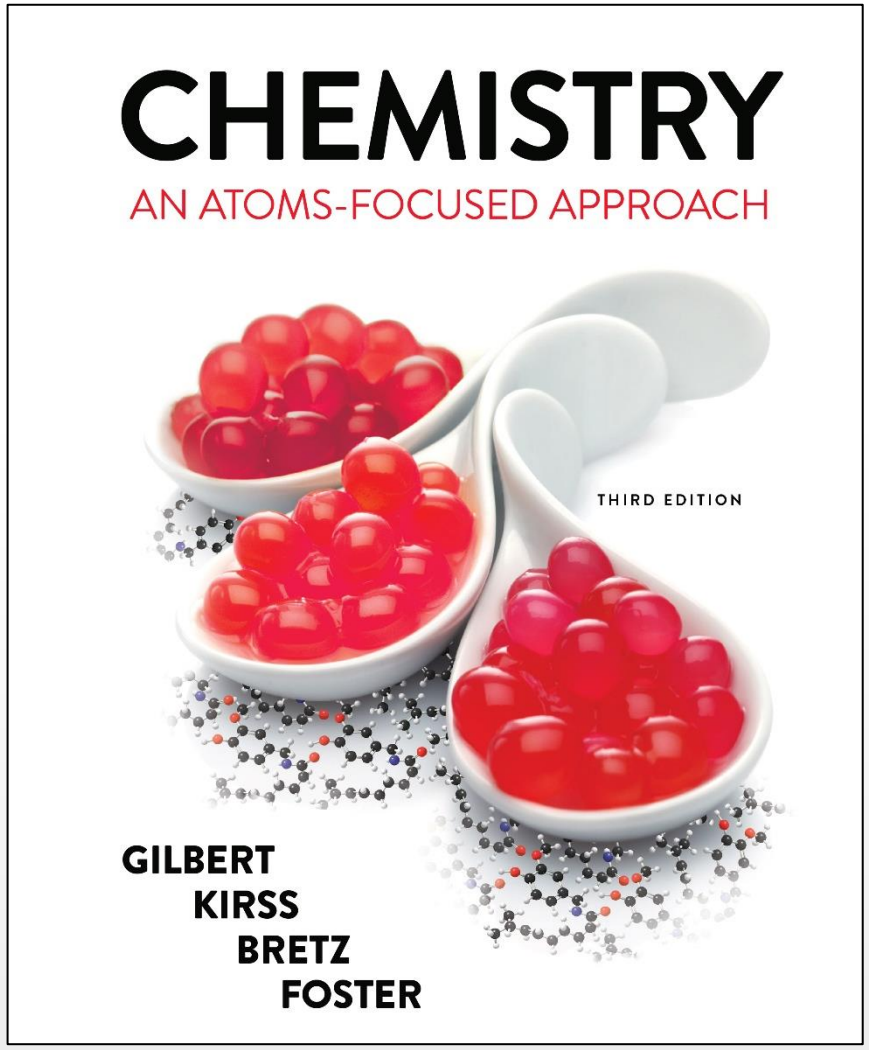
Chapter 1



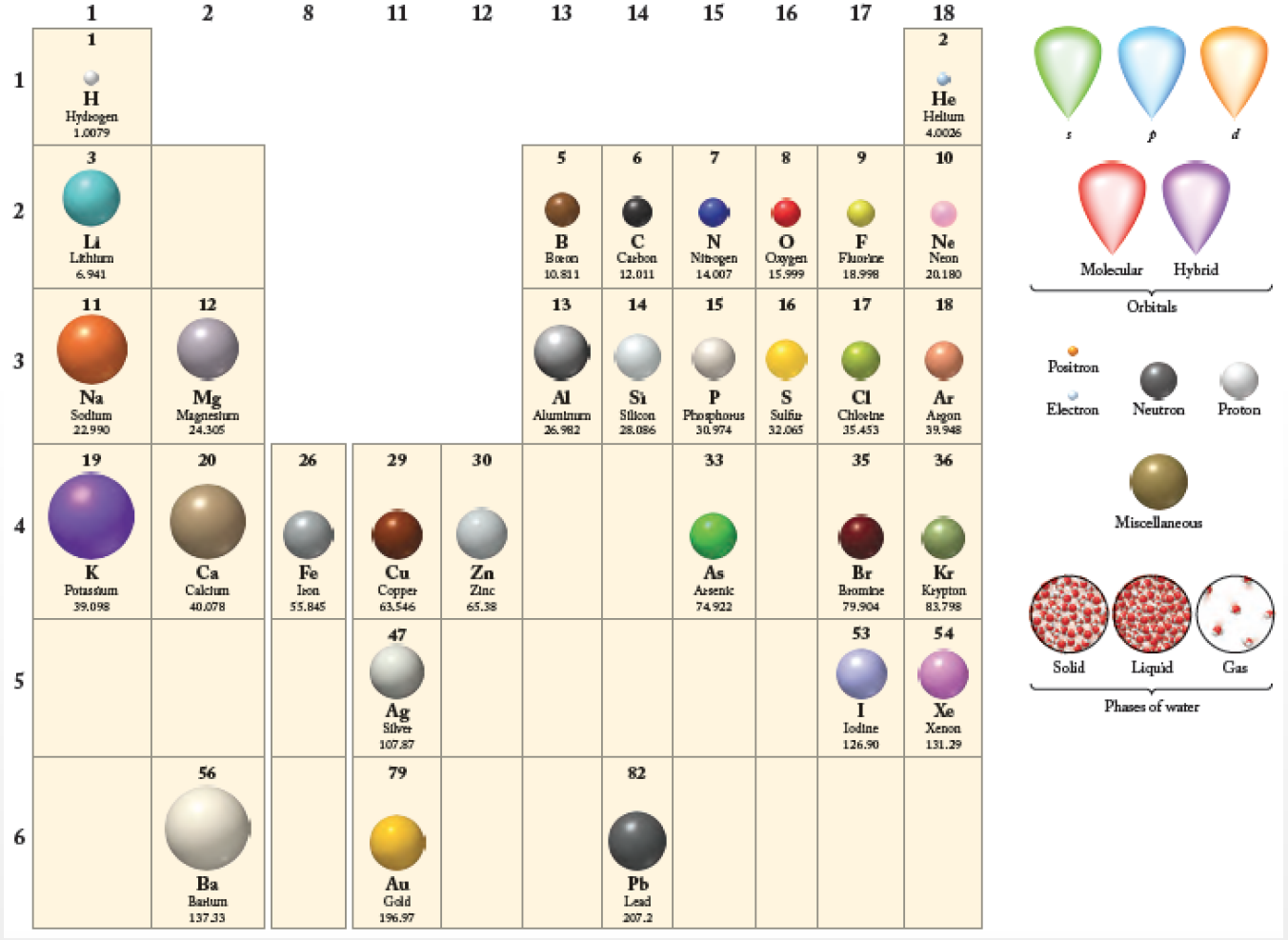
Matter and Energy: An Atomic Perspective

Covered Chapter Titles in "Chemistry: An-Atoms Focused Approach" (3rd edition)
Ch1: Matter and Energy: An Atomic Perspective
Ch2: Atoms, Ions, and Molecules: The Building Blocks of Matter
Ch3: Atomic Structure: Explaining the Properties of Elements
Ch4: Chemical Bonding: Understanding Climate Change
Ch5: Bonding Theories: Explaining Molecular Geometry
Ch6: Intermolecular Forces: Attractions between Particles
Relevant for the last lab experiment: **Section 8.1: Solutions and Their Concentrations** **Section 8.2: Dilutions**
Ch7: Stoichiometry: Mass Relationships and Chemical Reactions

Jan. 05	Course Logistics, Student Learning Goals
Jan. 07	Ch 1 Part I
Jan. 12	Ch 1 Part II
Jan. 14	Ch 2 Part I
Jan. 19	Ch 2 Part II
Jan. 21	Ch 3 Part I
Jan. 26	Ch 3 Part II
Jan. 28 (R)	Exam 1 (Chapters 1, 2 and 3)
Feb. 02	Ch 4 Part I
Feb. 04	Ch 4 Part II
Feb. 09	Ch 4 Part III/ Ch 5 Part I
Feb. 11	Ch 5 Part II
Feb. 16	Ch 5 Part III
Feb. 18 (R)	Exam 2 (Chapters 4 and 5)
Feb. 23	Ch 6 Part I
Feb. 25	Ch 6 Part II
Mer. 02	Ch 6 Part III/ Ch 7 Part I
Mar. 04	Ch 7 Part II / Ch 8 (8.1 and 8.2, relevant for lab only)
Mar. 09	Ch 7 Part III
Mar. 11	Revision
Mar. 17	Final Exam (11:30 am -2:30 pm; Online; All Chapters)

Atomic Color Palette

Throughout the text, atoms in the book will be represented according to this scheme, which can be found inside the back cover.

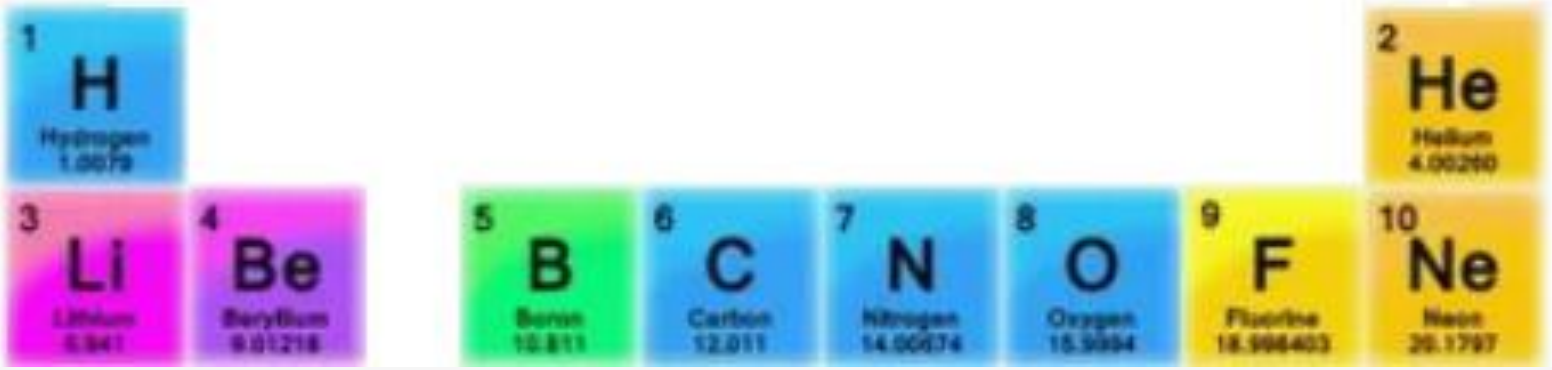


Elements and PTE

First 10 Elements

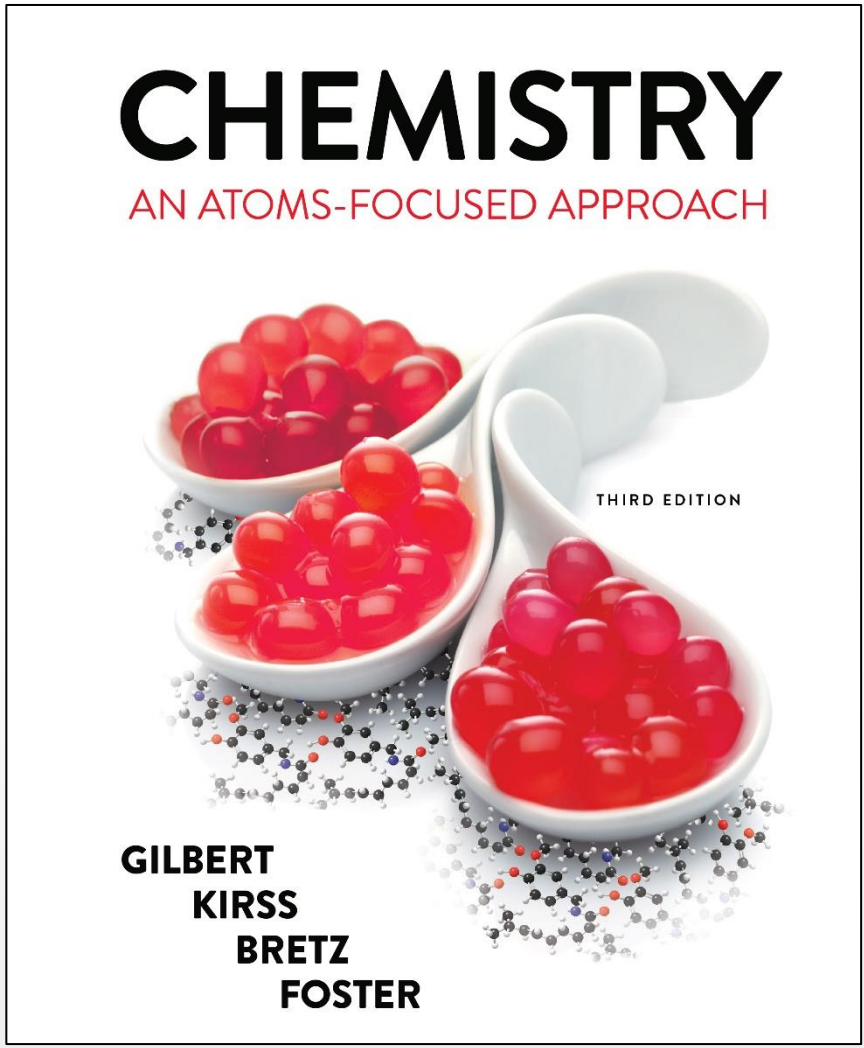
Images for PTE https://www.youtube.com/watch?v=YdXuSftZELQ

PTE Song https://www.youtube.com/watch?v=rz4Dd1I_fX0 and other related videos.



https://www.ofarrellschool.org/apps/video/watch.jsp?v=149862

Chapter 1: Outline



States of Matter

- **Matter** – anything that occupies space and has mass
- **Vacuum (free space)** - space devoid of matter
- **Mass** – defines the quantity of matter in an object

Vacuum Level Ranges

Atmospheric Pressure	760 Torr
Low Vacuum (Rough)	760 to 25 Torr
Medium Vacuum (Rough)	25 to 1 x 10^{-3} Torr
High Vacuum (Hard)	1 x 10^{-3} to 1×10^{-9} Torr
Ultra High Vacuum	1 x 10^{-9} to 1×10^{-12} Torr
Extremely High Vacuum	<1 x 10^{-12} Torr
Outer Space	1 x 10^{-6} to <3×10^{-17} Torr

R. J. Fradette et al: in Understanding Vacuum and Vacuum Measurement

States of Matter

Solids

Definite shape and volume

Liquids

Occupies definite volume, but flows to assume the shape of its container

Gases (vapors)

Neither definite volume nor shape; expands to fill its container

Plasma (not covered)

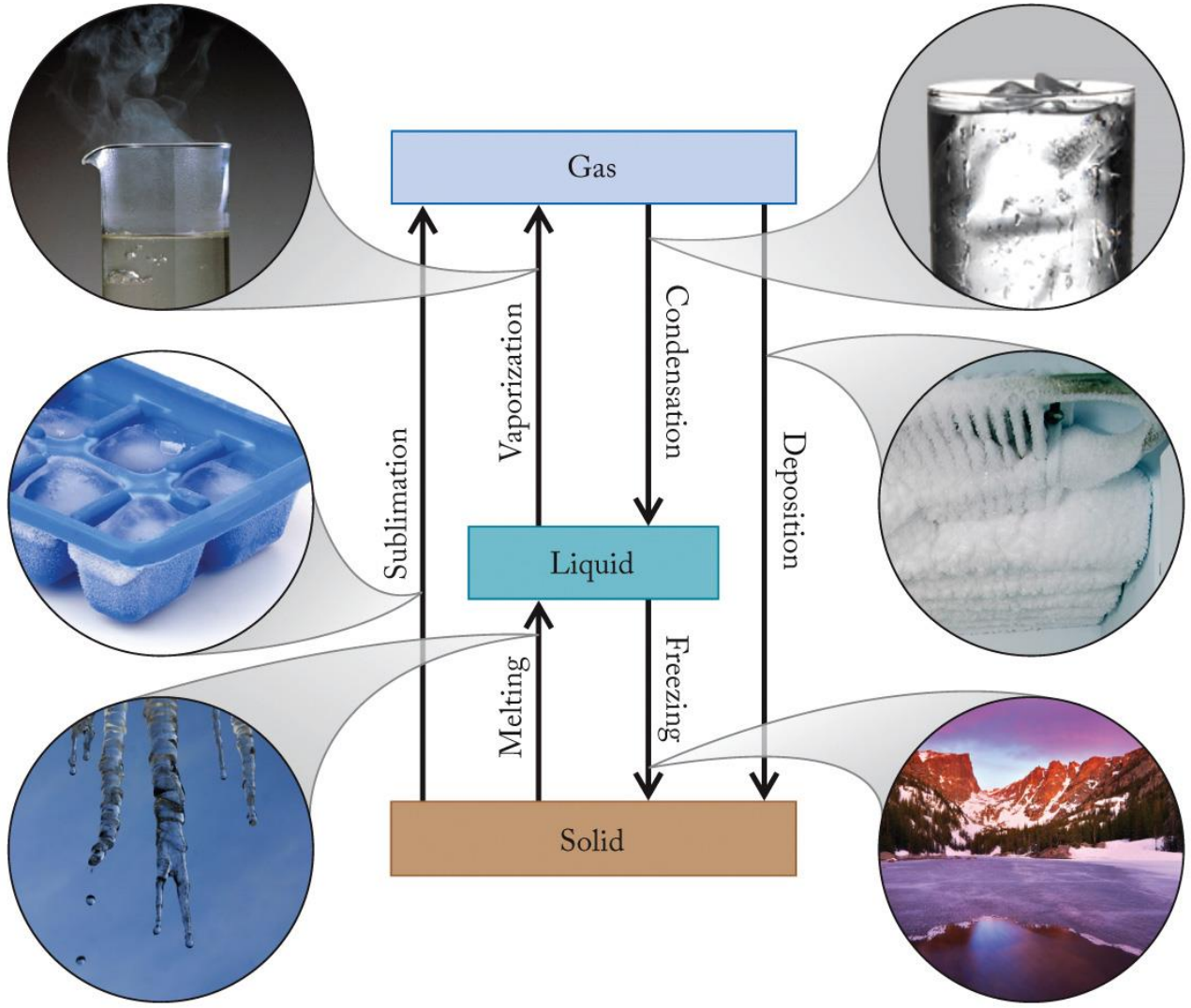
States of Matter

Changes of state

Transformation from one state to another due to addition or removal of heat.

Transitions

- Melting
- Freezing
- Condensation
- Vaporization
- Sublimation
- Deposition

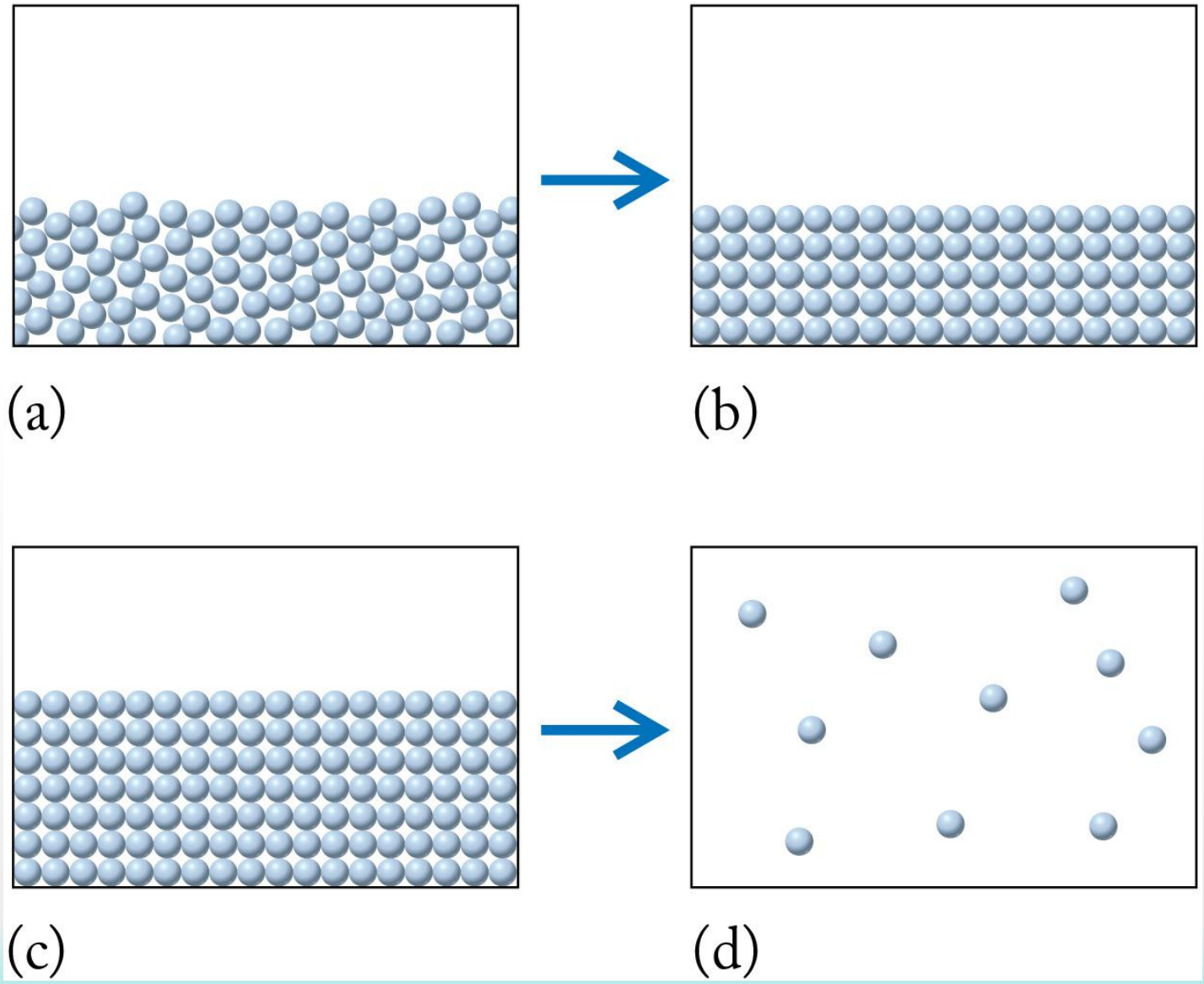


Examples

Which physical state does each part (a-d) of this Figure represent?

What change of state does each arrow indicate?

What would the changes of state be if both arrows pointed in the opposite direction?

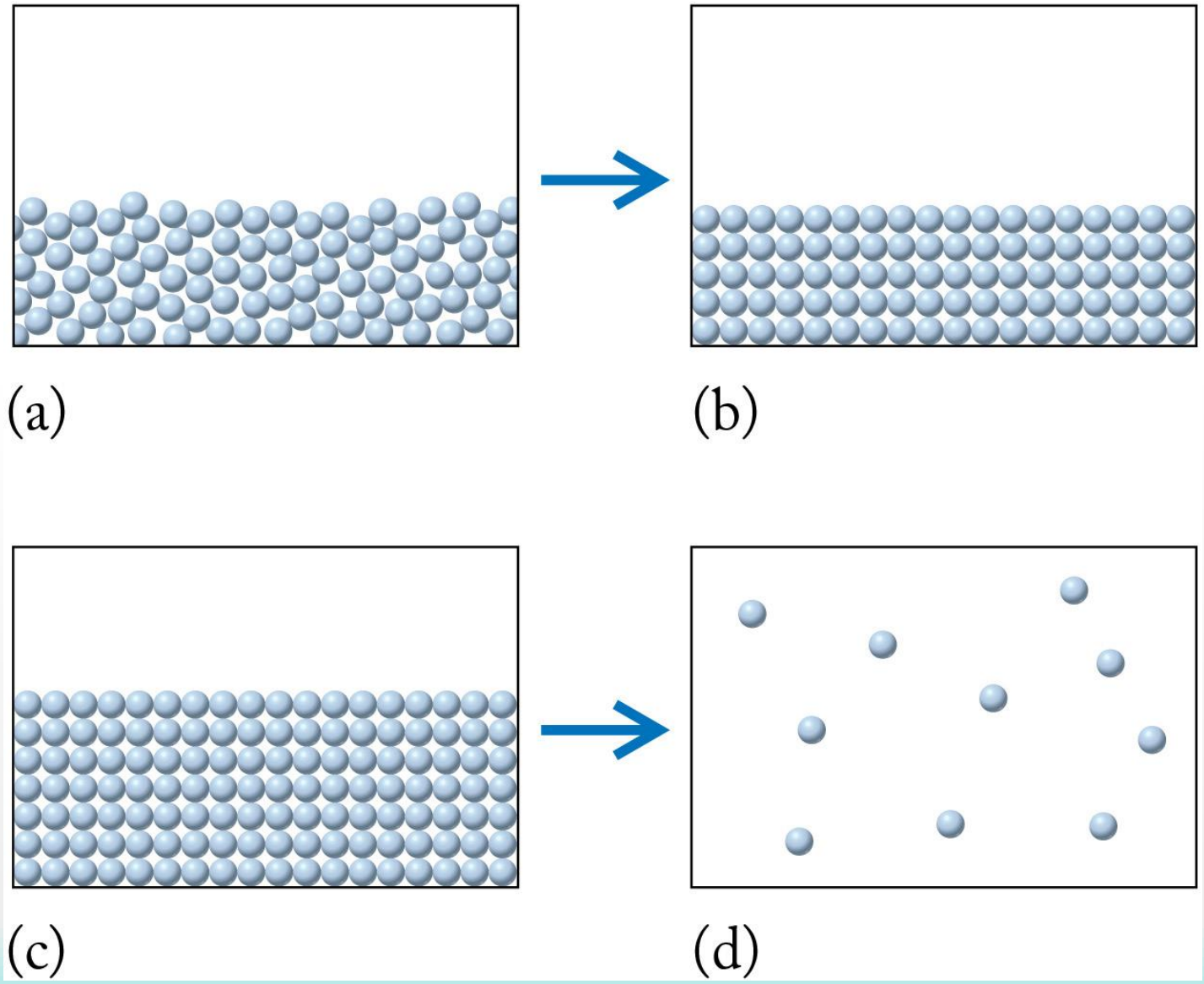


Examples

Which physical state does each part (a-d) of this Figure represent?
(a): liquid
(b) and (c): solid
(d): gas

What change of state does each arrow indicate?
(a) → (b) or liquid → solid : freezing
(c) → (d) or solid→ gas: sublimation

What would the changes of state be if both arrows pointed in the opposite direction?
(b) → (a) or solid → liquid: melting
(d) → (c) or gas → solid: deposition



Definitions

- **Energy** – the capacity to do work or generate heat.

  - Work is the exertion of a force through a distance.

    $$w = F \times d$$

  - Potential Energy: stored energy due to its composition (glucose) or position (runner in blocks)

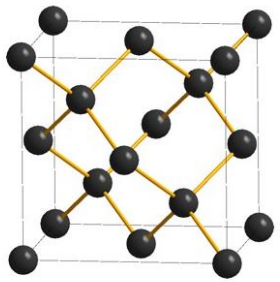
  - Kinetic Energy: energy of motion

    $$\text{KE} = \frac{1}{2}mu^2$$

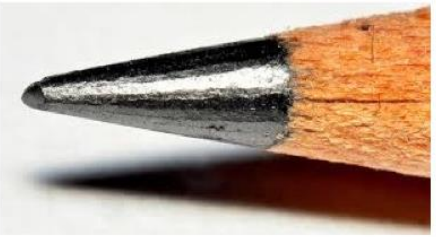
The Law of Conservation of Energy states that energy cannot be created or destroyed, but it can be converted from one form to another.

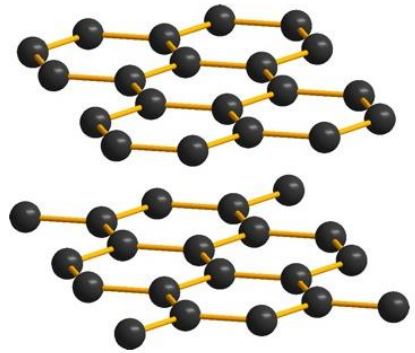
Definitions

- **Chemistry** – the study of the composition, **structure**, and properties of matter and of the energy consumed or given off when matter undergoes a change



Cubic



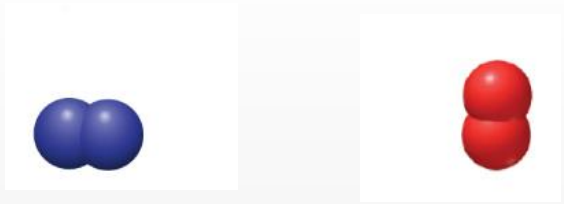


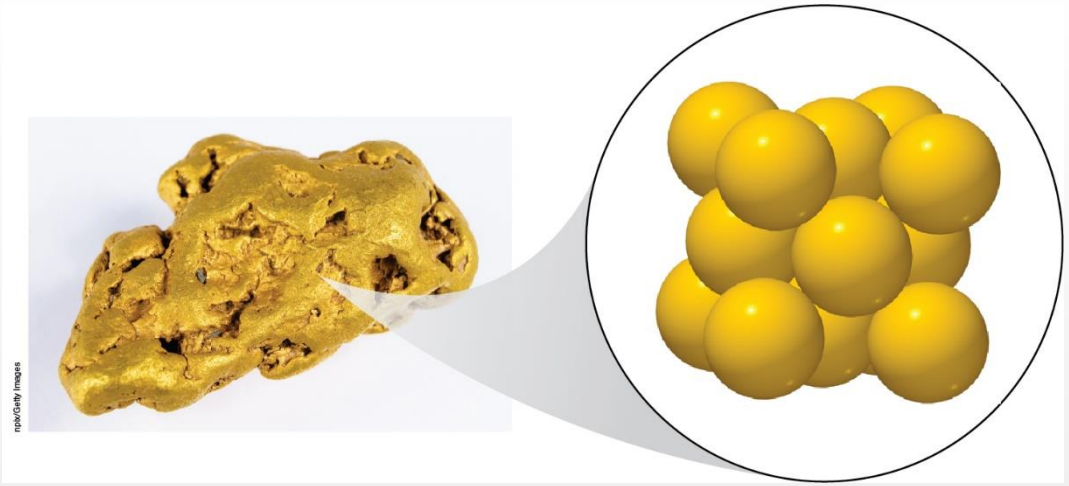
Hexagonal

Diamond and graphite are different forms of carbon that can be transformed into each other.

Element

- **Element:** a pure substance that cannot be separated into simpler substances. Can be a gas, a liquid or a solid.
- Examples: nitrogen (N_2), oxygen (O_2), gold (Au), Neon (Ne), krypton (Kr)

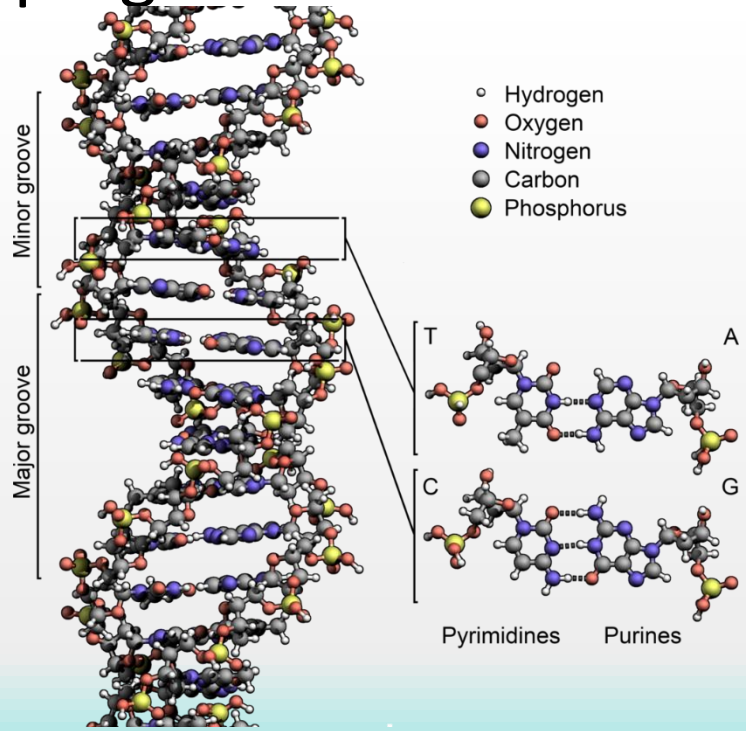




Compounds

There are 3 classes of compounds (also pure substances):
molecular, metallic and ionic compounds

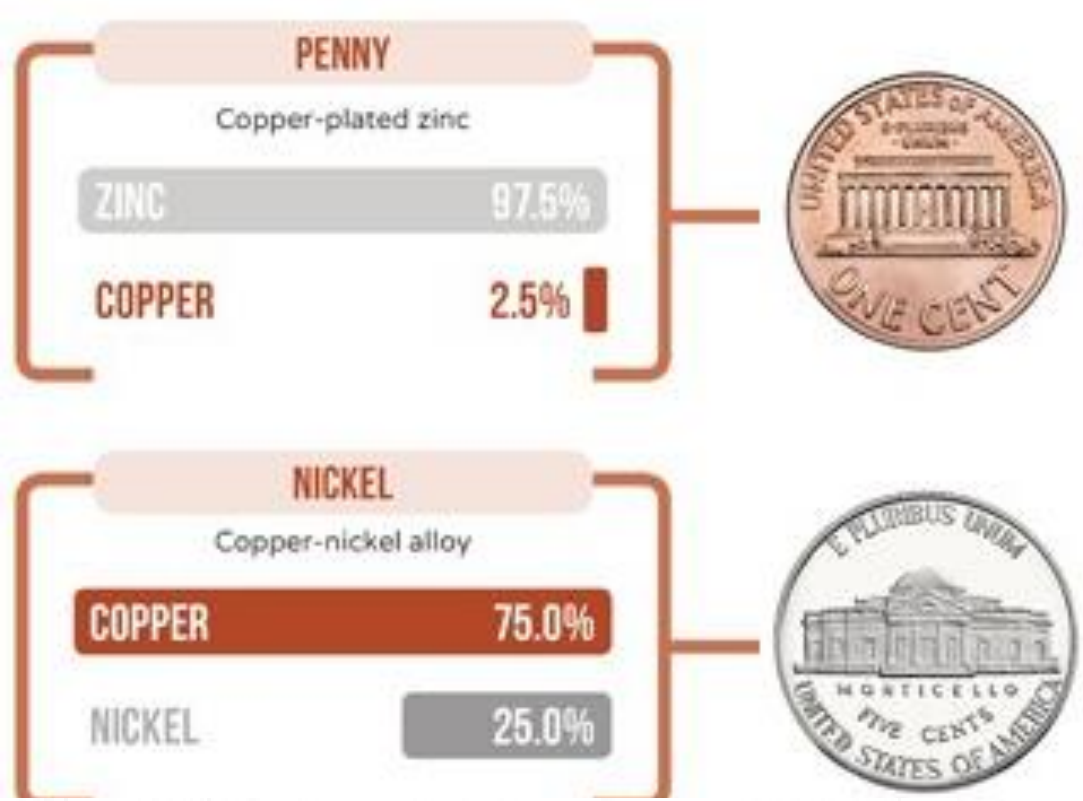
- **Molecular compounds** are made of *at least two different* ***covalently*** *bonded* ***non-metals*** (typically at the top right of the PTE, including H and excluding noble gases).
  - Examples: water (H_2O), carbon dioxide (CO_2), DNA



Compounds

There are 3 classes of compounds: **molecular, metallic and ionic compounds**

- **Metallic compounds ($Nd_2Fe_{14}B$, Neodymium magnet)** are made of *at least 2 different* ***metals***
  - *Examples: coins*



Compounds

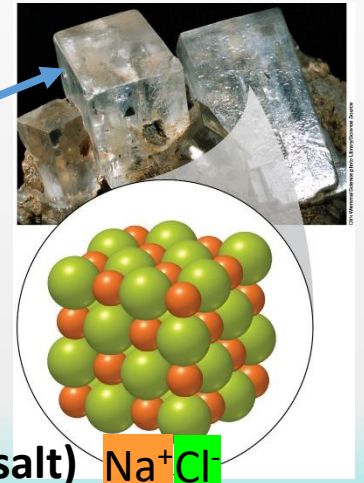
There are 3 classes of compounds: **molecular, metallic and ionic compounds**

- **Ionic compounds** are made from metals (become positively charged) and non-metals (become negatively charged). They consist of positively and negatively charged particles called **ions**.
  - **Cations** – Positively charged ions
    - Calcium ion Ca^{2+}
    - Sodium ion (Na ➔ **$Na^+ + e^-$**
  - **Anions** – Negatively charged ions
    - Chloride ion **Cl^- (has an extra e^-)**
    - Hydroxide ion OH^-

cation + anion ➔ ionic compound

$Ca^{2+} + 2OH^- \rightarrow Ca(OH)_2$

$Na^+ + Cl^- \rightarrow NaCl$

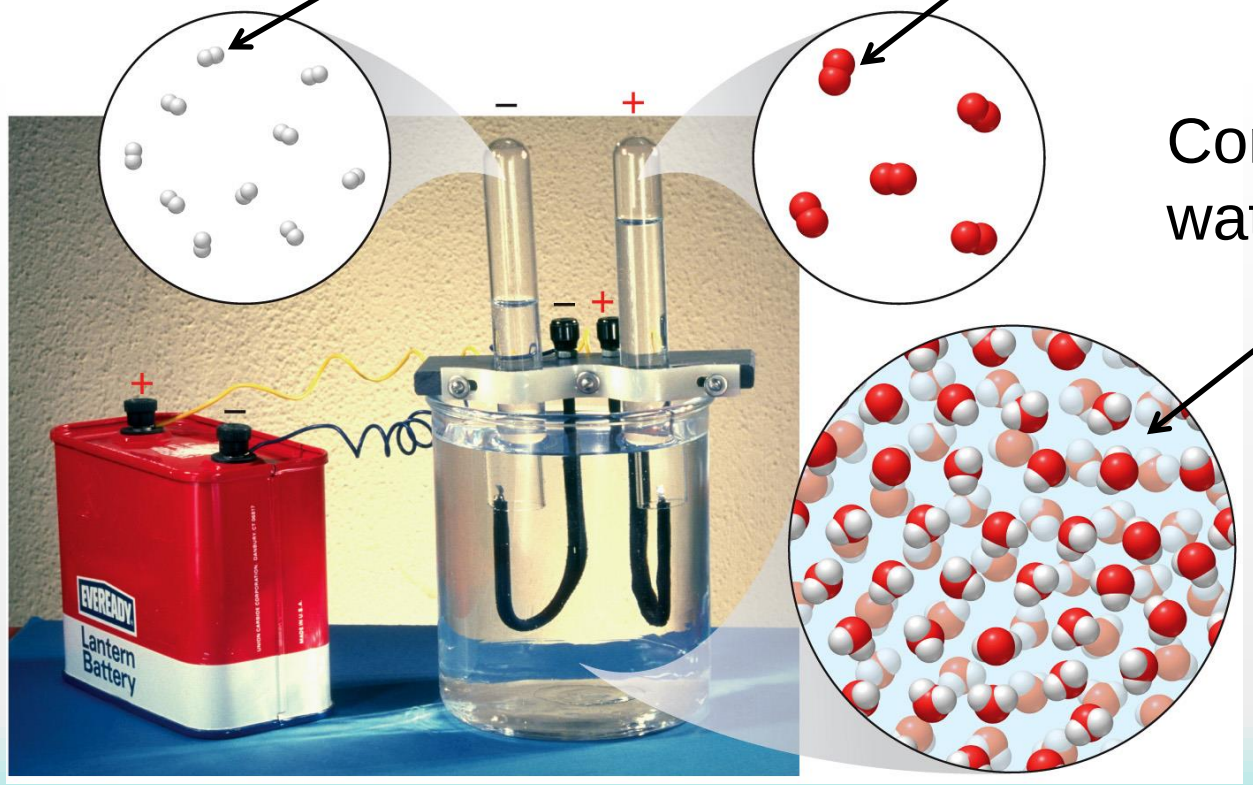


Sodium chloride (table salt) Na^+Cl^-

Law of Constant Composition

- A compound always contains the same proportion of its component elements.

Elements: hydrogen (H_2) and oxygen (O_2)



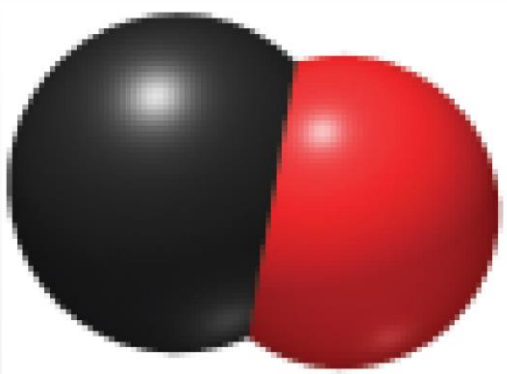
Compound: water (H_2O)

Note: The different phases of water (solid, liquid, gas) always have the same composition.

Dissociation of water will always produce 1 part of oxygen and 2 parts of hydrogen.

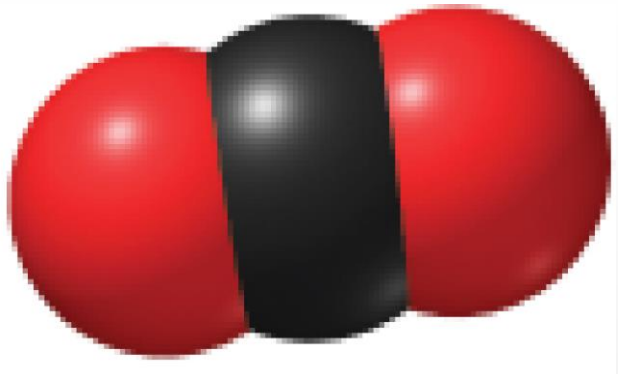
Law of Multiple Proportion

- When it is possible to have two different masses of one element react with a given mass of another element, the two masses of the first element must be a small, whole-number ratio.



carbon monoxide

CO



carbon dioxide

CO_2

C combines with O in CO_2 and CO in a 2:1 ratio (a small, whole-number ratio)

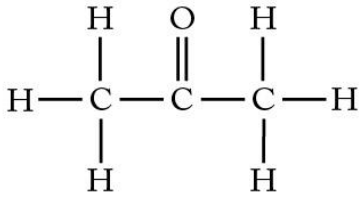
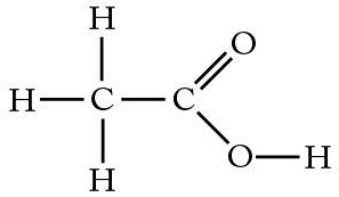
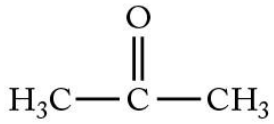
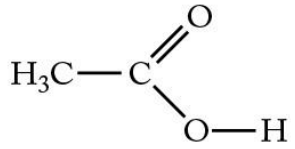
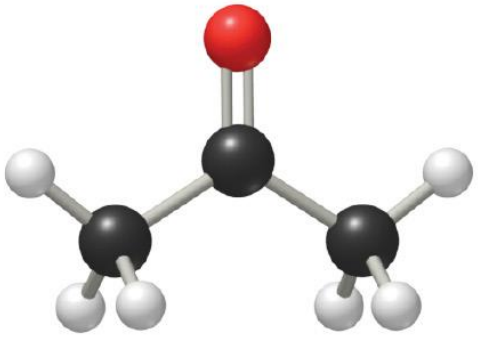
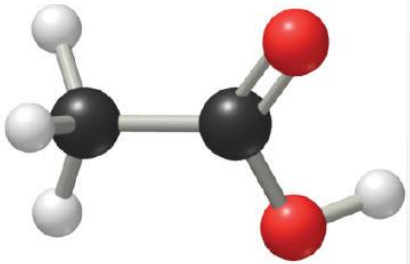
Chemical formula: A Particulate View

- **Chemical formula**
  - Notation for representing elements and compounds
  - Consists of symbols of constituent elements and subscripts identifying the number of atoms of each element in one molecule
    - Water H_2O
    - Ammonia NH_3
    - Ethanol C_2H_6O
    - Glucose $C_6H_{12}O_6$

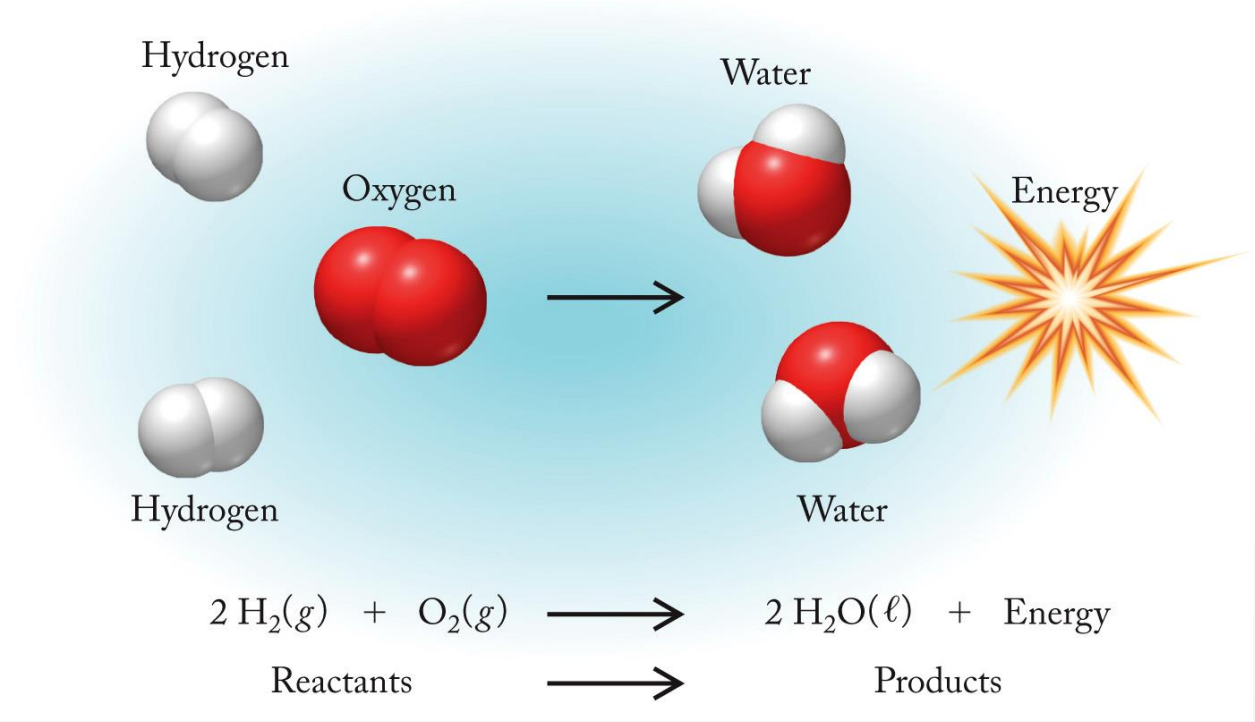
Chemical Formulas

- Chemical formulas provide information about the ratios of the elements in molecular compounds but not how they are bonded.
- To communicate information about bonding and shape, arrangement of atoms can be represented in three other ways:
  - Structural formulas
  - Ball-and-stick model
  - Space-filling model

Chemical Formulas, Structures and Models

	Acetone	Acetic acid
(a) Molecular formulas:	C_3H_6O	$C_2H_4O_2$
(b) Structural formulas:		
(c) Condensed structural formulas:		
(d) Ball-and-stick models:		
(e) Space-filling models:		

Chemical Reactions



Chemical reaction

- The transformation of one or more substances into different substances

Mixtures

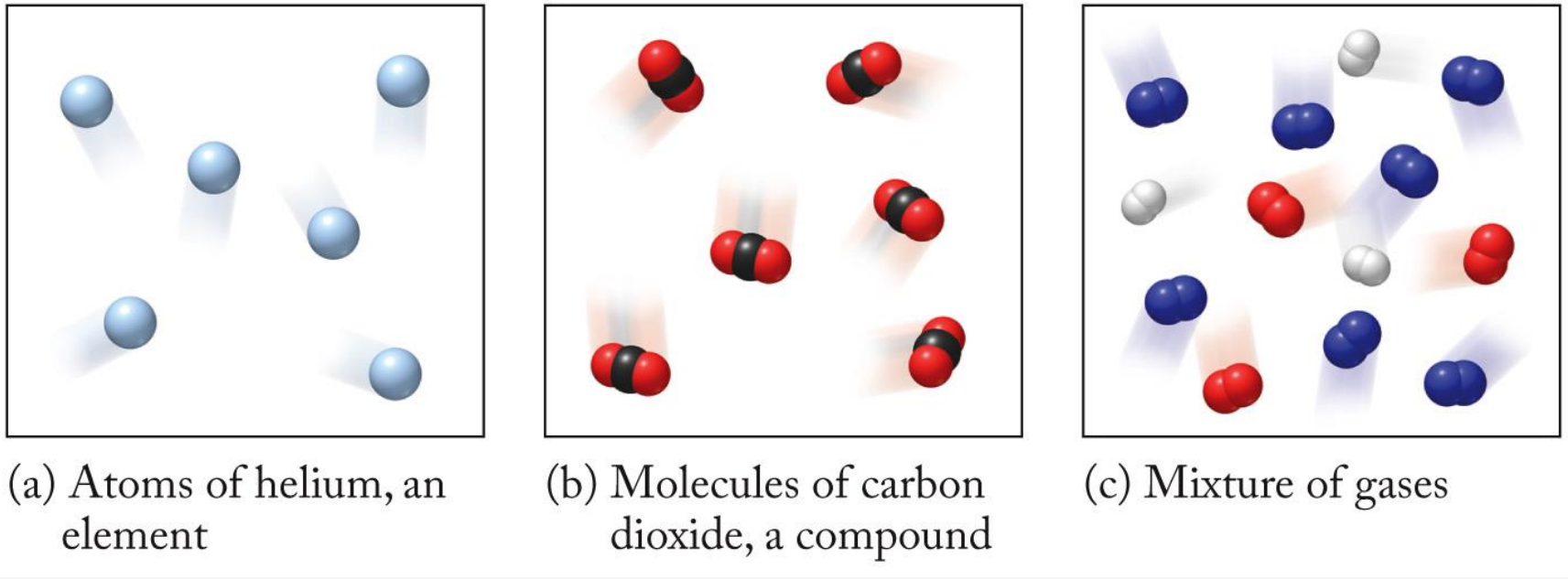
- **Definition**
  - Combination of two or more pure substances
  - Can be separated by physical processes

Mixtures

- **Homogeneous**
  - Components are distributed uniformly throughout the sample and have no visible boundaries or regions.
  - Also called a solution (often liquids, but may also be solids or gases)

- **Heterogeneous**
  - Components are not distributed uniformly and may have distinct regions of different composition.

Pure Substances vs. Mixtures



(a) Atoms of helium, an element

(b) Molecules of carbon dioxide, a compound

(c) Mixture of gases

Pure substance

Pure substance

Homogeneous mixture

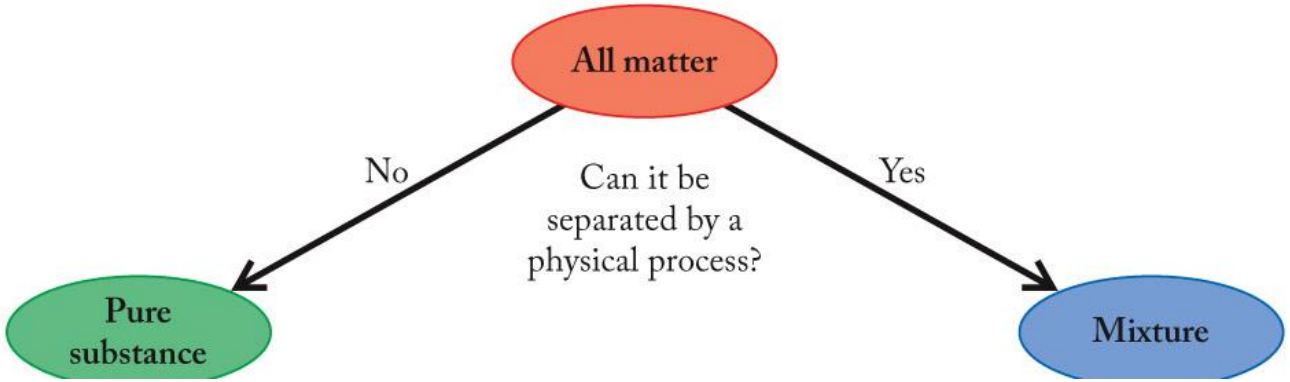
Classes of Matter

- **Pure substance**
  - Same physical and chemical properties throughout (**e.g., gold, water, sugar**).
  - Cannot be separated into simpler substances by a physical process

- **Physical process**
  - A transformation of a sample of matter, such as a change in physical state, that does not alter the chemical identity of any substance in the sample

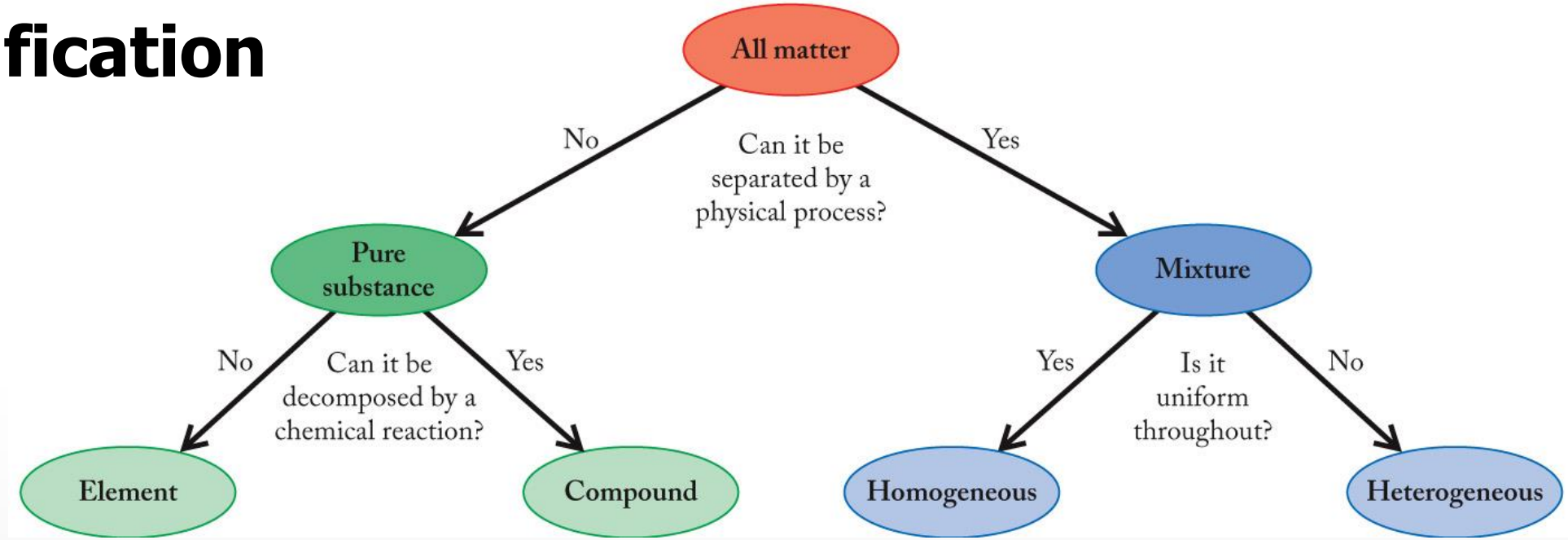
Classes of Matter

Classification



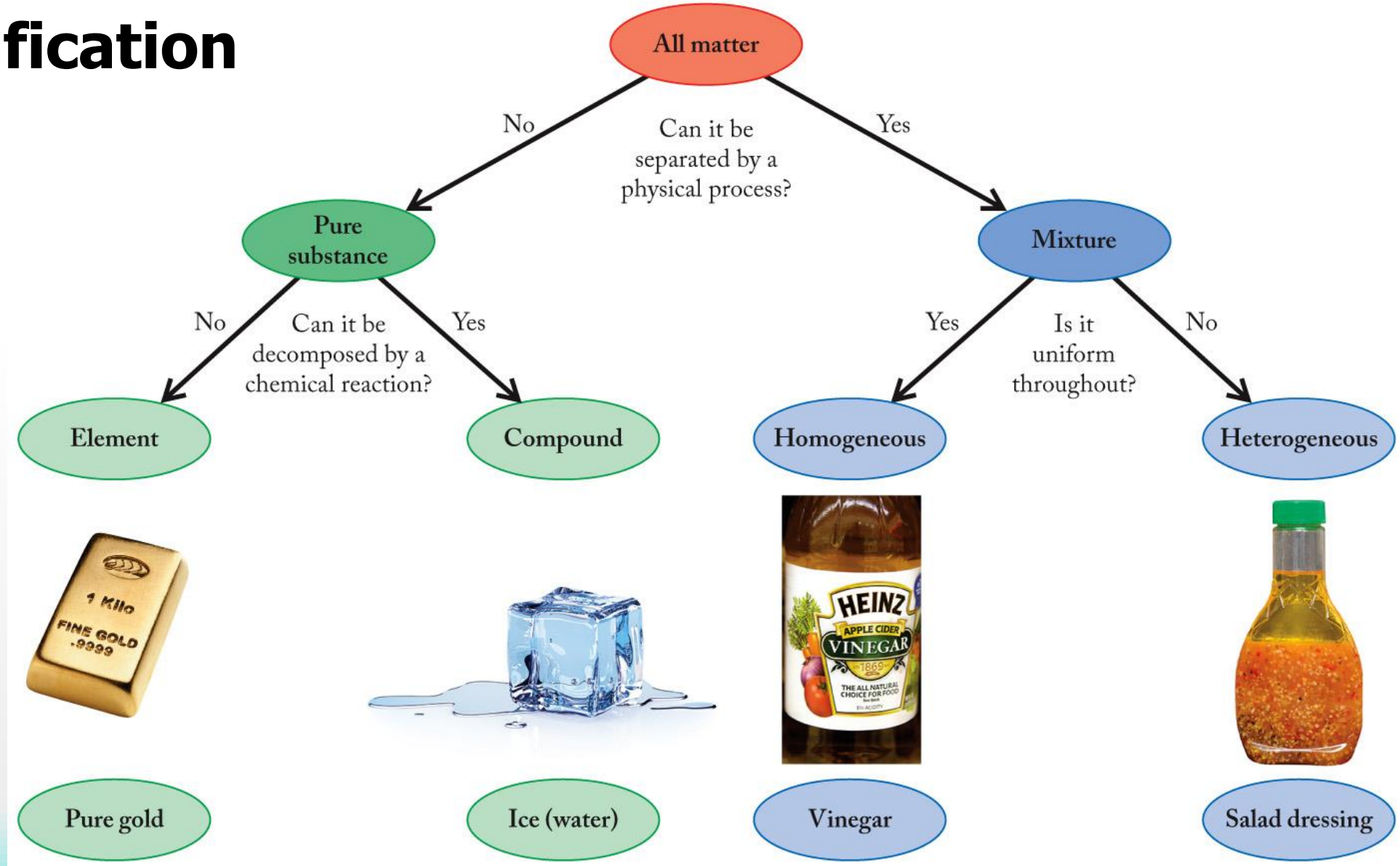
Classes of Matter

Classification



Classes of Matter

Classification



Separating Mixtures

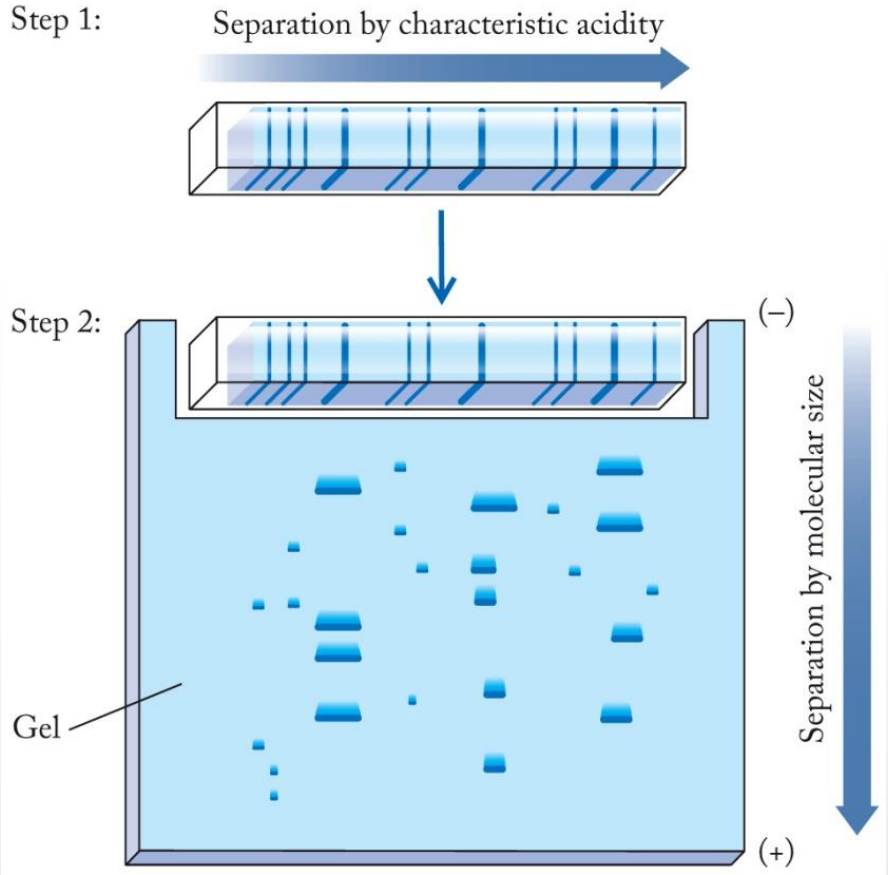
Check out this video: https://m.youtube.com/watch?v=ASMnfoe1Q-g

Constituents in a mixture can be isolated by physical means (i.e., no chemical reactions are needed).

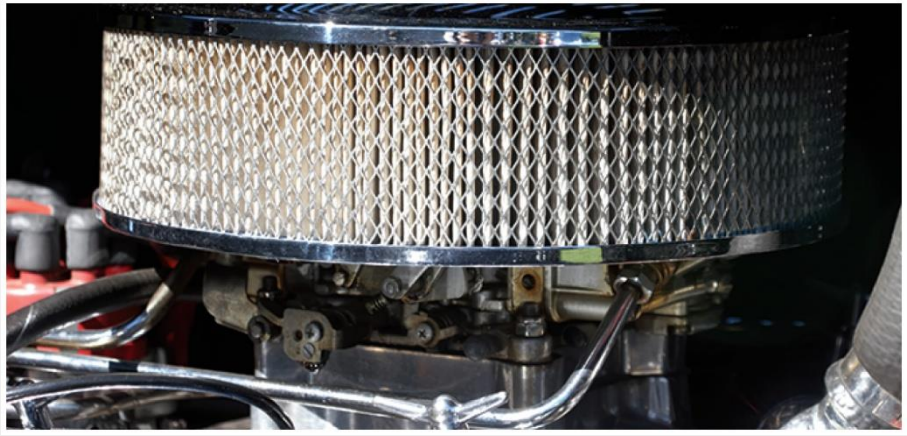
- **Centrifugation** – a process for separating suspended solid particles by applying a centripetal force to allow sedimentation of a heterogeneous mixture.

Separating Mixtures

- **Electrophoresis** – a process for separating molecules based on their charge and size



- **Filtration** – a process for separating solid particles from a liquid or gas by passing the mixture through a medium that retains the particles



Separating Mixtures

- **Distillation** – a separation technique in which the more volatile components of a liquid mixture are vaporized and then condensed, thereby separating them from less volatile components

Properties of Matter

- **Chemical property:**
  - A property of a substance that can be observed only by reacting it to form another substance (**chemical reaction**)
  - Examples: **flammability, corrosion**

Note: The physical and chemical properties of compounds are often very different from the physical and chemical properties of the elements that make up the compound.

Properties of Matter

- **Physical property:**
  - A property of a substance that can be observed without changing it into another substance
  - Examples:
    - Luster
    - Hardness
    - Color
    - State (solid, liquid, gas)
    - Melting point and boiling point
    - Density (mass/unit volume)

Substance	State	Color	Melting Point(C)	Boiling Point (C)
Neon	gas	colorless	-249	-246
Oxygen	gas	colorless	-218	-183
Chlorine	gas	green/yellow	-101	-34
Ethanol	liquid	colorless	-117	78
Mercury	liquid	silver/white	-39	357
Bromine	liquid	red-brown	-7	59
Water	liquid	colorless	0	100
Sulfur	solid	yellow	115	445
Sodium Chloride	solid	white	801	1413
Gold	solid	yellow	1064	2856
Copper	solid	red-yellow	1084	2562

Properties of Matter

- **Intensive property:**
  - A property that is independent of the amount of substance present
  - Examples**: color, luster, melting and boiling points, hardness, and density**

- **Extensive property:**
  - A property that varies with the quantity of the substance present
  - Examples**: volume, mass**

COAST: A Framework for Solving Problems

- Collect and Organize
  - Identify key concepts and skills required to solve problem and assemble information needed.
- Analyze
  - Evaluate information and relationships or connections; sometimes units will help identify steps needed to solve the problem.
- Solve
  - Perform calculations, check units, etc.
- Think About It
  - Is the answer reasonable? Are the units correct?

Practice: Distinguishing Physical and Chemical Properties

- Which of the following properties of copper are physical and which are chemical?
  - Copper has a density of 9.00 g/cm^3.
  - Copper is a reddish-brown solid.
  - Copper forms a green patina of copper(I) oxide upon exposure to oxygen and environmental conditions.
  - Copper has a melting point of 1085°C.

Practice: Distinguishing Physical and Chemical Properties

C&O

Physical properties are those that can be observed without changing the substance.
Chemical properties describe how a substance reacts with other substances.

Analyze

Density, color, and melting point are all ways to describe the substance without changing it.
The formation of a patina indicates a change in substance.

Solve

Density, color, and melting point are all physical properties.
Formation of copper(I) oxide is a chemical property.

Think About It

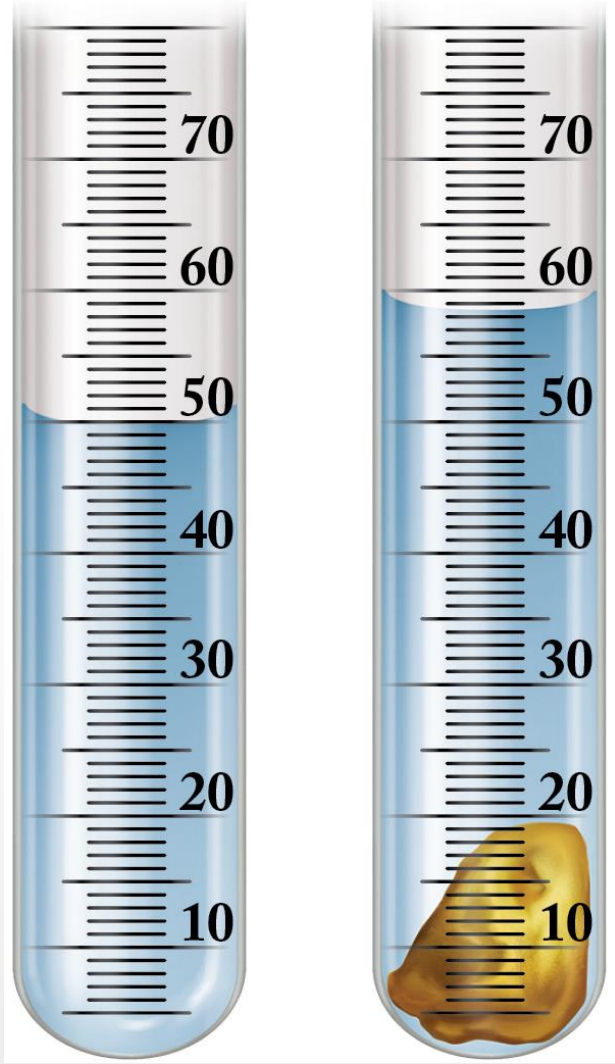
The change from reddish brown copper to a green substance indicates a change in the substance so it must be chemical.

Density

- Density
  - Ratio of the mass of an object/substance to the volume of the object/substance:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

- For solids, the units are usually g/cm^3.
- For liquids, the units are typically g/mL.
- For gases, units are typically g/m^3 or g/L.



Practice: Calculating Density

A metal coin is found on the beach. When taken into the laboratory it was found to have a mass of 3.90 grams. The diameter is 1.91 cm and its thickness is 0.150 cm.

Calculate the density of the coin.

What other information could be used to confirm the metal composition?

Sample Exercise 1.1: Distinguishing Physical and Chemical Properties

Which properties of gold are chemical and which are physical?

a. Gold metal, which is insoluble in water, can be made soluble by reacting it with a mixture of nitric and hydrochloric acids known as aqua regia.
b. Gold melts at 1064°C.
c. Gold can be hammered into sheets so thin that light passes through them.
d. Gold metal can be recovered from gold ore by treating the ore with a solution containing cyanide, which reacts with and dissolves gold.

A. Properties (a) and (c) are chemical properties of gold.
B. Properties (b) and (c) are physical properties of gold.
C. Properties (a) and (d) are chemical properties of gold.
D. Properties (b) and (d) are physical properties of gold.
E. Properties (b), (c) and (d) are physical properties of gold.

Sample Exercise 1.1: Distinguishing Physical and Chemical Properties

Collect, Organize, and Analyze

Which properties of gold are chemical and which are physical?

a. Gold metal, which is insoluble in water, can be made soluble by reacting it with a mixture of nitric and hydrochloric acids known as aqua regia.
b. Gold melts at 1064°C.
c. Gold can be hammered into sheets so thin that light passes through them.
d. Gold metal can be recovered from gold ore by treating the ore with a solution containing cyanide, which reacts with and dissolves gold.

- Chemical properties describe how a substance reacts with other substances.
- Physical properties can be observed or measured without changing one substance into another.
- Properties (a) and (d) describe reactions that chemically change gold metal into compounds of gold that dissolve in water.
- Properties (b) and (c) describe processes in which elemental gold remains elemental gold. When it melts, gold changes its physical state from solid to liquid, but not its chemical identity. When gold is hammered flat, it is still solid, elemental gold.

Sample Exercise 1.1: Distinguishing Physical and Chemical Properties

Solve

Which properties of gold are chemical and which are physical?

a. Gold metal, which is insoluble in water, can be made soluble by reacting it with a mixture of nitric and hydrochloric acids known as aqua regia.
b. Gold melts at 1064°C.
c. Gold can be hammered into sheets so thin that light passes through them.
d. Gold metal can be recovered from gold ore by treating the ore with a solution containing cyanide, which reacts with and dissolves gold.

A. Properties (a) and (c) are chemical properties of gold.
B. Properties (b) and (c) are physical properties of gold.
C. Properties (a) and (d) are chemical properties of gold.
D. Properties (b) and (d) are physical properties of gold.
E. Properties (b), (c) and (d) are physical properties of gold.

Sample Exercise 1.1: Distinguishing Physical and Chemical Properties

Think About It

Which properties of gold are chemical and which are physical?

a. Gold metal, which is insoluble in water, can be made soluble by reacting it with a mixture of nitric and hydrochloric acids known as aqua regia.
b. Gold melts at 1064°C.
c. Gold can be hammered into sheets so thin that light passes through them.
d. Gold metal can be recovered from gold ore by treating the ore with a solution containing cyanide, which reacts with and dissolves gold.

When possible, rely on your experiences and observations.

- Gold jewelry does not dissolve in water, so dissolving gold metal requires a change in its chemical identity: it can no longer be elemental gold.
- Physical processes such as melting do not alter gold's chemical identity. Gold can be melted and then cooled to produce solid gold again.

Chapter 1: Outline

1.1 The States of Matter
1.2 Classes and Properties of Matter
1.3 Exploring the Particulate Nature of Matter
1.4 Forms of Energy
1.5 COAST: A Framework for Solving Problems
1.6 Formulas and Models
1.7 Expressing Experimental Results
1.8 Unit Conversion and Dimensional Analysis
1.9 Assessing and Expressing Precision and Accuracy