Ch01

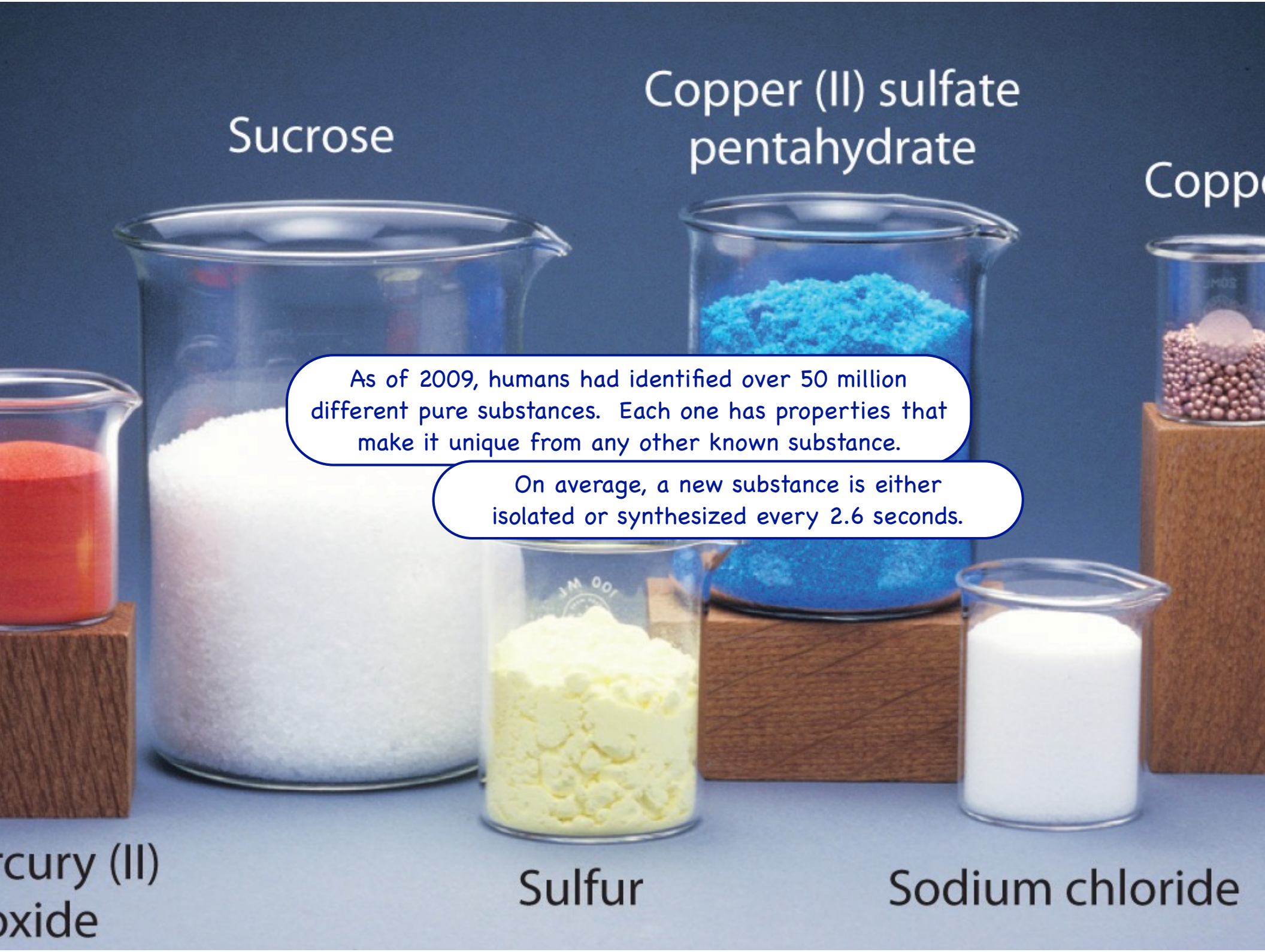
If you are enrolled
or on the wait list–sign
the roll sheet!
If you are trying to add the
class, add your name!

Matter

Understanding the differences between matter.

By understanding atoms & molecules.

version 1.5


Sucrose
Copper (II) sulfate pentahydrate
As of 2009, humans had identified over 50 million different pure substances. Each one has properties that make it unique from any other known substance.
On average, a new substance is either isolated or synthesized every 2.6 seconds.
rcury (II) oxide
Sulfur
Sodium chloride

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- Understanding Matter
  - Composition, Structure, Properties, and Reactions.
  - Atomic Theory
    - The first theory of chemistry.

- Properties of Matter
  - Extensive Properties
  - Properties of State
    - Gas, Liquid & Solid States
  - Classifying Matter
    - Different Purity
      - Pure Substances & Mixtures
    - Different Consistency
      - Homogenous & Heterogeneous

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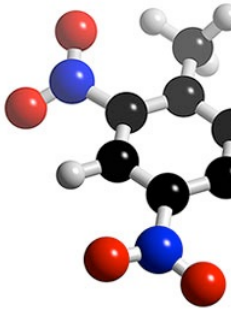
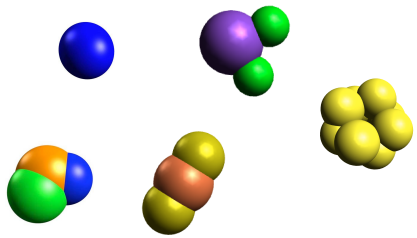
- A closer look at those particles…
  - Atoms, Molecules, & Ions





Chemistry

noun ˈkeməstrē

"The science of the composition, structure, properties and reactions of matter, especially of atomic and molecular systems."

— Webster

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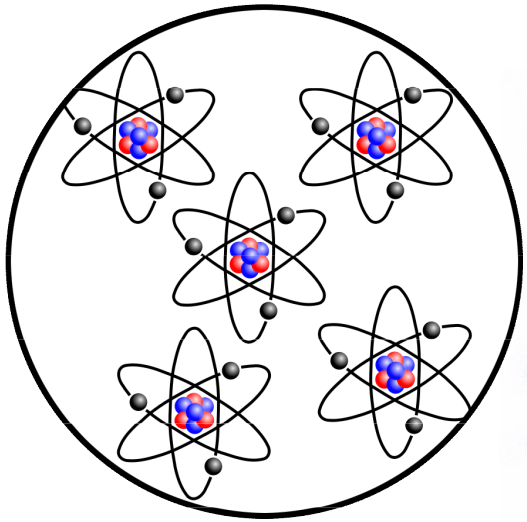

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— Webster

What makes it unique?

Properties are observable differences.
Properties are what makes this matter different than that matter.

Properties of Matter

- gas at room temperature
- 2.4 times heavier than air
- color is yellowish-green
- odor is disagreeable
- melting point –101˚C
- boiling point –34.6˚C
- dissolves in water

Chlorine

Gold

- solid at room temperature
- 1.7 times heavier than lead
- color is yellow
- taste is metallic
- density is 19.3 g/mL
- malleable (shapeable)
- not soluble in water

- solid at room temperature
- 90% lighter than gold
- color is white

Salt

- solid at room temperature
- 90% lighter than gold
- color is white

Sugar

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Salt

- solid at room temperature
- 90% lighter than gold
- color is white
- has no odor
- melts at 801˚C (1,474˚F)
- very brittle
- soluble in water

- solid at room temperature
- 90% lighter than gold
- color is white
- smells sweet
- melts at 186˚C
- less brittle
- partially soluble in water

Sugar

Extensive Properties

- Properties are observable differences.
  - We can distinguish between different matter by observing its properties.
  - There are different classes of properties.
  - The first distinction we'll make in properties is whether they are extensive or intensive.
- Extensive properties vary with the amount (extent) of the substance.
- Intensive properties do not change with the amount of the substance.
  - Intensive properties are inherent, the amount of substance doesn't change them.

Intensive Properties

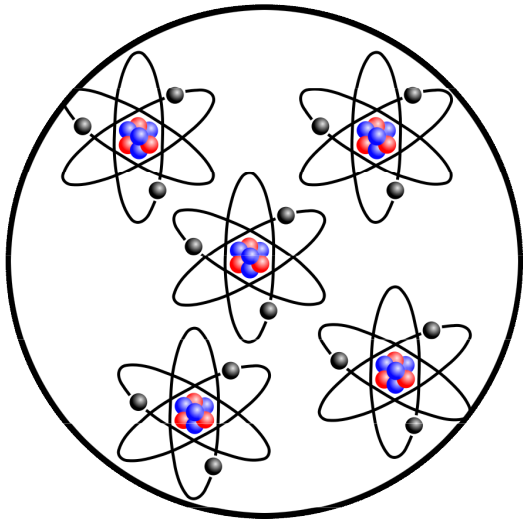
- Color, yellow
- Taste, metallic
- Density, 19.3 g/mL
- Temperature, 23 ˚C
- Hardness, 2.5 Mohr

Extensive Properties

- Mass, 235 grams
- Length, 62 cm
- Volume, 12.2 cm^2
- Energy, 23 kJ
- Atoms, how many

Chemistry predicts & explains matter.

- You can divide all substances into smaller pieces of matter.
- The smallest pieces of a substance, that are still that substance, are atoms and molecules. (We'll just call them particles for now.)
  - **This is atomic theory. The first theory of chemistry.**
  - Chemists explore these small particles and through observation and experiment, offer reliable explanations for the reactivity and properties of the substances they compose.
- This semester, we will help you use scientific method to deduce the composition and understand the structure of the particles that make up all matter in the universe.
- Once you know a substances composition and structure, we will show you how to predict and explain many of the properties and reactivity of those substances.
  - Given similar white powders, you will be able to predict which:
    - Dissolves in water.
    - Floats in water.
    - Turns pink in water.
    - Burns in water.
    - Freezes water.
    - Changes into water.
- Chemistry is the science of matter.



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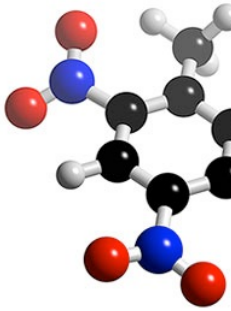
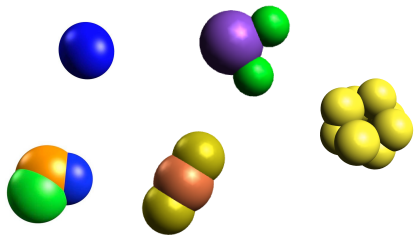
- A closer look at those particles…
  - Atoms, Molecules, & Ions





States of Matter

- Properties of state.
  - Some matter has a fixed shape (solids)
    - some doesn't (liquids & gases)
  - Some matter has a fixes volume (solids & liquids)
    - some doesn't (gases)
  - Some matter is compressible (gases)
    - some isn't (solids and liquids)

We can explain this with atomic theory.

States of Matter

- Matter can exist in different states.
  - Just like your clothes exist in different states:
    - Stretched out thinly across your bed.
    - Crumpled into a shapeless pile.
    - Tightly folded in a neat packet.
  - We'll talk about three states of matter (yes, there are more)
    - Gas (stretched out matter)
    - Liquid (crumpled up matter)
    - Solid (tightly folded matter)
- Your shirt is still a shirt, whether it's crumpled, folded, or stretched out.
- Water is still water, whether it's liquid, solid, or gas.
- A sample of matter can have different properties, depending on it's state.
- These are properties of the state, not of the matter.
  - Macroscopic Properties: Shape, Volume, Compression
  - Microscopic Properties: Structure, Density, Cohesion
  - Other Properties: Energy (heat)

H_2O

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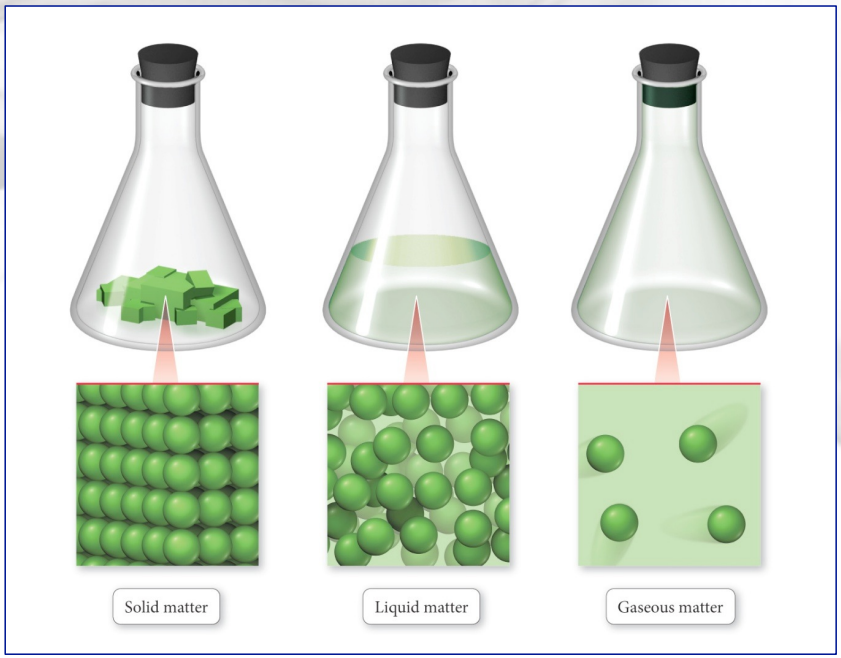

	Gas	Liquid	Solid
Shape	Variable	Variable	Fixed
Volume	Variable	Fixed	Fixed
Compression	Extreme	Slight	None
Structure	Dispersed	Variable	Fixed
Density	Least	Between	Most
Cohesion	Least	Between	Most
Energy	Most	Between	Least

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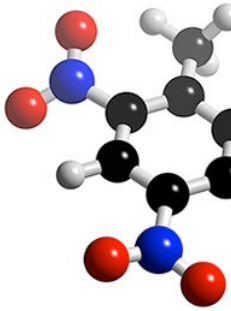
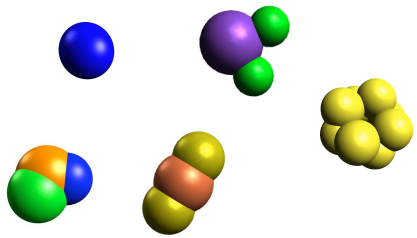




Classifying Matter

- Not all matter is the same matter.
  - I know that because the properties I observe of one substance are not the same as the properties I observe of a different substance.
  - Because of those different properties it's easier to build a car out of steel than out of mercury, and it's easier to breathe oxygen than water.
- Steel is not the same as mercury, water is not the same as oxygen.
- There are different *differences*.
  - What causes steel to have different properties from mercury, is *not* what causes water to have different properties from oxygen.
- To understand matter better, it may be useful to understand the potential ways matter can differ.
- Two important ways matter can differ is by Purity and Consistency.

- Let's observe salt and pepper.

Observing Salt & Pepper

- Salt is made of sodium and chloride.
  - Table salt is 39.3% sodium by weight and 60.7% chloride.
    - Always.
  - Salt has the same properties.
    - It has the same taste, same color, same melting point, hardness…
    - Always.
  - Salt from your grocery store, salt from the red sea, salt in France, salt in Japan, salt from the moon…
    - Salt has constant composition and constant properties.

Observation

- Pepper is made of carbon, hydrogen, and oxygen.
  - Pepper from Argentina may be 57.2% carbon.
  - Pepper from Italy may be 62.4% carbon.
  - Pepper from Spain may taste different than pepper from Greece.
  - Pepper from Spaghetti Factory may be darker than pepper from Macaroni Grill.
  - It's still pepper… just different.
    - Pepper has a variable composition and variable properties.

Observation

Observation

Law

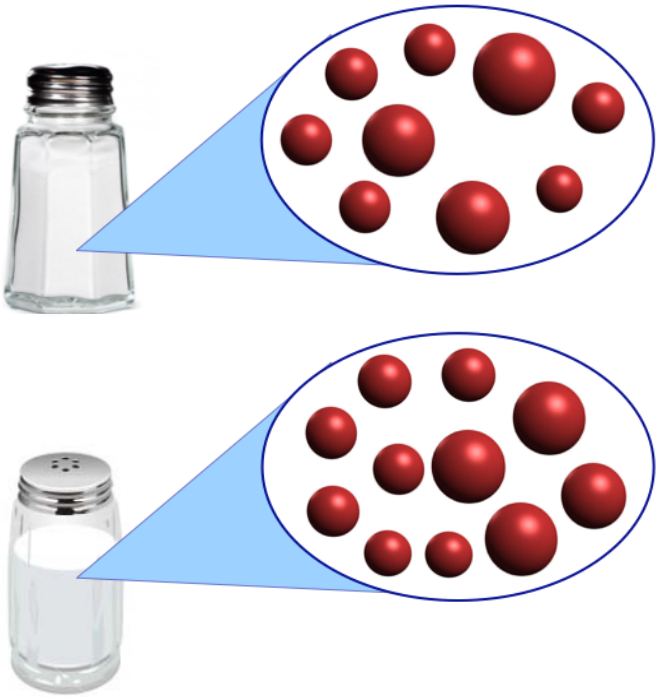
All matter in the universe either has:

Constant properties and composition (like salt).

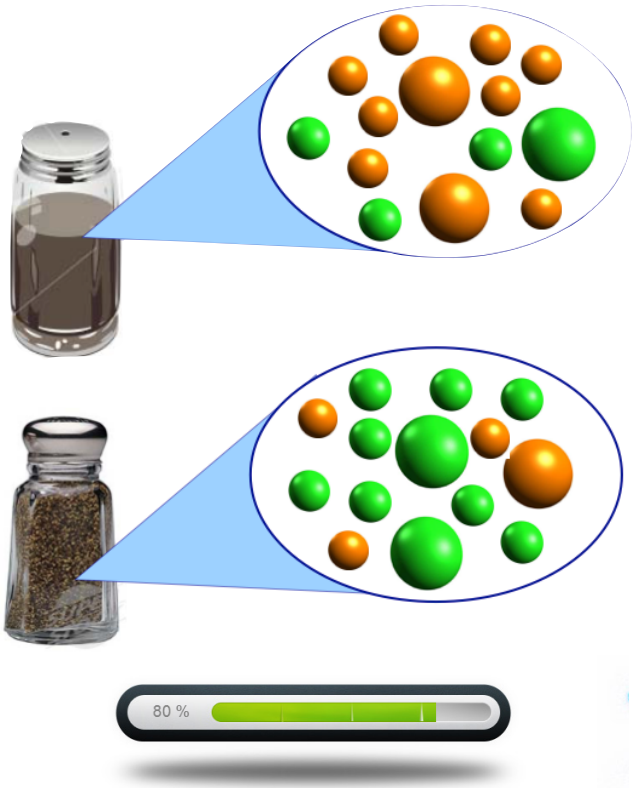
Variable properties and composition (like pepper).

Explaining Salt and Pepper

- Some properties result from the particles that make up matter. Hypothesis
- Some matter (pure matter) is composed of only one kind of particle. Hypothesis
  - So it's properties never change.
- Some matter (mixtures) are composed of more than one kind of particle. Hypothesis
  - So it's properties can vary with the ratio of those particles.



Same taste, same color, same melting point, hardness… Always.



less spicy

more spicy

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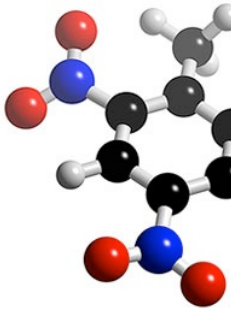
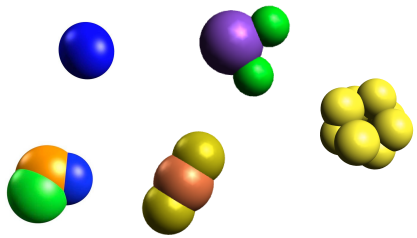




Classifying Matter

- Two important ways matter can differ is by Purity and Consistency.
- Consistency also produces differences in the properties of a sample.
- Let's observe salt, fine ground pepper, and whole pepper.

Salt, Fine Pepper & Whole Pepper

PURE SUBSTANCE

- Salt, pure substance.
  - Different samples:
    - Same composition
    - Same properties
  - Different sections of the same sample:
    - Same composition
    - Same properties

MIXTURES

- Fine pepper, mixture.
  - Different samples:
    - Different composition
    - Different properties
  - Different sections of the same sample:
    - Same composition
    - Same properties

HOMOGENEOUS

- Whole pepper, mixture.
  - Different samples:
    - Different composition
    - Different properties
  - Different sections of the same sample:
    - Different composition
    - Different properties

HETEROGENEOUS

Some matter is not uniform throughout.

Matter that has phases, parts of the matter with distinct physical boundaries in which there are different properties than the rest of the matter, is heterogenous.

Consistency in Mixtures

Sugar mixed with salt.

A heterogeneous mixture that contains phases of salt crystals and sugar crystals.

(one part can taste more salty, another more sweet)

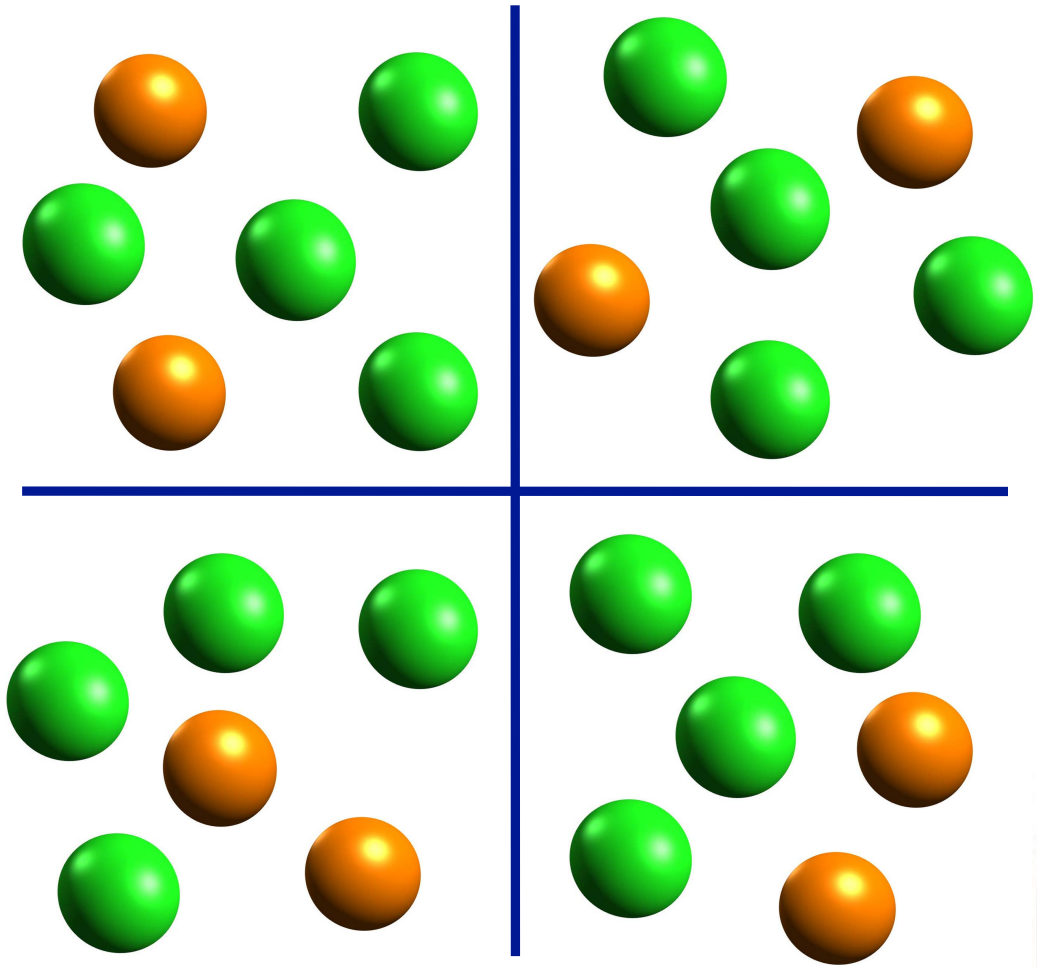
Sugar mixed with water.

A homogeneous mixture that contains one phase.

(every sip tastes just as sweet)

Some Mixtures are Homogenous

- Matter is made up of billions of particles.
- Some mixtures are so well mixed that every time you divide it you get the same stuff.
- That's why every drop of maple syrup on your plate tastes the same.
- No matter how you cut it up, it's the same stuff.
- Even though we know syrup is made of sugar and water (different stuff)



Some Mixtures are Homogenous

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Even though we know syrup is made of sugar and water (different stuff)

Some Mixtures are Heterogeneous

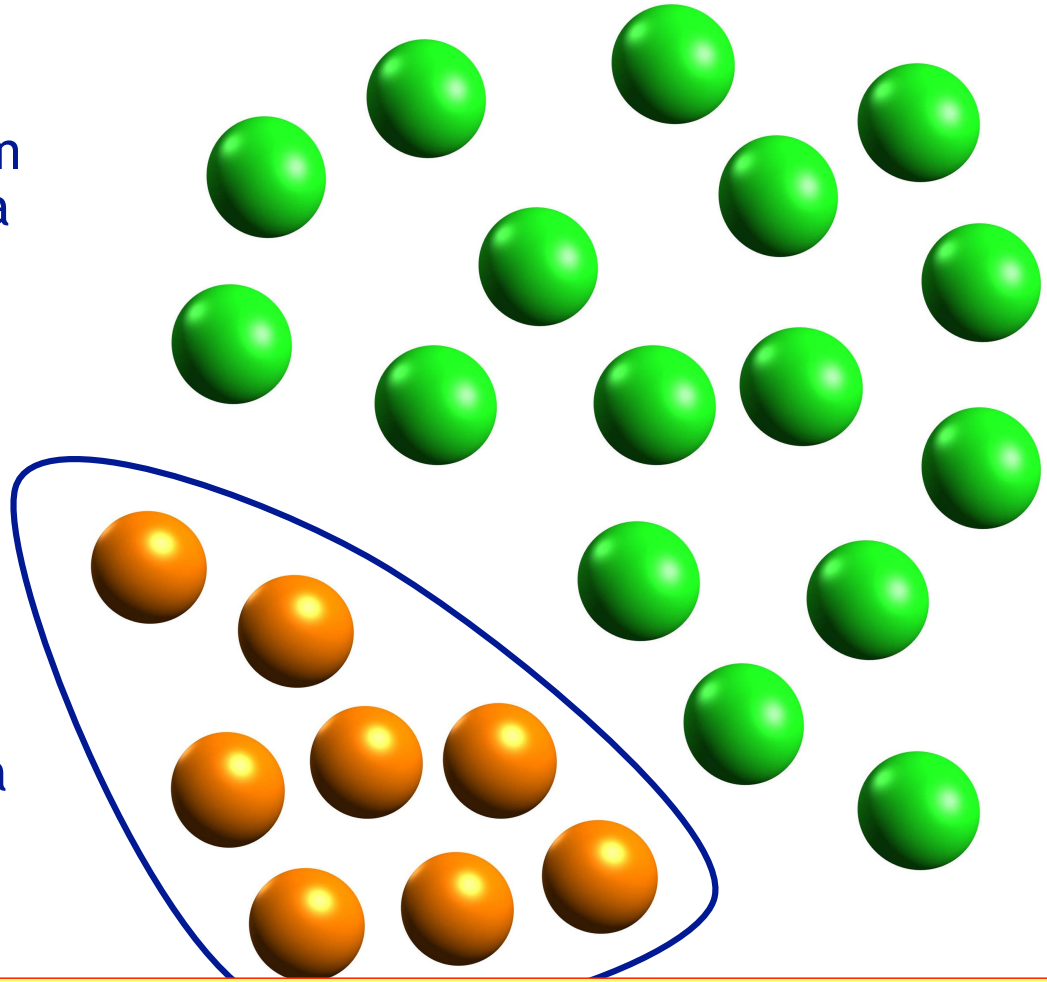
Some mixtures have phases.

A phase is a homogenous part of a system separated from the rest of the system by a physical barrier).

Whenever a system has phases, it is heterogeneous.

Heterogenous systems can have different physical properties in different parts of the system.

That's why every bite of pizza does not taste the same.



A sample is heterogeneous if it has phases.

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Consistency & Purity

Consistency

Does the matter have phases?

NO = homogenous

YES = heterogeneous

YES = mixture

Purity

Does the matter have variable composition, variable properties?

NO = pure substance

(probably)

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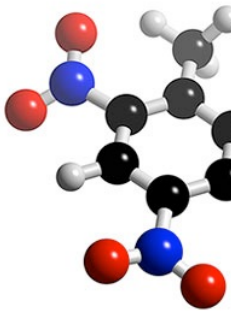
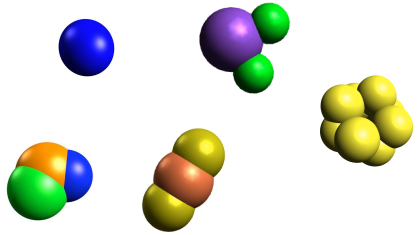


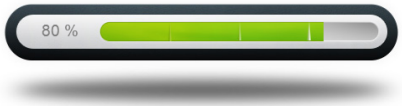


Properties of Matter

- Mixtures have variable properties.

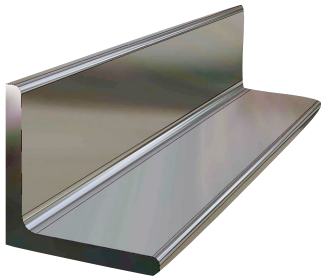
  (Unlike pure substances whose properties never vary.)

  - Chemists build mixtures that meets our needs.
    - We make a drink more sweet, by mixing in more sweet stuff (sugar).
    - We make a paint more red, by mixing in more red stuff (red dye).
    - We make a ring that's more shiny, by mixing in more shiny stuff (gold).



- The properties of mixtures are a blending of the properties of the pure stuff that is mixed together to make them.
  - In a mixture, there is some stuff in it which provides that physical property.
  - It's useful to identify the source of those properties.
  - It's useful to separate out the pure substances that provide that property.
    - This gives us a palette to work with.
    - A concentrated source of a property.

- Chemists spend a lot of time, separating mixture and isolating pure substances.
- We take advantage the different physical properties of the pure substances in a mixture to separate those pure substances.



Iron Brimstone

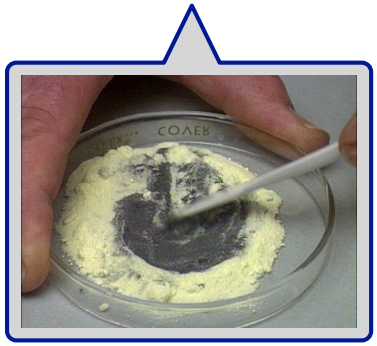
- A fireworks additive called iron brimstone can be made by stirring pure iron powder into pure sulfur powder.
- Pure iron always burns the same way. Pure sulfur always burs the same way.
- Iron Brimstone can burn differently. It burns hotter or brighter depending on the ratio of iron to sulfur you combine.
  - We hypothesize Iron Brimstone's variable behavior is because it is a mixture of iron particles and sulfur particles.
  - We hypothesize Iron Brimstone still contains the original sulfur and iron particles.
- We can test that hypothesis by putting a magnet to Iron Brimstone and pulling the pure iron particles out of the mixture.

Iron

- hard to burn
- burns bright yellow

Sulfur

- easy to burn
- burns dull



Fireworks Additive

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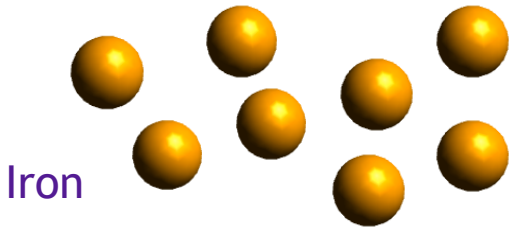

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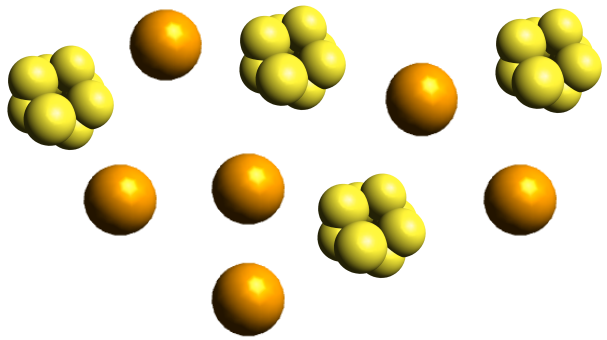

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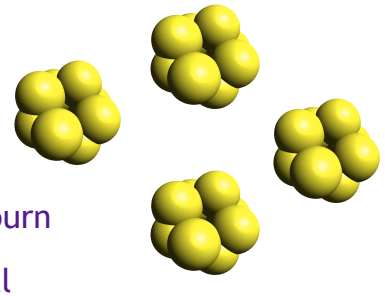

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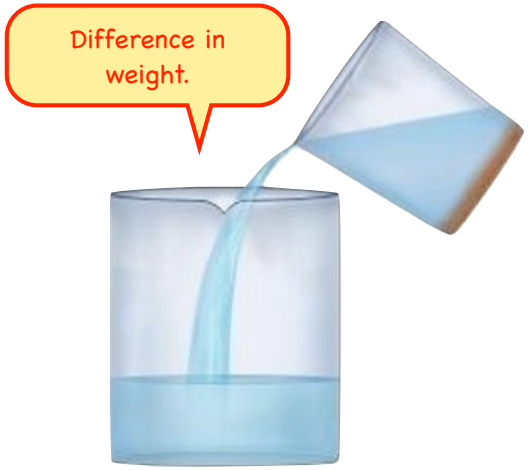
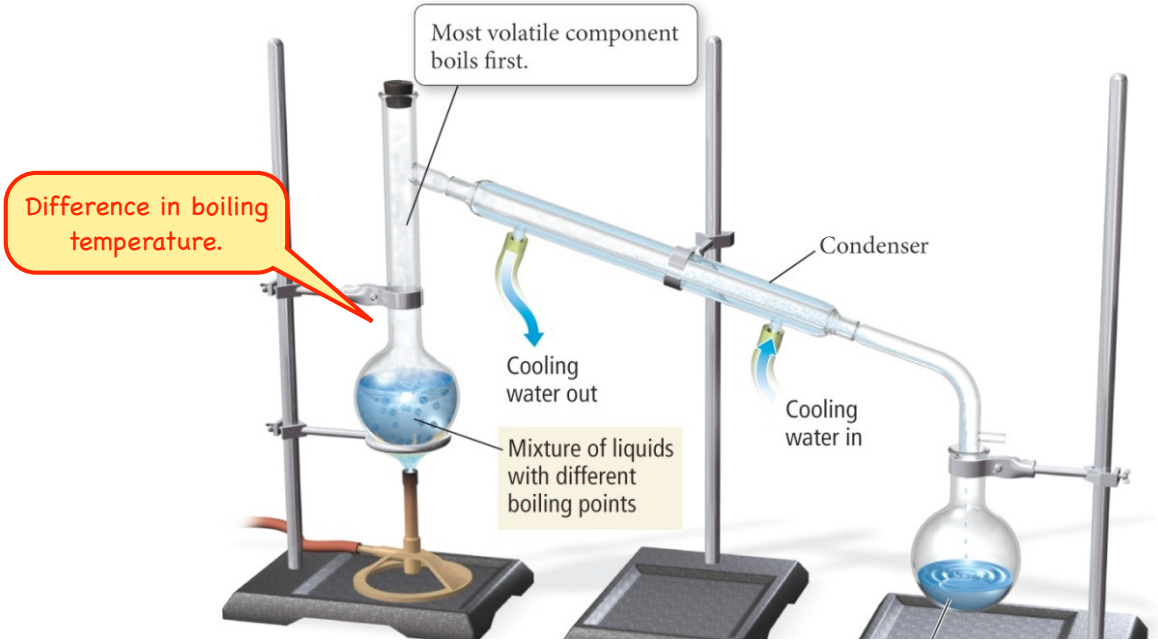
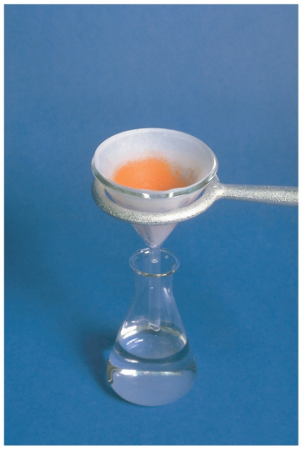
- We take advantage the different physical properties of the pure substances in a mixture to separate those pure substances.
  - Decanting: A mixture of sand and water can be separated by decanting—carefully pouring off the water into another container.
  - Distillation: A mixture of liquids can usually be separated by distillation, a process in which the mixture is heated to boil off the more volatile (lower boiling) liquid. The volatile liquid is then re-condensed in a condenser and collected in a separate flask.

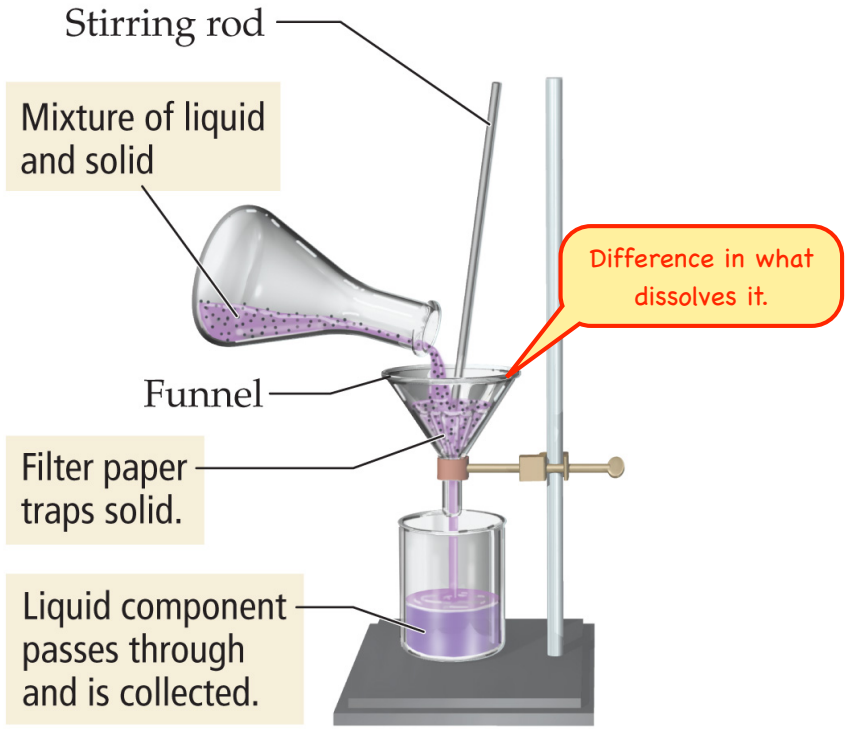




Properties of Matter

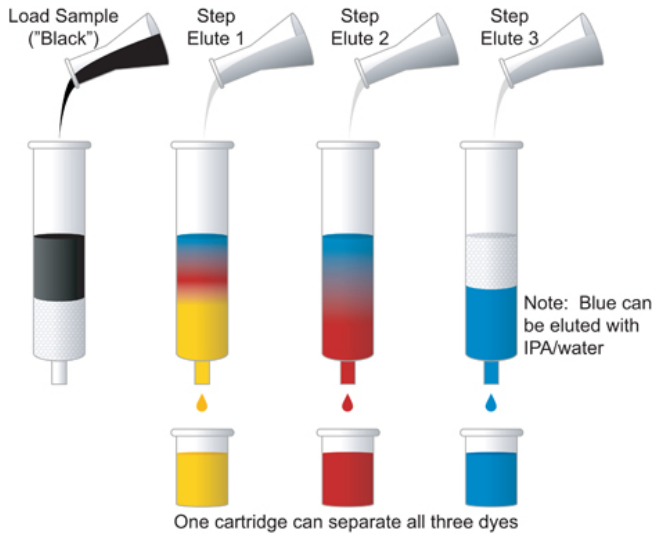
- Chemists spend a lot of time, separating mixture and isolating pure substances.
- We take advantage the different physical properties of the pure substances in a mixture to separate those pure substances.
  - Filtration: A mixture of an insoluble solid and a liquid can be separated by filtration—process in which the mixture is poured through filter paper in a funnel. Most coffee machines rely on this process to separate the mixture of coffee beans and coffee beverage.

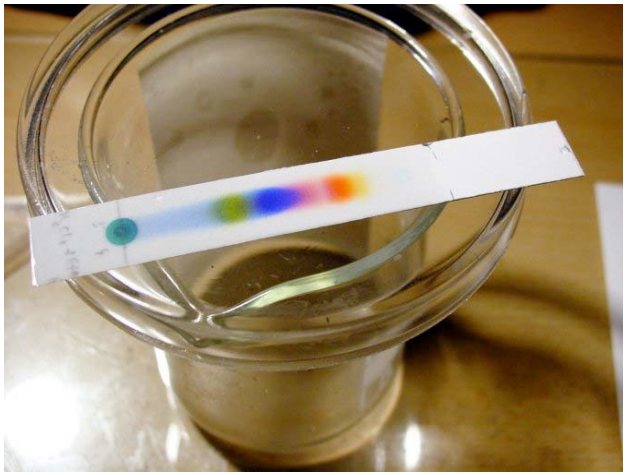


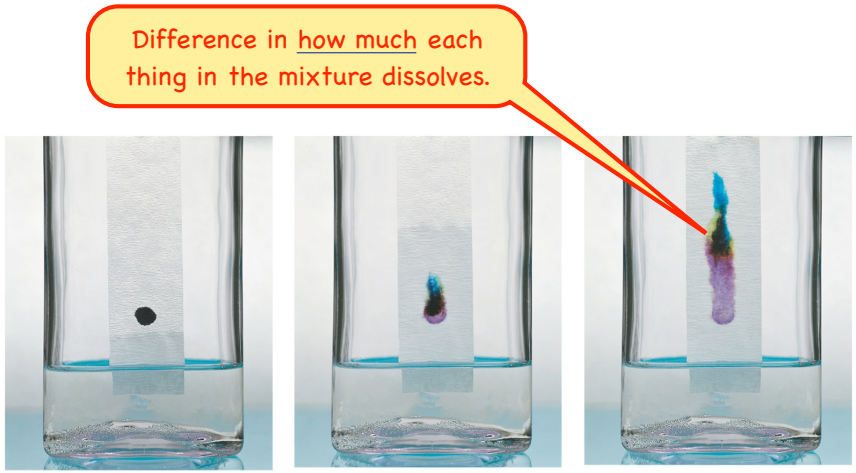


Properties of Matter

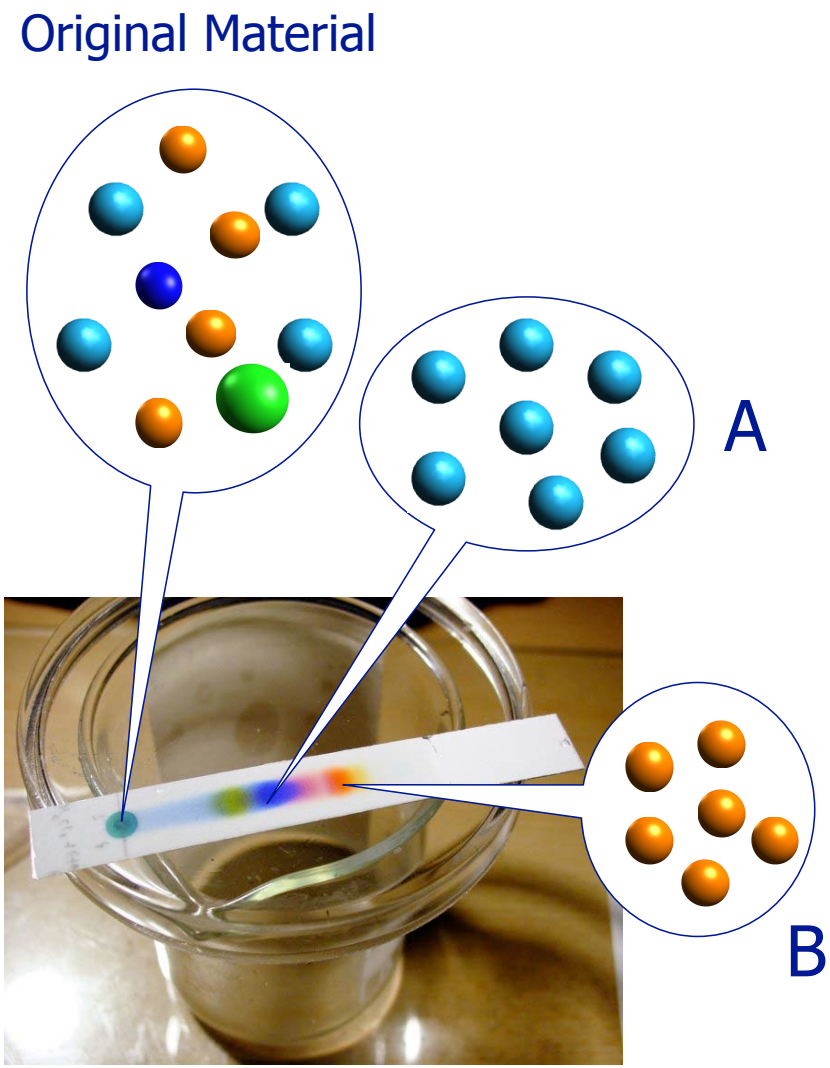
- Chemists spend a lot of time, separating mixture and isolating pure substances.
- We take advantage the different physical properties of the pure substances in a mixture to separate those pure substances.
  - Chromatography separates substances when both are soluble, but one is *more* soluble than the there other.
  - Column Chromatography: runs samples down a tube filled with silica gel. The more soluble material is more easily carried along by the solvent.
  - Thin Layer Chromatography: runs samples up a silica plate coated with silica gel.







Separating Mixtures



If you can physically separate a substance into samples with different properties —it must be a mixture.

Two ways to demonstrate a mixture:

(1) Find two samples of the substance, where one has weaker properties than another.

(2) Separate a substance into two samples, where where one has weaker properties than another.

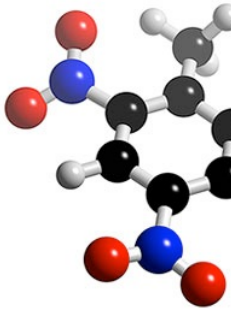
A pure substance will always have the same properties.

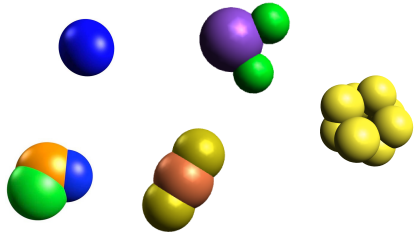
Ch01

Matter

- Understanding Matter
  - Composition, Structure, Properties, and Reactions.
  - Atomic Theory
    - The first theory of chemistry.
- Properties of Matter
  - Extensive Properties
  - Properties of State
    - Gas, Liquid & Solid States
  - Classifying Matter
    - Different Purity
      - Pure Substances & Mixtures
    - Different Consistency
      - Homogenous & Heterogeneous

- Separating & Combining Matter
  - Mixtures
    - Blending Existing Properties
    - Separating Mixtures based on difference in properties.
    - Decantation, Filtration, Distillation, Chromatography
  - Compounds
    - New Properties
  - Reactions
    - Chemical Changes
    - Chemical Properties
- A closer look at those particles…
  - Atoms, Molecules, & Ions





When new properties appear.

- Sometimes when we combine substances, a new property appears.
- Properties define substances.
  - A new property means a new substance has appeared.
  - There is a fundamental difference between combing matter to form a mixture and transmuting it into a new substance.

- A cow, a dog, and a cat go into an empty room. It doesn't surprise you to hear a mixture of barking, mooing, and meowing coming out of it.

- A cow, a dog, and a cat go into an empty room. Then you hear a bird singing from the room… that's different.

Experiment: Iron & Sulfur

Iron

- hard to burn
- burns bright yellow

stir together

heat & pressure

Iron Pyrite

- does not burn
- lustrous (shiny)
- maleable
- not attracted to magnets
- cannot be separated mechanically
- has constant properties
- is always 46.6% iron and 53.4 % sulfur
- a pure substance

Sulfur

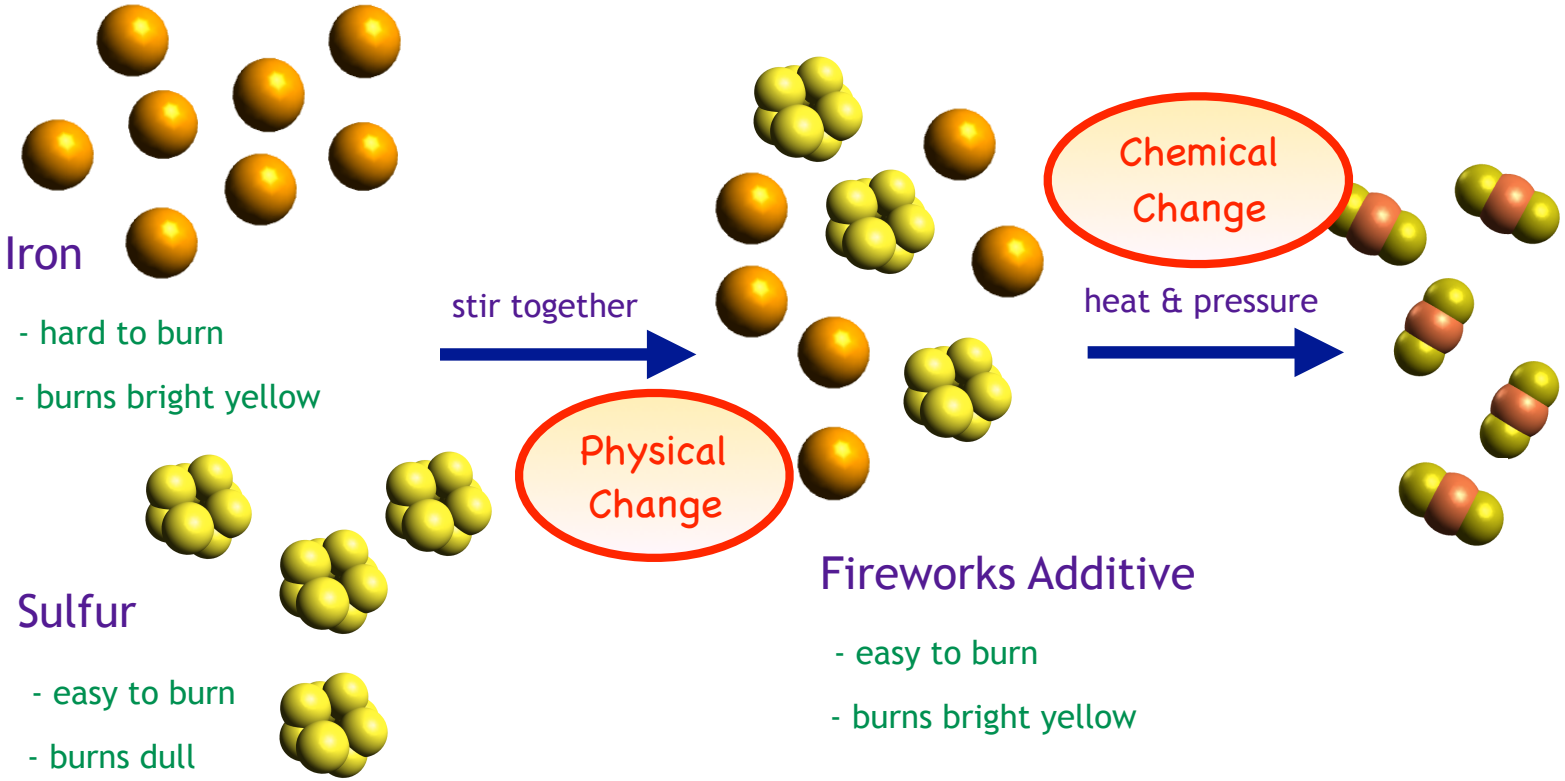
- easy to burn
- burns dull

Fireworks Additive

- easy to burn
- burns bright yellow

- How did we go from a mixture to a pure substance?
  - We changed the particles — we created a new substance.
- We know a new substance was created because we see properties that didn't exist before.
  - Not just more or less of a property that was already there, but something entirely new.
- We can isolate a pure substance that did not exist in the original mixture.
- A new substance, responsible for the new properties.

Experiment: Iron & Sulfur



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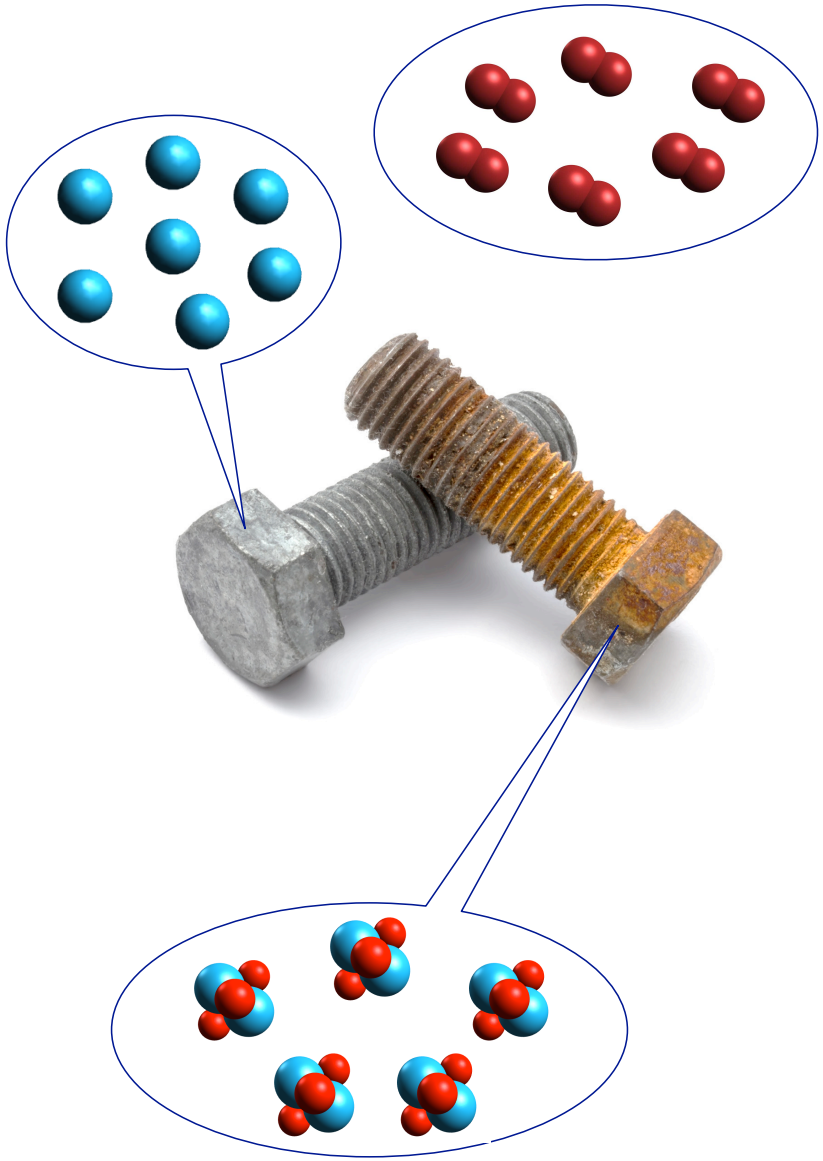
Chemical Change

A chemical change (reaction) occurs if new substances are formed.

During a chemical change, particles change, transforming the original substances into different substances.



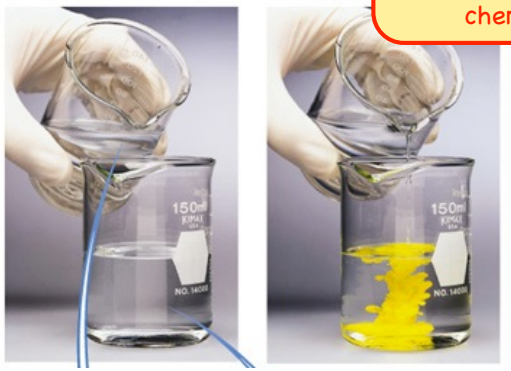
You know a new substance has formed if you see new properties.

Regardless of what new properties you see, any new property indicates a new substance has been created.

Observing Chemical Change

- We change matter in many ways.
- Physical changes alter the state or appearance of matter, but do not result in new substances.
  - Tearing paper, boiling water, melting iron, cutting wood.
  - It's the same substance before and after, the form just changes.
- Chemists are more interested in changes that produce new substances.
  - The transmutation of matter.
- Chemical change, chemical reactions, are those which result in new substances are produced.
- If a new substance is formed, new properties will appear.
  - Not just an enhancing, dulling, or blending of existing properties.
    - If you mix something salty with something tasteless, a "less salty" result is not a new property.
    - If you mix something yellow and something red, an orange result is not a new property.
    - If you mix two spicy things, a very spicy result *probably* is not a new property.
  - Evidence of a chemical change is a property that distinctly did not exist before the reaction.
    - Mixing two liquids a producing a gas (bubbles) is evidence.
    - Mixing two clear liquids and producing an orange product is evidence.
    - Mixing something salty and something sour and producing something sweet is evidence.
    - Mixing something that smells like roses with something that smells like honey and producing something that smells like rotten eggs is evidence.
- Chemical reactions often capture or release energy. (we'll talk about this more in chapter 5)
  - The appearance of heat, flames, or absorbing heat is evidence of energy being released or captured.

Three indicators of a chemical change.



new color

heat

bubbles

Properties of Chlorine

Physical properties exist without chemical reaction.

Physical Properties

- gas at room temperature
- 2.4 times heavier than air
- color is yellowish-green
- odor is disagreeable
- melting point -101˚C
- boiling point -34.6˚C
- dissolves in water

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Chemical Properties

- It will not burn in oxygen.
- It will support the combustion of certain other substances.
- It can be used as a bleaching agent.
- It can be used as a water disinfectant.
- It can combine with sodium to form sodium chloride.

Chemical properties are related to chemical reactions.

Ch01

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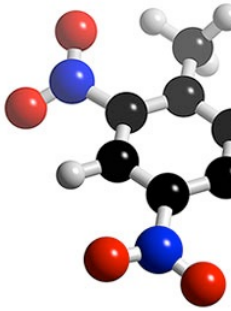
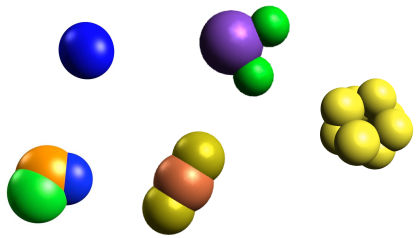
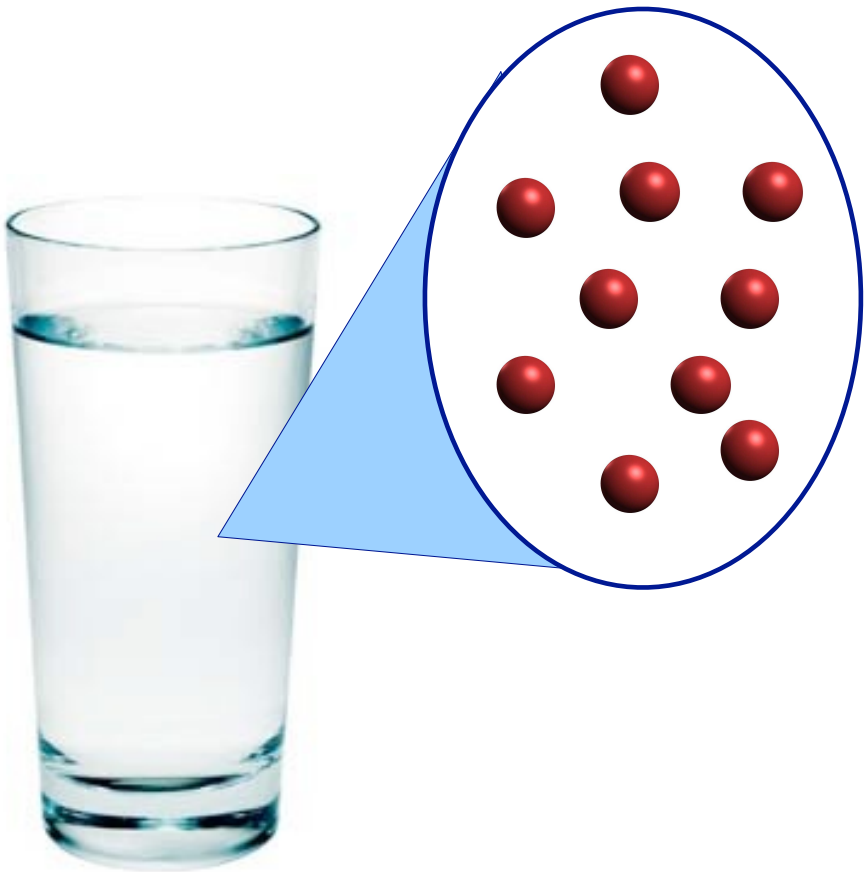


A closer look at those particles…

- Atoms, Molecules, & Ions



Atoms, Molecules, & Ions



- A pure substance is made up of identical particles.
- We haven't talked about how those particles can differ from particles in a different pure substance.
  - Next chapter we'll start a very long conversation on that topic.
- For now, let's just say those particles can be made up of different flavored pieces called atoms.

Atoms, Molecules, & Ions

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- We haven't talked about how those particles can differ from particles in a different pure substance.
  - Next chapter we'll start a very long conversation on that topic.
- For now, let's just say those particles can be made up of different flavored pieces called atoms.
- If all the atoms in a substance are the same flavor, we call it an element.
- Elements are those 118 substance that can not be broken down by chemical reaction.
- Everything else is a compound.

Experiment: Oxygen & Hydrogen

hydrogen

properties:
gas at room temp
burns easily
colorless
lighter than air

oxygen

properties:
gas at room temp
helps things burn
colorless
lighter than air

Physical Change

mixture of hydrogen & oxygen

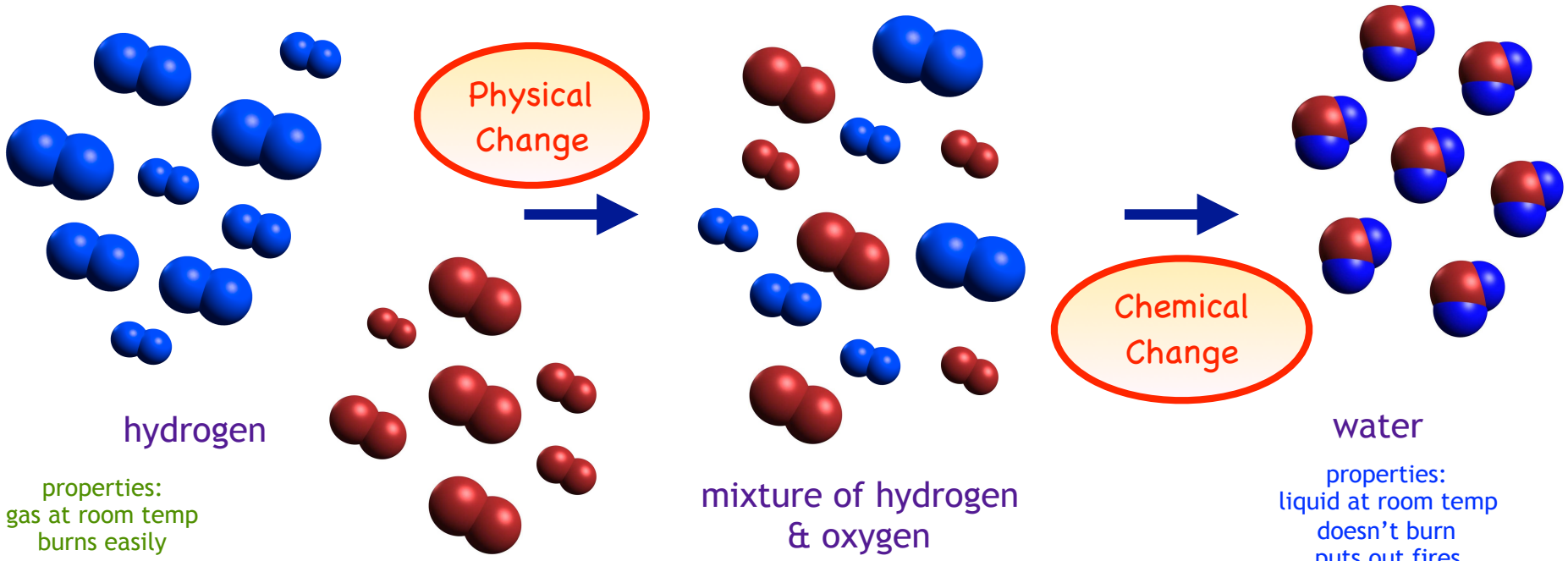
properties:
gas at room temp
burns *really* fast
colorless
lighter than air

Chemical Change

water

properties:
liquid at room temp
doesn't burn
puts out fires
colorless
heavy

Experiment: Oxygen & Hydrogen



hydrogen

properties:
gas at room temp
burns easily
colorless
lighter than air

oxygen

properties:
gas at room temp
helps things burn
colorless
lighter than air

mixture of hydrogen & oxygen

properties:
gas at room temp
burns *really* fast
colorless
lighter than air

water

properties:
liquid at room temp
doesn't burn
puts out fires
colorless
heavy

Elements & Compounds

propane

carbon dioxide

water

carbon dioxide

carbon

oxygen

water

hydrogen

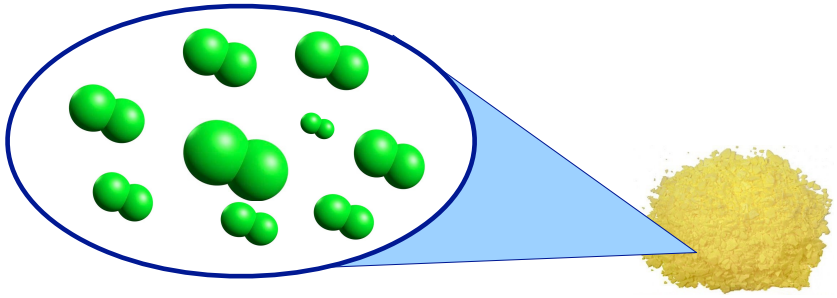
oxygen

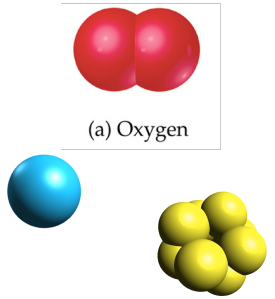
oxygen

- We can use chemical reactions to break down substances.
- If you burn propane that chemical reaction produces carbon dioxide and water.
- That mixture can be separated into pure substances.
- Those substances an be broken down into still more substances by chemical reaction.
- Every substance we know can be broken down.
- **Except for 118 known substances.** Like oxygen.
- There's something different about elements.

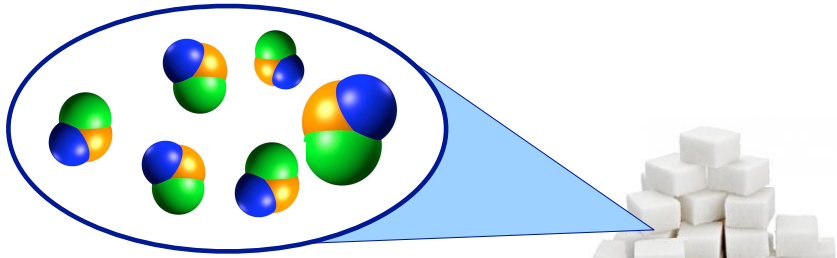
Elements & Compounds

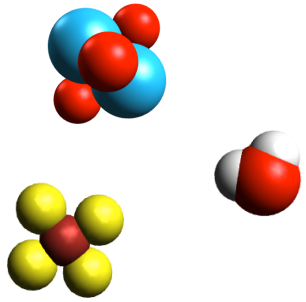
We use the word element two ways: it's used to describe the flavor of an atom and it's also how we name a substance made only of that flavor atom.





	Particle	Substance
1 kind of atom	Element or Ion	Element
2 or more kinds of atoms	Molecule or Ion	Compound





- Atoms are the building blocks of matter.
- Each element is made of only one kind of atom.
- A compound is made of two or more different kinds of elements.

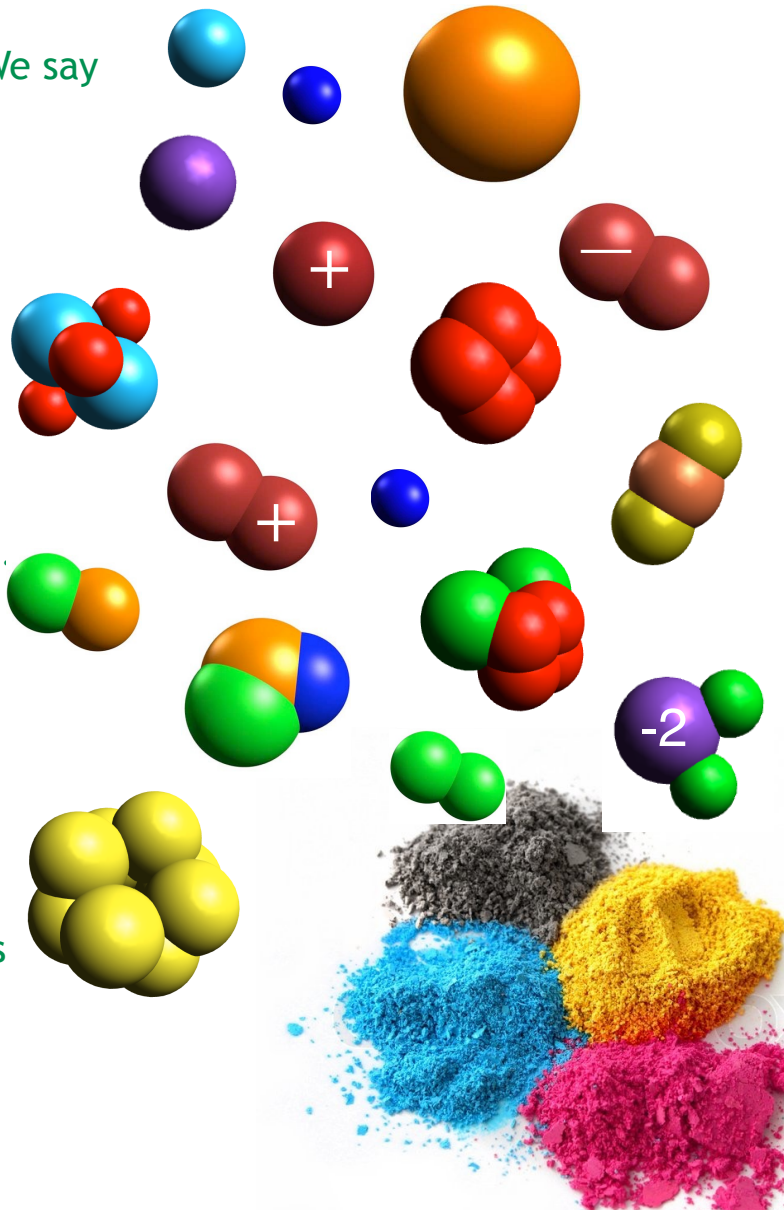
An Overview of Atom Size Particles

We will discuss the details of these differences in the next few chapters. For now, I just want to share the "big picture" with you.

This slide will reappear a lot. in upcoming lectures.

. We say particle when we want to be vague or comprehensive.

- Matter is made up of either ions or molecules.
  - Ions are charged particles (+ or -).
  - Molecules are neutral particles (no charge).
- Ions and molecules are made up of atoms.
  - Monatomic particles are just a single atom.
  - Diatomic particles are particles made of two atoms.
  - Polyatomic particles are made of more than two atoms.
- Atoms come in 118 flavors (elements).
  - If a sample of matter contains only one flavor atom, we say that sample is an element.
    - Yes, we use the word element two ways!
  - If a sample of matter contains two elements we say it is a binary compound or just a compound.
  - If a sample of matter contains more than two elements we say that sample of matter is a compound.



Questions?