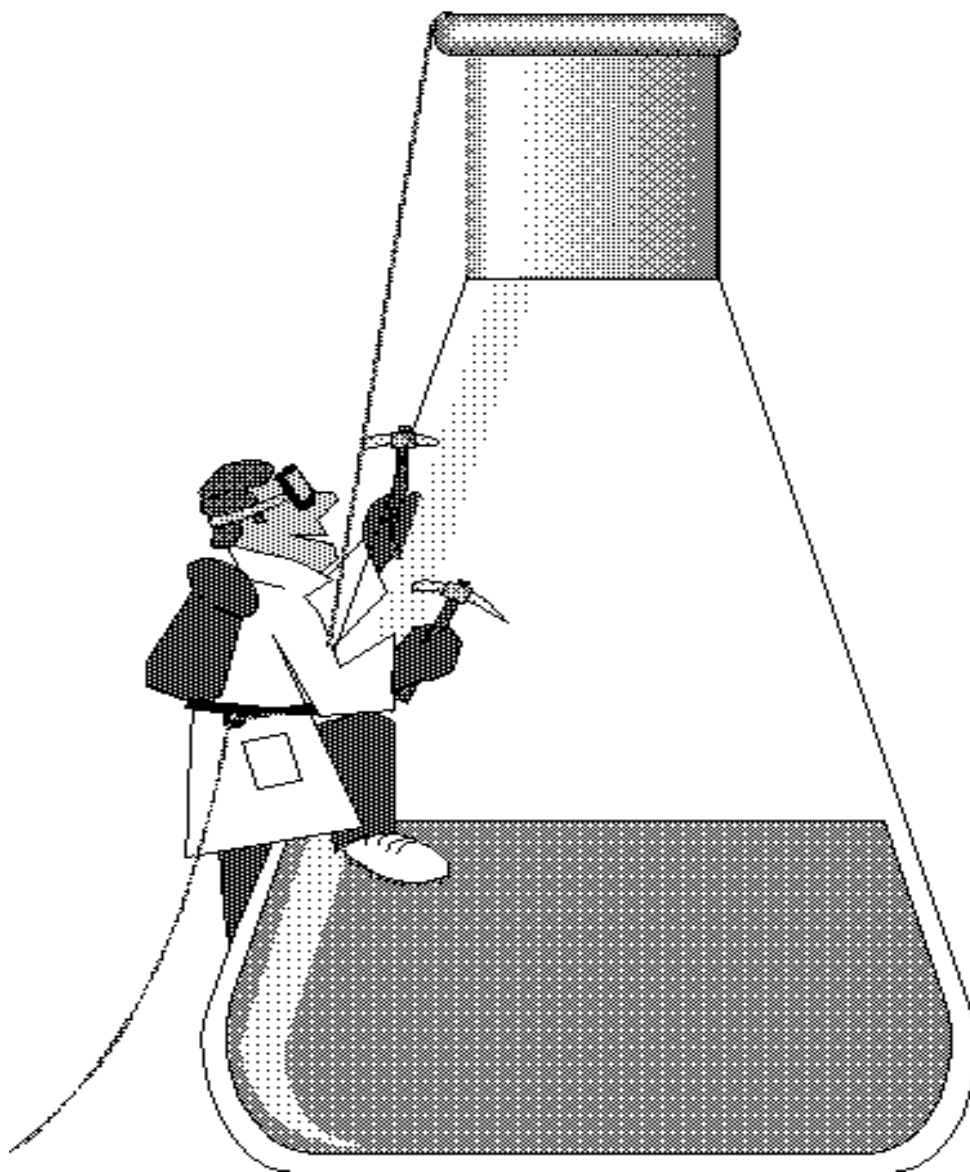


Chemistry 513
Mr. Szkolar

Introduction to Chemistry & Matter (Chapters 1 & 2)



Chemistry is the study of substances in terms of

Composition what is it made of

Structure how is it put together

Properties what characteristics does it have

Reactions and Energies

Physical how does it change form – small energies (joules)

Chemical how does it behave with other substances – larger energies (kilojoules)

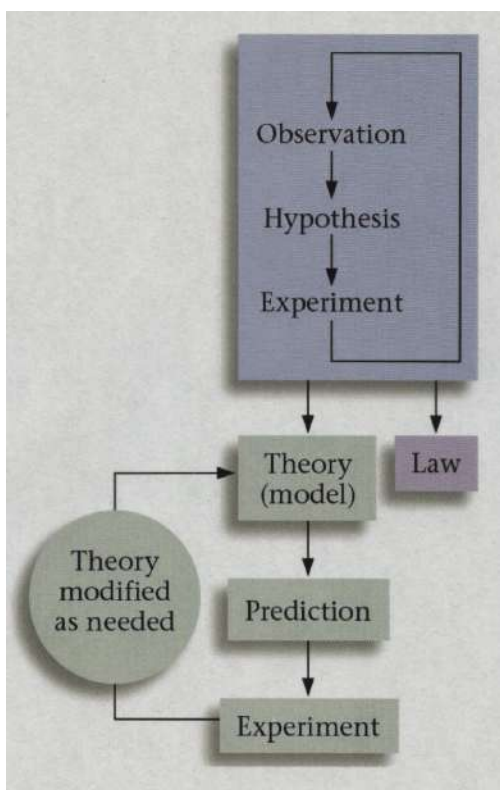
Nuclear how does its nucleus behave – really large energies (megajoules)

Scientific Method

- Making observations
 - Facts obtained by observing and measuring events in nature
- Writing a hypothesis
 - A statement that explains the observations
- Doing experiments
 - Procedures that test the hypothesis

Law:

Theory:



Activities of Science

- Assembling important facts and observations.
- Organizing the information and seeking **regularities**, or patterns, in it.
- Trying to explain why the regularities exist – construct **models**.
- Communicating the findings and their explanations to others.

SOME KEY IDEAS

Conservation Laws

$$\text{initial(i)} = \text{final (f)}$$

Mass: mass of reactants = mass of products (Lavoisier)

Energy: energy is neither created or destroyed, only changes form

Charge: electrons lost (oxidation) = electrons gained (reduction)

MATTER

Matter - anything that occupies space and has mass.

Mass - the quantity of matter possessed by a body or a measure of its inertia; can be measured two ways:

- 1) **gravitational mass (weight)** - the result of mass and the pull of gravity. Mass and weight are not the same - weight varies as gravitational attraction varies. The terms are used interchangeably since the earth's gravitational attraction is essentially constant. Weight is a force due to gravity and is measured with a *scale*. Mass is an inherent property of matter and is independent of gravity. Mass is measured using a *balance*.

Let's compare balances and scales on the Earth and the Moon. We will mass/weigh a 5 kilogram ball using each instrument first on Earth and then on the Moon. But first, what is the numeric equality relating mass (kilograms) and weight (pounds)?

$$1.0 \text{ kg} = \underline{\hspace{1cm}} \text{ lb}$$

On Earth:



balance =



scale =

on Moon:



balance =



scale =

Most of the mass of everyday objects is in protons and neutrons, and a little bit more in electrons. Identifying the mass of an object basically comes down to saying how many nucleons are in it. A nucleon is either a proton or a neutron. A person having a mass of 75 kg has about 50, 000, 000, 000, 000, 000, 000, 000, 000 nucleons. How would we express this in scientific notation? (Note: don't confuse this figure with the national debt you and your children and probably your grandchildren will have to pay).

2) **inertial mass** - a measure of the resistance to a force that tends to change the motion of a body. "A body at rest tends to remain at rest. A body in motion tends to continue moving in a straight line at a constant speed - even when an outside force is pushing or pulling on it." (Newton's First Law of Motion). All bodies with mass have this resistance to forces that tend to change their motion. The greater the force needed to overcome this resistance the greater the mass of the body.

Substance - refers to any particular variety of matter that always has the same properties and composition, regardless of how and where a sample of it is obtained. Samples of a substance are said to be homogeneous - the properties and composition are the same throughout the sample.

Properties - the characteristics by means of which one kind of matter may be distinguished from any other kind of matter. There are two major types of properties:

1) **physical properties** - those characteristics that may be observed without changing the chemical composition of a substance - e.g. color, taste, odor, density, melting point.

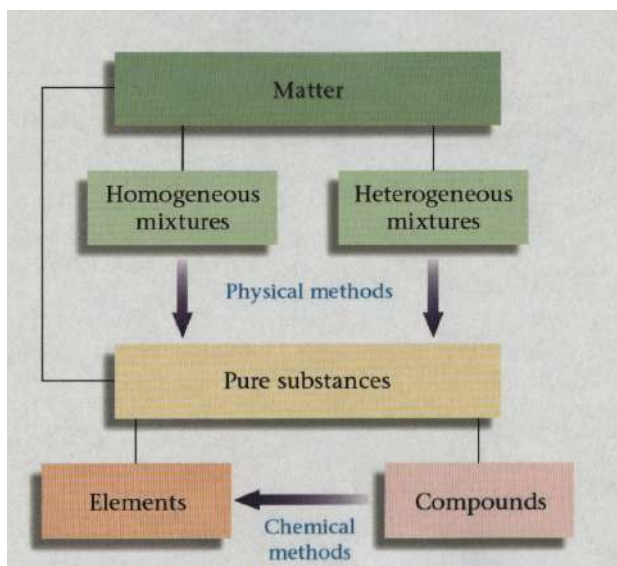
2) **chemical properties** - those characteristics that describe how a substance interacts (or fails to interact) with other substances to produce new substances - e.g. activity, combustibility.

In addition, there are intensive and extensive properties:

extensive properties – depend on how much of a particular sample is on hand; examples include volume, weight and mass

intensive properties – properties that do not depend on the size of the sample; examples include melting point, boiling point and density

Matter may be classified according to the following scheme:

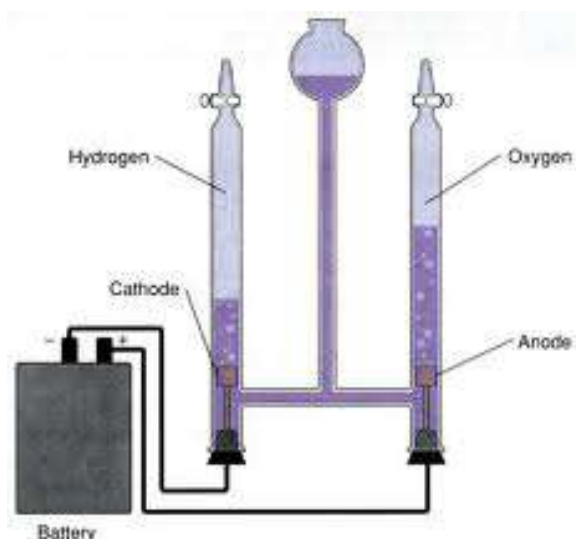


I) **Elements** - substances which cannot be decomposed into simpler substances by means of an ordinary chemical change; e.g. gold, iron. All atoms of a given element have the same number of protons (atomic number) in their nucleus.

- the elements on the Periodic Table are arranged according to increasing atomic number.
- the Periodic Table consists of 18 vertical columns termed **groups or families**; the elements within a group have similar chemical properties (because they have the same number of electrons in their outermost shell (level) – called valence electrons.
- the Periodic Table consists of 7 horizontal rows called **periods**. The period number indicates the level (shell) in which an atom's valence electrons are found.
- most elements are metals; the metalloids or semimetals occur along the “steps” separating the metals from the nonmetals – these include B, Si, As, and Te.
- most elements in nature occur as monatomic atoms – that is they occur as single atoms bonded to each other in a sample of that element; a few exist as diatomic molecules – two atoms bonded together – these are H₂, N₂, O₂, F₂, Cl₂, Br₂, and I₂; in addition phosphorous occurs as a tetratomic molecule (P₄) and sulfur as an octatomic molecule (S₈).

- most elements occur as solids at room temperature and pressure. The only two liquids are mercury (Hg) and bromine (Br₂); the elements which are gases include H₂, N₂, O₂, F₂, Cl₂, and the Noble gases (Group 18 – He, Ne, Ar, Kr, Xe, Ar and So.

II) **Compounds** - substances made up of two or more elements chemically combined, e.g. water, carbon dioxide. Compounds can be decomposed by ordinary chemical means into simpler substances. For example, heating sugar will decompose it to water and carbon. Another way in which a compound like a salt (consisting of a metal chemically combined with a nonmetal) can be decomposed is by a process called electrolysis. If we pass an electric current through a molten (melted) salt, it will break the compound into the elements that make it up; one element at the positive electrode (designated the anode) and the other at the negative electrode (designated the cathode)



Can you write a chemical equation representing this reaction?

The elements in a compound are combined in a definite proportion by mass. This is a statement of the *Law of Constant Composition*. To determine the percentage composition by mass of the elements in a compound, we first determine the mass of the compound and then the percent of each element is the mass each element contributes over the total mass times 100. Water, for example has a total mass of 18 amu (atomic mass units). The percentage of hydrogen = $\frac{2}{18} \times 100 = 11.2\%$ and oxygen = $\frac{16}{18} \times 100 = 88.8\%$. Another way of saying this is that in 100. Grams of water we have 11.2 g of hydrogen and 88.8 g of oxygen.

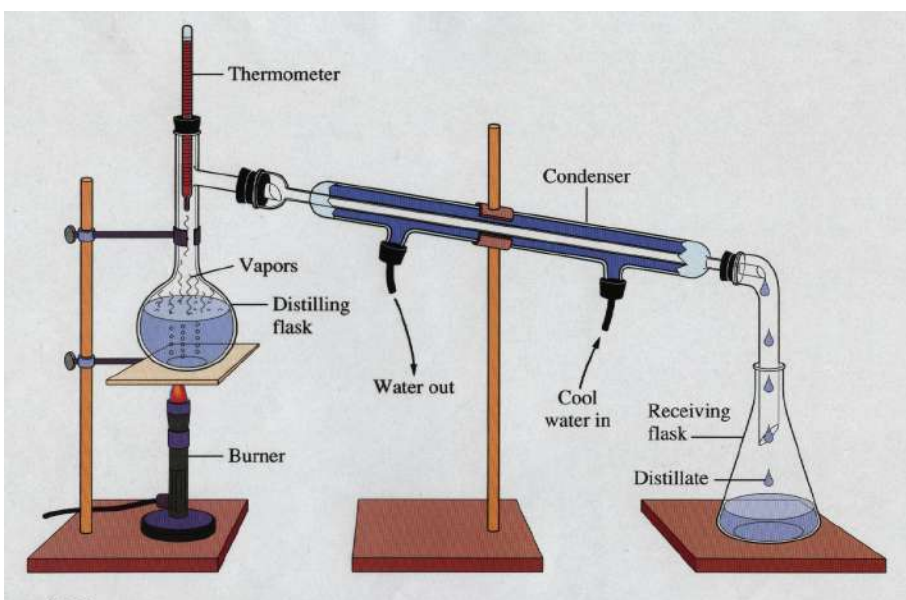
Problem: Determine the percentage by mass of each of the elements in any sample of carbon dioxide:

II) **Mixtures** - consist of two or more substances physically combined, each of which retains its individual properties. Hence, the properties of a mixture are intermediate between those of its components. Mixtures may be homogeneous - i.e. a solution of salt water, or they may be heterogeneous - having nonuniform composition throughout - e.g. soil, concrete.

- the composition of a mixture is not fixed by mass (as in the case of compounds).
- the components of a mixture are held together by physical means; the elements in a compound are held together as a result of a chemical reaction – chemical bonds
- the components of a mixture can be separated by means; those of a compound require chemical methods

Physical methods of separation (based on *differences in physical properties*) include:

distillation – separation on the basis of difference in boiling points.



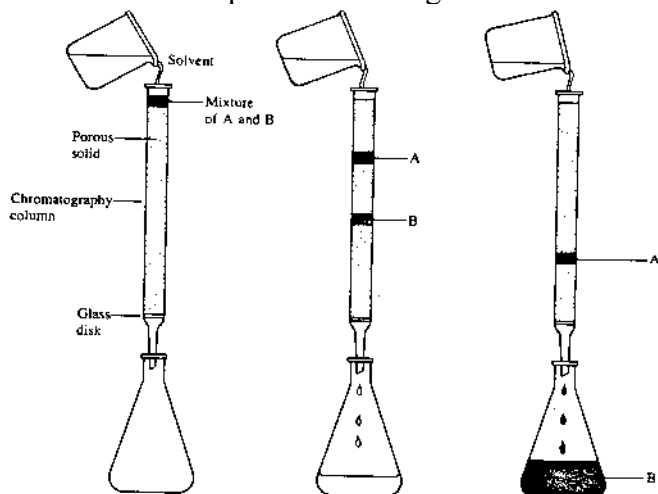
filtration – separation of a liquid from a solid (on basis of size)

centrifugation - separation on the basis of difference in density

extraction – separation based on difference in solubility

chromatography – separation on the basis of adherence to a mobile vs stationary phase

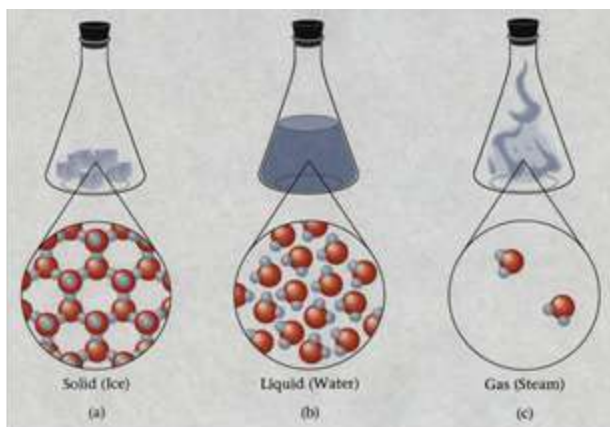
in illustration on the next page, for example, component A has a greater adherence for the stationary column while component B has a greater adherence to the mobile solvent



Matter can undergo two kinds of changes:

- 1) **physical changes** - those that produce new physical properties without altering the chemical properties - no new substance is formed; e.g. melt ice, magnetize iron.

Note that for most substances, the solid phase is the densest phase. The particles making up the substance are held together by “electrostatic” (meaning plus – minus attractions) forces of attraction in a crystalline arrangement. This means the particles can only move (i.e. vibrate) in fixed positions in the crystal. In the liquid phase the forces of attraction are a little weakened and the substance is a little less dense. The particles are still hold to each other but now they can “move” around each other (i.e. they can also rotate). In the gas phase the forces of attraction are not effective and the particles are separated and fly around randomly. The gas phase is the least dense. Can you think of any exceptions to the phase-density relation described here?



Particle diagram models



H₂ and O₂ gases



H₂O gas



H₂O liquid

Key: hydrogen ○

oxygen ●

- 2) **chemical changes** - those that produce new substances that differ in chemical properties and composition from the original substances, e.g. iron rusts, milk sours, paper burns.

Demonstration

Hydrogen

| | | | |
|-------------------------|---------|--------------------|------------|
| Symbol: | H | | |
| Atomic number: | 1 | Boiling point (K): | 20.4 |
| Atomic mass: | 1.00795 | Melting point (K): | 13.4 |
| Oxidation states: | 1, -1 | Density: | 0.0899 g/L |
| Electron Configuration: | | 1s ¹ | |

Of every 1,000 atoms in the Earth's crust, about 150 are hydrogen. Because of its low atomic mass, hydrogen constitutes less than one percent of the mass of the Earth's crust. However, it appears to be the most abundant element in the universe. More than eighty-eight percent of all atoms in the universe are hydrogen, and about ninety percent of the mass of the Sun is hydrogen. On Earth, hydrogen occurs in thousands of compounds, from water and hydrocarbons to acids and proteins.

Hydrogen is almost nonexistent in the elemental form in nature. Because of its low density, hydrogen molecules do not remain in the atmosphere for very long – they simply rise and drift into space. Any unreacted hydrogen produced in the laboratory today may be thousands of miles away by tomorrow.

Its small size and mass make hydrogen unique among the elements in properties and reactions. Hydrogen was discovered in 1776 by Henry Cavendish when he treated active metals with dilute nonoxidizing acids. Other chemists soon began experimenting with hydrogen and amazed themselves and others with its properties. Pilatro de Rozier filled his lungs with hydrogen and set fire to the gas coming out of his mouth. When he repeated the experiment with a mixture of air and hydrogen, an explosion resulted. Cavallo, a Frenchman, filled soap bubbles with hydrogen and ignited them. Joseph Black, Chair of Chemistry at Edinburgh, astounded his dinner guests by filling a calf's bladder with hydrogen and allowing it to float to the ceiling.

Reaction:

Symbols:

Names:

Masses:

Chemical or physical reaction?

Substance

Physical Properties

Chemical Properties

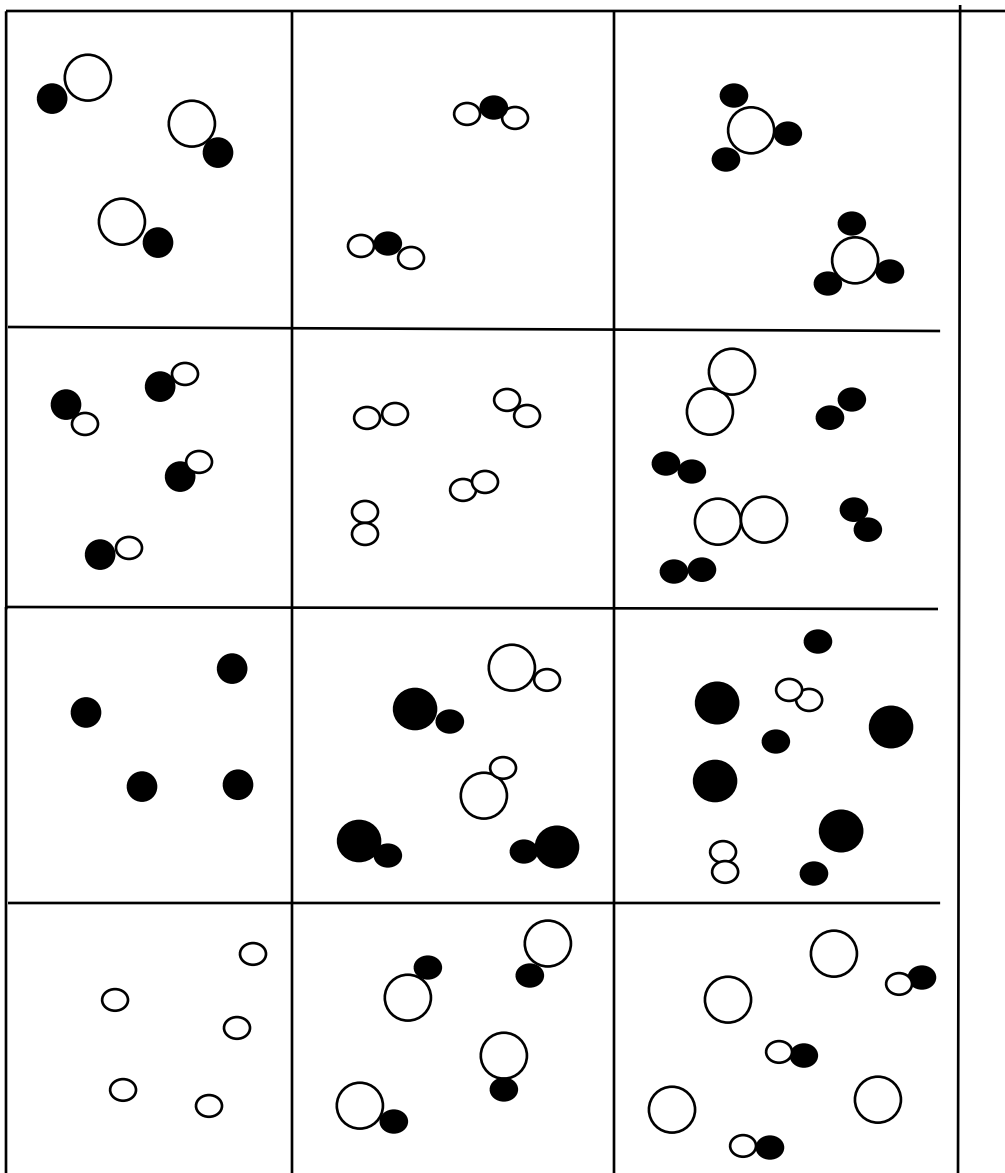
Zn(s)

HCl(aq)

H₂(g)

Reaction of hydrogen gas in “air”:

Is this a physical or chemical change? Explain.



Identify all square(s) that represent:

1. mixtures:
2. pure substances:
3. elements:
4. compounds: