gas has neither a fixed shape nor a fixed volume. It will expand to fill any space that is available to it.

Color the headings Elements and Compound. Color the titles, the atoms, and the symbols in the remainder of the plate. The colors that are conventionally used in textbooks and molecular models are white or yellow for hydrogen and red for oxygen. Use both colors for the water molecule (two Hs and one O) and its empirical formula.

All matter, living or nonliving, is made up of one or more of only 106 fundamental substances called elements. Only 92 of these elements occur naturally; the other 14 have been produced artificially, and they break down in very tiny fractions of a second.

An element is a substance that cannot be broken down into anything simpler by ordinary chemical means. (Elements can be broken down by the immense forces inside stars or accelerators, but such forces are not considered "ordinary.") The smallest particle of an element that can be obtained by those ordinary means is called an atom. Although it is possible for a single atom to exist separately from other atoms, *hydrogen, oxygen,* and a few other elements have atoms that tend to pair up. When two or more atoms attach to one another, they make up a molecule. If the atoms are of the same kind, we have a molecule of an element, such as the hydrogen molecule or the oxygen molecule. If the atoms are of different kinds, they form a molecule of a compound. As you will see in the next few plates, a compound can have properties that are very different from those of the elements that make it up. Thus two atoms of hydrogen (a gas) and one atom of oxygen (another gas) will form a molecule of water (which becomes a liquid as soon as it cools). A compound always has a fixed ratio of the elements making it up, which is expressed in the *empirical formula* for that compound.

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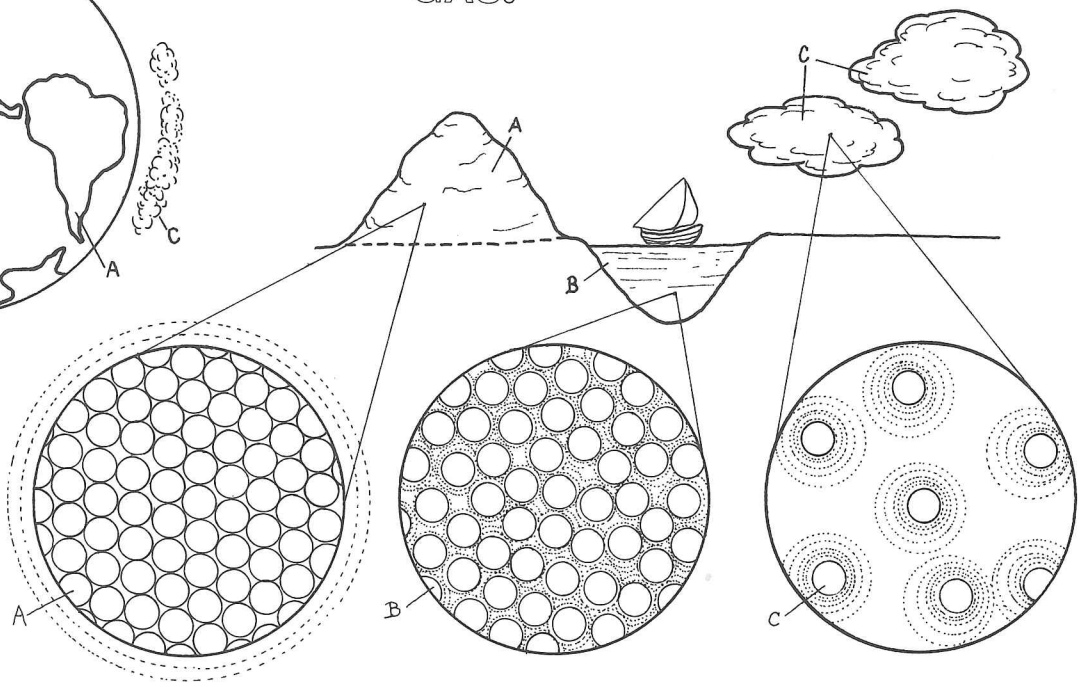
EARTH★

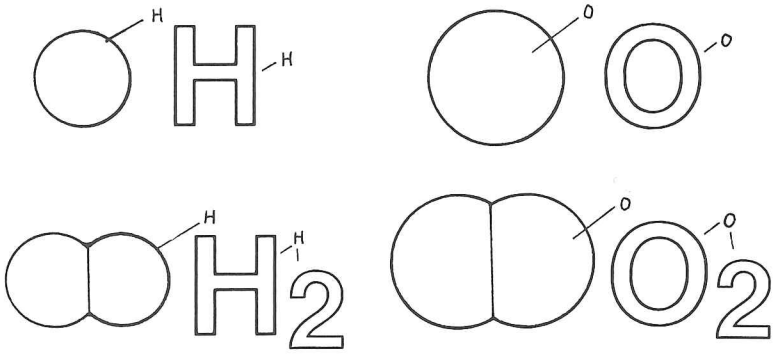
STATES OF MATTER★

SOLID A
LIQUID B
GAS C



ELEMENTS★

HYDROGEN ATOM/
SYMBOL H
OXYGEN ATOM/
SYMBOL O



COMPOUND★

EMPIRICAL
FORMULA H_2O