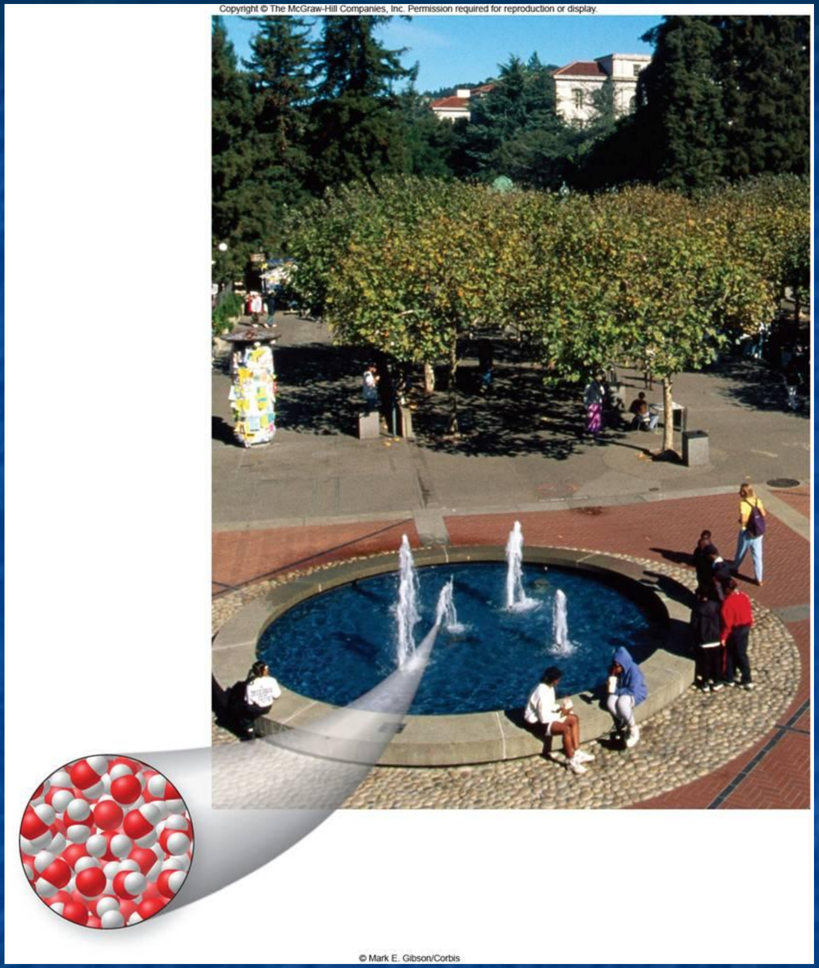
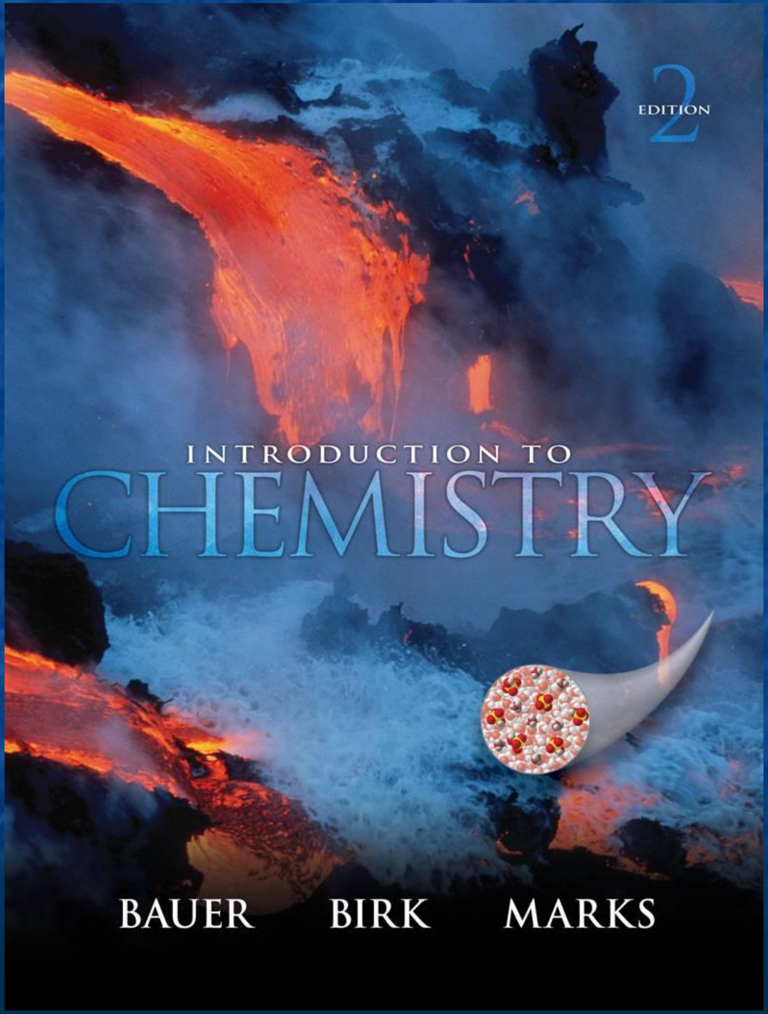
Chapter 1:

Matter and Energy

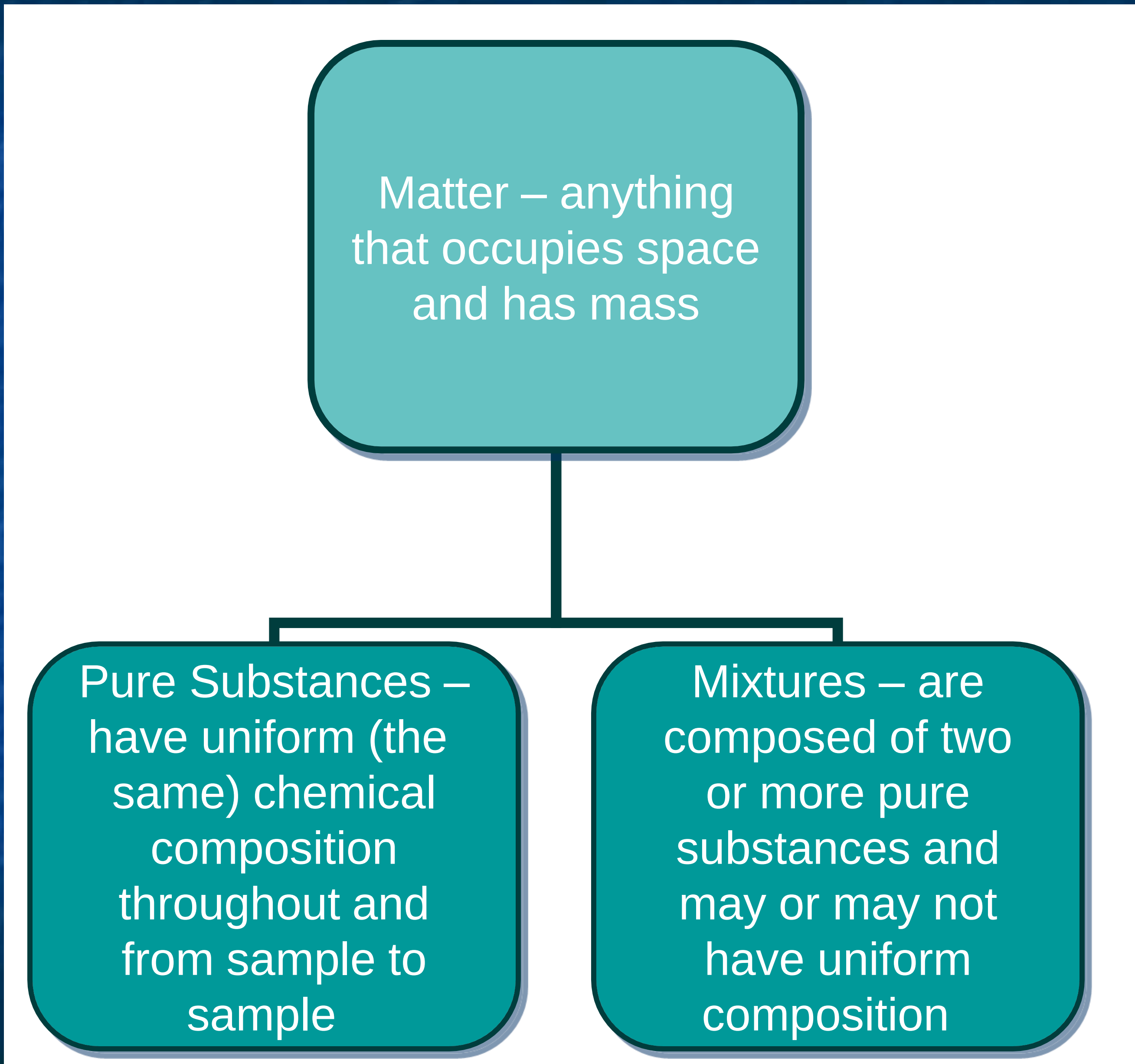


1.1 Matter and Its Classification

- Matter is anything that occupies space and has mass.
- Forms of energy are NOT matter. Heat and light, for example, do not occupy space and have no mass.
- Consider the different forms of matter and energy in this picture.



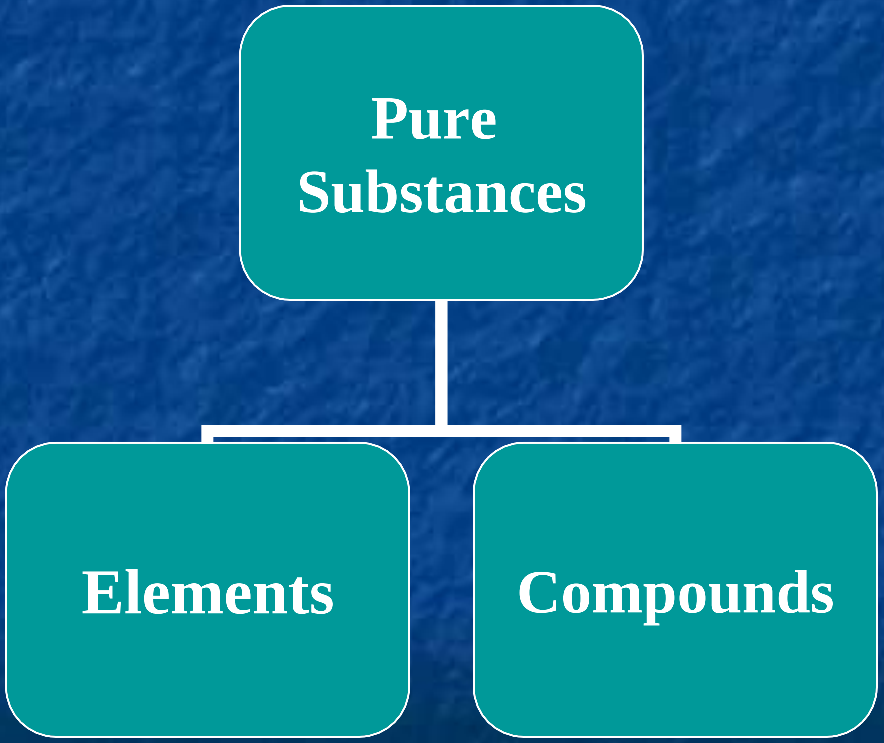
Chemical Classifications of Matter



Composition of Matter

Pure Substances:

- have the same composition throughout, and from sample to sample.
- can be further classified as either elements or compounds.



Pure Substances

- Have uniform, or the same, chemical composition throughout and from sample to sample.
- Two kinds of pure substances
  - Elements
    - An element is a substance that cannot be broken down into simpler substances even by a chemical reaction.
    - Elements are separated further into metals and nonmetals.
  - Compounds
    - A compound is a substance composed of two or more elements combined in definite proportions.

Elements

- An element is a substance that cannot be broken down into simpler substances even by a chemical reaction.
- All known elements are organized on the periodic table.

Figure 1.3

- Metals (main-group)
- Metals (transition)
- Metals (inner-transition)
- Metalloids
- Nonmetals

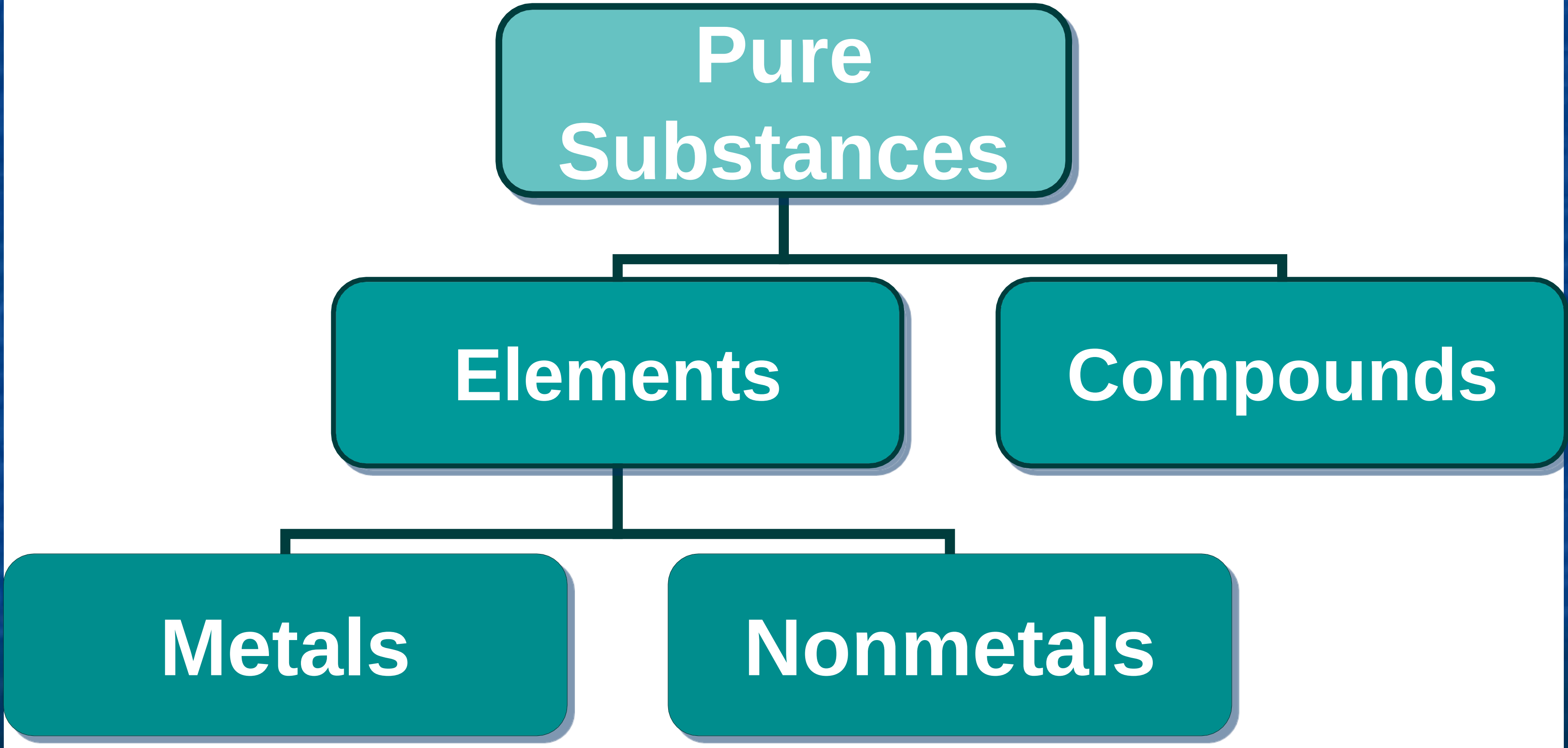
MAIN-GROUP ELEMENTS | TRANSITION ELEMENTS | MAIN-GROUP ELEMENTS

Period	IA (1)	IIA (2)	IIIB (3)	IVB (4)	VB (5)	VIB (6)	VIIB (7)	VIIIB (8)	VIIIB (9)	VIIIB (10)	IB (11)	IIB (12)	IIIA (13)	IVA (14)	VA (15)	VIA (16)	VIIA (17)	VIIIA (18)
1	1 **H** 1.008																	2 **He** 4.003
2	3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.41	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
6	55 **Cs** 132.9	56 **Ba** 137.3	57 **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (263)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (267)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (281)	111 **Rg** (272)	112 (285)	113 (284)	114 (289)	115 (289)	116 (292)		

INNER-TRANSITION ELEMENTS

Period															
6 Lanthanides	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
7 Actinides	90 **Th** 232.0	91 **Pa** (231)	92 **U** 238.0	93 **Np** (237)	94 **Pu** (242)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Pure Substances



Activity: Classification of Matter

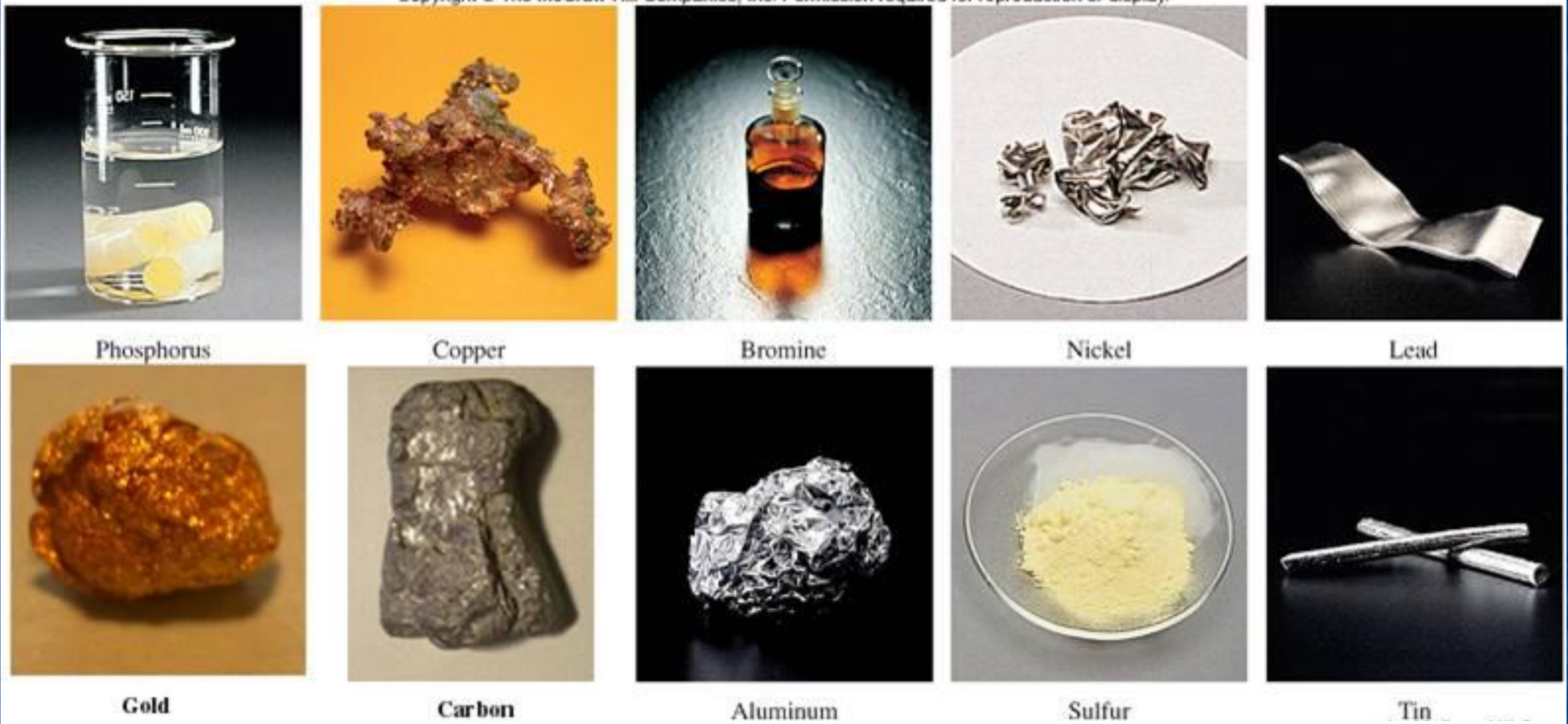


Figure 1.4

Activity Solution: Classification of Matter

Metals can be distinguished from nonmetals by the luster and ability to conduct electricity. Since we do not know how each of elements in Figure 1.4 conduct electricity, we need to use luster as our measure. Nonmetals are usually dull, with the exception of carbon (as diamond). Elements that are gases at room temperature are also nonmetals. Therefore, the nonmetals in Figure 1.4 are phosphorus, bromine, carbon, and sulfur.

Activity: Classifying Metals and Nonmetals

Which of the following are metals? Which are nonmetals?

1. Phosphorus - P
2. Gold - Au
3. Carbon - C
4. Copper - Cu
5. Bromine - Br
6. Aluminum - Al
7. Sulfur – S
8. Nickel - Ni
9. Lead - Pb
10. Tin - Sn

Atoms

- Matter is composed of atoms.
  - An atom is the smallest unit of an element that retains the chemical properties of that element.

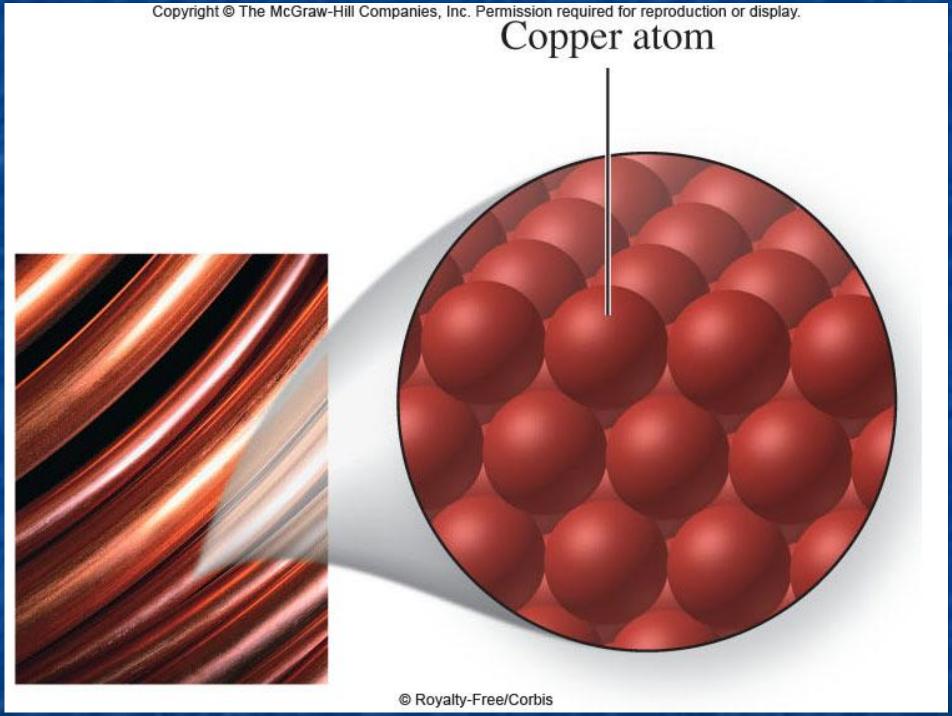


Figure 1.8

Atoms and Molecules

- Atoms can be found combined together in molecules.
  - Molecules are composed of two or more atoms bound together in a discrete arrangement.
  - The atoms bound together in a molecule can be from the same element or from different elements.

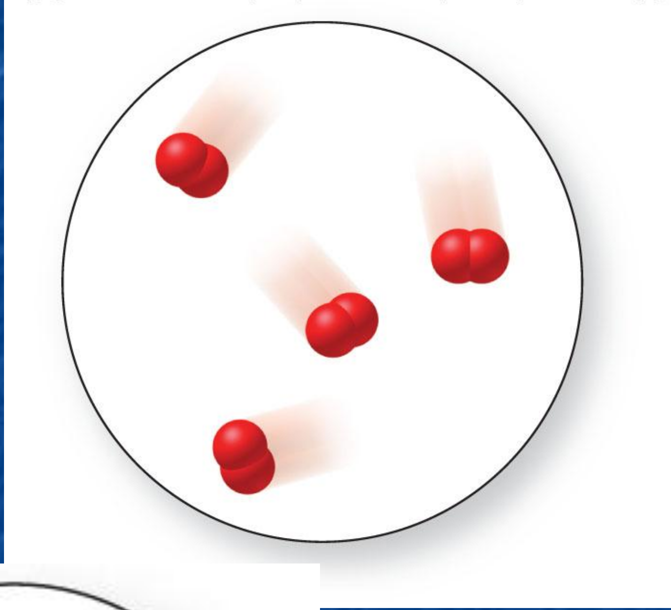


Figure 1.11

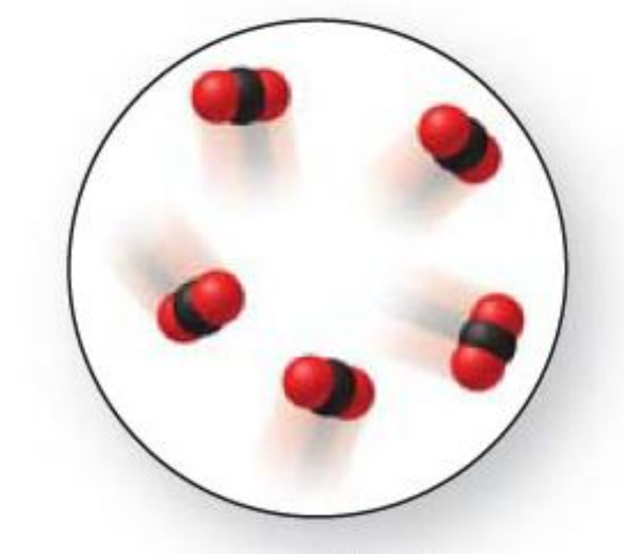


Figure from p. 22

Compounds

- A compound is a pure substance composed of two or more elements combined chemically in definite proportions.
- A compound has properties that are different from those of its component elements.

Iron pyrite

Figure 1.5

Compound: Iron pyrite, Fe_2S_3

Elements: Iron, Fe, and Sulfur, S

Compounds

- Pure sand is the compound silicon dioxide, which has the fomula SiO_2.
- What does the formula tell us about the combination of elements in this compound?

Activity: Elements and Compounds

- Identify each of the following as an element or compound.

1. $C_6H_{12}O_6$
2. H_2O
3. Br_2
4. Sodium phosphate

Mixtures

- A mixture is a combination of two or more elements or compounds .
- Mixtures differ from pure compounds in that their components can be separated by physical processes.

- Examples:
  - Bronze
  - Salt water
  - Air

Salt Being Separated by Evaporation

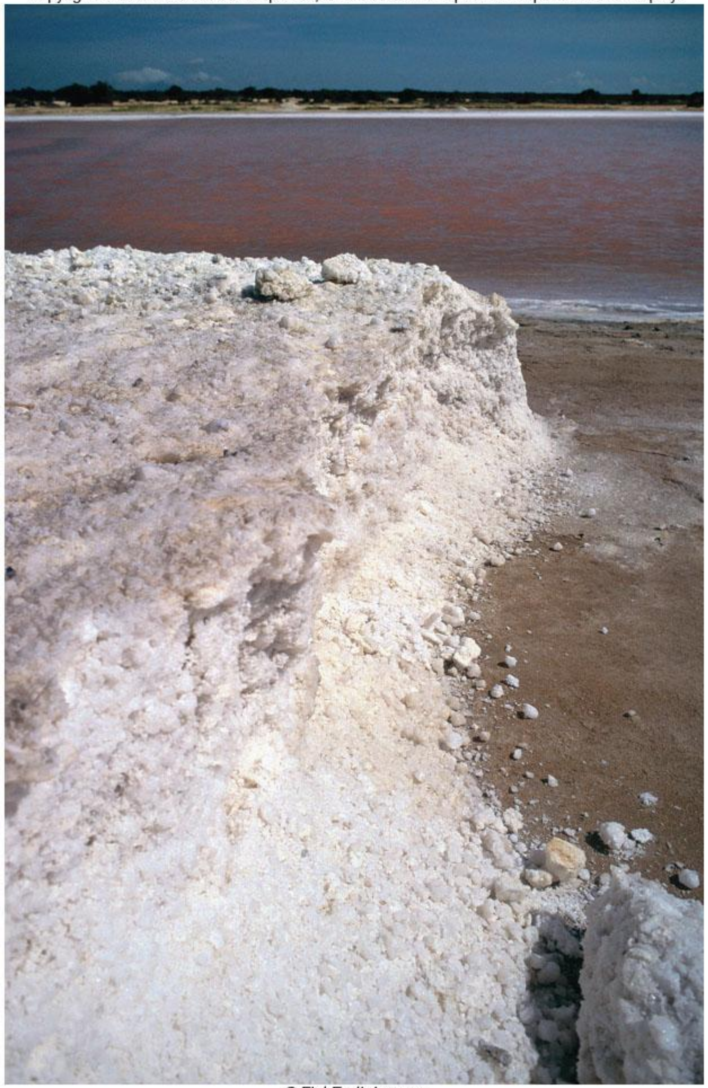


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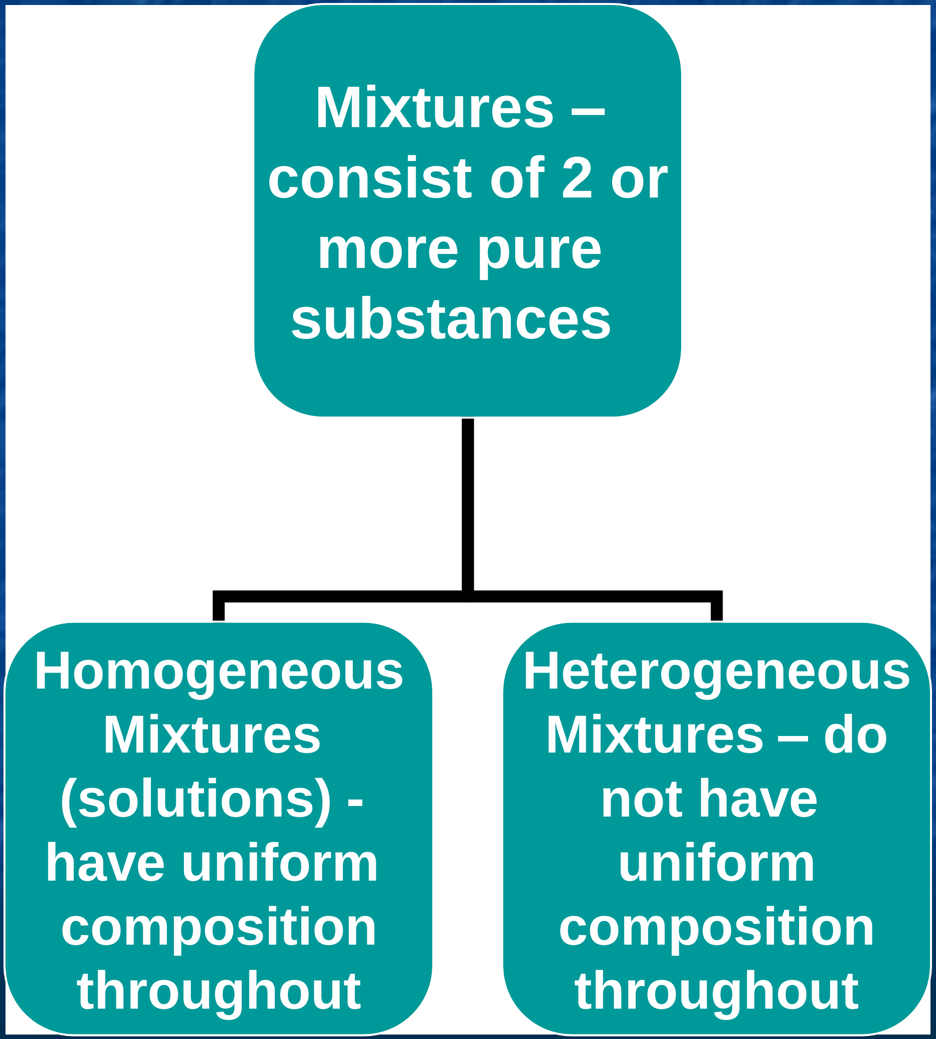
Figure 1.6

Mixtures

- Mixtures can be further classified as homogeneous and heterogeneous.
- Homogeneous mixtures have the same composition throughout.
- Heterogeneous mixtures do not.



Mixtures

- Classify each of the following mixtures as *homogeneous* or *heterogeneous*:
  - Salt water
  - Pizza
  - Tap water
  - Air
  - Brass (an alloy of copper and zinc)
  - Potting soil
  - Cake mix

Classification of Matter

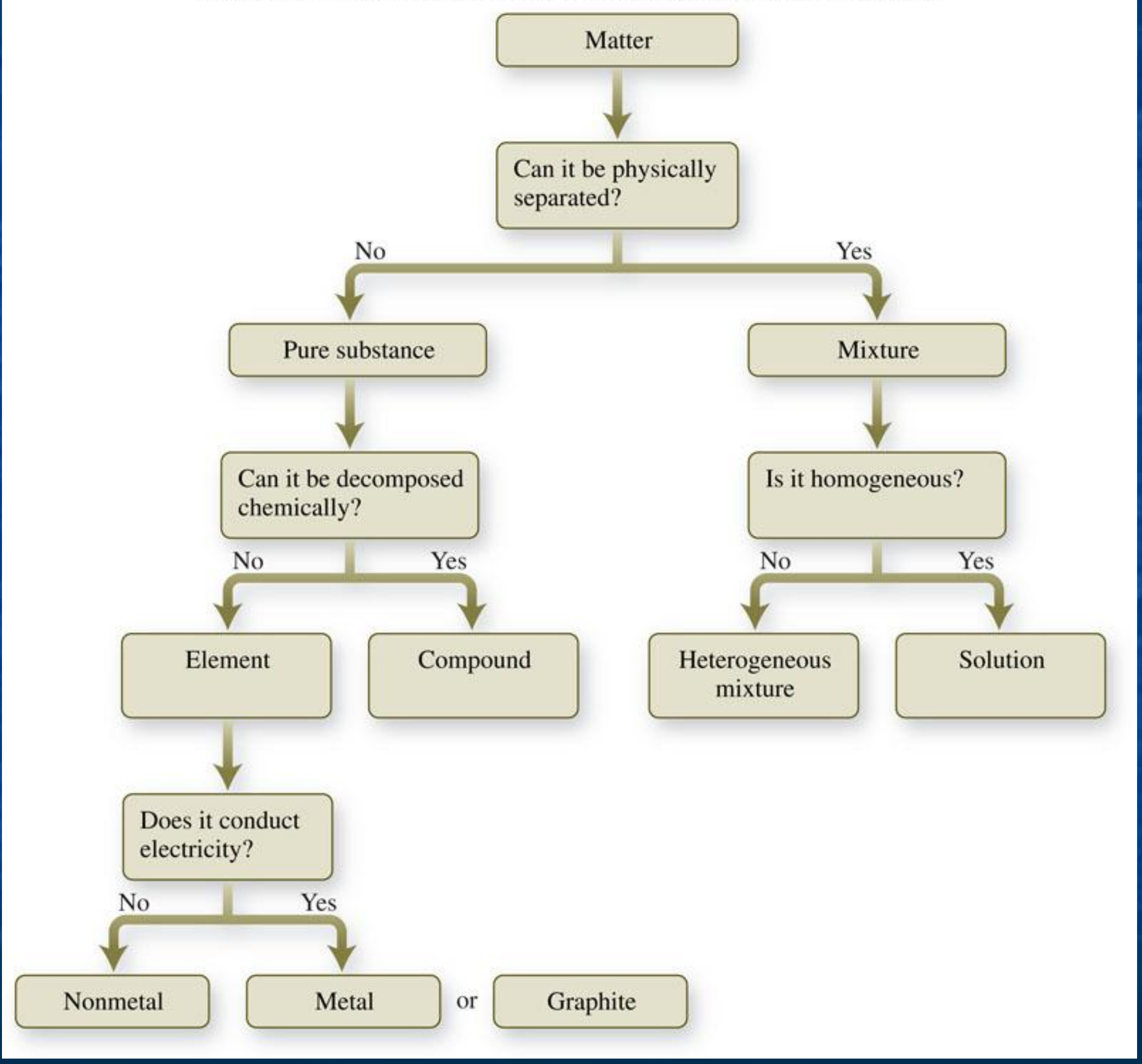


Figure 1.7

Molecular-Level Representations of Matter – Copper Atoms

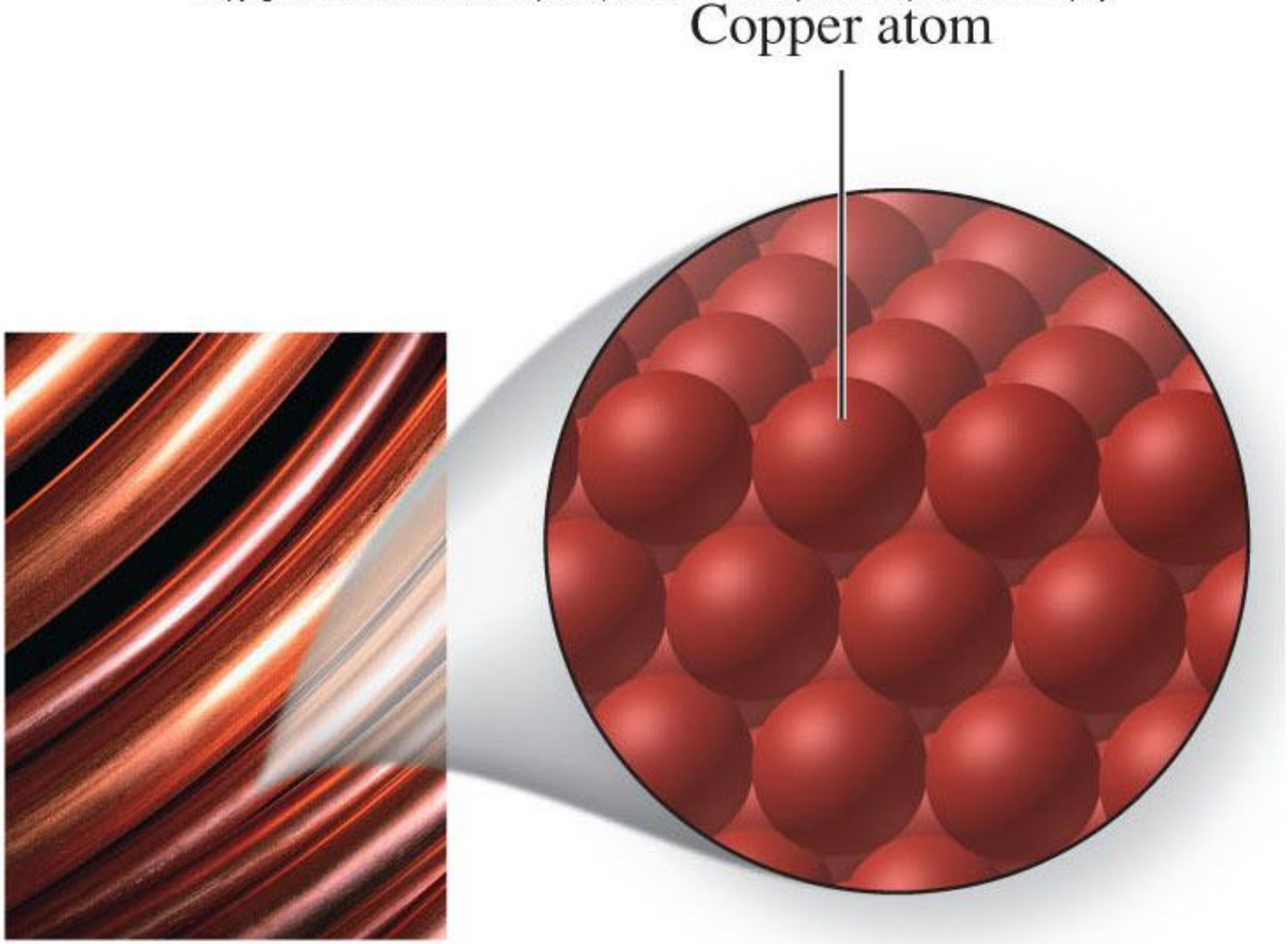


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Figure 1.8

Molecular-Level Representations of Matter – Helium Atoms

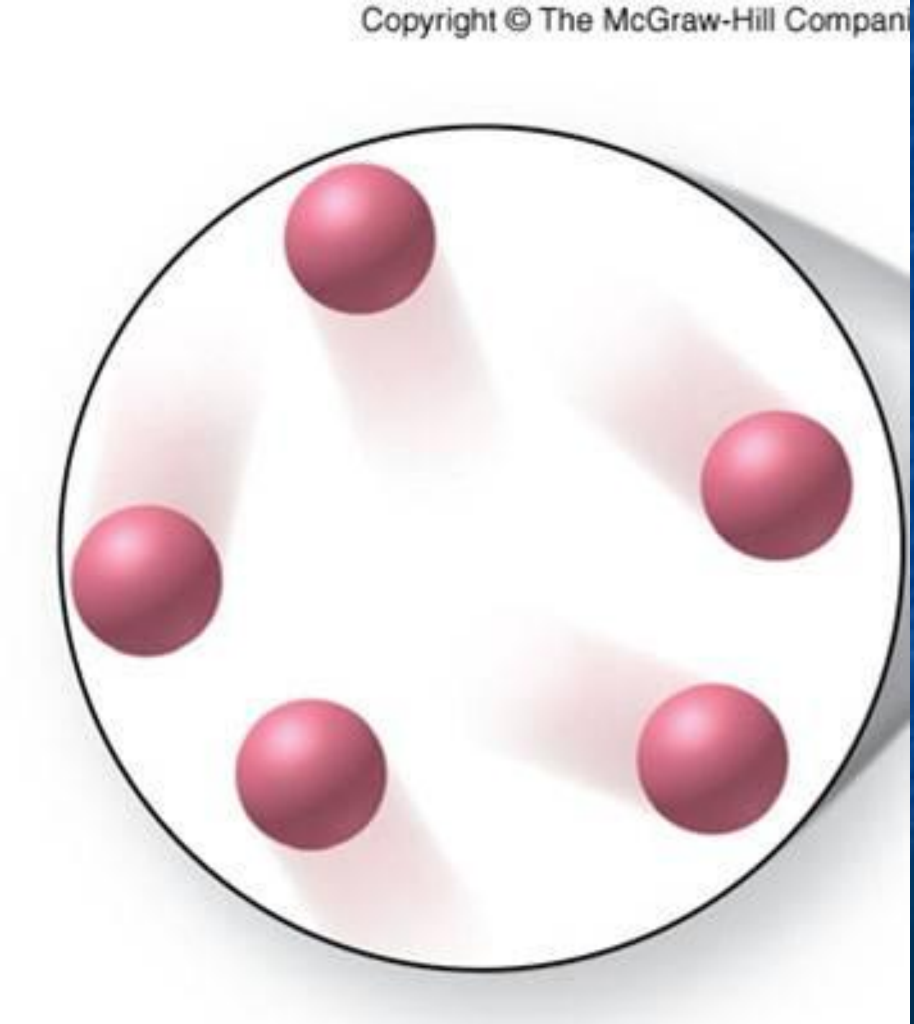

Figure 1.9

Activity: Molecular-Level Representations

- Does this image represent atoms or molecules?
- Is this an element, compound, or mixture?

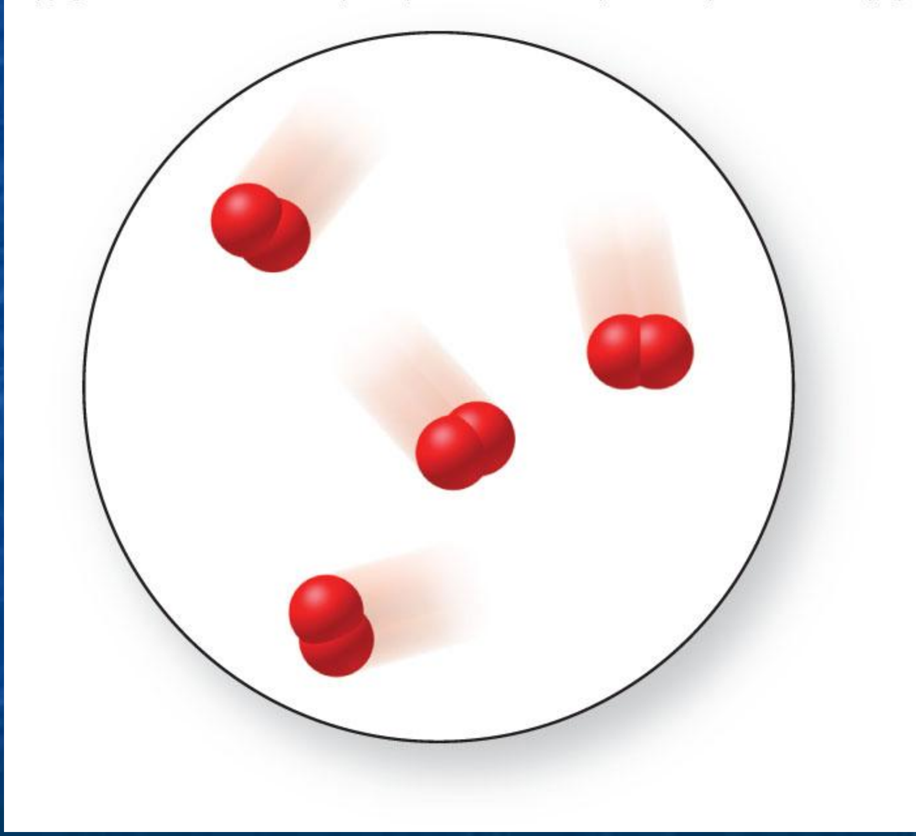

Figure 1.11

Molecular-Level Representations of Matter – water molecules

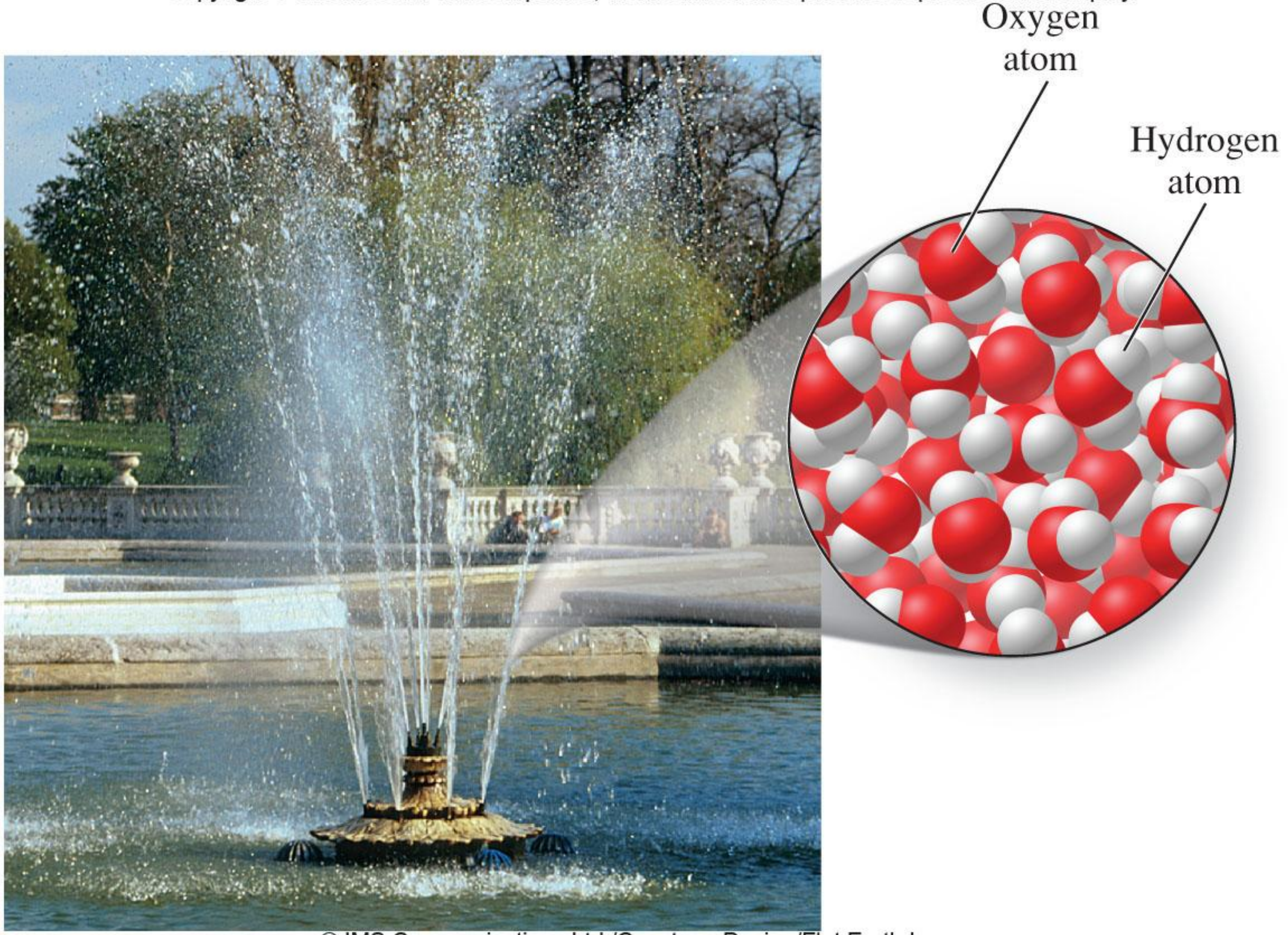

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Figure 1.10

Different Ways to Represent Water

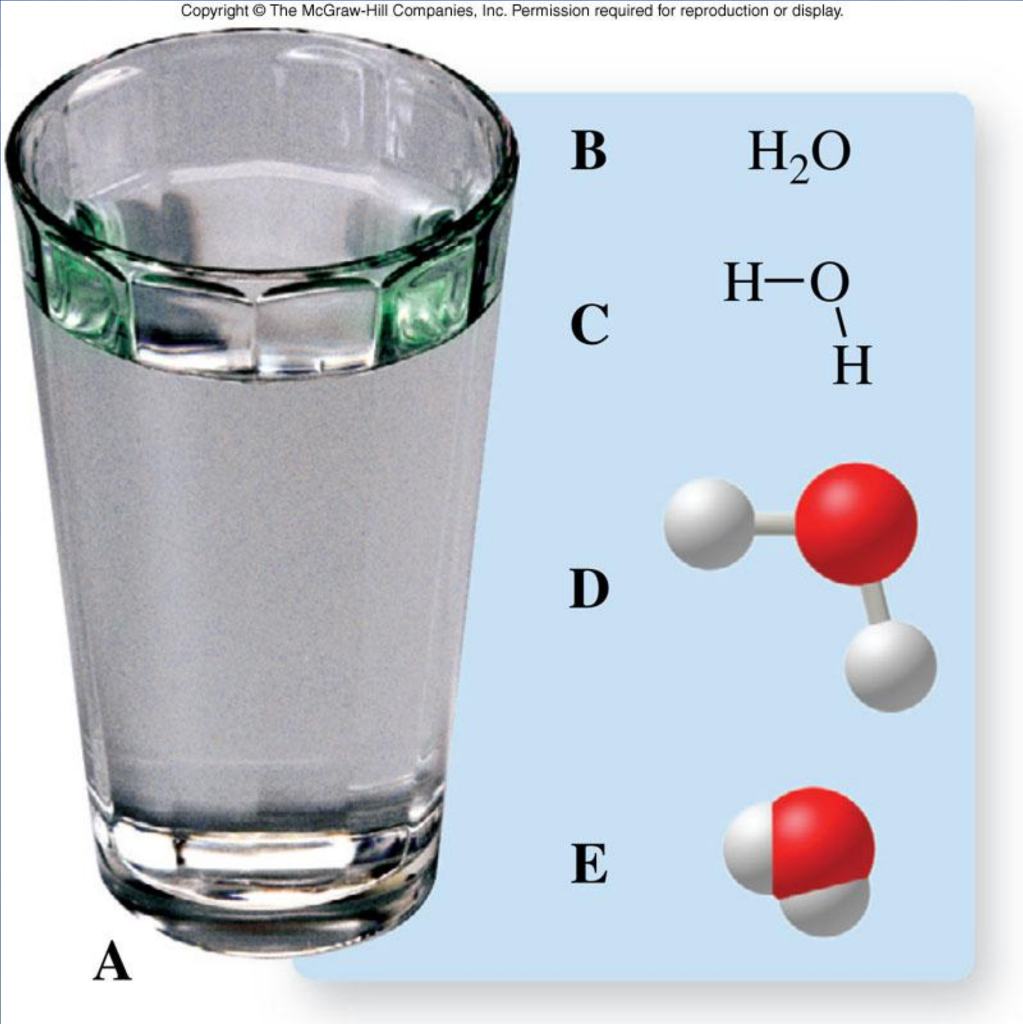


Figure 1.12

Activity: Classification

Classify each of the following as an element, compound, or mixture.

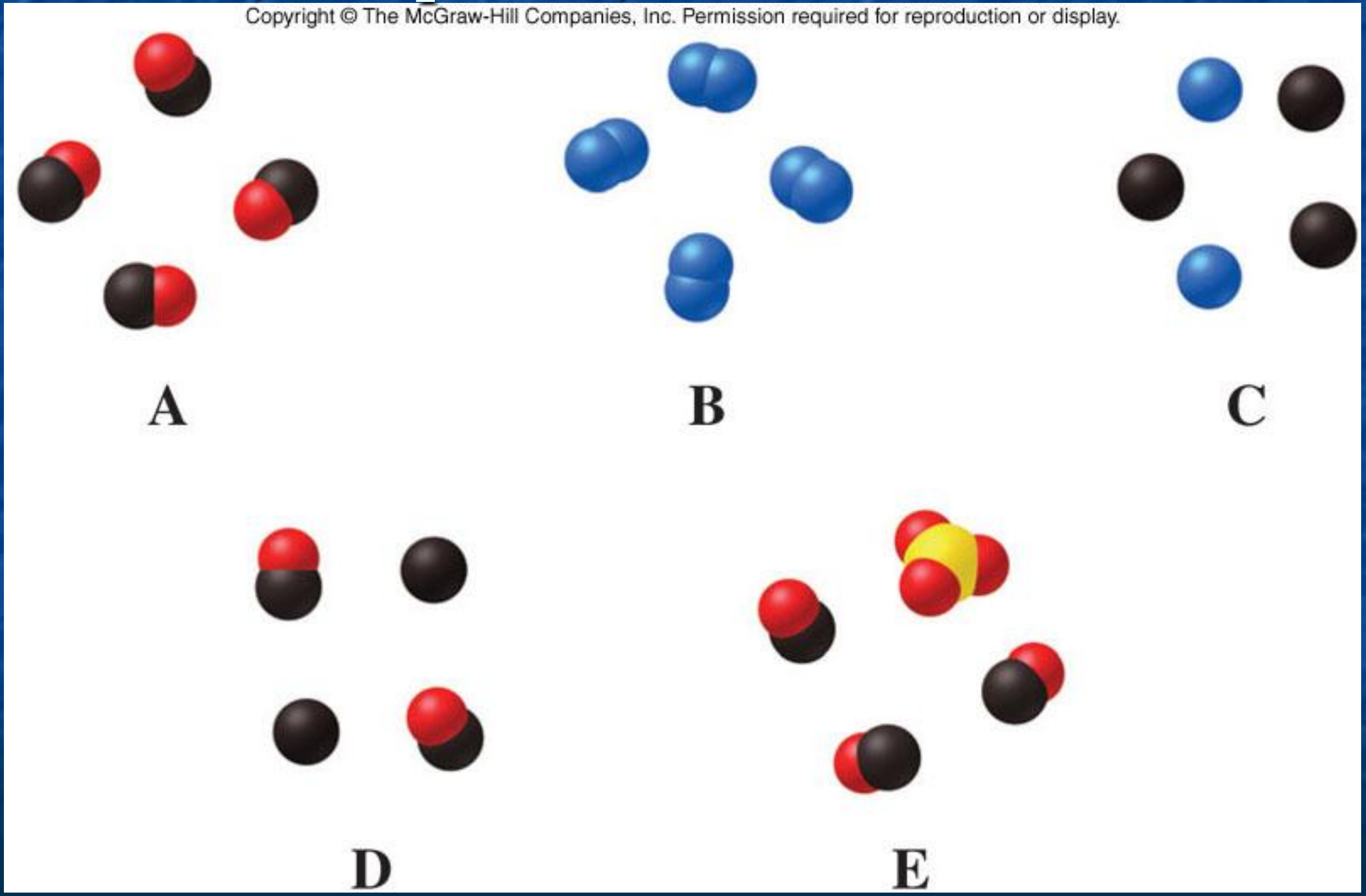


Figure from p. 48

Activity Solutions: Classification

Classify each of the following as an element, compound, or mixture.

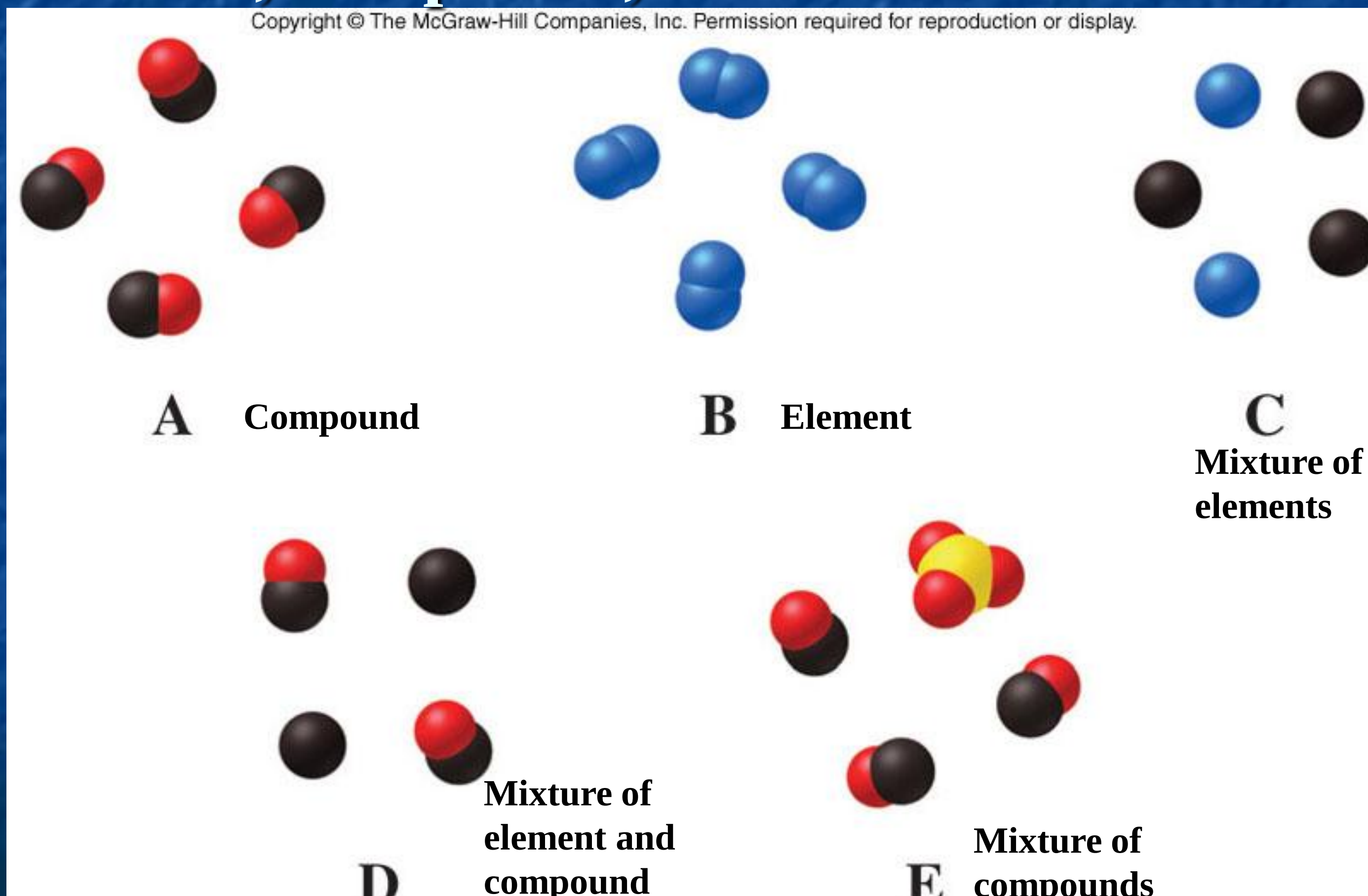


Figure from p. 48

States of Matter

- A different way to classify matter is by its physical state: solid, liquid, or gas.
  - What are the macroscopic properties of each?
  - How do the atoms and molecules of solids, liquids, and gases behave differently?

States of Matter

TABLE 1.2 | Characteristics of the Physical States of Matter

Solid	Liquid	Gas
fixed shape	shape of container (may or may not fill it)	shape of container (fills it)
its own volume	its own volume	volume of container
no volume change under pressure	slight volume change under pressure	large volume change under pressure
particles are fixed in place in a regular (crystalline) array	particles are randomly arranged and free to move about until they bump into one another	particles are widely separated and move independently of one another

Activity: States of Matter

- Discuss the following questions:
  - How does a solid differ from a liquid?
  - How does a gas differ from a liquid?
  - How does a solid differ from a gas?

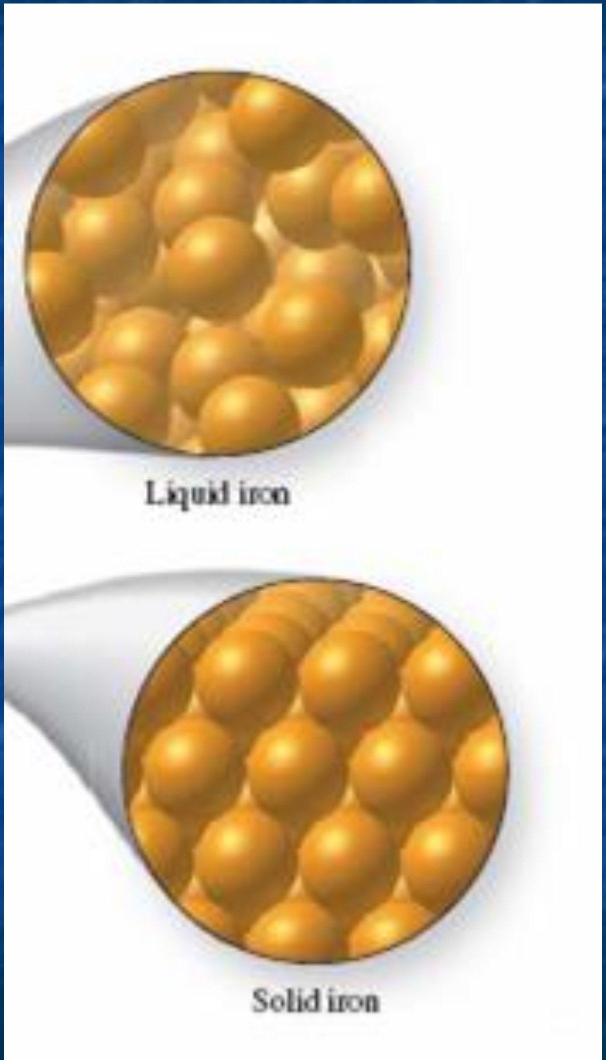


Figure 1.14

Gases can be compressed

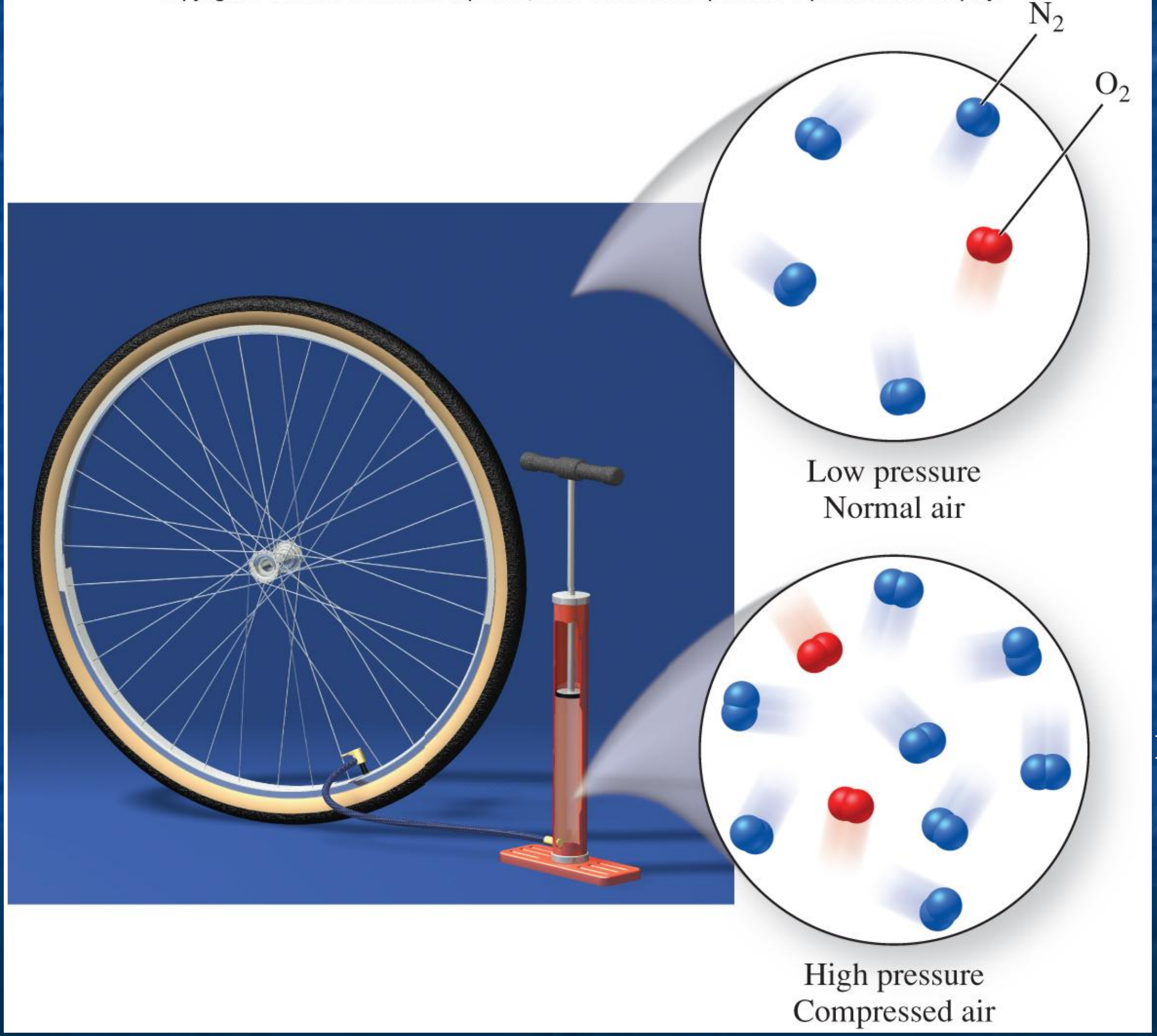


Figure 1.15

Water vapor condenses from the air onto the cold surface of the glass.

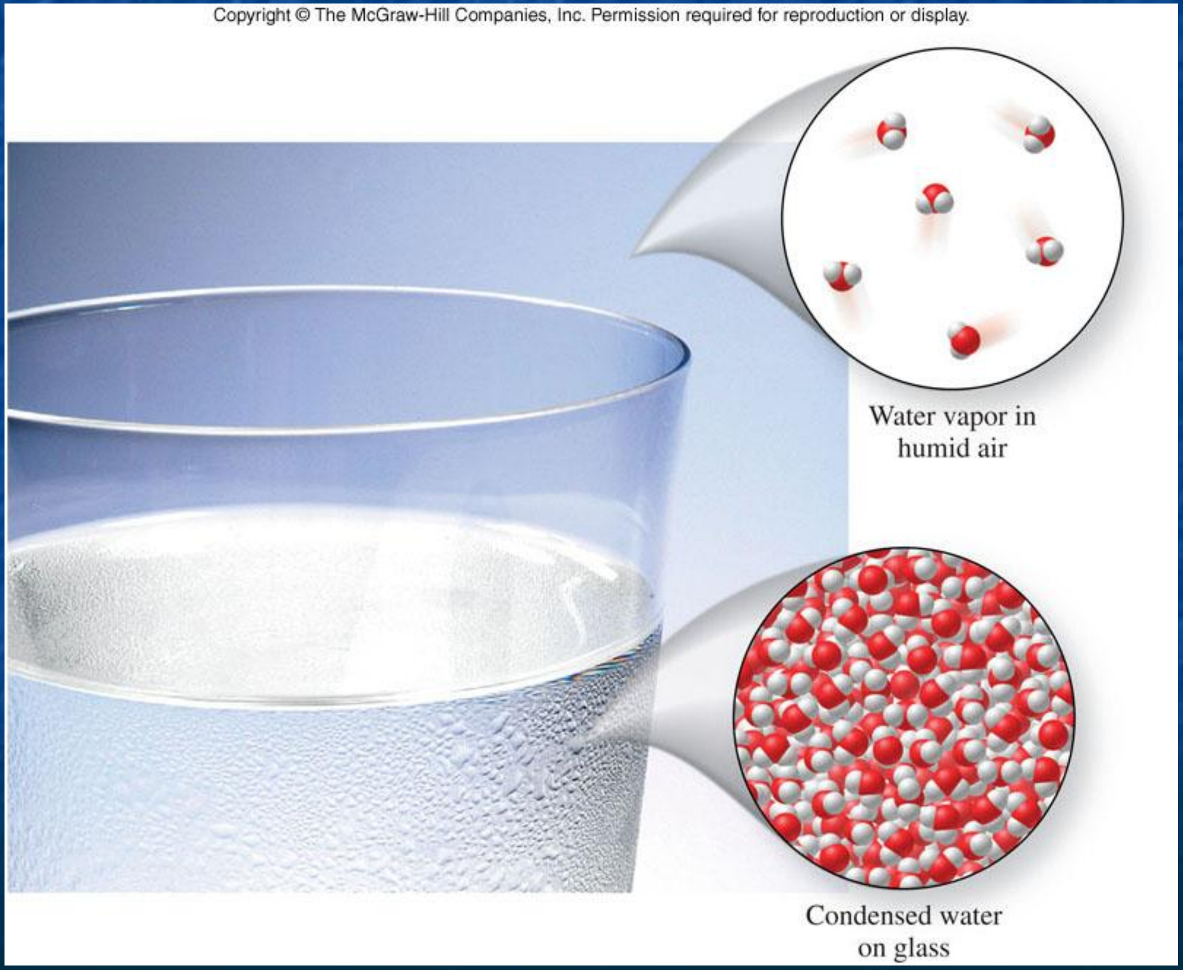


Figure 1.16

Symbols Used in Chemistry

- Symbols for physical states
  - are found in parenthesis by the elemental symbol or chemical formula
  - designate the physical state
    [ex. solid, liquid, gas, aqueous]

TABLE 1.3 | Symbols for Physical State

Physical State	Symbol	Example (bromine)
solid	(*s*)	$Br_2(s)$
liquid	(*l*)	$Br_2(l)$
gas	(*g*)	$Br_2(g)$
aqueous (dissolved in water)	(*aq*)	$Br_2(aq)$

Symbols Used in Chemistry

Name	Symbol
helium	$He(g)$
chlorine	$Cl_2(g)$
silver	$Ag(s)$
water	$H_2O(l)$
carbon dioxide	$CO_2(g)$
methane (natural gas)	$CH_4(g)$

Activity: Physical State Symbols

- **Sodium chloride (or table salt) can be represented symbolically as NaCl(*s*).**
- **Describe what symbol NaCl(*aq*) represents, and describe what it looks like on a macroscopic scale.**
- **Describe what NaCl(*aq*) looks like on a molecular scale.**

1.2 Physical and Chemical Changes and Properties of Matter

- A physical property is a characteristic that we can observe without changing the composition of a substance.
- Examples
  - Color
  - Odor
  - Mass
  - Volume
  - Density
  - Temperature

Color, Odor: qualitative properties

Mass, Volume, Density, Temperature: quantitative properties

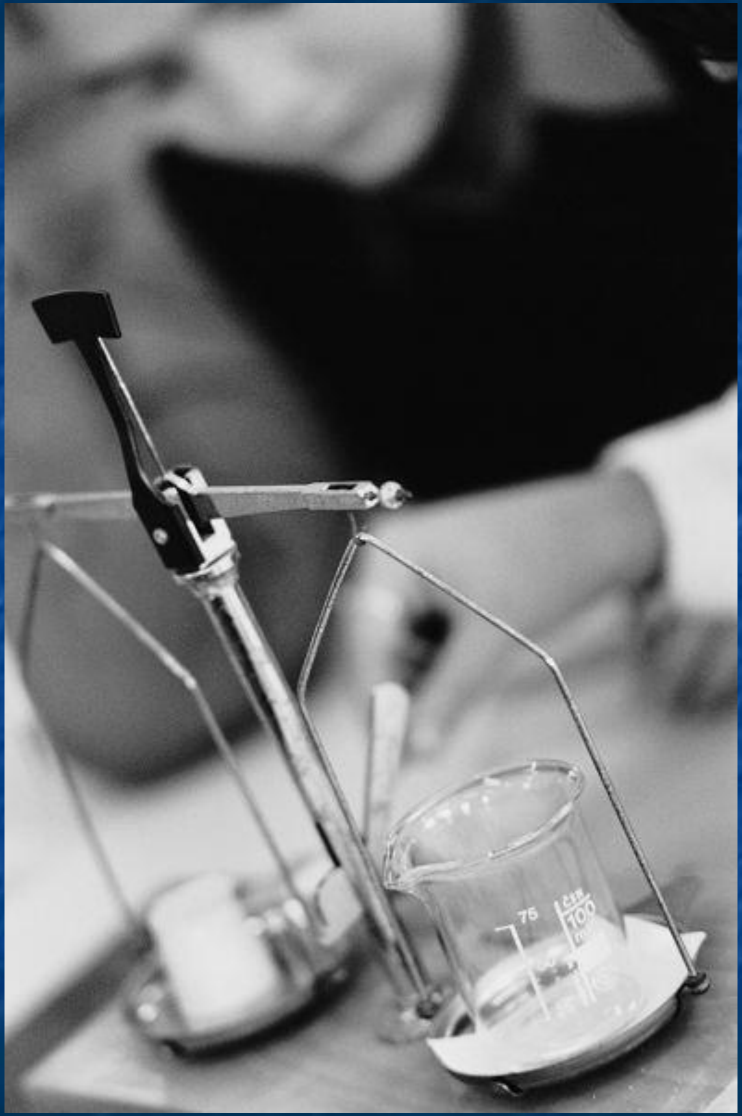
Units and Conversions
(See Math Toolbox 1.3)

<u>**Metric Base Units and Derived Units**</u>

- Length: meter (m)
- Mass: kilogram (kg)
- Time: second (s)
- Temperature: kelvins (K)
- Number of particles: mole (mol)

Mass

- Mass:
  - measures the quantity of matter
  - is essentially the same physical quantity as weight, with the exception that weight is bound by gravity, mass is not
  - common units are grams (g)



Conversion
(See Math Toolbox 1.3 & back cover of text)

Prefixes (Table 1.4)			Mass measurements
giga-	G	10^9	1 Gg = 10^9 g
mega-	M	10^6	1 Mg = 10^6 g
kilo-	k	10^3	1 kg = 10^3 g
centi-	c	10^{-2}	1 cg = 10^{-2} g
milli-	m	10^{-3}	1 mg = 10^{-3} g
micro-	μ	10^{-6}	1 μg = 10^{-6} g
nano-	n	10^{-9}	1 ng = 10^{-9} g
pico-	p	10^{-12}	1 pg = 10^{-12} g

Conversion

(See Math Toolbox 1.3 & back cover of text)

Prefixes (Table 1.4)			Length measurements
giga-	G	10^9	1 Gm = 10^9 m
mega-	M	10^6	1 Mm = 10^6 m
kilo-	k	10^3	1 km = 10^3 m
centi-	c	10^{-2}	1 cm = 10^{-2} m
milli-	m	10^{-3}	1 mm = 10^{-3} m
micro-	μ	10^{-6}	1 μm = 10^{-6} m
nano-	n	10^{-9}	1 nm = 10^{-9} m
pico-	p	10^{-12}	1 pm = 10^{-12} m

Volume

- **Volume:**
  - amount of space a substance occupies
  - can be calculated by measuring the sides of a cube or rectangular side, then multiplying them

Volume = length x width x height

  - common units are centimeters cubed (cm^3) or milliliters (mL)

Figure 1.18

Volume

- Volumes of liquids are usually measured in units of milliliters (mL).
- 1 mL = 1 cm^3 exactly
- How many mL in 1 L?

Some 250-mL, 500-mL, and 1-L containers

Figure 1.18

Activity: Volume Unit Conversions

- Convert 25.0 mL to L.

  0.0250 L

- Convert 25.0 mL to quarts (1 L = 1.057 qt)

  0.0264 L

Density

- **Density:**
  - the ratio of the mass to its volume
  - units are g/mL (solids and liquids) or g/L (gases)
  - See Table 1.6 for a listing of densities for common substances

Figure 1.19

Density

TABLE 1.6 | Densities of Some Common Substances

Substance	Physical State	Density (g/mL)*
helium	gas	0.000178
oxygen	gas	0.00143
cooking oil	liquid	0.92
water	liquid	1.00
mercury	liquid	13.6
gold	solid	19.3
copper	solid	8.92
zinc	solid	7.14
ice	solid	0.92

*At room temperature and at normal atmospheric pressure, except gases at 0 degrees Celsius (°C) and water at 4°C.

Density

- Which liquid is the most dense? Which is least dense?
- Compare the density of the Dead Sea water and of the person.

Figure 1.19

The cube of gold has a greater mass than that of aluminum. Which cube has the greater density?

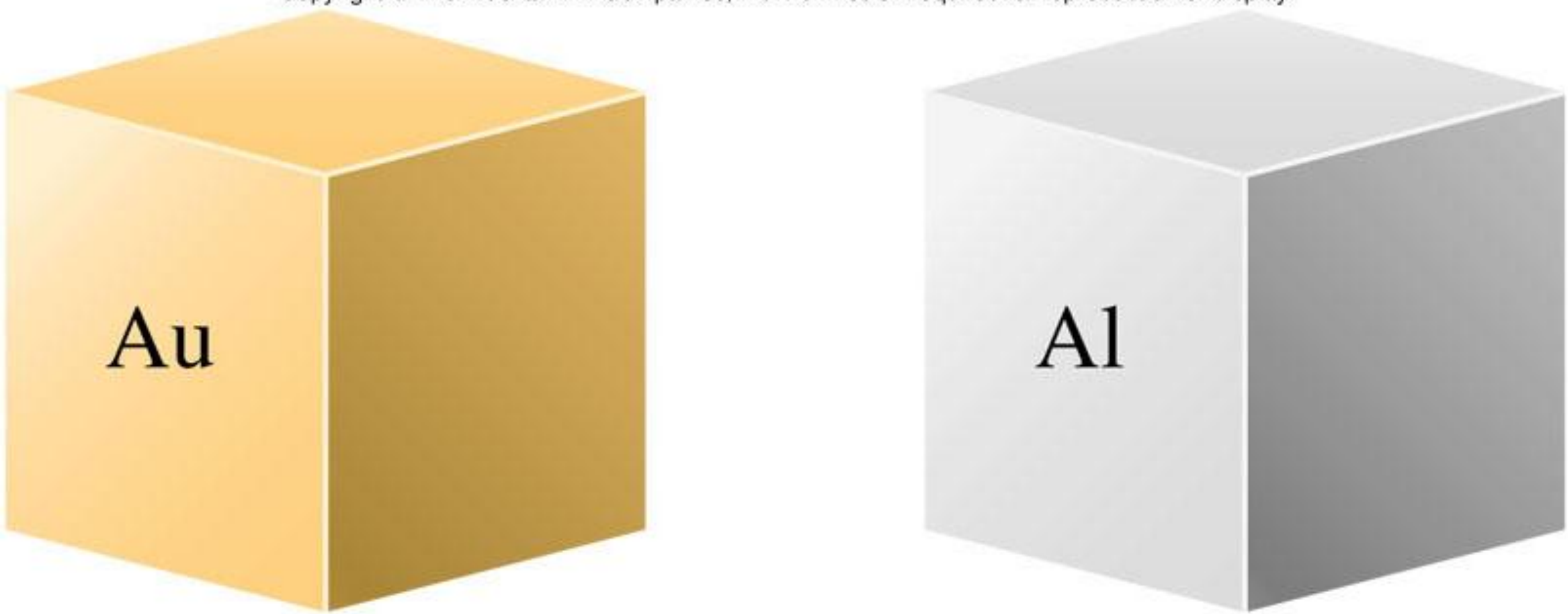
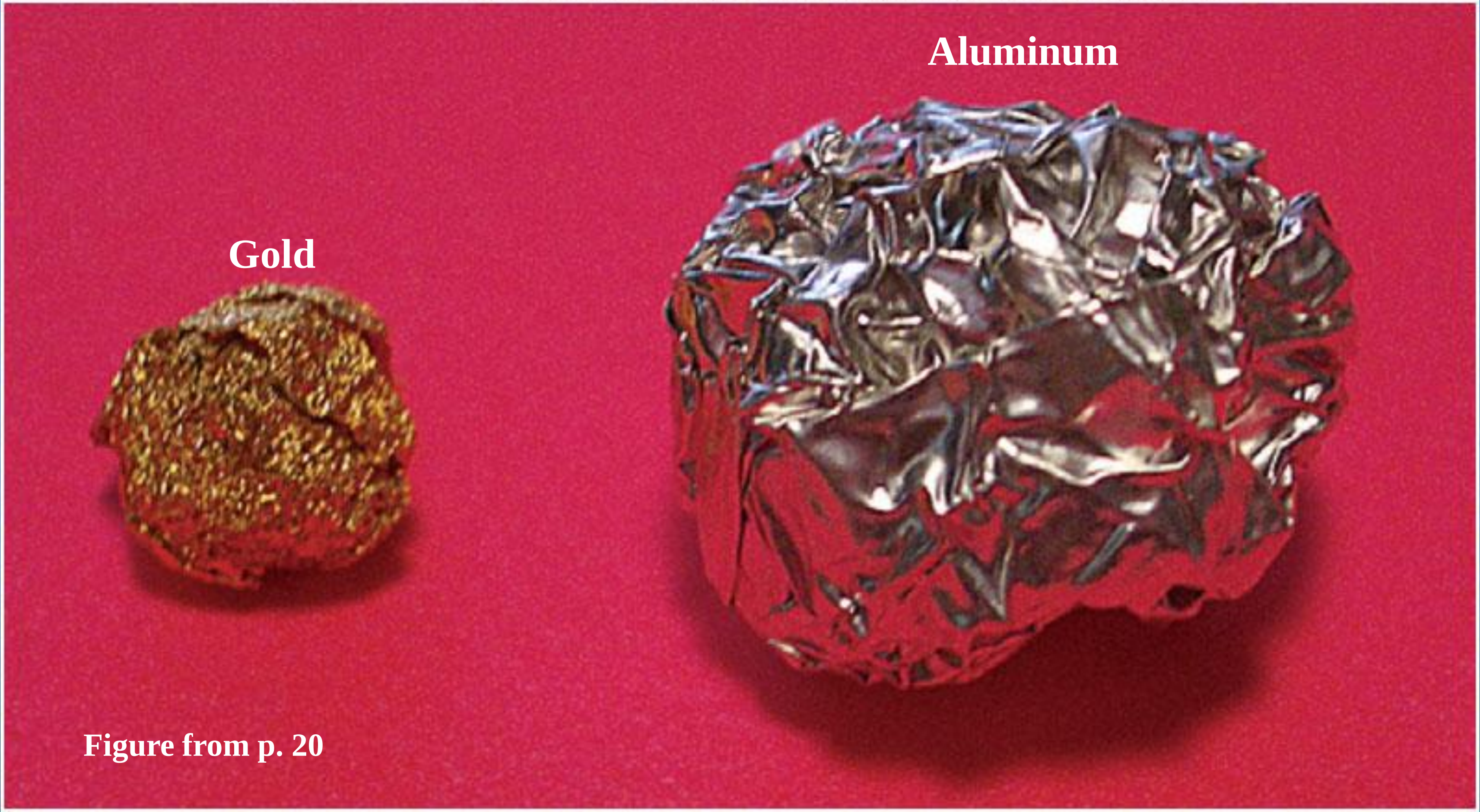


Figure 1.20

Given that these samples of metals have the same mass, which has the greater density?



Density = mass/volume

- **Why is regular soda more dense?**

Figure from p. 20

Why is ice less dense than liquid water?

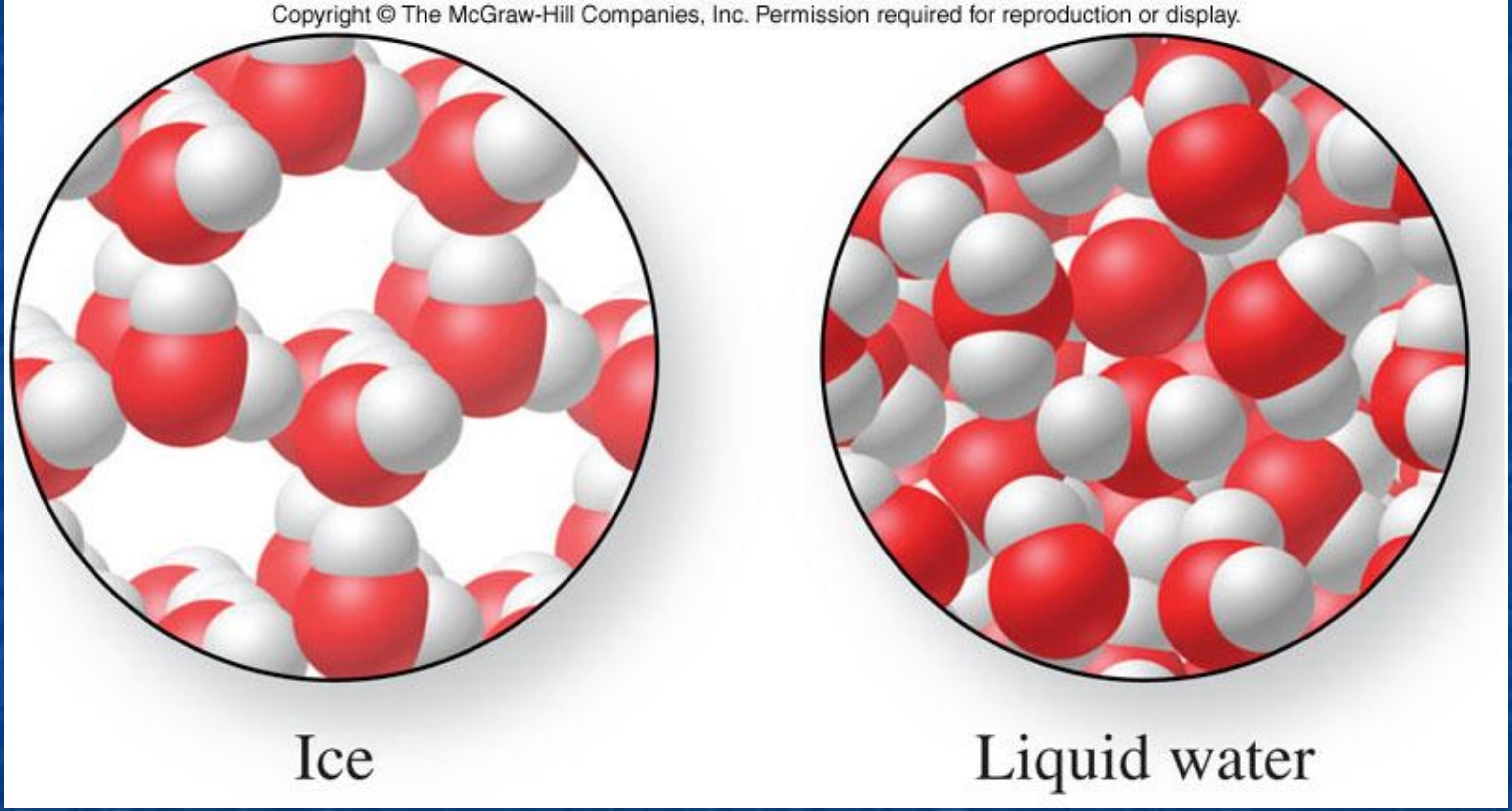


Figure from p. 21

Homework

- Homework: (Read Sections 1,2 and 3)
- Problems P. 45 #1,2, 23-30, 42, 45-52, 58-62, 70, 71, 86-98