Chapter 1. Matter

1.1 What is Chemistry

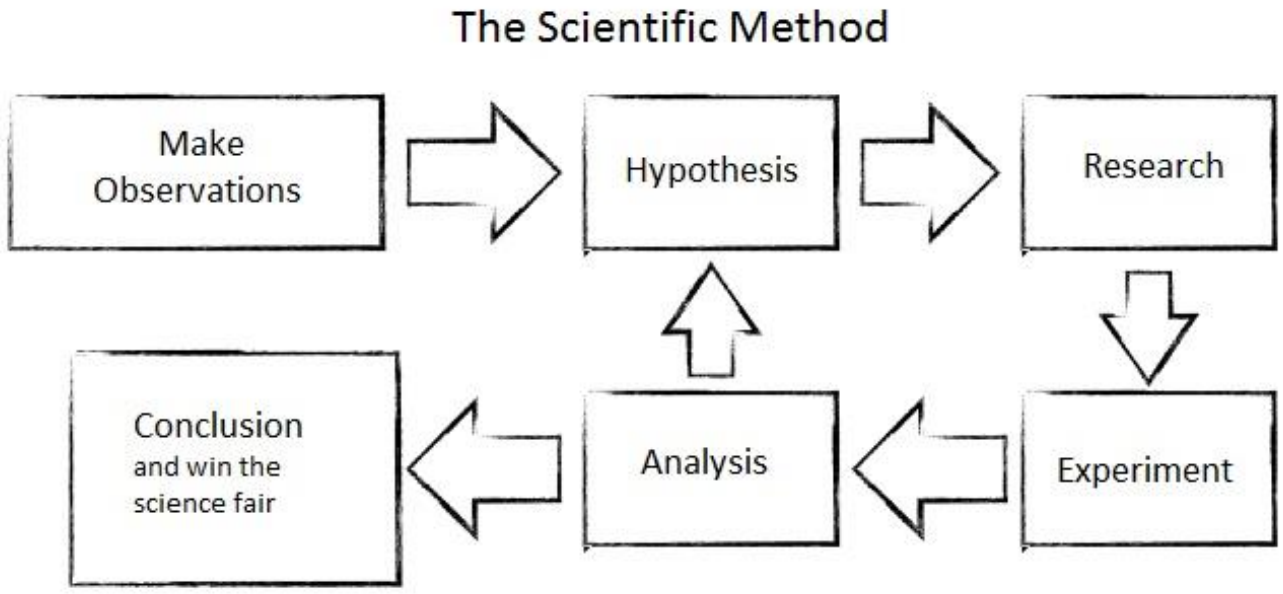
CHEMISTRY – The study of the structure, composition, properties and reactions of matter and the energy changes associated with matter. In other words the study of atoms, how atoms combine to form compounds, and how atoms and compounds react with each other.

Chemistry is the central science - helps you understand related fields such as biology, physics, geology, medicine, engineering and agriculture.

Chemistry has several branches:

- Inorganic – the study of metal compounds and basically all non-organic compounds
- Organic – the study of Carbon and carbon compounds
- Physical – the study of the atom, subatomic particles, and the interface with physics, radiation and chemical reaction rates
- Analytical – the study of qualitative and quantitative determinations of the chemical components of substances.
- Biochemistry – the study of chemical reactions in living things, cancer, genetics
- Environmental – the study of how humans are changing our world
- Chemical Education – the study of teaching and learning chemistry

1.2 The Scientific Method:



1. Make observations about natural phenomenon.
2. Formulate hypothesis (an explanation for the phenomenon).
3. Perform research about the hypothesis

4. Perform experiments to disprove the hypothesis
5. Analysis the results, refine hypothesis accordingly and repeat experiments as needed
6. Draw a conclusion, perhaps publish a scientific paper! Or Win the science fair!

1.3 The 3 States of Matter

Matter: Anything that has mass and occupies space.

Matter exists in one of three physical states: solid, liquid, or gas.

gas: Particles are far apart and are in constant random motion.

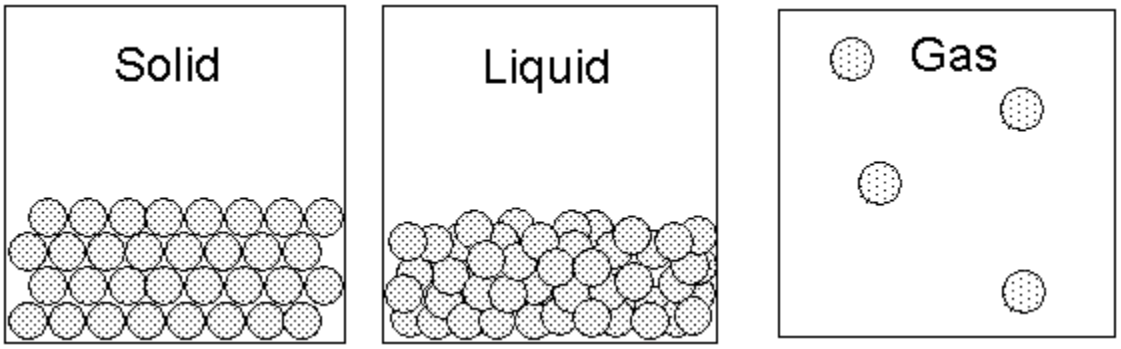
- Gases assume the shape of the container, they do not have their own shape.
- Volume is variable also (changeable):
  - If volume increases, particles move farther away to fill entire container.
  - If volume decreases, particles move closer together.
  - Note the particles do not themselves change size, only the distance between them

liquid: Particles are close together touching, but are free to move and slide past one another.

- Liquids assume the shape of the container, they do not have their own shape.
- Volume is constant (can't compress). Liquids have a definite volume.

solid: Particles are packed tightly together; these particles vibrate but remain in their place.

- Solids have their own definite, fixed shape.
- Volume is constant. Solids have a definite volume.



1.4 Properties of Solids, Liquids and Gases

Solids

1. Solids have a definite fixed shape and a fixed volume.
2. Solids are either crystalline or noncrystalline.
3. Solids are not compressible since the particles are close to one another.
4. Most solids have a slightly higher density than their corresponding liquid.

- Ice is an important exception since ice is less dense than water.

5. Solids do not mix by diffusion or osmosis.

Liquids

1. Liquids take the shape of their container, but have a constant volume.
2. Liquids usually flow readily but different liquids flow at different rates.
3. Liquids are not compressible since the particles are close together.
4. Liquids have much higher densities relative to gases.
5. Soluble liquids will mix together to form a uniform mixture.

Gases

1. Gases have an indefinite shape ⇒ gas takes the shape of its container
2. Gases can expand or compress
   → If the volume is increased, the gas particles move apart to fill the larger volume.
   → If the volume is decreased, the gas particles move closer together.
3. Gases have low densities
   → approximately 1000 times less dense than liquids and solids
   → air is about 0.001 g/mL compared to water that is 1 g/mL
4. Different gases will mix completely in the same container and form a uniform mixture.
5. A gas confined in a container will exert pressure since the constantly moving particles strike the walls of the container.

1.5 Physical and Chemical Properties of Matter

Physical Properties: Properties or characteristics of a substance that you observe. Examples include:

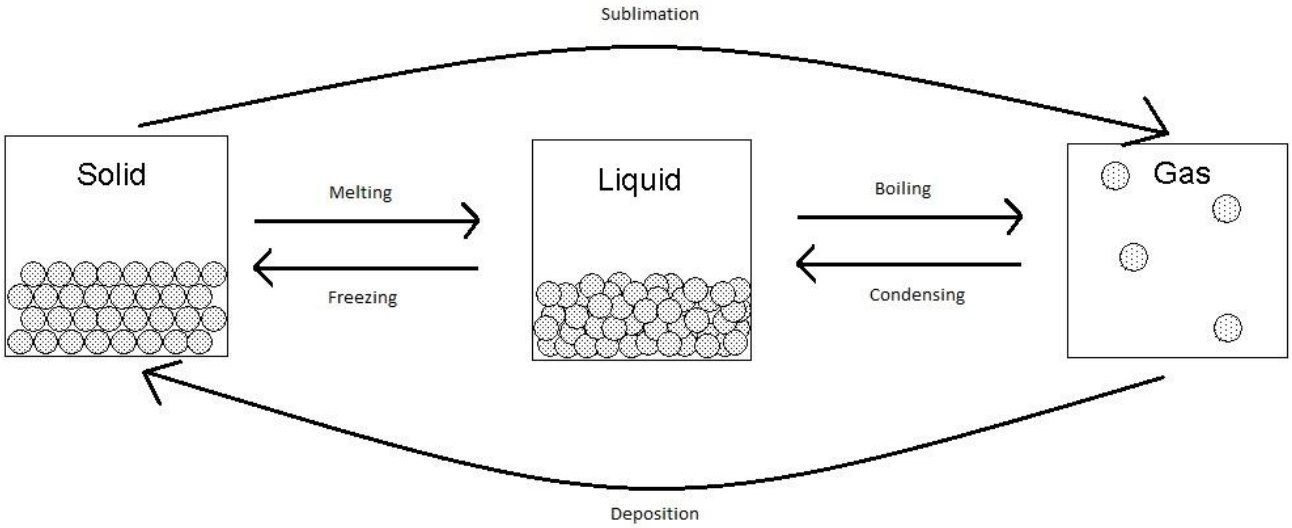
physical state (solid, liquid, gas)	electrical & heat conductivity
color (red, blue, colorless)	solubility
density	hardness
melting and boiling points	odor

Chemical Properties: describe how a substance reacts/behaves. Examples would be corrosive, toxic, inert, reactive, oxidizes, decomposes, rusting such as hydrogen reacts explosively with oxygen or iron rusts slowly in air.

1.6 Physical and Chemical Changes

Physical change: a process that does not alter the chemical composition of the substance, no bonds are broken or formed, the molecular formula stays the SAME

- substance only changes its physical state or shape or form
- Examples: boiling water, melting gold, breaking glass, dissolving salt in water, freezing ice, cutting paper
- An example would be the boiling of methanol: CH_3OH (l) → CH_3OH (g)
  Notice how the chemical formula did not change, only the state of matter changed



Chemical change: a process that changes the chemical composition of the substance, the chemical formula is CHANGED

- Starting substance is destroyed and a new substance with different properties is formed.
- Indicators of chemical change:
  - Oxidation of matter (burning or rusting)
  - Release of gas bubbles (fizzing) without heating it
  - Formation of insoluble solid (precipitation)
  - Release of heat or light
  - Change in color or odor.
- An example is the decomposition of hydrogen peroxide: $2\ H_2O_2(l) \rightarrow 2\ H_2O(l) + O_2(g)$ Note the chemical formula changed from H_2O_2 to something different

1.7 Elements, Compounds, and Mixtures: Classifying Matter

Element:

- consist of only one type of atom, all the atoms are the same
- a substance that cannot be broken down further by chemical reaction
- carbon (C), hydrogen (H_2), sulfur (S_8), copper wire (Cu)

Compound

- consist of two or more different elements bonded together and has a specific formula like $MgCl_2$ or CO_2
- a substance that can be chemically separated into its elements
- For example ethanol (C_2H_5OH) can be broken down to C, H, & O

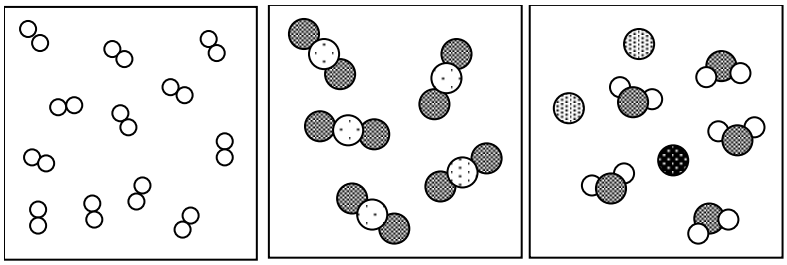
Two or more substances can combine physically to form **mixtures**.

Mixture

- consist of two or more compounds and/or elements, but has *no specific formula*
- has variable composition with definite or varying properties

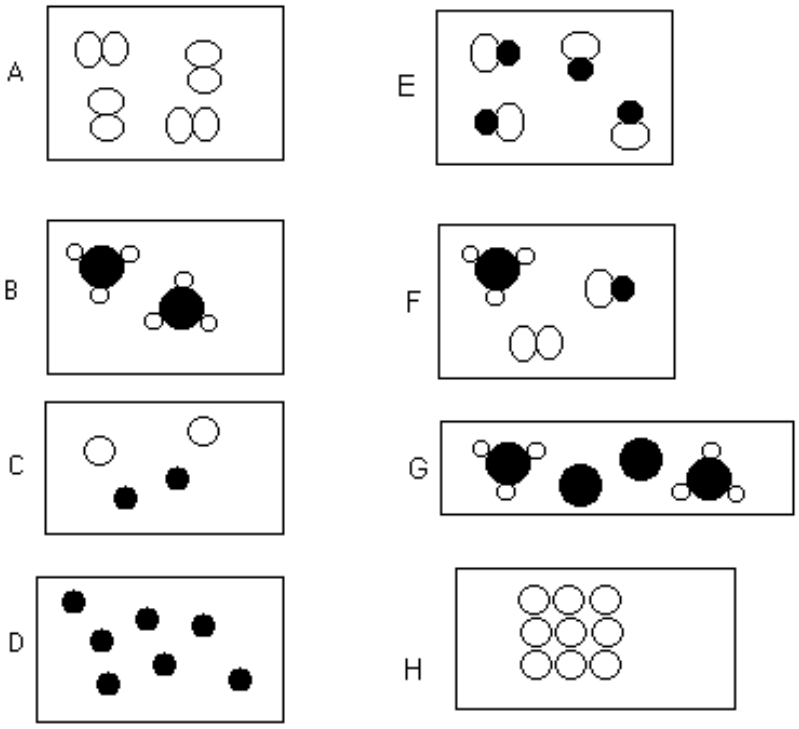
- a mixture can be physically separated into its component elements and/or compounds
- Metal alloys like 10-K to 18-K gold; coarse mixtures like sea water or sand; gas mixtures like air which consists of nitrogen, oxygen, and other trace gases.

Molecular-level Images: represent substances as atoms and molecules



An element **A compound** **A mixture**

Classify A to H as element, compound, or mixture.



1.8 Element Names and Symbols

Each element has a unique name, symbol, and number.

Oxygen is the most abundant element in the Earth's crust, and in the human body.

Convention for writing chemical symbols

- Capitalize first letter of element name: hydrogen H, carbon C
- If the letter is already used, include the second letter (in lower case) of the name: helium He, calcium Ca, cobalt Co

Note that element names are all lower case such as carbon, oxygen, lead, etc…

Note: Some symbols come from Latin names:
e.g. lead is Pb = *plumbum* gold is Au = *aurum* (which means "golden dawn")

FOR EXAMS KNOW THE NAMES AND SYMBOLS OF THE FIRST TWENTY ELEMENTS OF THE PERIODIC TABLE & THE FOLLOWING ELEMENTS

Ag = silver Au = gold Pb = lead Br = Bromine I = iodine Hg = mercury

First Twenty Elements Table

H = hydrogen	O = oxygen	P = phosphorus
He = helium	F = fluorine	S = sulfur
Li = lithium	Ne = neon	Cl = chlorine
Be = beryllium	Na = sodium	Ar = argon
B = boron	Mg = magnesium	K = potassium
C = carbon	Al = aluminum	Ca = calcium
N = nitrogen	Si = silicon	

(There will be a few more later this semester.)

1.9 Physical States of the Elements and Which Elements are Diatomic

Physical States of the Elements at 25 ˚C and normal atmospheric pressure

Normal Physical State of the Elements:

- Only mercury (Hg) and bromine (Br_2) are liquids
- H_2, N_2, F_2, O_2, Cl_2, and all Noble gases (Group VIIIA) are gases
- All other elements are solids

You should know if an element is a solid, liquid, or gas given only the Periodic Table!

Many elements exist as **diatomic** molecules: H_2, N_2, F_2, O_2, I_2, Cl_2, Br_2. An easy way to remember them is the silly saying "Have no fear of ice cold beer!" These elements prefer to buddy up when alone. However, once they bond to something else they are NOT diatomic anymore.

1.10 Metals, Nonmetals, and Semimetals

Properties of Metals vs. Nonmetals

Metals	Nonmetals
shiny appearance	dull appearance
Malleable, ductile, most solids	Brittle, many gases
density – usually high	density – usually low
Good conductors of heat & electricity	Poor conductors (make better insulators)

Semimetals: Have properties intermediate between metals and nonmetals. e.g. silicon

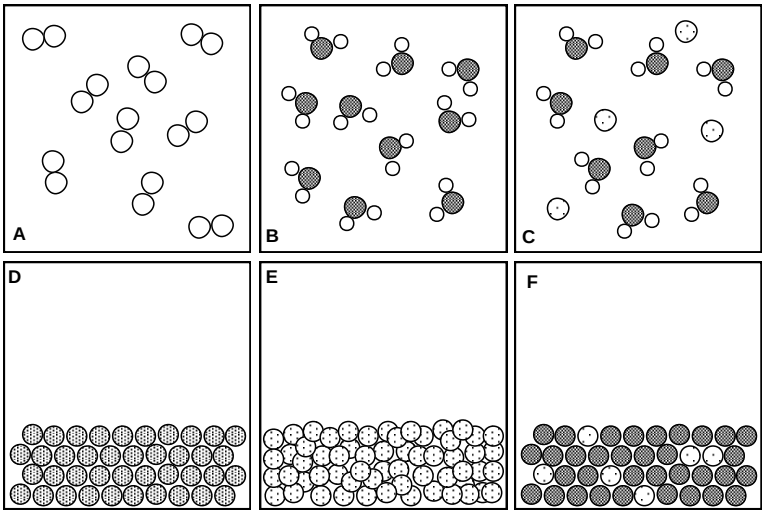
Location of nonmetals, semimetals, metals on the Periodic Table

- Nonmetals (except H) are located on the top-right of the Periodic Table, right of the stair step line
- Semimetals are along the stair-step line following B (except Al is a metal)
- All remaining elements are metals, they are to the left of the stair step line

You should know if an element is a metal, nonmetal, or semimetal based on its position in the Periodic Table!

Practice Problems

1.



For each figure above, indicate if it represents *an element, a compound, or a mixture* AND if it represents a *solid, liquid, or gas.*

A: _____ B: _____ C: _____

D: _____ E: _____ F: _____

2. Which physical state has variable volume and variable shape?

3. Write the chemical symbol for potassium, phosphorus, oxygen, and sodium.

4. Write the name for Li, N, Au, and Ag.

5. What is the physical state at room temperature and pressure for chlorine, bromine, iodine, and carbon?

6. Is water freezing a chemical or physical change?

7. Is TNT exploding a chemical or physical change?

8. What is the name of the physical change when a gas turns into a solid?

9. Name the diatomic elements without looking.

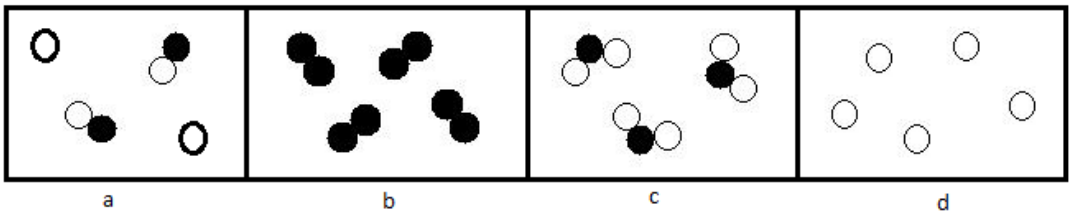
10. What diatomic element is a solid at room temp and pressure?

11. What diatomic element is a liquid at room temp and pressure?

12. Are the following properties physical or chemical? Red, toxic, liquid, soluble in water, rough, corrosive.

13. Are the following physical or chemical changes?
    a. $H_2O(l) \rightarrow H_2O(g)$
    b. $2\ NH_3(g) \rightarrow N_2(g) + 3\ H_2(g)$
    c. $C(s) + 2\ H_2(g) \rightarrow CH_4(g)$
    d. $C_6H_6(l) \rightarrow C_6H_6(s)$

14. Are the following an element, a compound, or a mixture?



15. Are these elements metals, nonmetals, or semimetals? Na, Al, H, Br, Si

Answers to Practice Problems

1. A. element gas B. compound gas C. mix gas
   D. element solid E. element, liquid F. mix solid
2. gas
3. K, P, O, Na
4. lithium, nitrogen, gold, silver
5. chlorine gas, bromine liquid, iodine solid, carbon solid
6. physical
7. chemical
8. deposition
9. H_2 N_2 F_2 O_2 I_2 Cl_2 Br_2
10. iodine
11. bromine
12. Red - physical, toxic - chemical, liquid - physical, soluble in water - physical, rough - physical, corrosive - chemical.
13. a – physical, b – chemical, c – chemical, d - physical
14. a – mixture, b - element, c – compound, d – element
15. Na - metal, Al - metal, H - nonmetal, Br - nonmetal, Si - semimetal