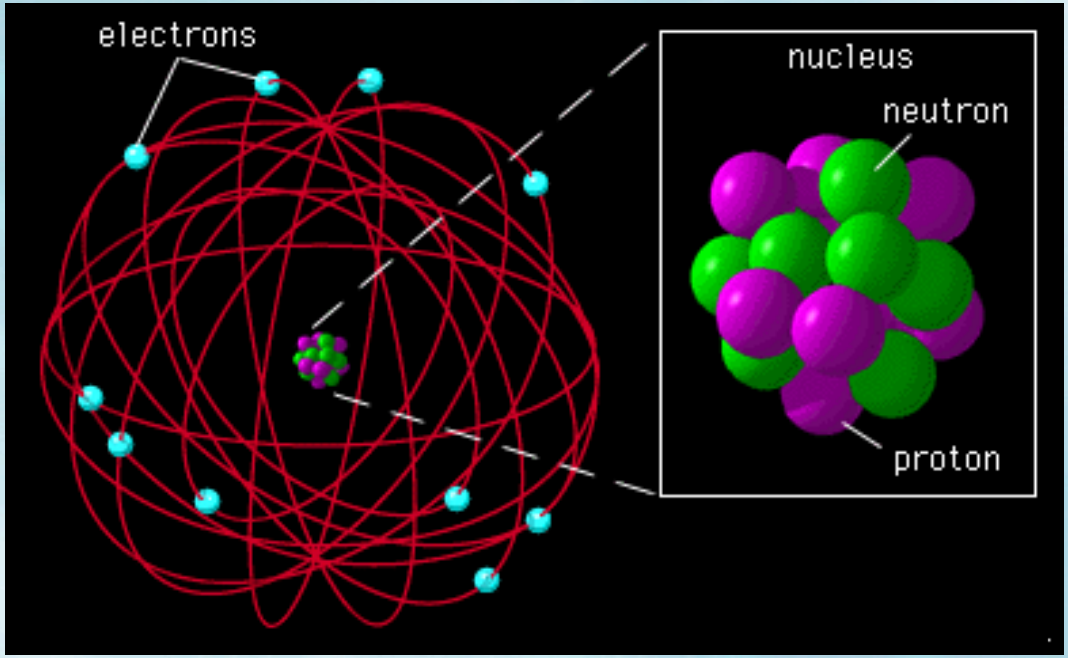
Introduction to Chemistry

General Chemistry 1

Slide Set A

The Modern Model of the Atom

Particle	Mass
Electron	9.11×10^{-31} kg
Proton	1.67×10^{-27} kg
Neutron	1.67×10^{-27} kg



Atoms are made up of three subatomic particles:

Proton (p^+):	Positively charged subatomic particle found in the nucleus of the atom.
Neutron (n^0):	Neutral subatomic particle found in the nucleus of the atom.
Electron (e^-):	Negatively charged subatomic particle found outside the nucleus.

The Basics

- **Chemistry** is the study of **matter**, its interactions and reactions, and the **energy** associated with those processes.

- **Matter** is substance that has mass and volume – all of the objects around us.

- **Energy** is the potential or capacity to move or change matter.

Alchemy

- Alchemy was the earliest attempts to practice chemistry as a “science”.
- Alchemists attempted to change cheap metals into gold, among other things.

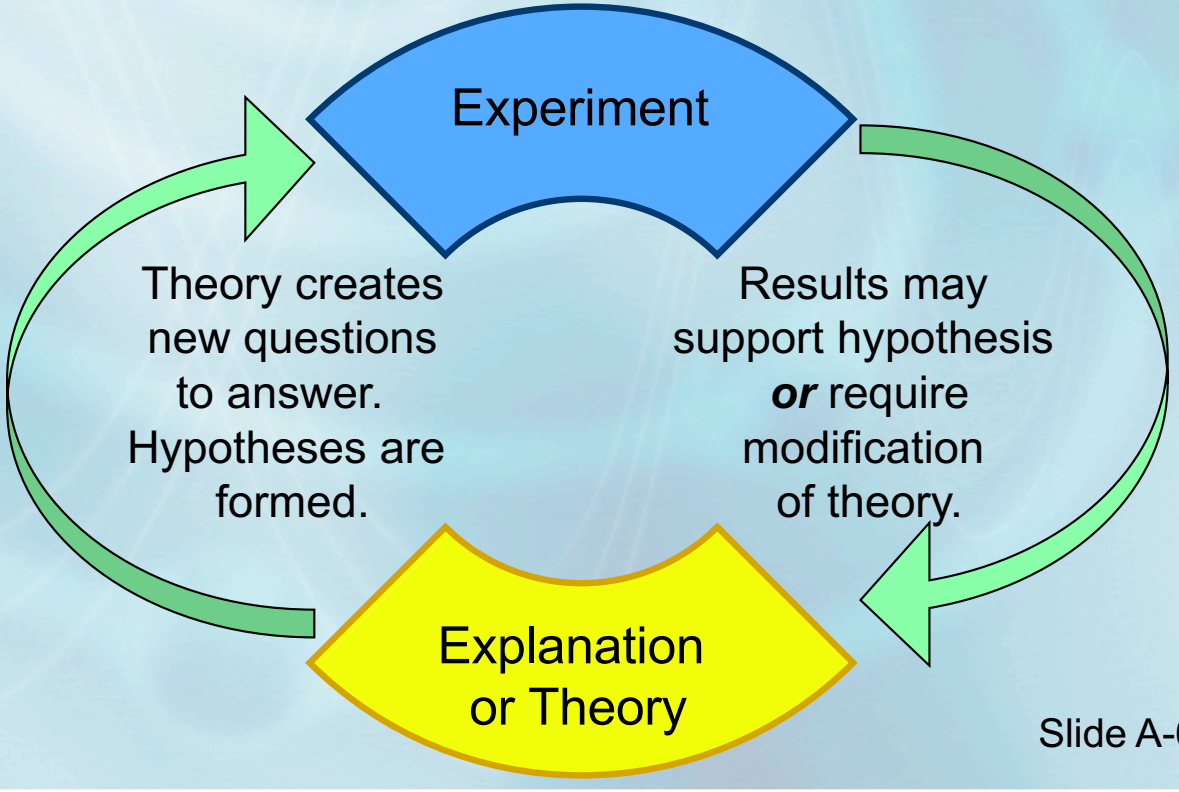
Modern Chemistry

- Modern Chemistry is often considered to have begun with the work of Antoine Lavoisier in the late 18th Century.
- Lavoisier was one of the first chemists to use **quantitative measurements** in chemistry.
- Lavoisier was an **experimentalist** – testing his theories in the physical world, rather than simply arguing them philosophically.

Scientific Method

- Lavoisier was one of the first chemists to apply a modern **Scientific Method** to his work.
- The scientific method is a cyclical process of **experimentation** - controlled observation and explanation to increase understanding about the universe:

Scientific Method:



Theory

- The scientific method, hypotheses, and experimentation are used to develop theories about the nature of matter.
- Theories are not absolute truths.
- Theories are the best explanation of observed phenomena.
- Theories are continually revised and updated.
- A good theory not only explains the observed data, but also accurately predicts what future observations should be.
- Many of the theories studied in this course are thought to be very close to the truth, because they have been tested numerous times.

Matter

- Matter is anything that has mass and volume.

- Matter is anything that we may think of as chemicals, physical objects, air, water, cars, people, etc. – All of this is composed of matter.

Matter

- In this course, we will study **chemical substances** (a material with distinct chemical properties that can be changed only by a chemical reaction) and **mixtures** of substances.
- **Elements** are substances composed only of atoms with the same atomic number. The atom cannot be subdivided by chemical means.
- Elements can combine to make a **chemical compound** (also a substance) in a chemical reaction. *Compounds have properties distinct from the elements that form them.*
- **Mixtures** are a physical combination of two or more substances that can be separated by physical means (without a chemical reaction).

ENERGY

Energy is the capacity to move or change matter. It can have many different forms:

- Kinetic Energy
- ***Heat Energy***
- Potential Energy
- ***Chemical Potential Energy***
- Electrical Energy

The Modern Model of the Atom

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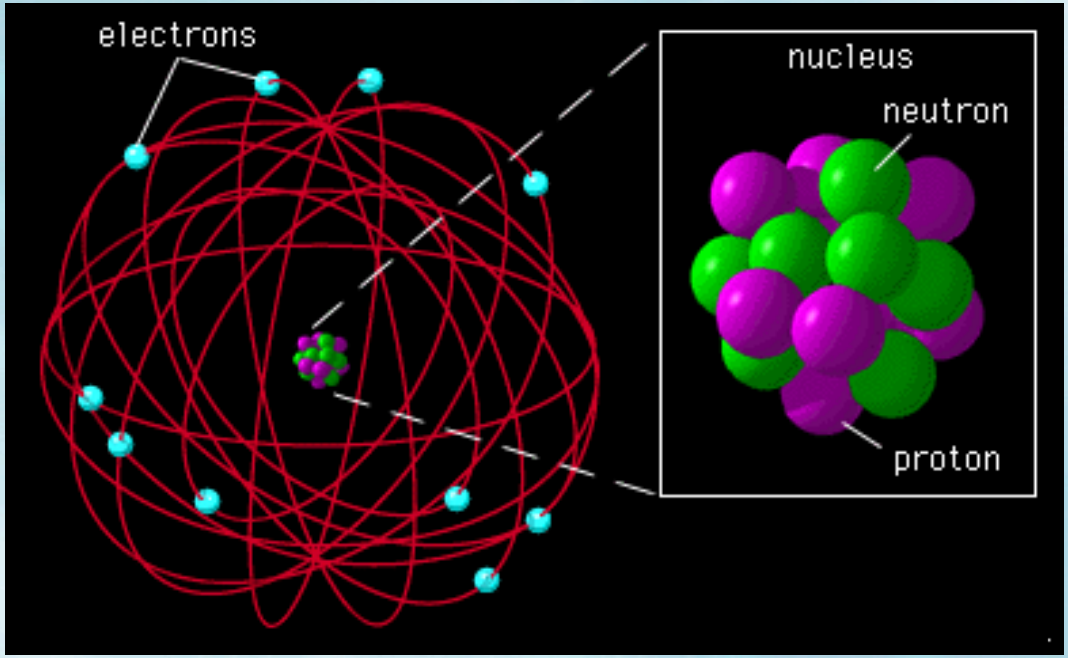

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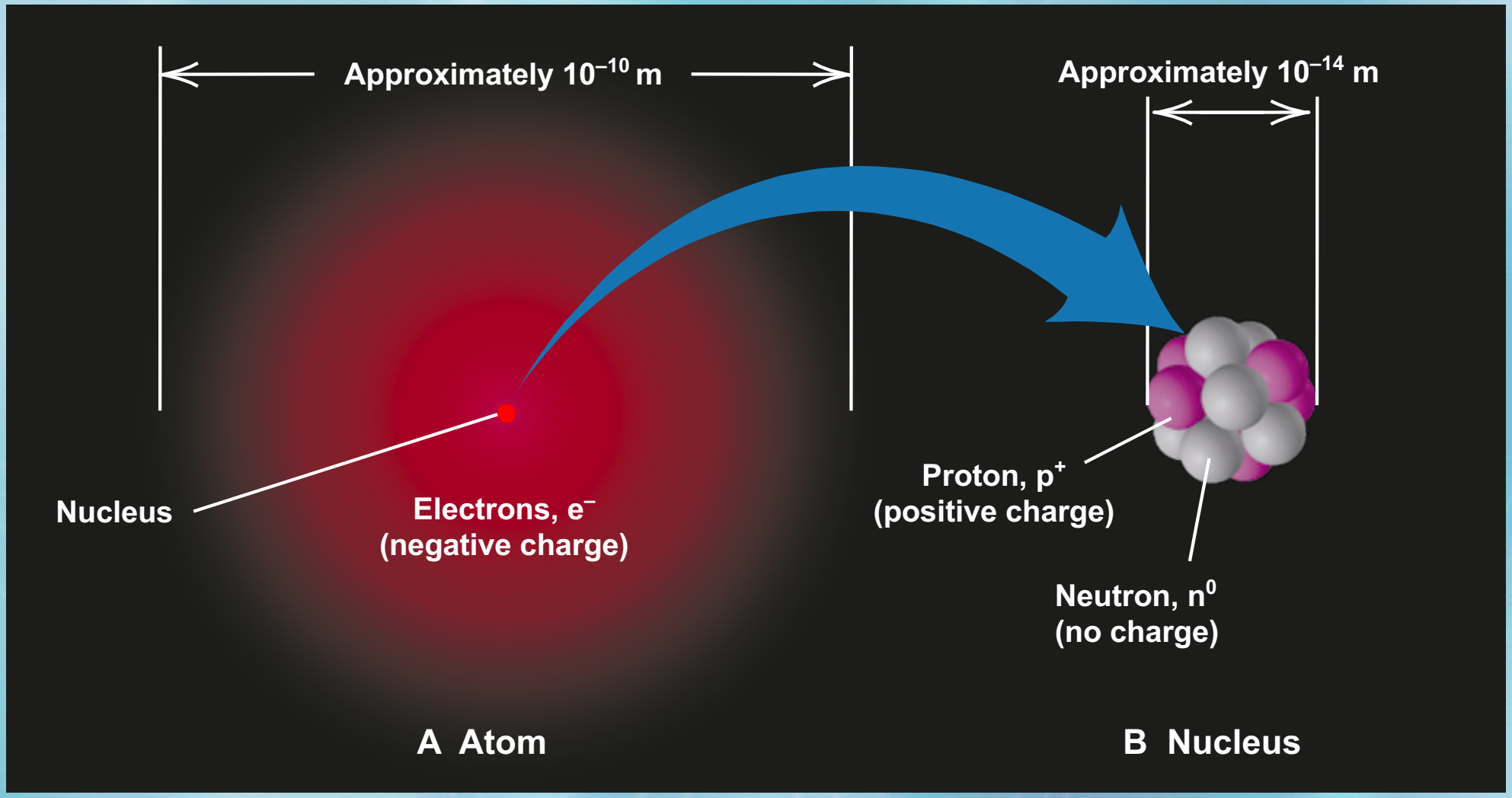
The Modern Model of the Atom

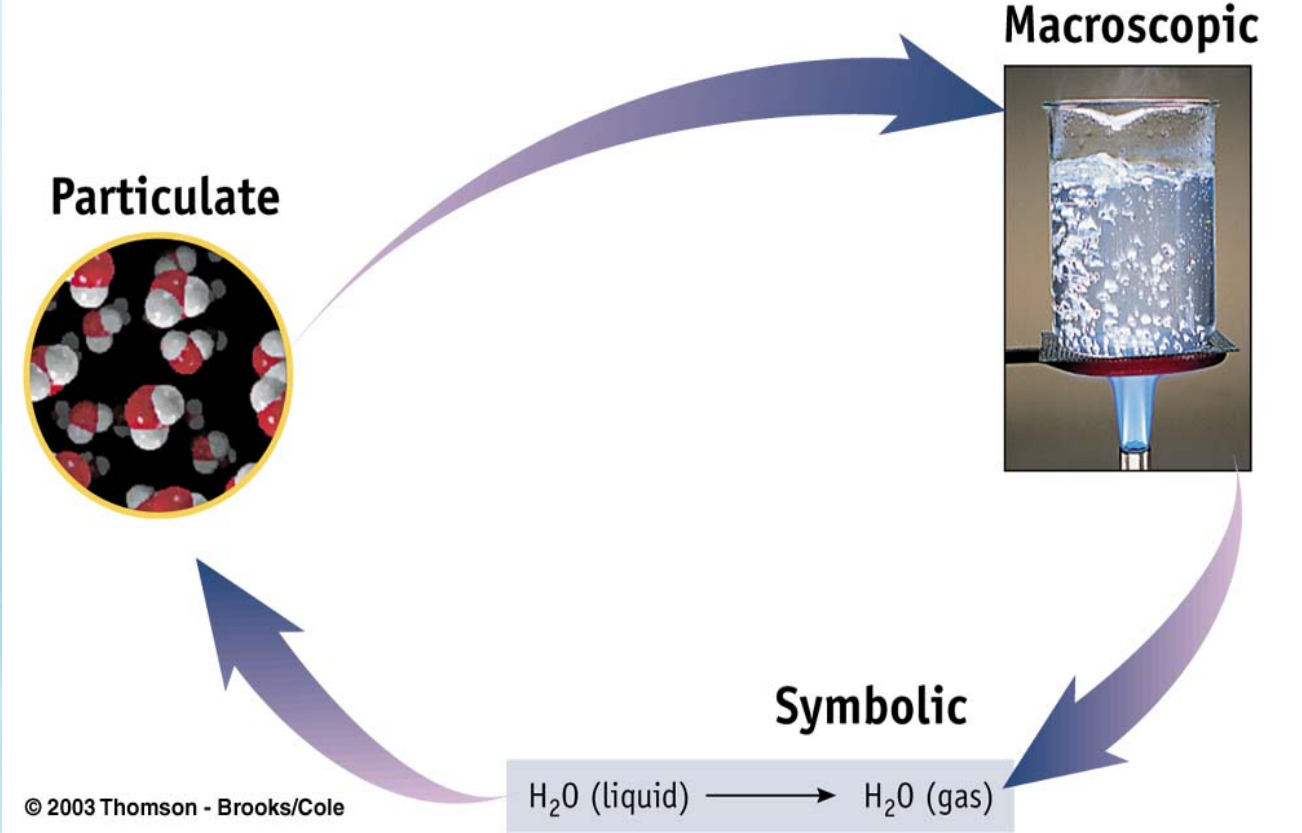


Elements

Macroscopic vs. Microscopic vs. Particulate

- ***Macroscopic:*** large scale, amounts generally seen with the naked eye. This is how we usually observe natural phenomena.
- ***Microscopic:*** small scale, amounts or sizes that cannot be seen without some sort of magnification aid.

- ***Particulate:*** Atoms, molecules, and ions. Cannot be visualized with a light microscope. Generally represented with models.



Periodic Table of the Elements

1 IA 11A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 VIII 8	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.933	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.09	35 Br Bromine 79.904	36 Kr Krypton 84.80
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 168.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

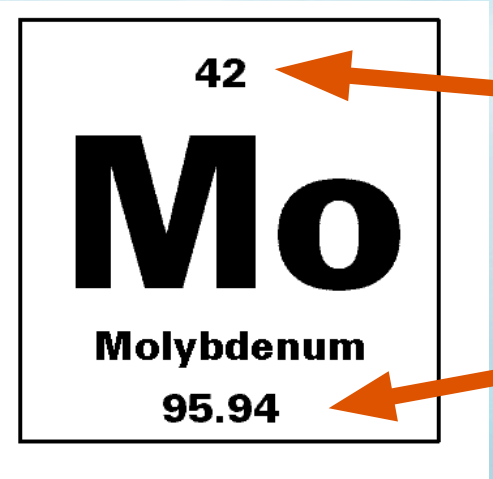
Lanthanide Series	57 La Lanthanum 138.906	58 Ce Cerium 140.115	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.966	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
Actinide Series	89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

Alkali Metal | Alkaline Earth | Transition Metal | Semimetal | Nonmetal | Basic Metal | Halogen | Noble Gas | Lanthanide | Actinide

Periodic Table

- The **periodic table** organizes the **elements**, by their atomic number (Z) and by repeating, or periodic, properties.
- Elements in the same family or group (column) share similar properties.
- Now, 118 elements are known, approximately 90 of which are naturally occurring. The rest have been prepared in a laboratory.

Interpreting an Element Box on the Periodic Table

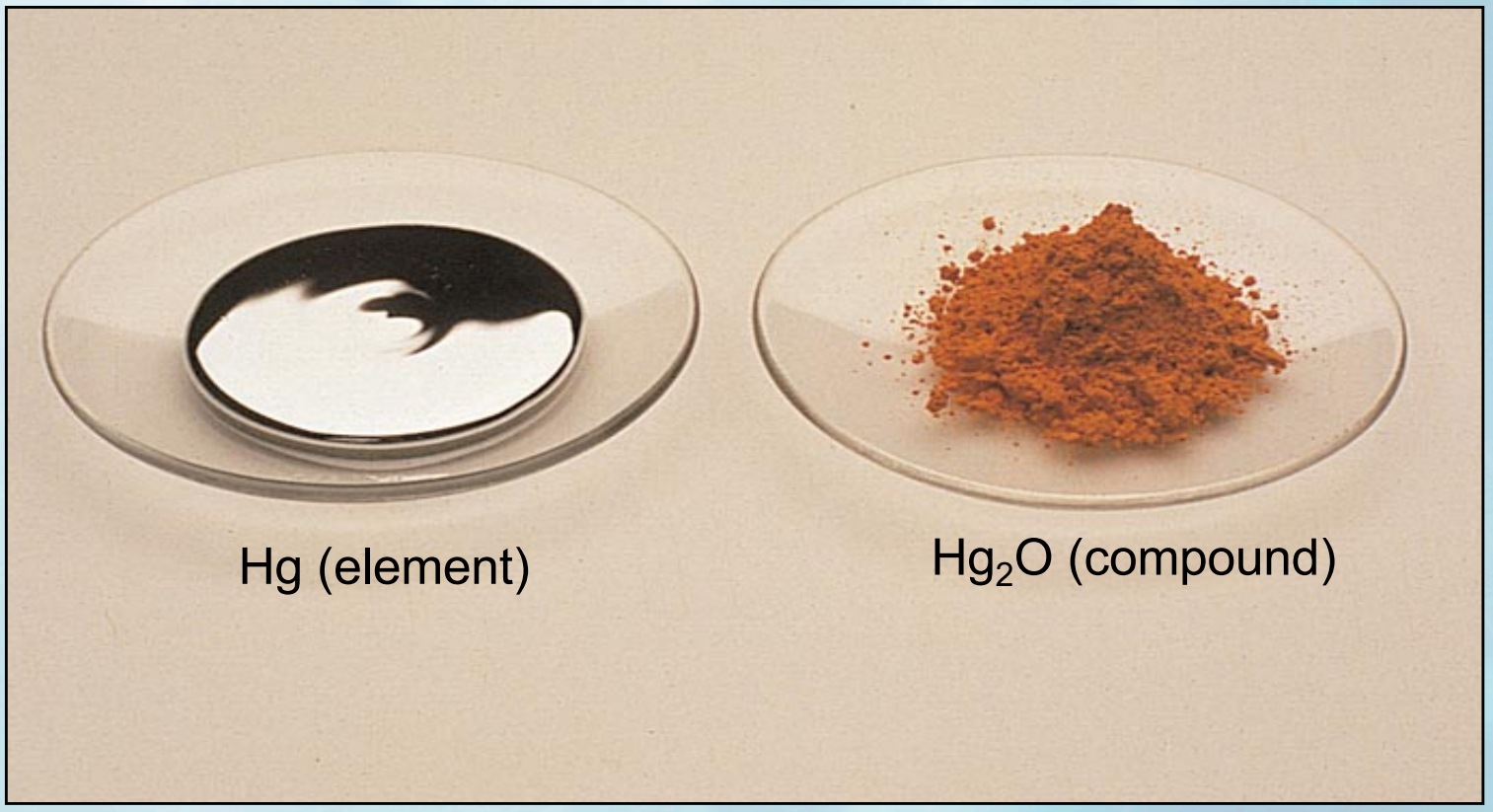


Atomic Number (Z = # protons)

Average Atomic Mass
(amu or g/mol)

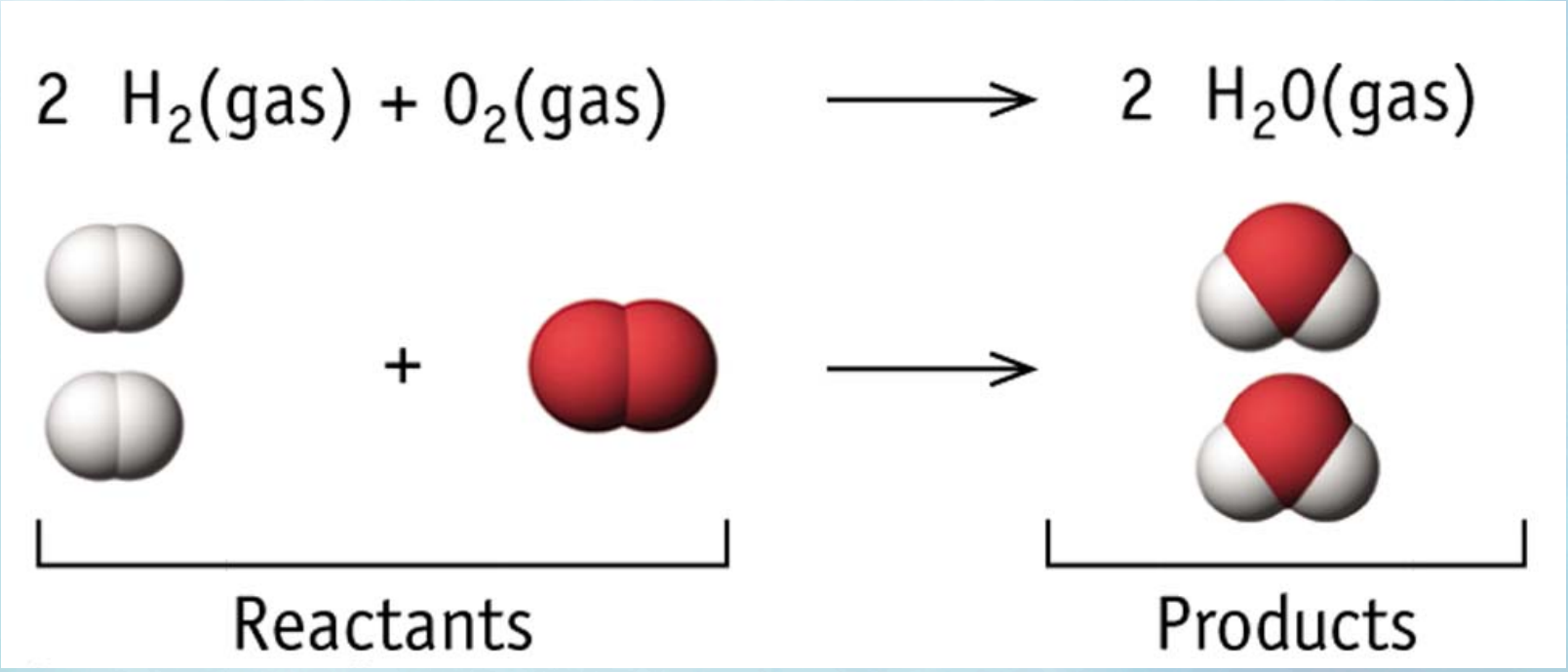
Compound formation

When elemental mercury is heated in air - where oxygen gas is present - Mercury (I) oxide is formed.

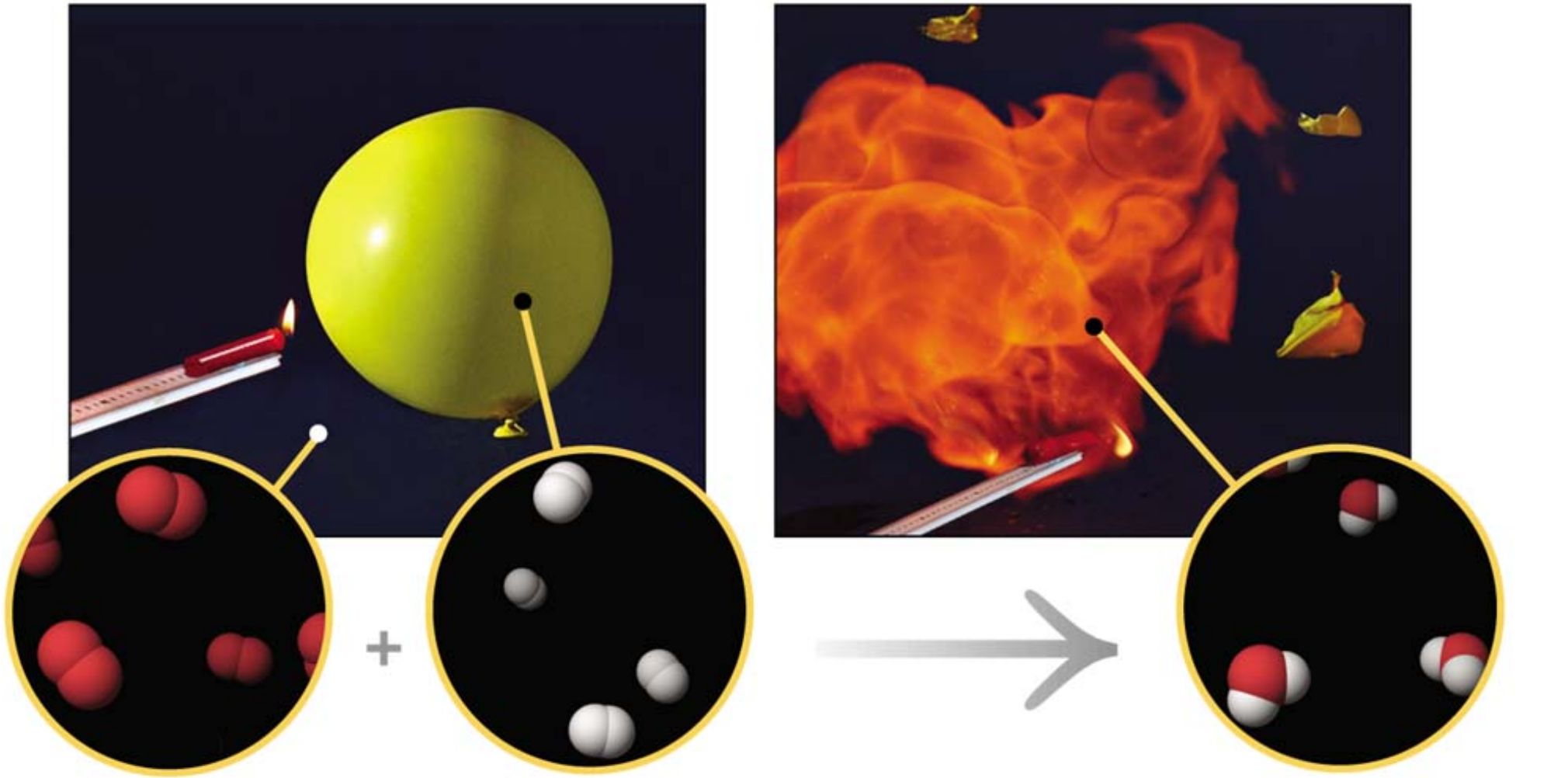


Chemical Reaction: Formation of Water

- Two hydrogen molecules and one oxygen molecule combine to make two water molecules.
- In their elemental diatomic forms, hydrogen is an explosive gas and oxygen supports combustion.
- However, as a compound, water is relatively non-reactive.



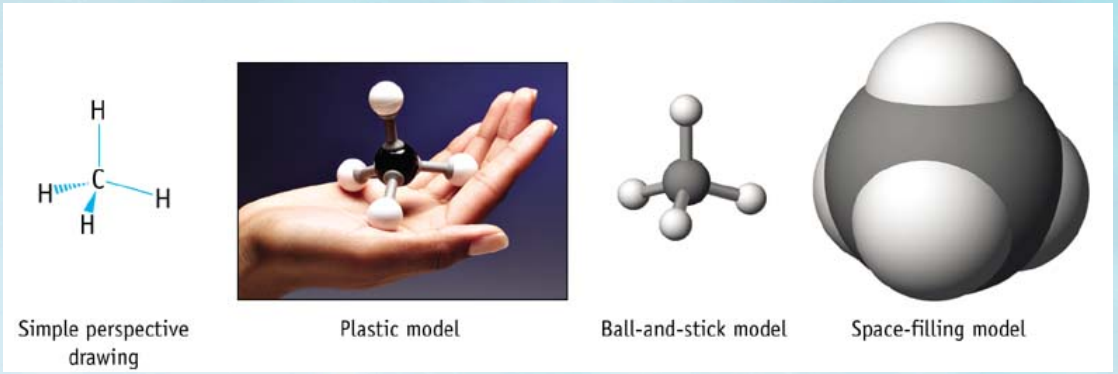
Chemical Reaction: Formation of Water



O_2 (gas) + H_2 (gas)

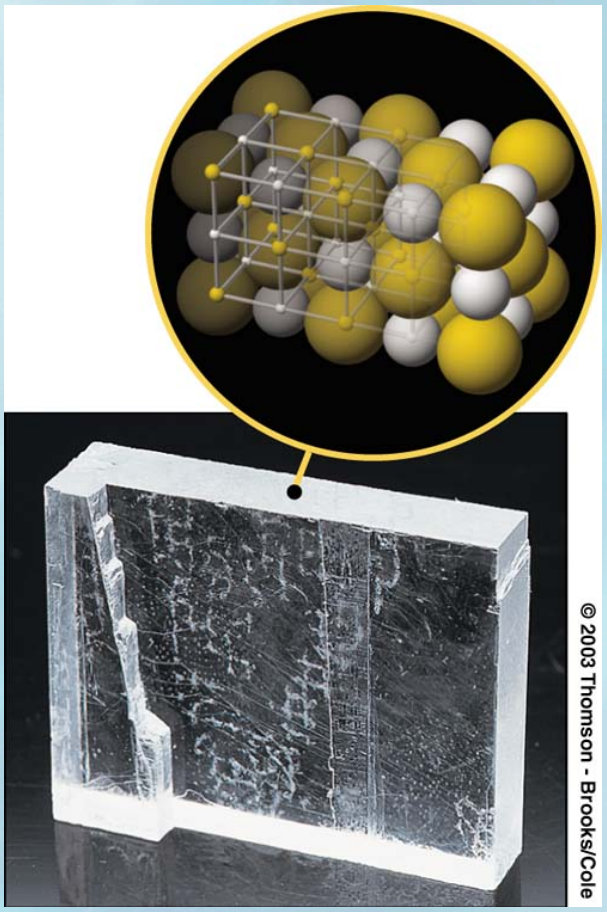
$2\ H_2(g) + O_2(g) \longrightarrow 2\ H_2O(g)$

Methane (CH_4) molecule

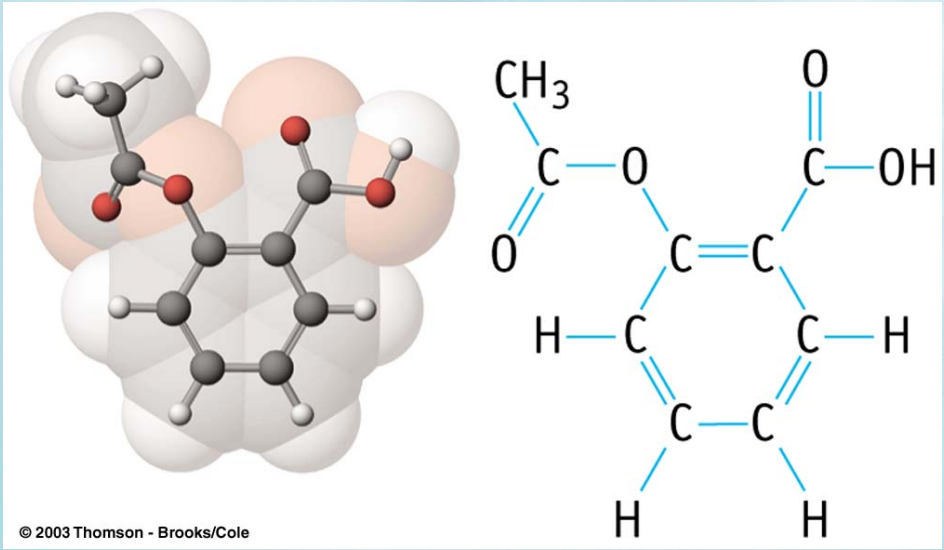


NaCl crystal

- There are no molecules of NaCl.
- The formula unit NaCl is the smallest ratio of Na^+ and Cl^- ions



Aspirin ($C_9H_8O_4$) molecule



NaCl

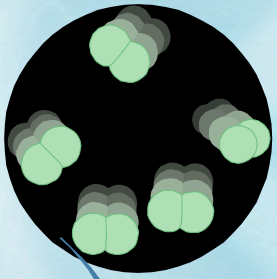
Elements sodium and chlorine reacting to form an ionic compound

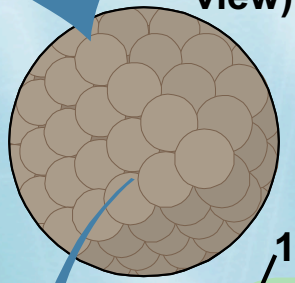
A The elements (lab view)

Sodium metal

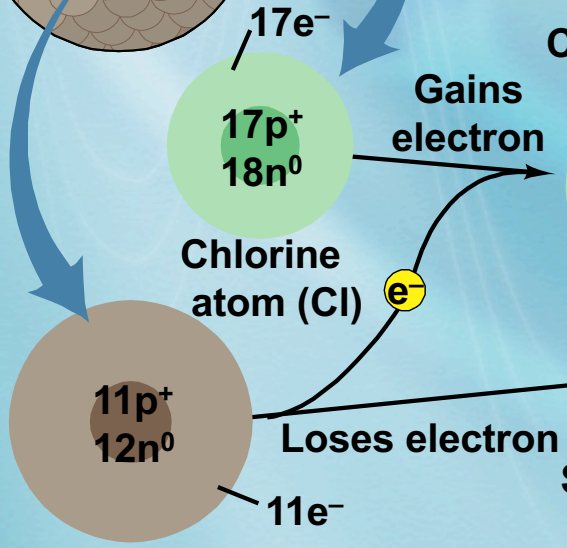
Chlorine gas

B The elements (atomic view)

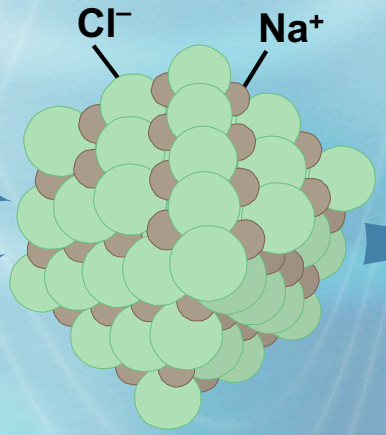




C Electron transfer



D The compound (atomic view): Na^+ and Cl^- in the crystal



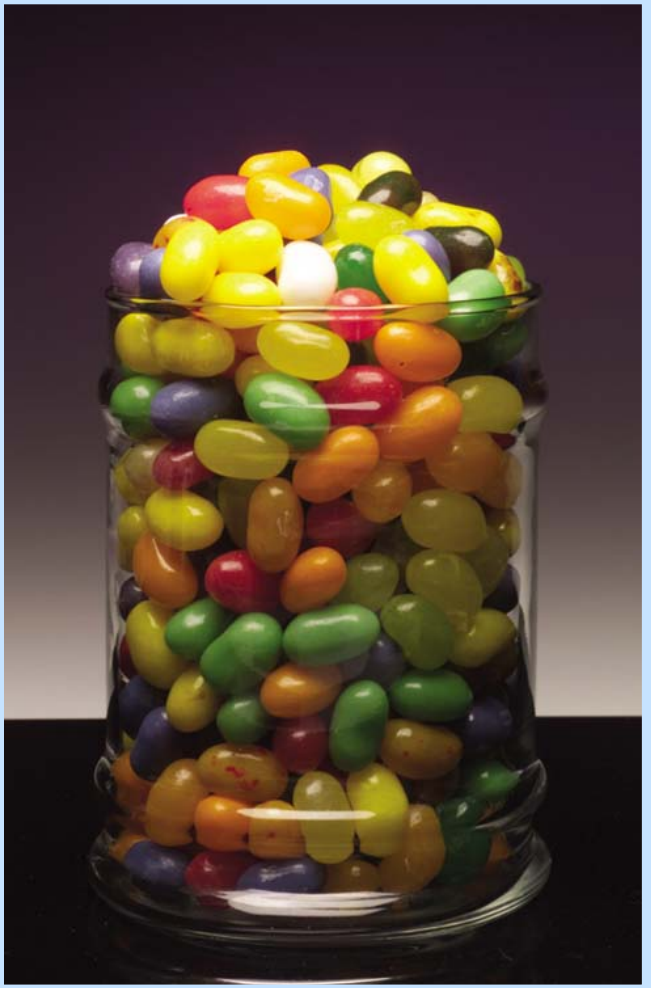
E The compound (lab view): sodium chloride crystal

Atoms, Ions, and Compounds

- **Atoms** are the smallest unit of an **element**.
- Atoms can share electrons to form **molecules**.
- Molecules are the smallest unit of a **covalent compound**.
- Atoms, usually metals, can lose electrons to form **cations** - positively charged ions.
- Atoms, usually nonmetals, can lose electrons to form **anions** - negatively charged ions.
- Cations and anions are attracted to one another and form **ionic bonds**.
- The **formula unit** is the smallest ratio of cations and anions in **ionic compounds**.

Mixtures

Saltwater - homogeneous mixture, also called a solution.



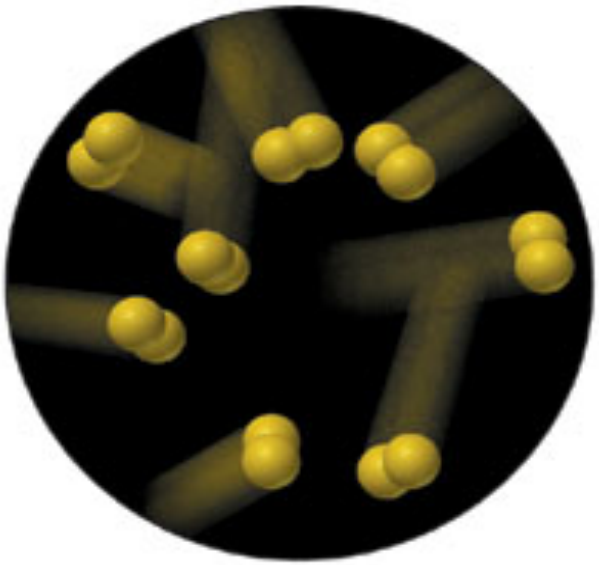
Jar of jelly beans - heterogeneous mixture

Substances & Mixtures: a particle view

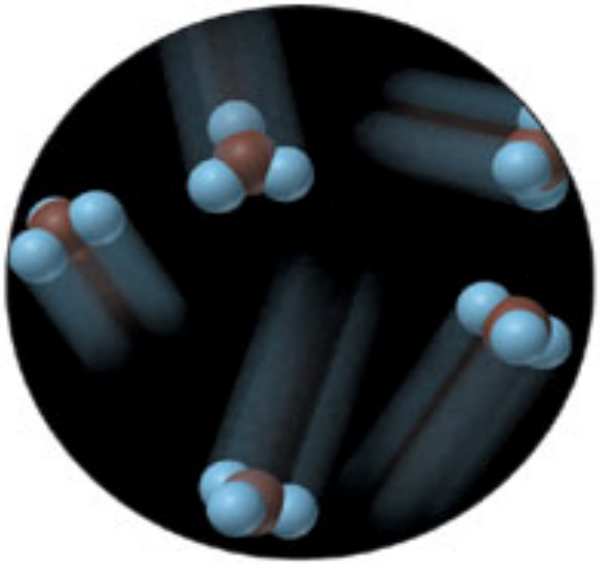
Substances: A, B, C

Mixture: D

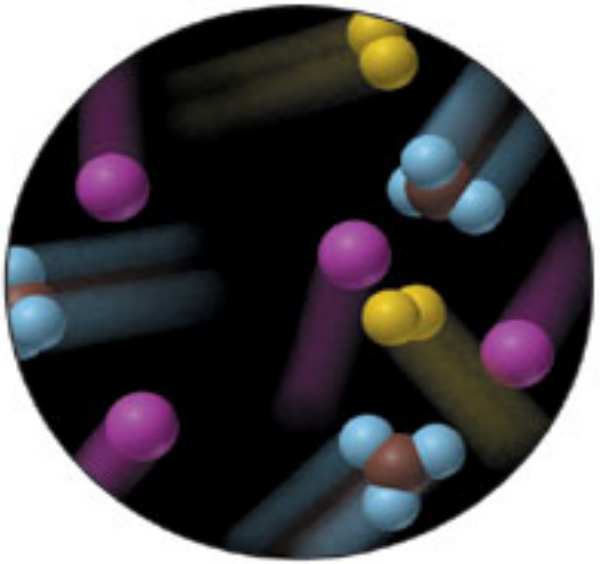
A Atoms of an element



B Molecules of an element



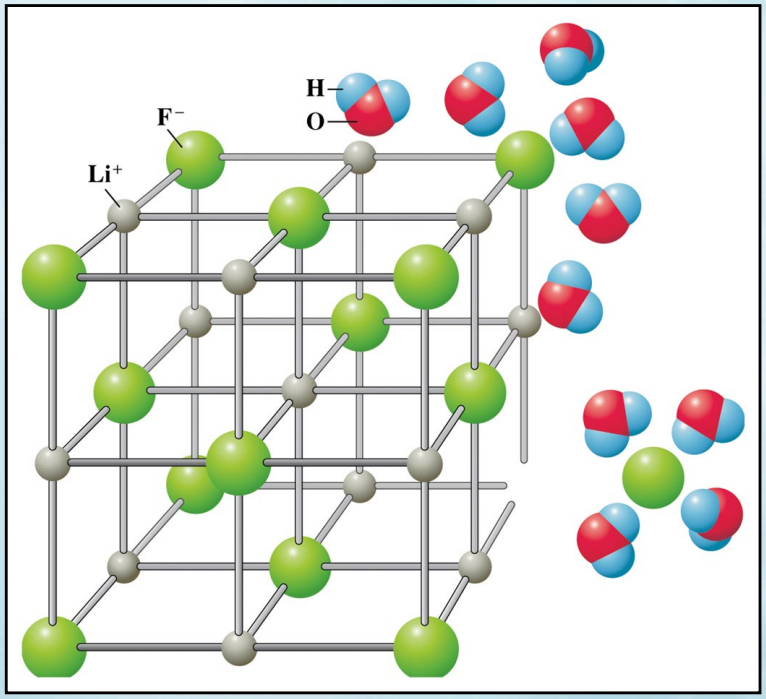
C Molecules of a compound

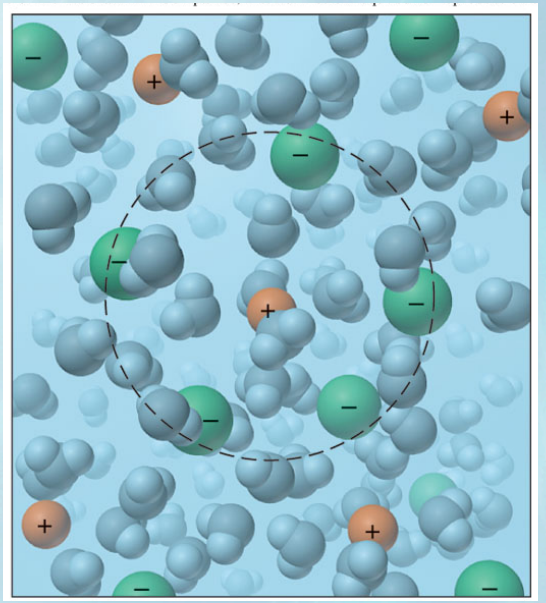


D Mixture of two elements and a compound

Dissolving Compounds

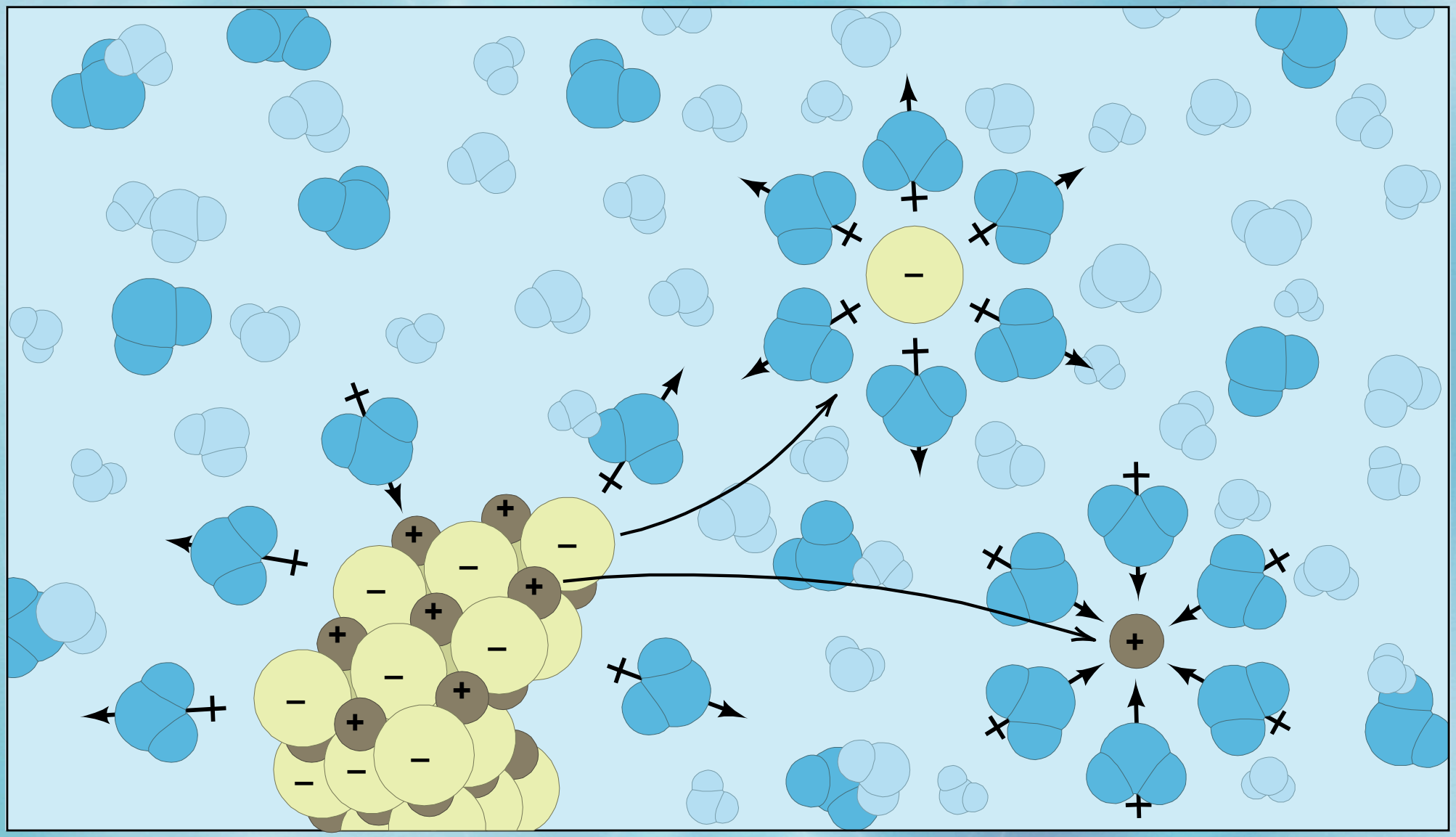
- When ionic compounds dissolve in water, they often dissociate into their individual ions.
- For example, when LiF dissolves in water, there are solvated Li^+ and F^- ions in solution.





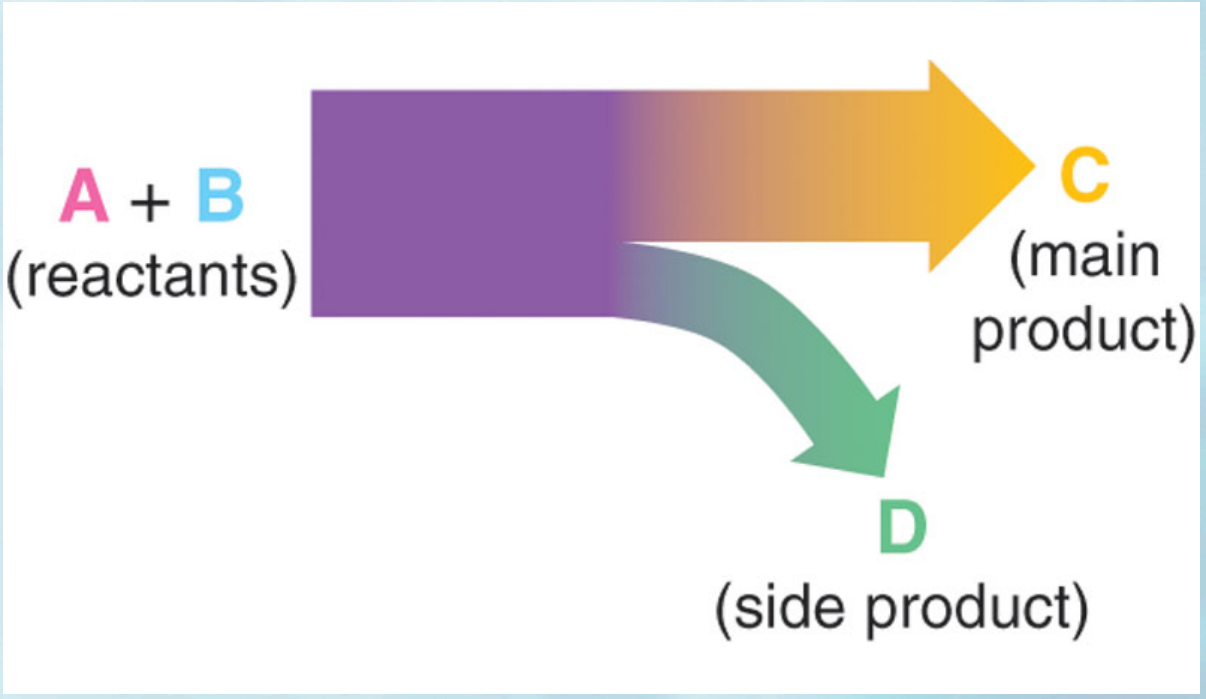
- **Molecular compounds do NOT dissociate when they dissolve in water.**

Dissolution of an ionic compound



Separation of mixtures

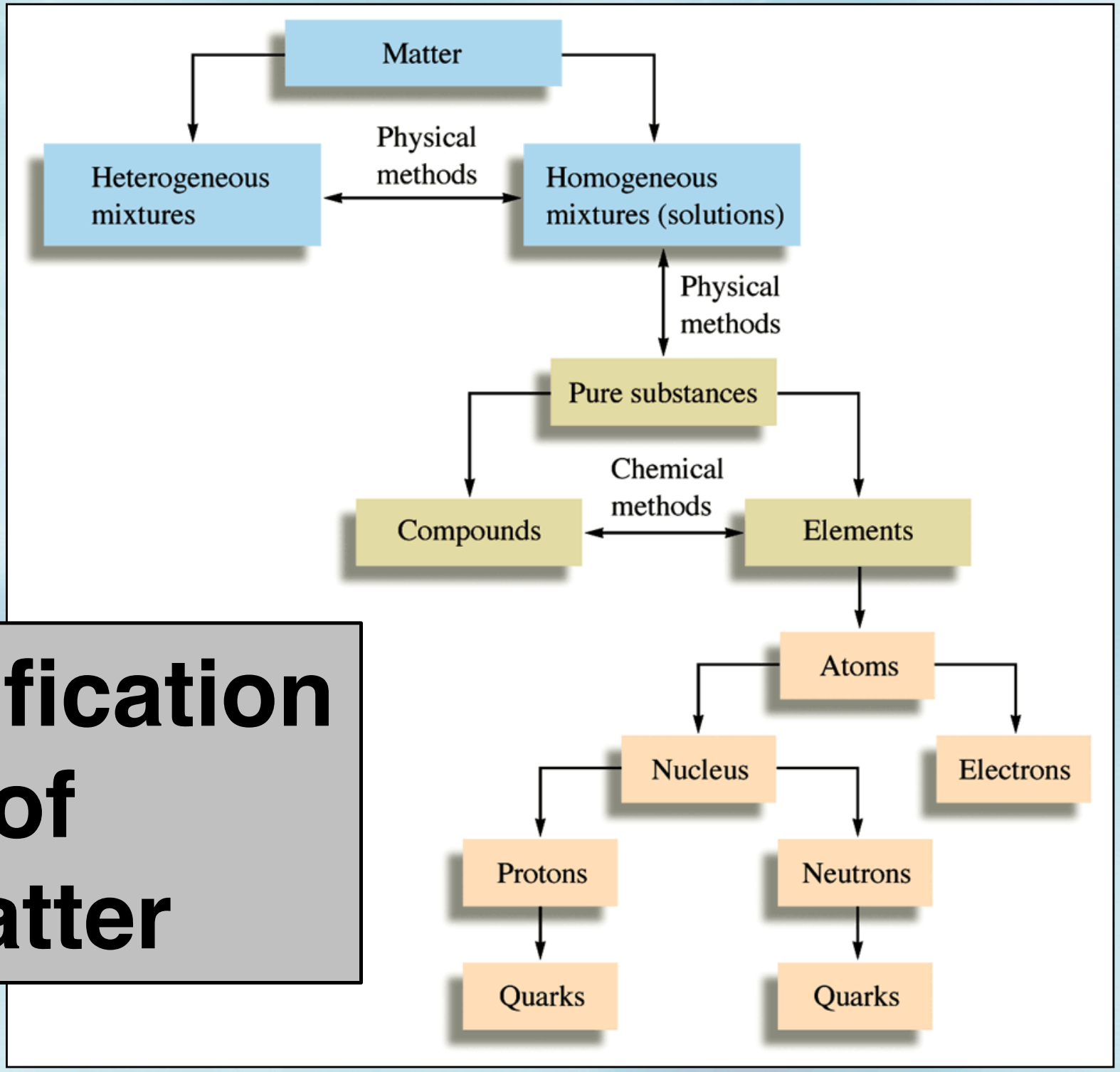
- In nature, some materials are mixtures and we wish to extract only one part of the mixture.
- In the chemistry laboratory, some reactions create a mixture of products. You may be interested in isolating a single product from that mixture.



Separation (& purification) of mixtures

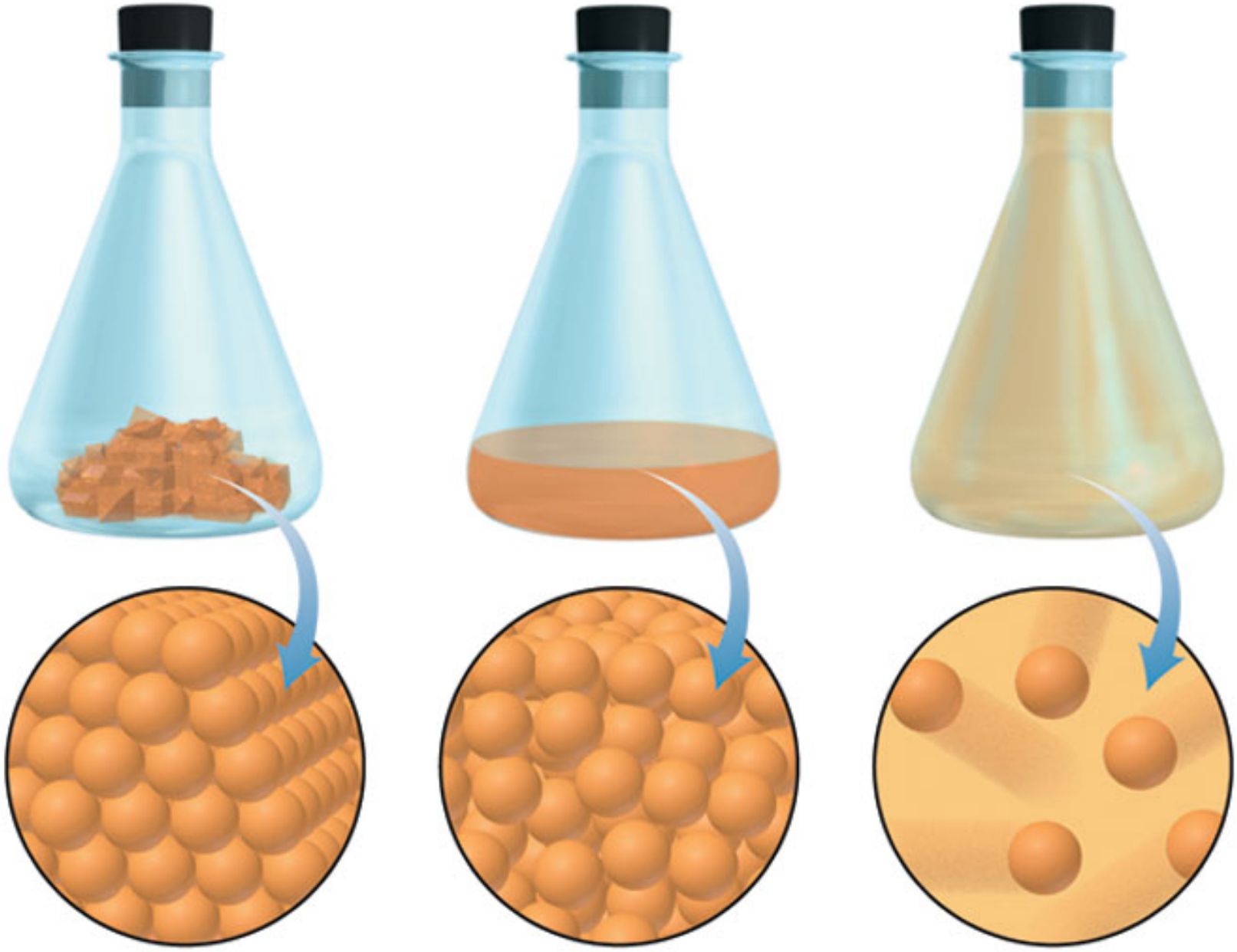
- ***Homogenous*** and ***heterogeneous*** mixtures are generally separated by different means. Some common means of separations in chemistry include:
  - Crystallization
  - Distillation
  - Chromatography
  - Extraction
  - Filtration
  - Exploiting other physical properties

Classification of Matter



Kinetic Molecular Theory

- Matter can exist in three primary states – solid, liquid, and gas.
- The ***Kinetic Molecular Theory*** explains how we may think of these three different phases at the particle level:
  1. Matter can be thought of as tiny particle spheres, called atoms or molecules.
  2. These particles are in constant motion.
  3. The kinetic energy of the molecules is directly proportional to the absolute (Kelvin) temperature.



Solid
Particles close together and organized

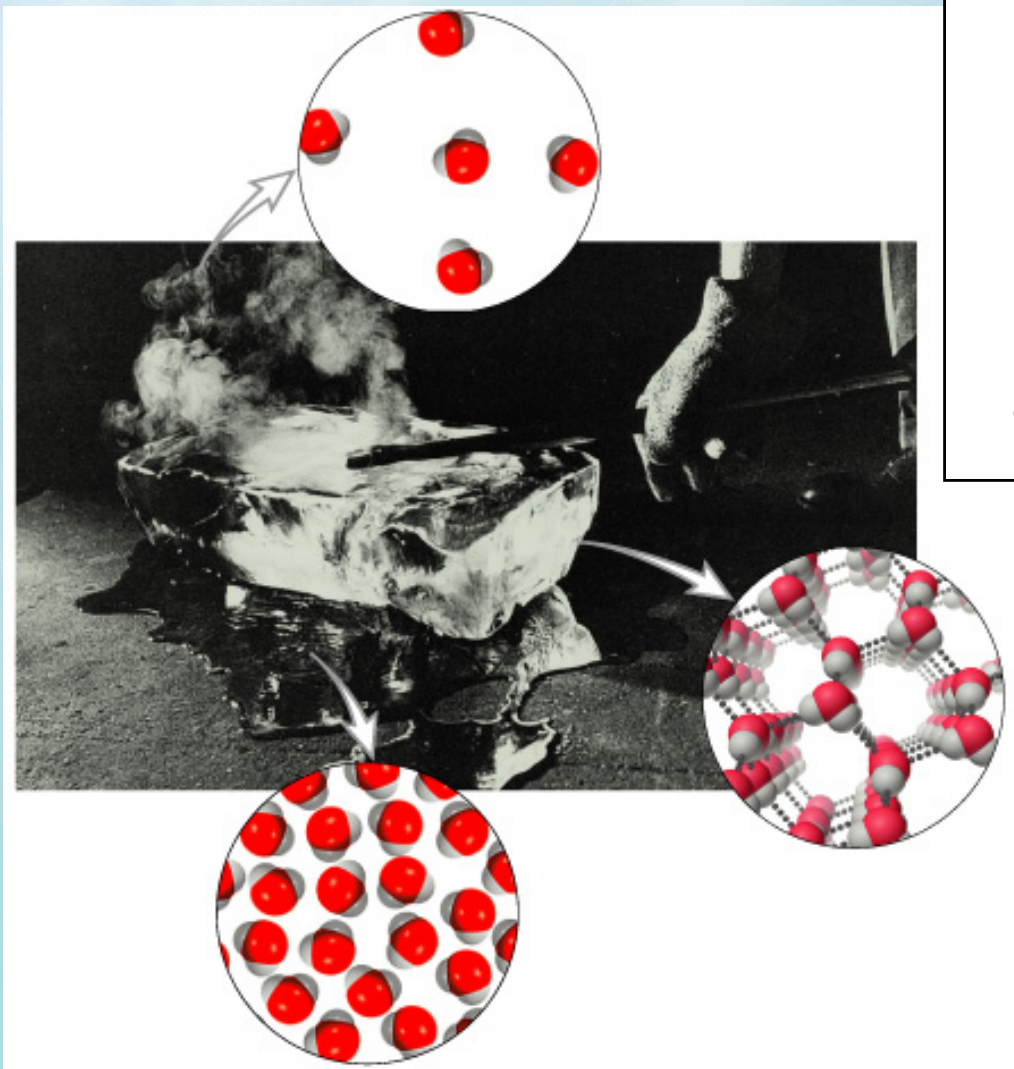
Liquid
Particles close together but disorganized

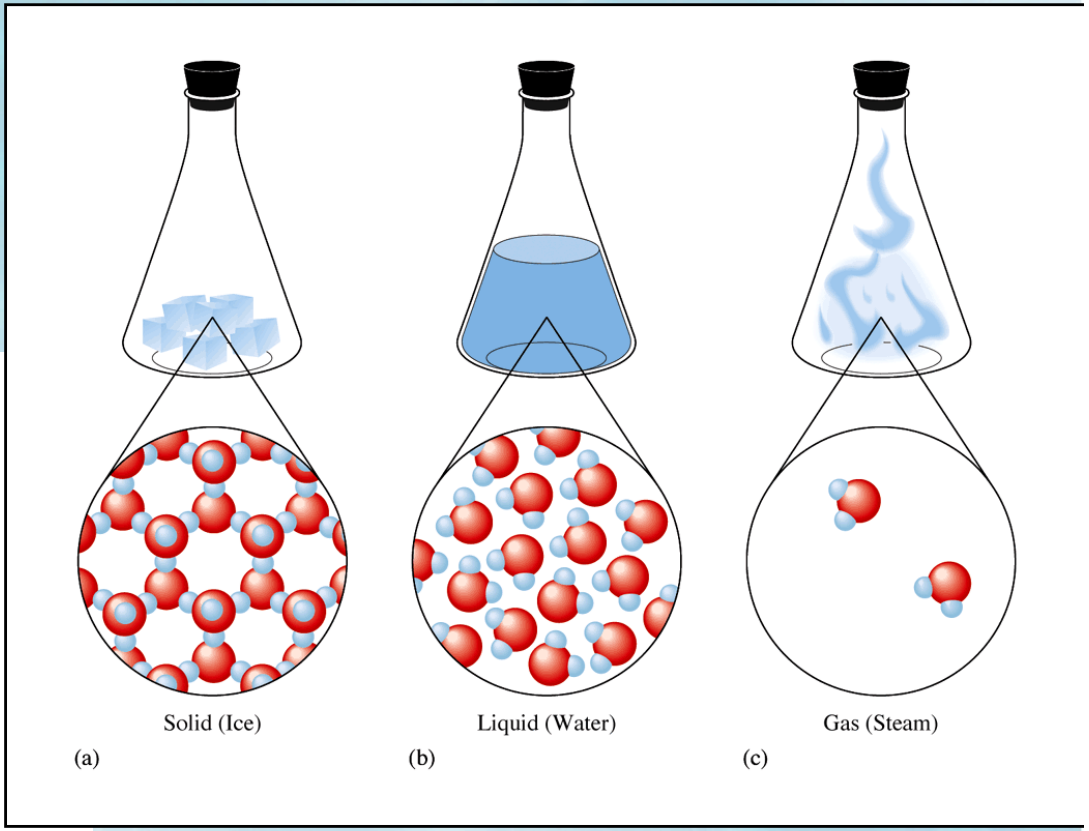
Gas
Particles far apart and disorganized

States (Phases) of Matter:

- ***Solid:*** State in which particles are generally tightly packed in to regular, repeating patterns, or crystals. *Solids have both a definite shape and volume.*
- ***Liquid:*** State in which particles are close to one another, but move freely past each other. *Liquids have a definite volume, but assume the shape of their container.*
- ***Gases:*** State in which particles are very distant from one another, and have little interaction. *Gases have no definite shape or volume.*

The three states of water.





Physical properties

- A characteristic that can be observed without changing the chemical composition of the substance.
  - Density
  - Boiling Point
  - Melting Point
  - Specific Heat Capacity

Chemical properties

- A characteristic of matter that relates to the reactivity of a substance.
  - Flammability
  - Corrosiveness

Table 1.1 Some Characteristic Properties of Copper

Physical Properties	Chemical Properties
Reddish brown, metallic luster	 Slowly forms a basic, blue-green sulfate in moist air
 Easily shaped into sheets (malleable) and wires (ductile)	 Reacts with nitric acid (photo) and sulfuric acid
Good conductor of heat and electricity	
 Can be melted and mixed with zinc to form brass	 Slowly forms a deep-blue solution in aqueous ammonia
Density = 8.95 g/cm^3	
Melting point = 1083°C	
Boiling point = 2570°C	

Physical Changes

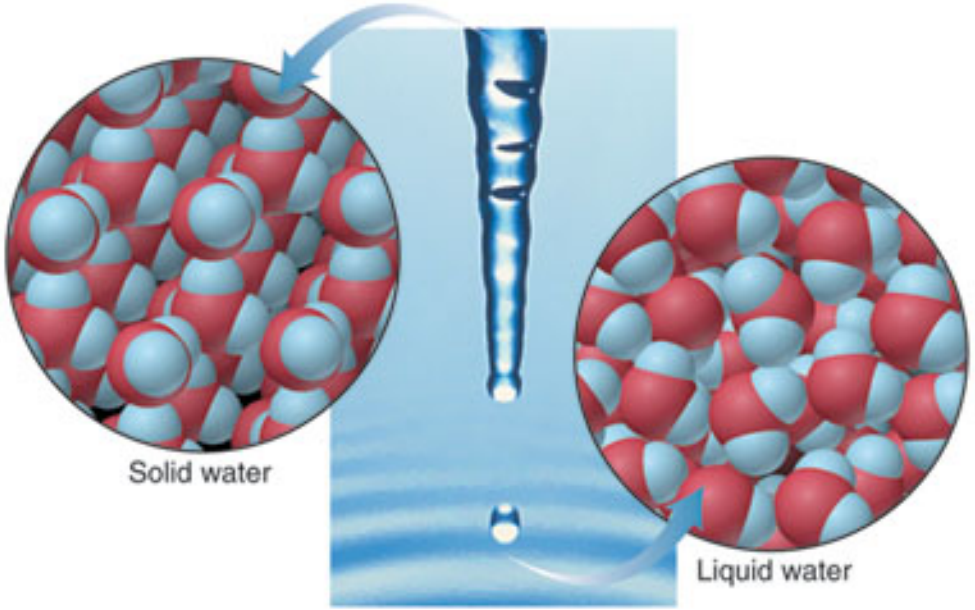
- A change in matter in which the chemical make-up of a substance is not changed.
  - Phase changes (freezing, boiling)
  - Breaking a glass
  - Dissolving a solid.

Chemical Changes

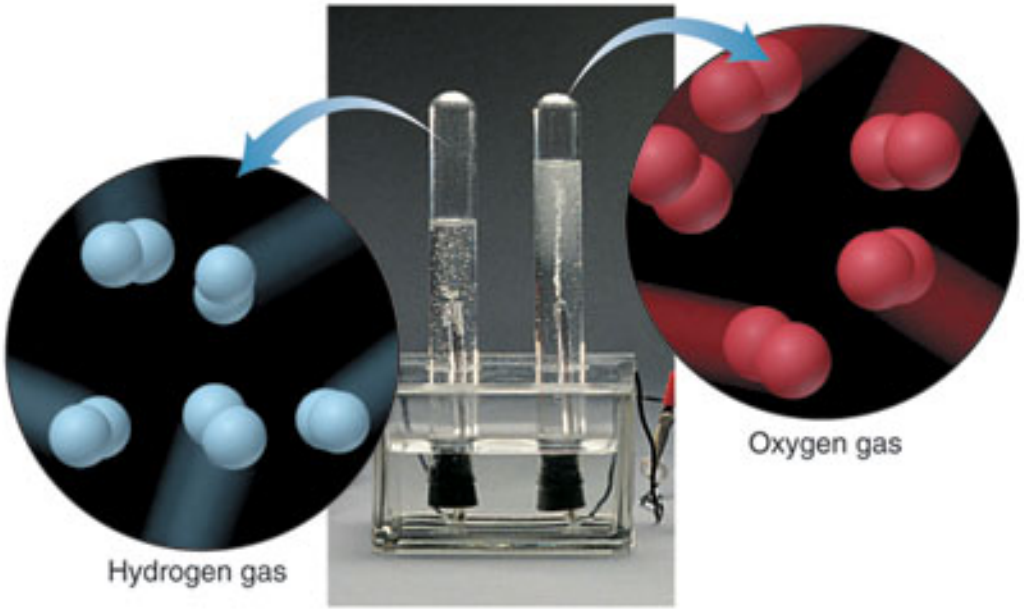
- One or more substance is transformed into one or more different substances.
- Iron reacting with oxygen to form rust.
- Wood burning in oxygen to form carbon dioxide and water.
- Water reacting with sulfur trioxide to form sulfuric acid.

Physical Change:

Chemical Change:



A Physical change:
Solid form of water becomes liquid form; composition does not change because particles are the same.



B Chemical change:
Electric current decomposes water into different substances (hydrogen and oxygen); composition does change because particles are different.