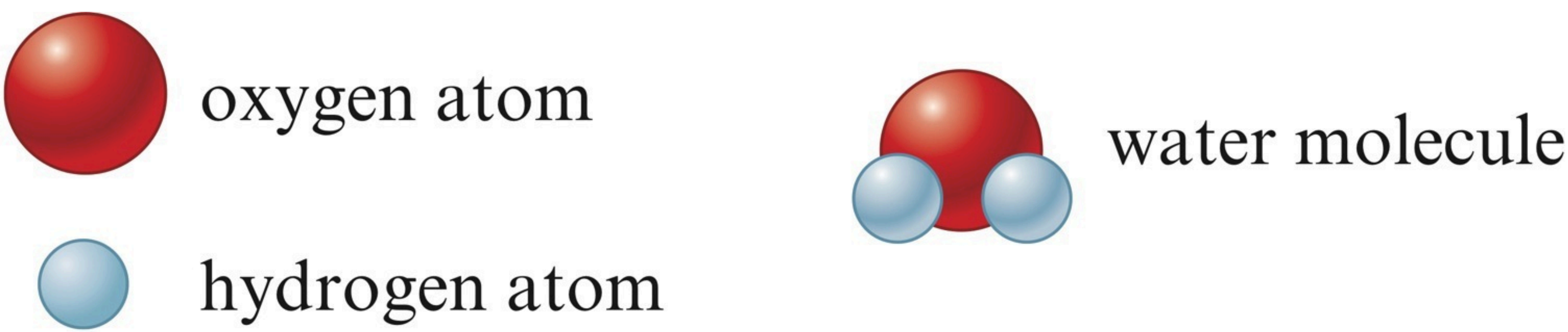
Ch 3. Matter and Energy

Matter

Atoms and Molecules

Matter is composed of fundamental particles called atoms.

- Atom: Basic building block of matter
- Molecule: A group of two or more atoms joined together and acting as a unit.



States of Matter

Three physical states (phases) of matter:

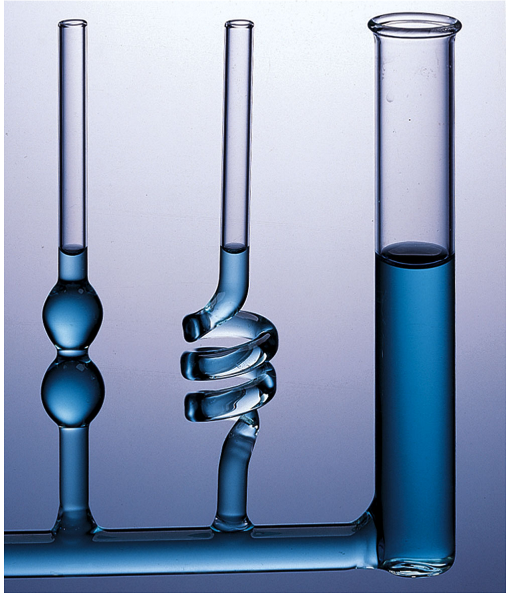
- Solid
- Liquid
- Gas

Physical State: Solid

- Rigid; has a fixed volume and shape
- Examples:
  - Ice cube, diamond, iron bar

Physical State: Liquid

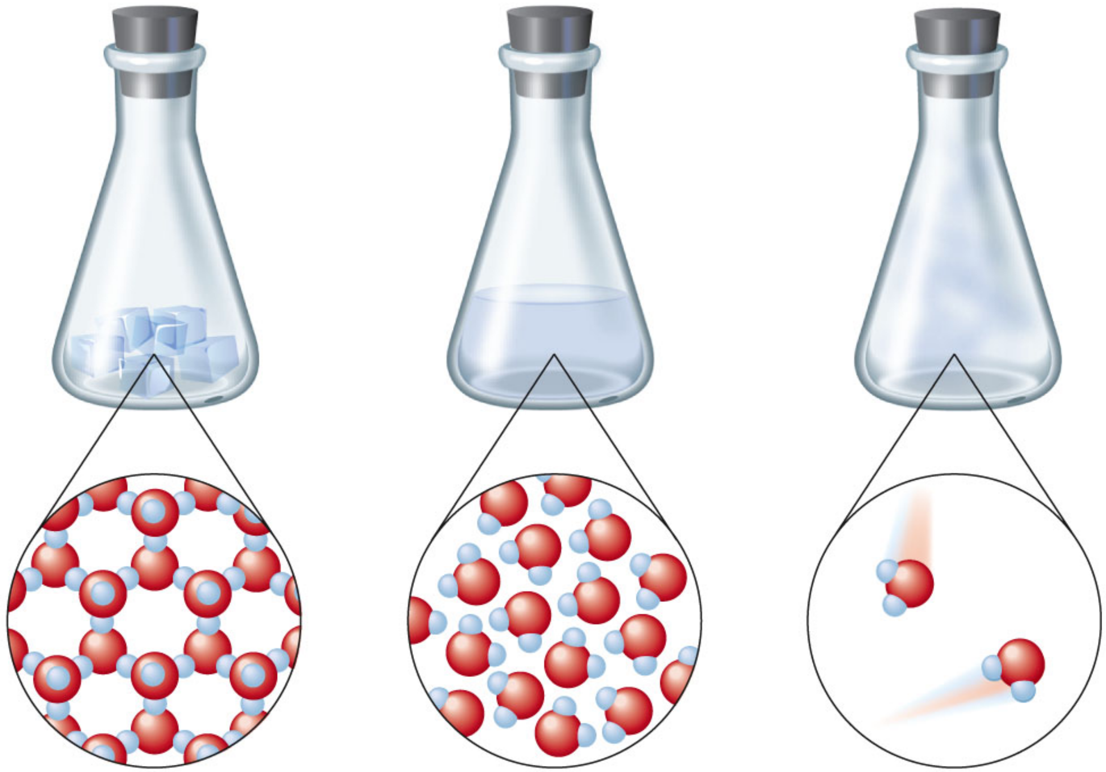
- Has a definite volume but no specific shape (takes shape of container)
- Examples:
  - Gasoline, water, alcohol, blood



Physical State: Gas

- Has no fixed volume or shape (takes the volume and shape of its container)
- Examples:
  - Air, helium, oxygen

Particle View: Three States of Water



Solid
Close together, fixed position

Liquid
Still close together, more movement

Gas
Far apart, random movement

Physical vs. Chemical Properties

Physical Properties

- Characteristics of matter that can be directly observed or measured.
- Characteristics that, if changed, do not change the chemical composition of the matter
- Examples:
  - Odor, color, mass, volume, state (*s*, *l*, or *g*), density, melting point, boiling point

Physical vs. Chemical Properties

Chemical Properties

- Characteristics that describe the behavior of matter
- A substance's ability to form new substances (i.e., to change its chemical composition)
- Examples:

  Flammability (burning), corrosiveness, reactivity with acids

Question: Physical vs. Chemical Properties

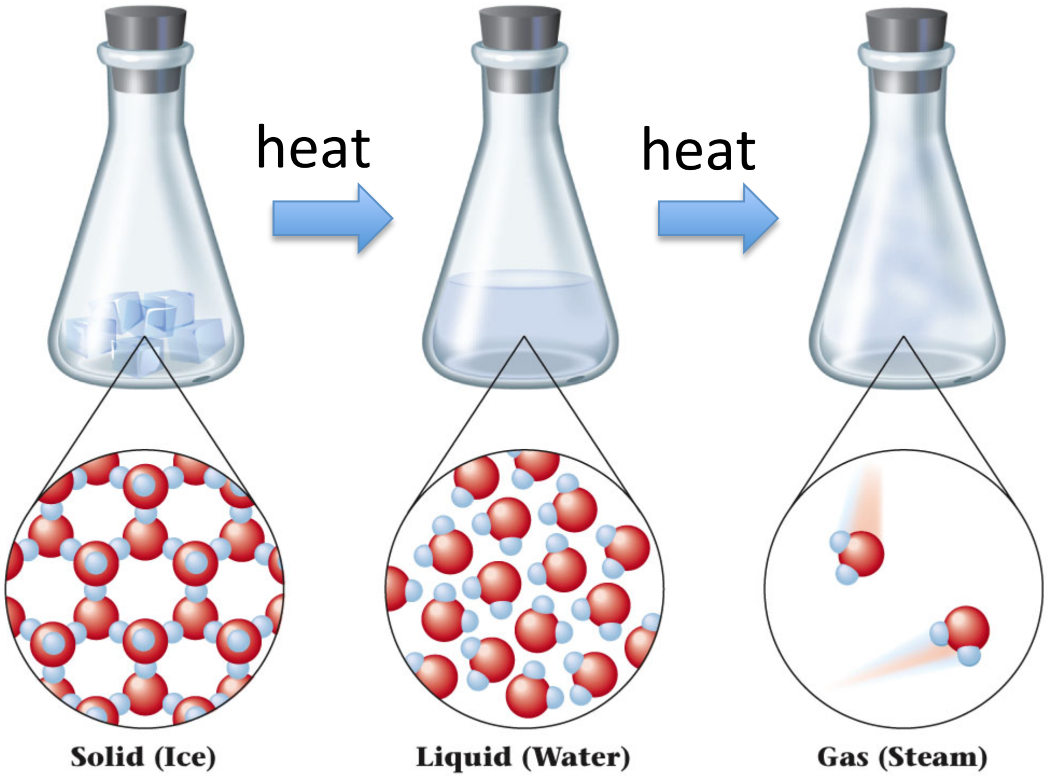
Q: Physical or chemical property?

- Freezing point of water at 0 °C
- Explosiveness of hydrogen gas
- Hardness of a diamond
- Flammability of propane
- High density of lead

Physical vs. Chemical Changes

- Physical Change
- Change in the *physical* properties of a substance, not in its chemical composition (No new substance formed!)
  - Examples: Boiling or freezing of water (change in state)
- Chemical Change = Chemical Reaction
  - Involve a change in chemical composition; a given substance changes into a different substance(s)
  - Examples: Wood burning, iron rusting

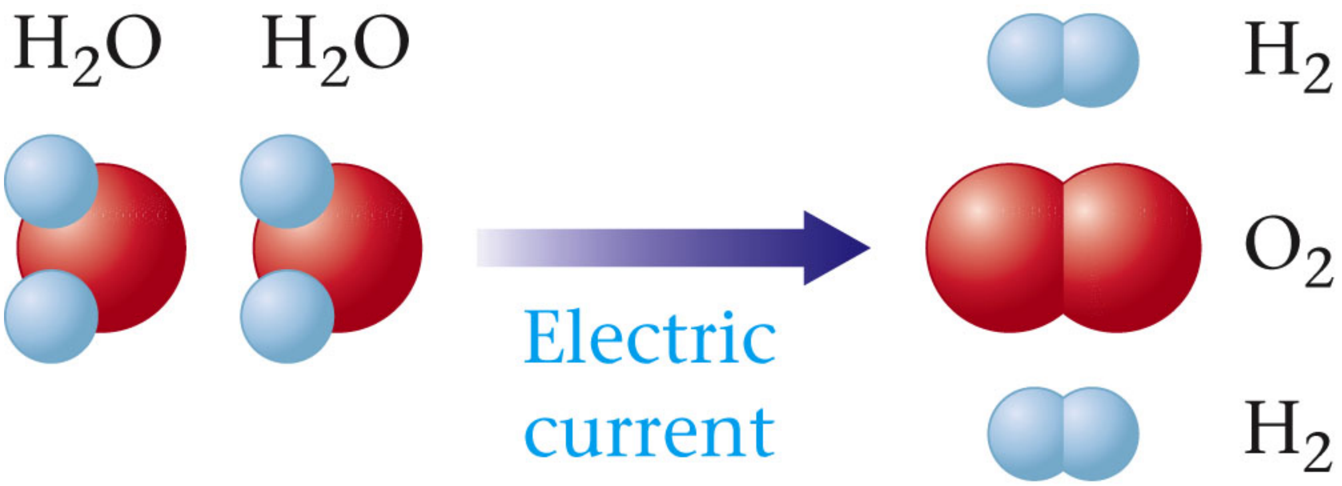
Physical Change of Water



- Phase change: In all three states, water molecules are still intact.
- Only motions of molecules and the distances between them change.

Chemical Change of Water

- Electrolysis of Water
  - Water decomposes to hydrogen and oxygen gases.



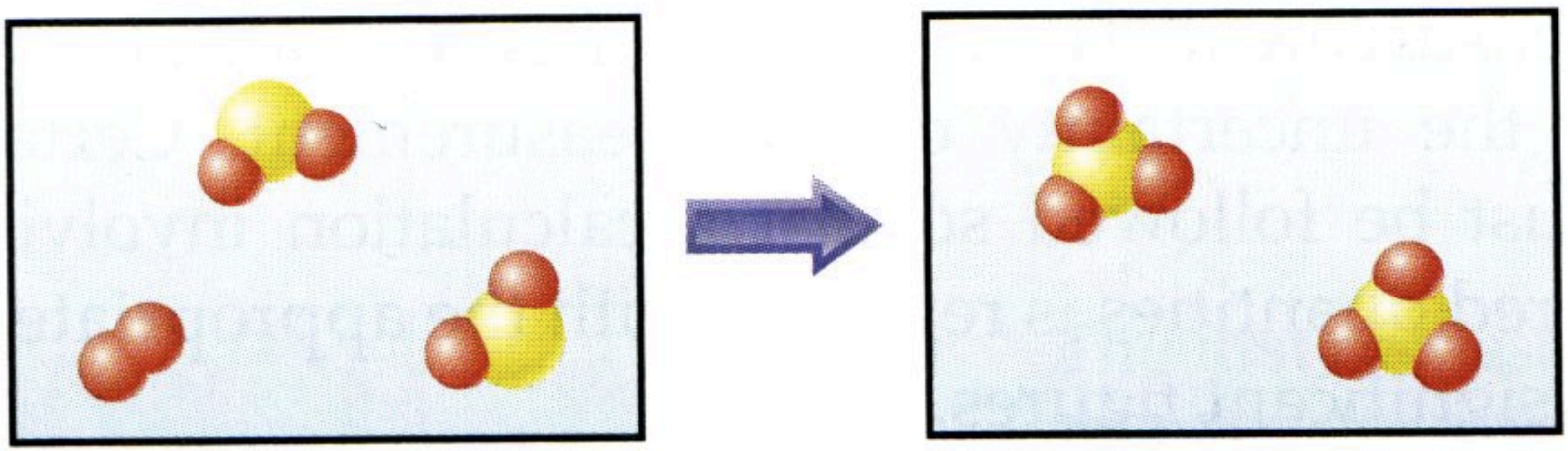
Question #1: Physical or Chemical Change

Physical or chemical change?

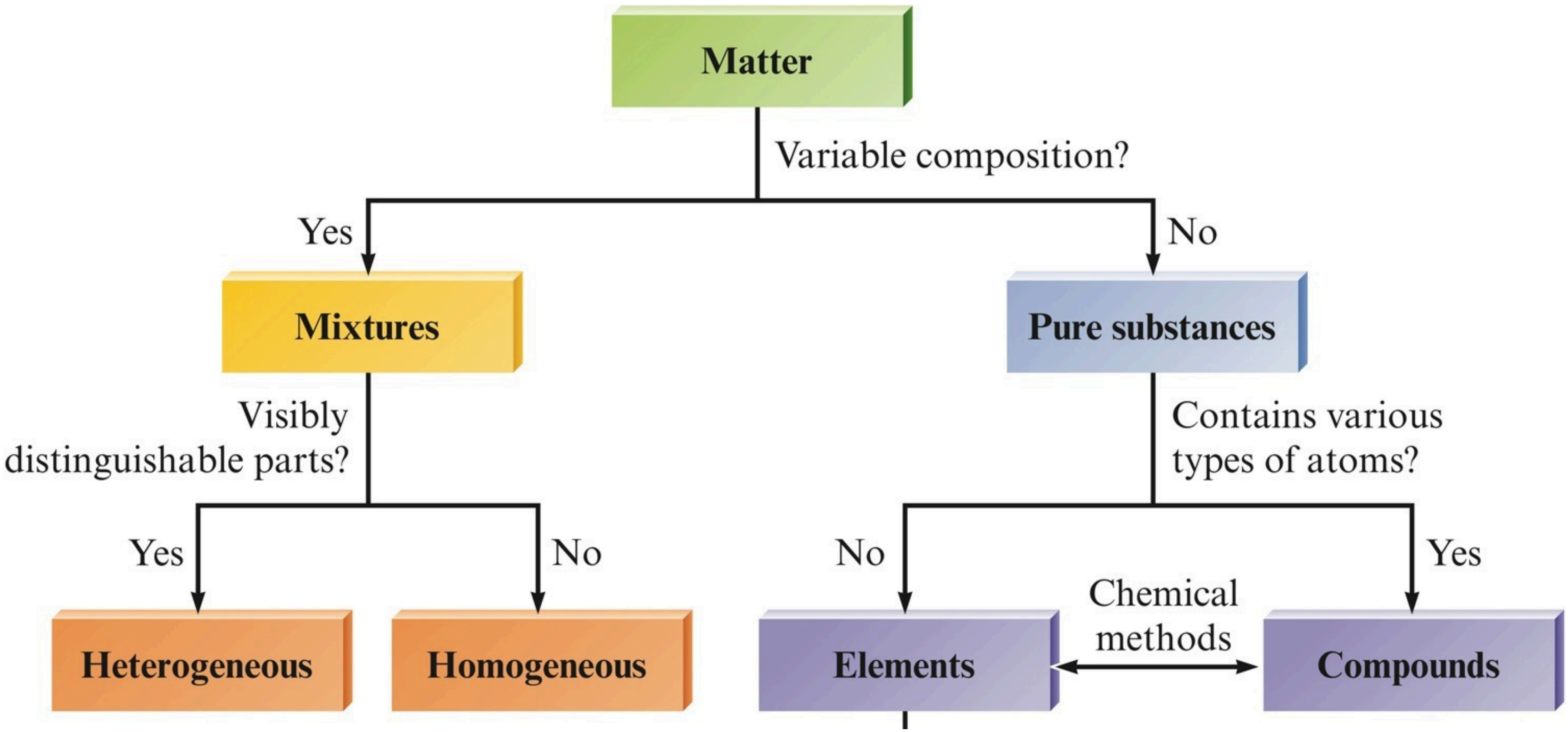
- Pulverizing (crushing) rock salt
- Sugar fermenting to form ethyl alcohol
- Dissolving of sugar in water
- Melting a popsicle on a warm summer day
- Iron combining with oxygen to form rust
- Steam from shower condenses on mirror

Question #2: Physical or Chemical Change

Is the following a physical or chemical change?



Different Categories of Matter



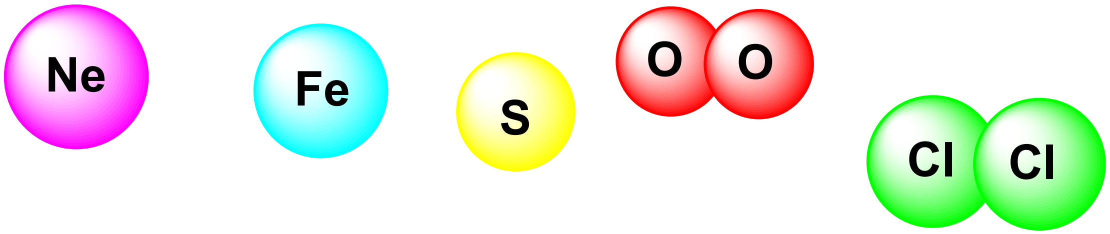
Elements vs. Compounds

A pure substance can be

Element or Compound

Elements

- Elements: Fundamental substances that cannot be broken down into other substances by chemical means
- Examples: Iron (Fe), aluminum (Al), oxygen (O_2), hydrogen (H_2)   [periodic table of the elements]
- Particle view: Each element contains only one type of atom (a basic building block of matter).



Elements

- All matter can be broken down chemically into about 100 different elements
- 88 elements are natural, and the rest are man-made.
- Elements vary tremendously in abundance.

Elements: Abundance on Earth

Table 4.1 Distribution (Mass Percent) of the 18 Most Abundant Elements in the Earth's Crust, Oceans, and Atmosphere

Element	Mass Percent	Element	Mass Percent
oxygen	49.2	titanium	0.58
silicon	25.7	chlorine	0.19
aluminum	7.50	phosphorus	0.11
iron	4.71	manganese	0.09
calcium	3.39	carbon	0.08
sodium	2.63	sulfur	0.06
potassium	2.40	barium	0.04
magnesium	1.93	nitrogen	0.03
hydrogen	0.87	fluorine	0.03
		all others	0.49

Elements: Abundance in Human Body

Table 4-2 Abundance of Elements in the Human Body

Major Elements	Mass Percent	Trace Elements (in alphabetical order)
oxygen	65.0	arsenic
carbon	18.0	chromium
hydrogen	10.0	cobalt
nitrogen	3.0	copper
calcium	1.4	fluorine
phosphorus	1.0	iodine
magnesium	0.50	manganese
potassium	0.34	molybdenum
sulfur	0.26	nickel
sodium	0.14	selenium
chlorine	0.14	silicon
iron	0.004	vanadium
zinc	0.003	

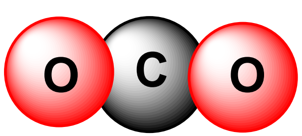
Compounds

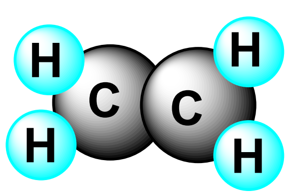
- Compounds: Substances made of least two different elements, that can be broken down into elements by chemical means

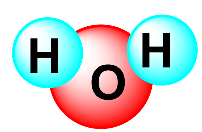
chemical changes

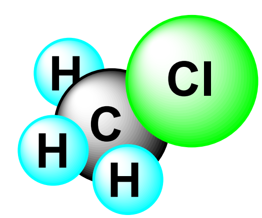
Compound → Elements

- Examples: Water (H_2O), carbon dioxide (CO_2), table sugar ($C_{12}H_{22}O_{11}$)
- Particle view: Each compound is made of atoms of least two different elements; *always has the same composition*.









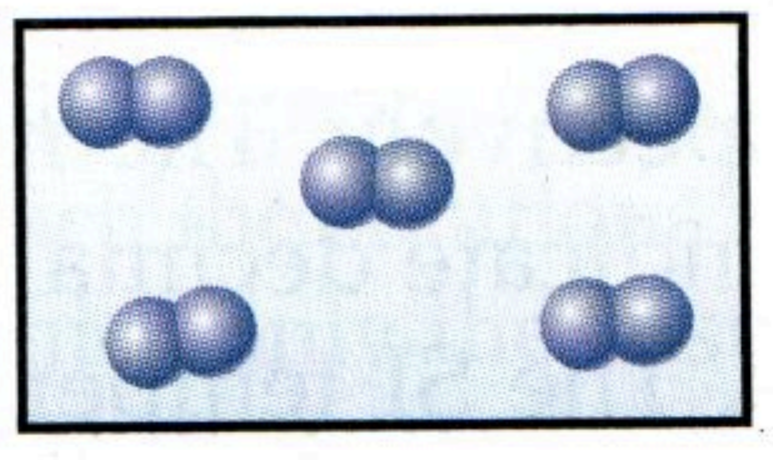
Question #1: Elements or Compounds

Which of the following are compounds?

- H_2O
- NaOH
- MnO_2
- H_2
- HF
- Ca

Question #2: Elements or Compounds

- Which one is a compound?



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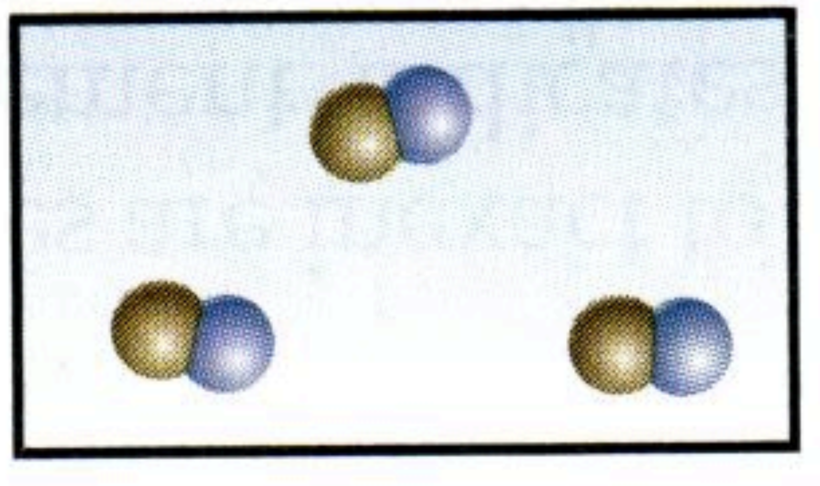

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Mixtures

Mixture

- Is a mix of different elements and/or compounds
- Has variable composition
- Can be separated into pure substances by physical means

Mixture —physical changes→ two or more pure substances

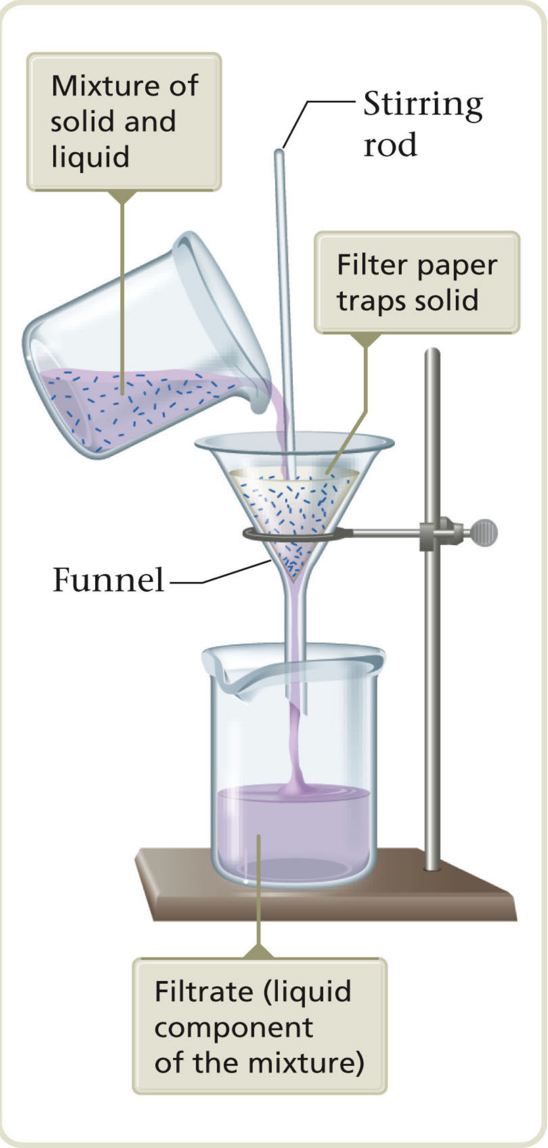
- Examples: Sea water, wood, wine
- Most substances in nature occur as mixtures.

Two Types of Mixtures: Homogeneous and Heterogeneous

- Homogeneous mixture
  - Same throughout; every region is same
  - Also called *solution*
  - Examples: Table salt dissolved in water, air, brass (copper and zinc)
- Heterogeneous mixture
  - Have different regions with different properties
  - Example: Sand and water mixture, oil and vinegar

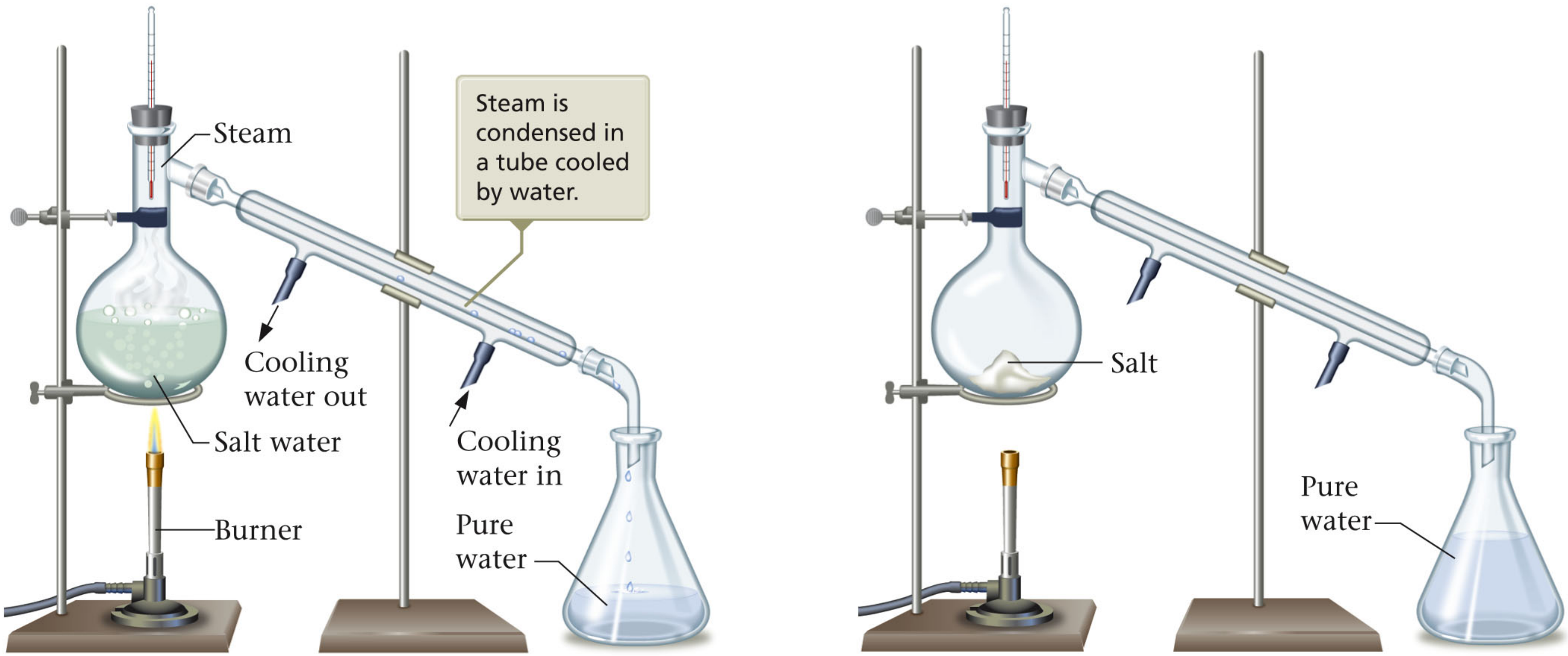
Separation of a Heterogeneous Mixture: Filtration

Filtration of sand and water mixture (difference in physical states)



Separation of a Homogeneous Mixture: Distillation

Distillation of Salt Water Solution (difference in boiling points)



Question #1: Pure Substances and Mixtures

Pure substance, homogeneous mixture, or heterogeneous mixture?

- Distilled water
- Mouthwash
- Jar of jelly beans
- Gasoline
- Soil
- Copper metal
- Oil and vinegar salad dressing
- Table salt
- Chocolate chip cookie

Energy: Introduction

Energy: Introduction

Energy

The two major components of the universe:

- Matter
- Energy

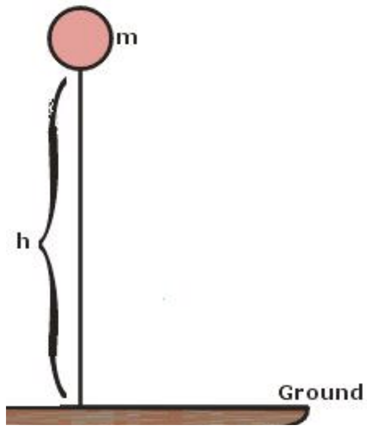
Energy

Energy: capacity to do work or produce heat

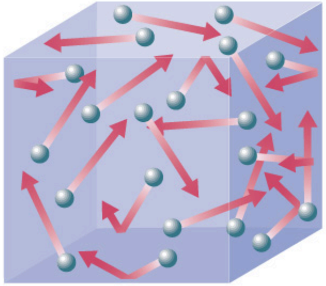
1. Work: the energy used move an object with a mass against a force
2. Heat: the energy transferred from a hotter object to a colder one (due to the difference temperature)

Two Types of Energy

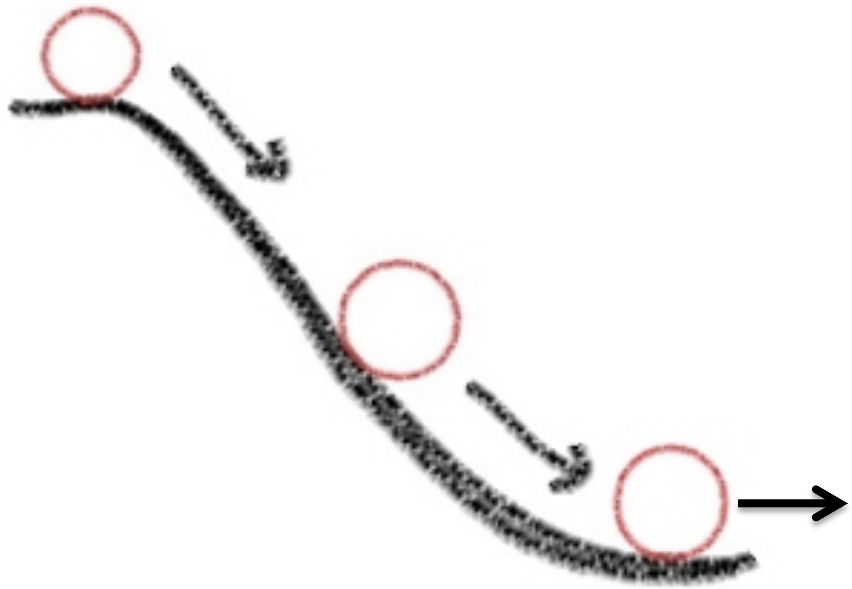
1. Potential Energy: energy due to position of object relative to other objects ("stored energy")
   - $E_p = mgh$



2. Kinetic Energy: energy due to motion of object
   - $KE = \frac{1}{2} mv^2$



Energy Can Be Converted from One Form to Another Form



Max potential energy
Min kinetic energy

Min potential energy
Max kinetic energy

Potential energy converted to kinetic energy

Energy Can Be Exchanged Between System and Surroundings

- System: the portion singled out for study
- Surroundings: everything else

- System + Surrounding = Universe

Law of Conservation of Energy

First Law of Thermodynamics:

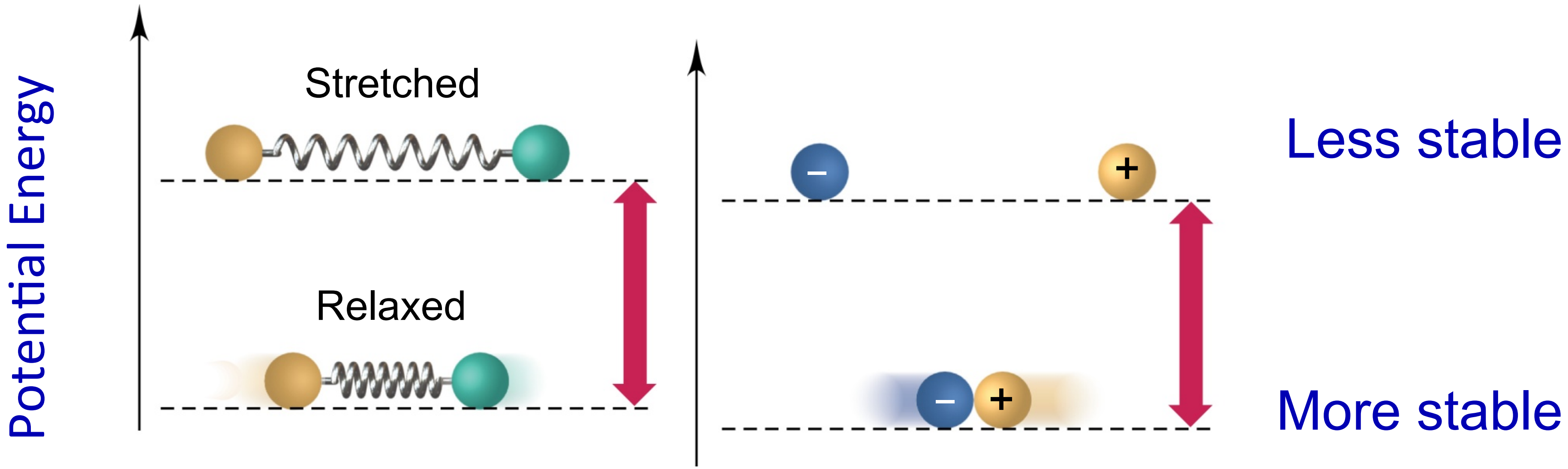
The total energy of the universe remains constant.

Law of Conservation of Energy:

Energy is neither created nor destroyed.

Lower Energy is More Stable

Situations of lower energy are more stable (more favored) than higher energy.



Energy Units

- SI Unit of energy = Joule

- 1 cal = 4.184 J
- 1000 cal = 1 kcal
- 1 kcal = 1 Cal (Capital C: nutritional calorie)
- 1 kW-h = 3.6×10^6 J

Ex Probs

Heat

Heat

- During a chemical or physical change, energy can be transferred as heat.

- Heat can be released or absorbed by the system.

Heat

- Heat: transfer or exchange of thermal energy caused by temperature difference [SI unit: J]

Heat is different from temperature!

Temperature: a measure of thermal energy, energy due to motion (avg kinetic energy)

[SI unit: K]

Enthalpy Change ~ Heat

- Enthalpy change (ΔH) = heat absorbed or released by a process*

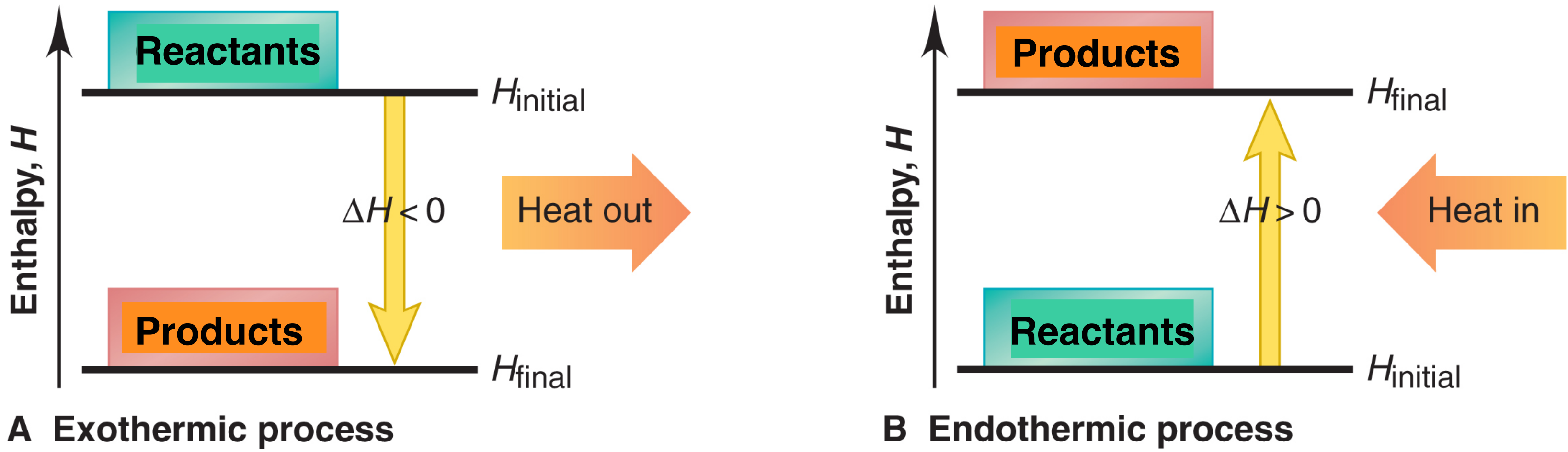
  (*under constant pressure)

$$\Delta H = H_{final} - H_{initial}$$

Exothermic vs. Endothermic Process

- Exothermic process (-ΔH): a process that releases heat
- Endothermic process (+ΔH): a process that absorbs heat

Exothermic vs. Endothermic Process



Exothermic

Releases heat

Endothermic

Absorbs heat

Q: Endothermic or Exothermic?

1. Ice melting into water
2. Water freezing into ice
3. Natural gas burning
4. Evaporation of sweat from skin

Specific Heat Capacity

- All substances change in temperature when heated, but the amount of heat needed to change the temperature by a certain amount differs for each substance.

- Specific heat capacity: the amount of heat that will raise the temperature of 1 g of substance by 1 °C. [Unit: J/g•°C]

Specific Heat Capacities

TABLE 3.4 Specific Heat Capacities of Some Common Substances

Substance	Specific Heat Capacity (J/g °C)
Lead	0.128
Gold	0.128
Silver	0.235
Copper	0.385
Iron	0.449
Aluminum	0.903
Ethanol	2.42
Water	4.184

Q: Would you use copper or aluminum to make a frying pan?

Heat Absorbed or Released

Relationship between heat absorbed or released by a given amount of substance and the temperature change:

Heat$_{\text{abs or rels}}$ = mass x specific heat capacity x ΔT

$q = m \times C \times \Delta T$ (where $\Delta T = T_f - T_i$)

Ex Probs