MATTER

MATTER: THE STUFF OF THE UNIVERSE
States of Matter

Solid

Liquid

Gas

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Condensed States: Solids

- **Solids**
  - Have a definite shape and volume
  - Molecules are
    - Tightly packed
    - Moving VERY slowly in place or only vibrating
    - Very strongly attracted to each other
    - Not compressible
Condensed States: Liquids

- Liquids
  - Have NO set shape but definite volume
  - Molecules are
    - Moving faster than in a solid at the same temperature
    - Loosely packed (slip and slide)
    - Strongly attracted to each other
    - Not compressible
    - Flow and take shape of container
Expanded States: Gas

- **Gas**
  - Have no definite shape
    - Depends on the container
  - Have no definite volume
    - Varies depending on temperature and pressure
  - Molecules are
    - Not very strongly attracted to each other
    - Flow
  - Moving faster than those in a liquid at the same temperature
  - As a result are
    - spread out as far as possible
    - moving freely past each other
    - compressible
Gas vs. Vapor

- **Gas**
  - In the gaseous state at room temperature
  - Example: oxygen, carbon dioxide

- **Vapor**
  - In the gaseous state when it is normally a solid or liquid at room temperature
  - Example: steam (water as a gas)
Plasmas

- Occur at extremely high temperatures
- Are ionized matter
  - May be some atoms or molecules but mostly
    - Nuclei and electrons floating around not attached
- Usually are good conductors of electricity
- Most common form of matter in the universe
  - Stars
- Here on Earth: flames, lightening, aurora borealis, plasma TVs, neon signs
Plasmas - The 4th State of Matter

- Magnetic fusion reactor
- Inertial confinement fusion
- Solar core
- Solar wind
- Solar corona
- Neon sign
- Lightning
- Interstellar space
- Aurora
- Flames
- Solids, liquids, and gases
- Too cool and dense for classical plasmas to exist.

Number Density (Charged Particles / m³)

Temperature (K)

10^2 10^3 10^4 10^9 10^15 10^21 10^27 10^33
Fully ionized plasma. Atoms in plasma become increasingly ionized.

Plasma Phase
Free electrons move among positively charged ions.

Molecular dissociation into component atoms.

Gas Phase
Atoms or molecules move essentially unconstrained.

Liquid Phase
Atoms or molecules remain together but move relatively freely.

Solid Phase
Atoms or molecules are held tightly in place.
You WILL clean up any mess you make today and always!
What is a non-Newtonian fluid?

You have to pull the trigger on a water pistol to get the water to squirt out. To make the water to come out faster, you have to pull the trigger harder. Fluids resist flow. This phenomenon is known as viscosity.

Newton devised a simple model for fluid flow that could be used to relate how hard you have to pull the trigger to how fast the liquid will squirt out of the pistol. Picture a flowing liquid as a series of layers of liquid sliding past each other.
The resistance to flow arises because of the friction between these layers. If you want one layer to slide over another twice as fast as before, you'll have to overcome a resisting force that's twice as great, Newton said.

The slower one layer slides over another, the less resistance there is, so that if there was no difference between the speeds the layers were moving, there would be no resistance.

Fluids like water and gasoline behave according to Newton's model, and are called *Newtonian fluids*. 
But ketchup, blood, yogurt, gravy, pie fillings, mud, and cornstarch paste DON'T follow the model. They're non-Newtonian fluids because doubling the speed that the layers slide past each other does not double the resisting force. It may less than double (like ketchup), or it may more than double (as in the case of quicksand and gravy). That's why stirring gravy thickens it, and why struggling in quicksand will make it even harder to escape.

For some fluids (like mud, or snow) you can push and get no flow at all- until you push hard enough, and the substance begins to flow like a normal liquid. This is what causes mudslides and avalanches.
Walking on Non-Newtonian Fluids

- Walking on cornstarch - en Español
- Mythbusters - Ninja Walking
PHYSICAL AND CHEMICAL PROPERTIES AND CHANGES
Physical Property

- Characteristic of a substance that can be observed without changing the identity (formula) of the substance

- Examples:
  - state of matter
  - density
  - color
  - melting pt.
  - odor
  - boiling pt.
Intensive v. Extensive Properties

- **Intensive (intrinsic) Property**: A property that does not change when the amount of substance changes
  - Color
  - Odor
  - Boiling point
  - Melting point
Intensive v. Extensive Properties

- **Extensive (extrinsic) property**: A property that changes depending upon the amount of substance present
  - Mass
  - Volume
  - Shape
  - Size
Density...Intensive or Extensive?

- Density data for a sample of gold.
- Density = mass / volume
  - Units are g/mL or g/cm³

<table>
<thead>
<tr>
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<td></td>
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<td></td>
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<tr>
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<td>7.62</td>
<td></td>
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<tr>
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<td>22.34</td>
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## Density...Intensive or Extensive?

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Chemical Property

- Ability of a substance to change to a different substance
- You must **change** the identity (formula) of the substance to observe a chemical property
- Examples:
  - flammability
  - reactivity with acids and bases
Physical Change

- Change in the **form** of the substance, not in its chemical nature
  - No chemical bonds broken or made
    - The chemical formula is the same before and after the change
      - The attractions between the molecules are made or broken, not the molecules themselves
  - Examples:
    - cutting/tearing
    - change in state (a.k.a. phase change): melting, boiling, evaporating, condensing, freezing
    - bending
Chemical Change (Reaction)

- Change one substance into another

- Atoms are reorganized
  - Bonds are broken and reformed in new ways

- Examples:
  - Burning
  - Mixing baking soda and vinegar
  - Digestion
  - Rusting
Signs of Chemical Change

- Change in:
  - state
    - Forming a precipitate (solid made from liquids)
    - Bubbling/fizzing
  - color
  - temperature
    - Hot (exothermic)
    - Cold (endothermic)
  - odor
- giving off light
Law of Conservation of Matter

- **Law of Conservation of Matter**: “matter cannot be created or destroyed”...but it can be rearranged and change forms (via chemical or physical reactions).
- Mass of the products (what is made) has the same mass as the reactants (starting material).
- Proposed by Antoine Lavoisier (1743-1794)
Mixture

- A blend of 2 or more pure substances
- Have variable compositions
  - No chemical formula
- Examples:
  - soda
  - salad dressing
  - alloys
  - coffee
  - salt water
  - air
Air: A Mixture

- Nitrogen
- Oxygen
- Helium
- Neon
- Water vapor
- Carbon dioxide
- Argon
Types of Mixtures

- **Homogeneous**
  - uniform
  - evenly mixed
  - cannot see different parts

- **Examples**
  - salt water
  - coffee
  - air
  - milk
Types of mixture, con’t

- **Heterogeneous**
  - not uniform
  - not evenly mixed
  - can see different parts

**Examples:**
- salad dressing
- sand
- concrete
- salsa
Subtypes of mixtures...

- **Solutions**: one thing dissolved in another; they do not separate upon standing or when filtered (particles are molecules)
  - Two parts:
    - Solvent- the thing that does the dissolving
    - Solute- the thing that gets dissolved
      
      Ex: Salt water – water is the solvent, salt the solute
  - Can be any state of matter
    - **Alloys** are solutions of metals (a solid solution)
  - Particles are not visible
Twenty-four-karat gold is an element.

Eighteen-karat gold is an alloy.

Fourteen-karat gold is an alloy.

(Alloys are homogeneous mixtures - specifically solutions of metals)

What is the solvent in 18K and 14K gold? Au

What is/are the solute(s) in 18K and 14K gold? Cu and Ag
Subtypes of mixtures...

- **Colloid** - microscopically mixed homogeneous solutions that will disperse light (Tyndall effect)
  - They will not separate out upon standing
  - Particles are bigger than those in a solution
  - Are visible only with an ultramicroscope
Tyndall Effect

True solution (No scattering of light)

Colloidal sol (Scattering of light)
Subtypes of mixtures...

- **Suspensions**: Heterogeneous mixture of two or more substances
  - Usually cloudy or opaque
  - May look like a solution but can separate when standing
  - Do NOT pass through filter paper
  - Particles are bigger than those of a colloid
  - Are visible with microscope or naked eye
## Comparison of Solutions, Colloids, and Suspensions

<table>
<thead>
<tr>
<th>Type of Mixture</th>
<th>Type of Particle</th>
<th>Effect of Light</th>
<th>Settling</th>
<th>Separation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>Small particles such as single atoms, ions, or molecules</td>
<td>Transparent</td>
<td>Particles do not settle</td>
<td>Particles cannot be separated by filters or semipermeable membranes</td>
</tr>
<tr>
<td>Colloid</td>
<td>Larger molecules or groups of molecules or ions</td>
<td>Tyndall effect</td>
<td>Particles do not settle</td>
<td>Particles can be separated by semipermeable membranes</td>
</tr>
<tr>
<td>Suspension</td>
<td>Very large particles that may be visible</td>
<td>Opaque</td>
<td>Particles settle rapidly</td>
<td>Particles can be separated by filters</td>
</tr>
</tbody>
</table>
Tyndall Effect in Nature
Classification of Matter

- Matter (materials)
  - Physical processes
    - Substances
      - Elements
      - Chemical reactions
      - Compounds
    - Mixtures
      - Homogeneous mixtures (solutions)
      - Heterogeneous mixtures
Separating Mixtures

- Mixtures can be separated by physical means
  - No chemical reactions or changes needed
  - 5 main methods are based on physical properties
    - Filtration
    - Evaporation
    - Crystallization
    - Chromatography
    - Distillation
Filtration

- Use a funnel and filter paper
- Separates a solid from a liquid
- Based on particle size
Separating Mixtures

- **Evaporation**: boiling off a liquid
- **Crystallization**: solid left behind from a solution crystallized when the liquid leaves

- Usually paired
  - sweat when it dries
  - seawater
  - rock candy formation
  - geode formation
Chromatography: “color writing”

- Using how quickly things move to separate them
  - Use specific ratios of movement through a medium (paper, water, column) based on how some molecules move through the medium

- Phases:
  - Stationary phase
    - stays in place (paper, the column)
    - Hangs onto parts of the mixture at different rates
  - Mobile phase
    - moves over the stationary phase
    - carries the parts of the mixture

- $R_f$ values constant for component of a mixture
  - Ratio of how far one component moves as compared to the whole

- Ex: running colors in ink when wet
Paper Chromatography

Paper chromatography separates mixtures using a solvent (water) that carries a solute (ink) up a strip of paper.

- Blue (doesn't stick well—carried far.)
- Red
- Yellow (sticks to the paper—not carried far.)
Column Chromatography

Protein mixture is added to column containing cross-linked polymer.

Protein molecules separate by size; larger molecules pass more freely, appearing in the earlier fractions.
Gas Chromatography

A Sample

Gasflow (He)

Detector

Column

High affinity to stationary phase

Low affinity to stationary phase

B
Distillation

- Separates 2 or more liquids
- One liquid has to have a lower boiling point
  - Heat both; the one with the lower BP is boiled out first
  - Can use condensation to collect materials as they boil out
- Used with crude oil (cracking) to isolate separate products
Distillation of Crude Oil: Cracking
Other methods...

- Use polarity (charge)
  - Magnetism

- Use density
  - For solids: mixture of pieces is placed in a solution
    - Some float and can be skimmed off
    - Some sink
  - For liquids: use a separatory funnel
Separatory Funnel

- Used for liquids that are immiscible (will not mix, like oil and water)
Pure Substance

- A substance with uniform and constant composition (set formula)
  - Ex: $H_2$, $Cl_2$, $C_6H_{12}O_6$, NaCl, $H_2O$, Fe

- Elements and compounds are both considered to be pure substances
What is an element?

- Element: A substance that can not be changed into a simpler substance(s) under normal laboratory conditions
  
  - A substance made up of only one type of atom is an elemental substance
How do we represent elements?

- Represented by symbols on the periodic table.
  - Usually comes from the name, a person, or a place.
  - One or two letters for those with official names.
    - First letter is ALWAYS capitalized.
    - Second letter is never capitalized.
  - Unofficially named elements have three letters, starting with a capital U.
Meet the Elements

- 118 Elements
  - 90 of those were discovered in nature
  - 28 were made by man; of those
    - Tc, Pm, and Pu were found to exist after being synthesized
    - Es found in residue from atomic testing
  - So… 94 elements are found in nature
Everything in nature is made up of elements.

Some elements are never found in their pure form in nature, but commonly are found bounded to other elements (in compounds).

ex: Na (sodium) is virtually non-existent in pure form, but found in common NaCl, a compound we call table salt.
## Elements in the Universe

<table>
<thead>
<tr>
<th>Element</th>
<th>Percent (by atoms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hydrogen</td>
<td>73.9</td>
</tr>
<tr>
<td>2. Helium</td>
<td>24.0</td>
</tr>
<tr>
<td>3. Oxygen</td>
<td>1.1</td>
</tr>
<tr>
<td>4. Carbon</td>
<td>0.46</td>
</tr>
<tr>
<td>5. Neon</td>
<td>0.13</td>
</tr>
<tr>
<td>6. Iron</td>
<td>0.11</td>
</tr>
<tr>
<td>7. Nitrogen</td>
<td>0.097</td>
</tr>
<tr>
<td>8. Silicon</td>
<td>0.065</td>
</tr>
<tr>
<td>9. Magnesium</td>
<td>0.058</td>
</tr>
<tr>
<td>10. Sulfur</td>
<td>0.044</td>
</tr>
</tbody>
</table>

- **Most abundant elements in Earth's crust**
  - Oxygen: 46.4%
  - Silicon: 28.2%
  - Magnesium: 2.33%
  - Sodium: 2.36%
  - Aluminum: 8.32%
  - Iron: 5.63%
  - Calcium: 4.15%
  - Titanium: 0.57%
  - Hydrogen: 0.14%

- **Most abundant elements in the human body**
  - Oxygen: 61%
  - Carbon: 23%
  - Hydrogen: 10%
  - Nitrogen: 2.6%
  - Calcium: 1.4%
  - Magnesium: 0.5%
  - Potassium: 0.2%
  - Sulfur: 0.2%
  - Sodium: 0.14%
When elements were discovered

Yellow boxes show the natural radioactive elements
Red boxes show synthetic elements

Found free in nature or metallurgy
Electrochemistry
Separation techniques
Nuclear synthesis

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Allotropes

- Allotropes are different forms of an elemental material
- Shown here are allotropes of carbon
  - Diamond, graphite, and buckminsterfullerene
- Difference is how the atoms are connected to each other
Molecule

- Is defined as two (2) or more atoms sharing electrons in definite proportions
  - $O_2$
  - $H_2$
  - $H_2O$
  - $C_6H_{12}O_6$

- Is the smallest unit of a compound that retains the chemical characteristics of the compound.
ELEMENTS THAT EXIST AS DIATOMIC MOLECULES

Remember:
BrINClHOF

These elements only exist as PAIRS. Note that when they combine to make compounds, they are no longer elements so they are no longer in pairs!
Compounds

- Two (2) or more DIFFERENT elements combined in definite proportions
- Has own, unique:
  - Formula (law of definite proportions)
  - Properties
    - Boiling point, freezing point, density, etc
- Need a chemical reaction to separate them into the elements it is made from
  - $2 \, \text{H}_2\text{O} \rightarrow 2\, \text{H}_2 \text{ and } \text{O}_2$
CHEMICAL COMPOUNDS are composed of atoms and so can be decomposed to those atoms.

The red compound is composed of

- nickel (Ni) (silver)
- carbon (C) (black)
- hydrogen (H) (white)
- oxygen (O) (red)
- nitrogen (N) (blue)
Formulas of Compounds (and Molecules)

- Tells how many atoms of each element are present.
- Uses symbols and subscripts

Rules:
- Each element is represented by its symbol
- The number of each type of atom is written as a subscript next to the element
- 1 is not written
Properties of Compounds

- properties differ from those of individual elements under the same conditions

- **EX:** table salt (NaCl)
  - Na is a metal
  - Cl$_2$ is a gas

- **Ex:** water (H$_2$O)
  - H$_2$ is a gas
  - O$_2$ also a gas
Law of Definite Proportions

- Proposed by Joseph Proust
- In samples of any chemical compound, regardless of the amount, the masses of the elements are always in the same proportions
  - $\text{H}_2\text{O}$ is always $\text{H}_2\text{O}$, and never $\text{H}_2\text{O}_2$
  - Once the formula is different, the materials and the properties are different
Law of Multiple Proportions

- Proposed by John Dalton
- When different compounds are formed from the same elements, different masses of one element combine with the same fixed mass as the other element in a ration of small whole numbers

- $\text{H}_2\text{O}$ vs $\text{H}_2\text{O}_2$
  - Same elements
  - Comparing the mass of $\text{O}$ in $\text{H}_2\text{O}_2$ to the mass of $\text{O}$ in $\text{H}_2\text{O}$ there is twice as much
  - It’s a 2 to 1 ratio by mass (2:1)
<table>
<thead>
<tr>
<th>Atom Combinations</th>
<th>Name</th>
<th>Characteristics</th>
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<tr>
<td></td>
<td>carbon monoxide</td>
<td>Carbon monoxide is a poisonous gas.</td>
</tr>
<tr>
<td></td>
<td>carbon dioxide</td>
<td>You breathe out carbon dioxide as a waste material and plants use carbon dioxide to make oxygen.</td>
</tr>
<tr>
<td></td>
<td>water</td>
<td>Water is the most important liquid on Earth.</td>
</tr>
<tr>
<td></td>
<td>hydrogen peroxide</td>
<td>Hydrogen peroxide is used to disinfect cuts and bleach hair.</td>
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What is the difference between compounds and molecules?

**Molecules**: two or more atoms bonded

**Compounds**: two or more atoms of different elements bonded

• The term molecule is more general, compound is more specific.

• Molecules can be elemental – like O$_2$, or Cl$_2$

• Compounds by definition can not be elemental.
Compounds can be broken into their elements by chemical reactions, such as **Electrolysis**. This is the decomposition of a substance (here, water) into its elements by an electric current.