Unit 2: Matter and Energy

Matter *Introductory Definitions*

matter: anything having mass and volume

mass: the amount of matter in an object

weight: the pull of gravity on an object

volume: the space an object occupies

units: L, dm^3, mL, cm^3 $\cancel{L^3}$

state of matter: solid, liquid, or gas (plasma, neutron star)

composition: what the matter is made of

copper: many Cu atoms

water: many groups of 2 H's and 1 O

properties: describe the matter

-- what it looks like, smells like, etc.

-- how it behaves

atom: a basic building block of matter

~100 diff. kinds

- ***Elements*** → contain only one type of atom

1. monatomic elements consist of unbonded, “like” atoms

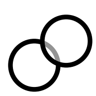
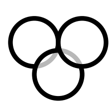
    e.g., Fe, Al, Cu, He

2. polyatomic elements consist of several “like” atoms bonded together

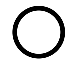
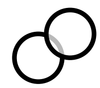
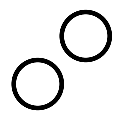
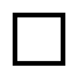
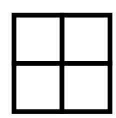
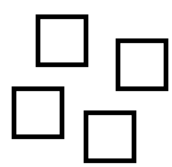
    diatomic elements: H_2 O_2 Br_2 F_2 I_2 N_2 Cl_2

    others: P_4 S_8

allotropes: different forms of the same element in the same state of matter

OXYGEN		CARBON
oxygen gas		elemental carbon
		graphite
ozone		diamond
		buckyball

molecule: a neutral group of bonded atoms

Description	Chemical Symbol	Model
1 oxygen atom	O	
1 oxygen molecule	O_2	
2 unbonded oxygen atoms	$2\ O$	
1 phosphorus atom	P	
1 phosphorus molecule	P_4	
4 unbonded phosphorus atoms	$4\ P$	

Elements may consist of either molecules <u>or</u> unbonded atoms.

- ***Compounds***

…contain two or more different types of atoms

…have properties that are different from those of their constituent elements

Na (sodium): explodes in water
Cl_2 (chlorine): poisonous gas
table salt ($NaCl$)

Atoms can only be altered by *nuclear* means.

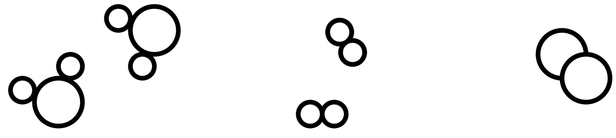
Molecules can be altered by *chemical* means.
(i.e., chemical reactions, chemical changes)

e.g., Dehydration of sugar

$$C_{12}H_{22}O_{11}(s) \longrightarrow 12\ C(s) + 11\ H_2O(g)$$

Electrolysis of water

$$2\ H_2O(l) \longrightarrow 2\ H_2(g) + O_2(g)$$



In a chemical reaction, the atoms are rearranged.

- ***Compound Composition*** $\rightarrow$ All samples of a given compound have the same composition.

Phosgene gas ($COCl_2$) is 12.1% carbon, 16.2% oxygen, and 71.7% chlorine by mass. Find # of g of each element in 254 g of $COCl_2$.

$$\text{X g C} = 254 \text{ g } (0.121) = \boxed{30.7 \text{ g C}}$$

$$\text{X g O} = 254 \text{ g } (0.162) = \boxed{41.1 \text{ g O}}$$

$$\text{X g Cl} = 254 \text{ g } (0.717) = \boxed{182.1 \text{ g Cl}}$$

A sample of butane (C_4H_{10}) contains 288 g carbon and 60 g hydrogen. Find…

A. total mass of sample

$$288 \text{ g C} + 60 \text{ g H} = \boxed{348 \text{ g}}$$

B. % of each element in butane

$$\%\,\text{C} = \frac{288 \text{ g C}}{348 \text{ g}} = 0.828 \qquad \%\,\text{H} = \frac{60 \text{ g H}}{348 \text{ g}} = 0.172$$

$$\boxed{82.8\%\ \text{C},\ 17.2\%\ \text{H}}$$

C. how many g of C and H are in a 24.2 g sample

$$\text{X g C} = 24.2 \text{ g } (0.828) = \boxed{20.0 \text{ g C}}$$

$$\text{X g H} = 24.2 \text{ g } (0.172) = \boxed{4.2 \text{ g H}}$$

A 550 g sample of chromium (III) oxide (Cr_2O_3) has 376 g Cr. How many grams of Cr and O are in a 212 g sample of Cr_2O_3?

$$\%\,\text{Cr} = \frac{376\ \text{g Cr}}{550\ \text{g}} = 68.4\%\ \text{Cr}\ \ \text{and}\ 31.6\%\ \text{O}$$

$$\begin{aligned} \text{X g Cr} &= 212\ \text{g}\ (0.684) = \boxed{145\ \text{g Cr}} \\ \text{X g O} &= 212\ \text{g}\ (0.316) = \boxed{67\ \text{g O}} \end{aligned}$$

Classifying Matter

- ***(Pure) Substances***

  …have a fixed composition

  …have fixed properties

ELEMENTS	COMPOUNDS
e.g., Fe, N_2, S_8, U	e.g., H_2O, NaCl, HNO_3

Pure substances have a chemical formula.

- ***Mixtures***

two or more substances mixed together

…have varying composition

…have varying properties

The substances are NOT chemically bonded, and they retain their individual properties.

Two types of mixtures…

<u>homogeneous</u>: (or <u>solution</u>) particles are microscopic; sample has same composition and properties throughout; evenly mixed

e.g., salt water
Kool Aid

<u>heterogeneous</u>: different composition and properties in the same sample; unevenly mixed

e.g., tossed salad
raisin bran

<u>alloy</u>: a homogeneous mixture of metals

e.g., bronze (Cu + Sn)
brass (Cu + Zn)
pewter (Pb + Sn)

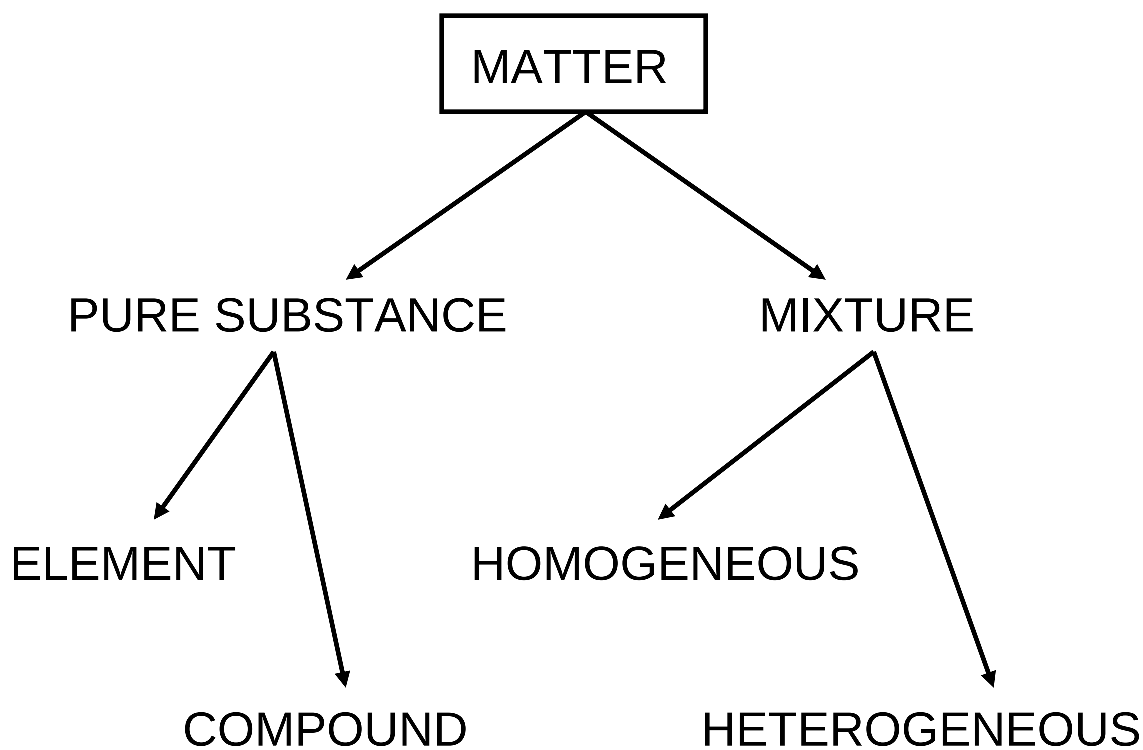
<u>suspension</u>: settles over time

e.g., liquid meds,
muddy water

Contrast…

24K GOLD	14K GOLD
pure gold	mixture
24/24 atoms are gold	14/24 atoms are gold
element	homogeneous mixture

- ***Chart for Classifying Matter***



A sample of bronze contains 68 g copper and 7 g tin.

A. Find total mass of sample.

$$68 \text{ g Cu} + 7 \text{ g Sn} = \boxed{75 \text{ g}}$$

B. Find % Cu and % Sn.

$$\% \text{ Cu} = \frac{68 \text{ g Cu}}{75 \text{ g}} = \boxed{90.7\% \text{ Cu and } 9.3\% \text{ Sn}}$$

C. How many grams of each element does a 346 g sample of bronze contain?

$\boxed{\text{Best answer: don't know.}}$

(Bronze is a mixture and isn't necessarily always 90.7% Cu and 9.3% Sn.)

However, assuming these % are correct…

$$\text{X g Cu} = 346 \text{ g } (0.907) = \boxed{314 \text{ g Cu}}$$

$$\text{X g Sn} = 346 \text{ g } (0.093) = \boxed{32 \text{ g Sn}}$$

- ***Separating Mixtures***

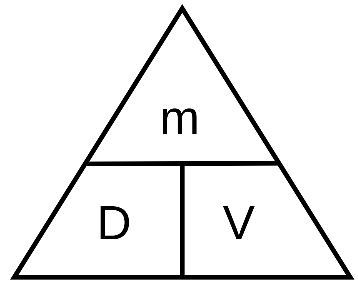
  …involves physical means, or <u>physical changes</u>

1. <u>sorting</u>: by color, shape, texture, etc.
2. <u>filter</u>: particle size is different
3. <u>magnet</u>: one substance must contain iron
4. <u>chromatography</u>: some substances dissolve more easily than others
5. <u>density</u>: "sink vs. float"
   perhaps use a <u>centrifuge</u>
   <u>decant</u>: to pour off the liquid
6. <u>distillation</u>: different boiling points

No chemical reactions are needed;
substances are NOT bonded.

$\boxed{\textbf{Density}}$ → how tightly packed the particles are

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \rightarrow \boxed{D = \frac{m}{V}}$$



Typical units: g/cm^3 for solids g/mL for fluids

liquids
and gases

To find volume, use…1. a formula

2. water displacement method

** Density of water = 1.0 g/mL = 1.0 g/cm^3

Things that are “less dense” float
in things that are “more dense.”

The density of a liquid or solid is nearly constant, no matter what the sample’s mass.

- ***Galilean Thermometer Problem***

On a cold morning, a teacher walks into a cold classroom and notices that all bulbs in the Galilean thermometer are huddled in a group. Where are the bulbs, at the top of the thermometer or at the bottom?

D_1

D_2

D_3

D_4

D_5

1. Bulbs have essentially fixed masses and volumes. Therefore, each bulb has a relatively fixed density.
2. The surrounding liquid has a fixed mass, but its volume is extremely temperature-dependent.
3. The density of the liquid can be written as…

$$D_{liq} = \frac{m_{liq}}{V_{liq}} \qquad \text{so…}$$

…if the liquid is cold: …but if it's hot:

$$\frac{m_{liq}}{V_{liq}} = D_{liq} \qquad \frac{m_{liq}}{V_{liq}} = D_{liq}$$

On a cold morning, where are the bulbs?

AT THE TOP

- ***Density Calculations***

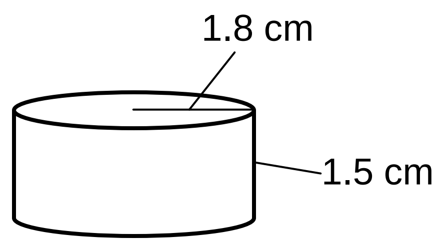
1. A sample of lead (Pb) has mass 22.7 g and volume 2.0 cm^3. Find sample's density.

$$D = \frac{m}{V} = \frac{22.7\ g}{2.0\ cm^3} = \boxed{11.35\ \frac{g}{cm^3}}$$

2. Another sample of lead occupies 16.2 cm^3 of space. Find sample's mass.

$$m = D\,V = 11.35\ \frac{g}{cm^3}\left(16.2\ cm^3\right) = \boxed{184\ g}$$

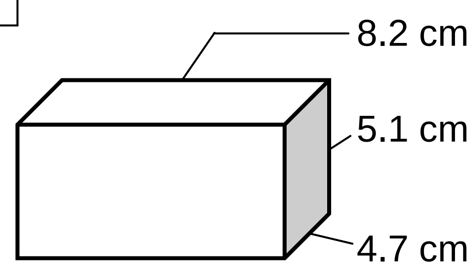
3. A 119.5 g solid cylinder has radius 1.8 cm and height 1.5 cm. Find sample's density.



$$V = \pi\, r^2\, h = 3.14\,(1.8\ cm)^2\,(1.5\ cm) = 15.3\ cm^3$$

$$D = \frac{m}{V} = \frac{119.5\ g}{15.3\ cm^3} = \boxed{7.81\ \frac{g}{cm^3}}$$

4. A 153 g rectangular solid has edge lengths 8.2 cm, 5.1 cm, and 4.7 cm. Will this object sink in water?



$$V = L\ W\ H = 8.2\ cm\,(5.1\ cm)\,(4.7\ cm) = 197\ cm^3$$

$$D = \frac{m}{V} = \frac{153\ g}{197\ cm^3} = 0.78\ \frac{g}{cm^3} \rightarrow \boxed{\text{NO; IT FLOATS}}$$

Properties of Matter

CHEMICAL properties tell how a substance reacts with other substances

PHYSICAL properties can be observed without chemically changing the substance

ONE OF THESE

AND

EXTENSIVE properties depend on the amount of substance present.

INTENSIVE properties do not depend on the amount of substance.

ONE OF THESE

Examples:

electrical conductivity…………………………..…..P / I

reactivity with water..……………………………C / I

heat content (calories)…………………….....…C / E

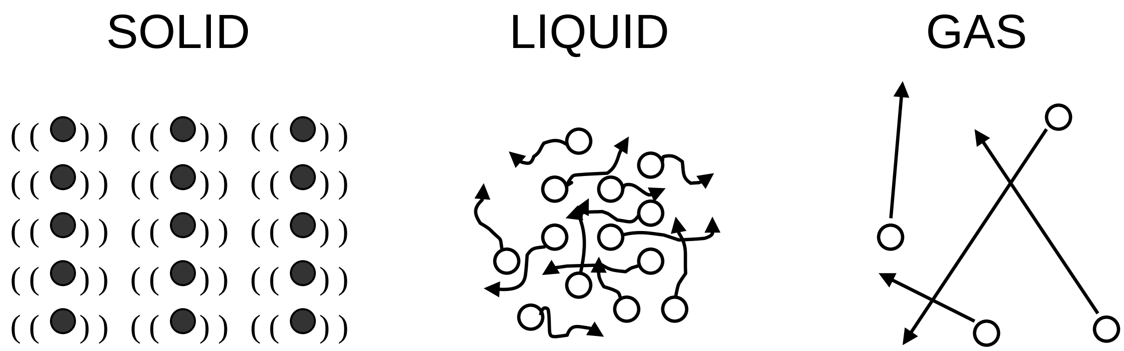
ductile: can be drawn (pulled) into wire……...P / I

malleable: can be hammered into shape..…..P / I

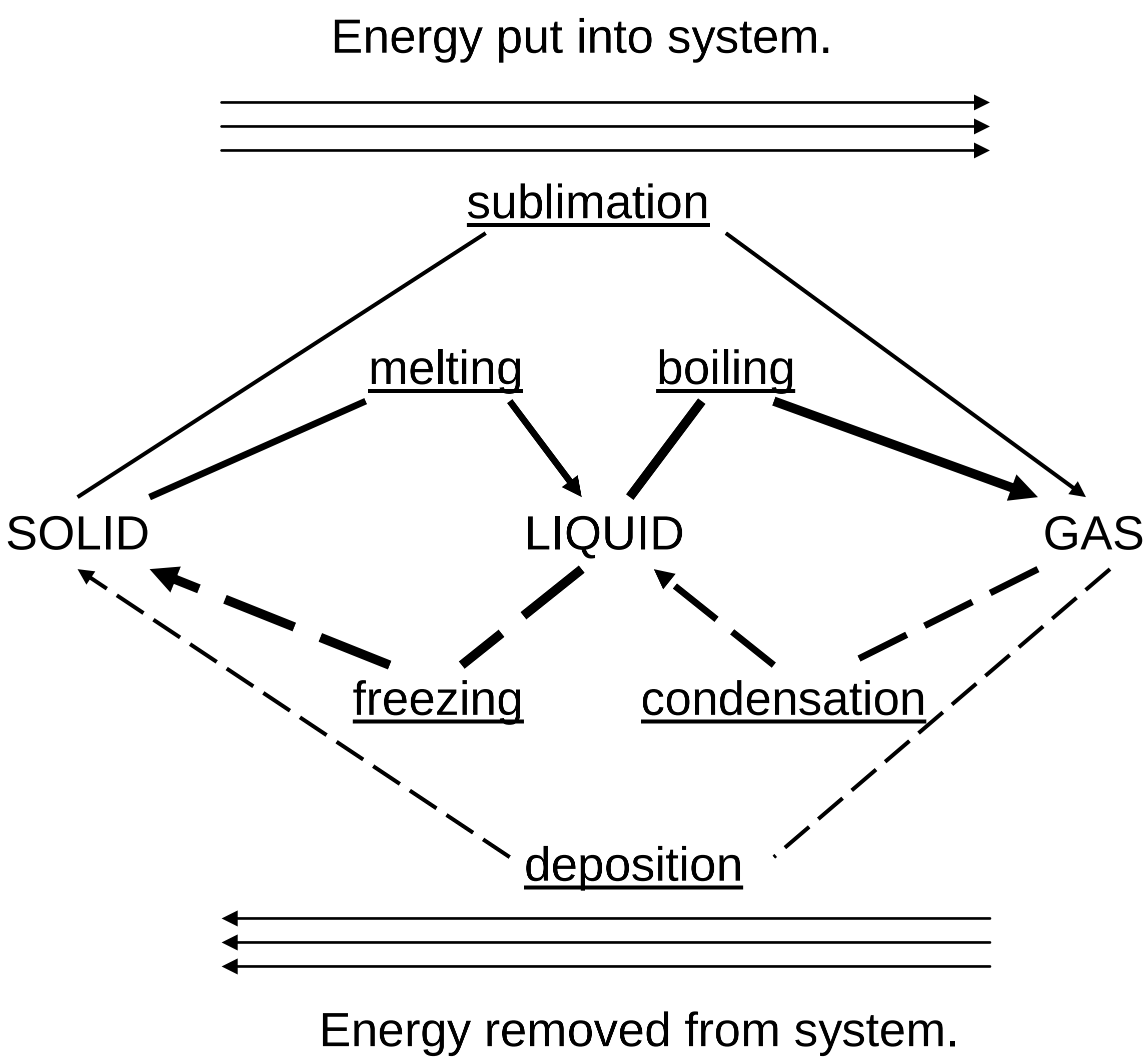
brittle……………………………..……………..P / I

magnetism……………………………………..P / I

States of Matter



Changes in State



$\boxed{\textbf{Energy}}$ → the ability to do work

<u>potential energy</u>: stored energy

-- stored in bonds between atoms

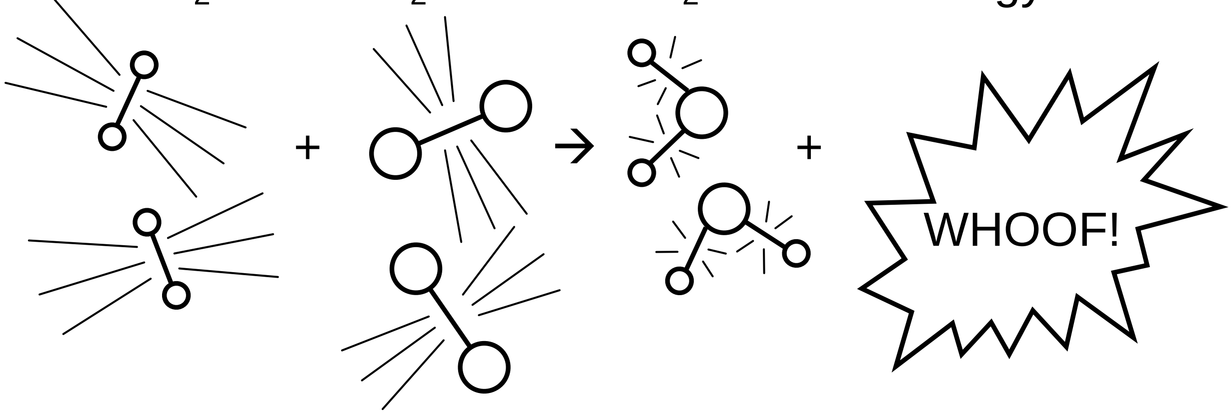
e.g., in food, gasoline, batteries

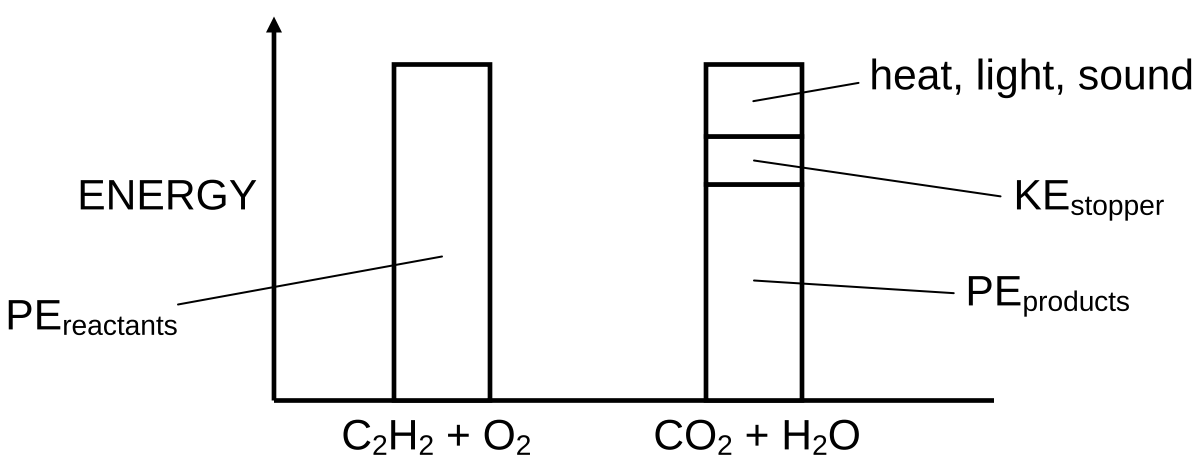
<u>kinetic energy</u>: energy of motion [$KE = \frac{1}{2} mv^2$]

-- "hot" gas particles move faster, have more KE

<u>Law of Conservation of Energy</u>: $E_{after} = E_{before}$

$2\ H_2 + O_2 \rightarrow 2\ H_2O + \text{energy}$

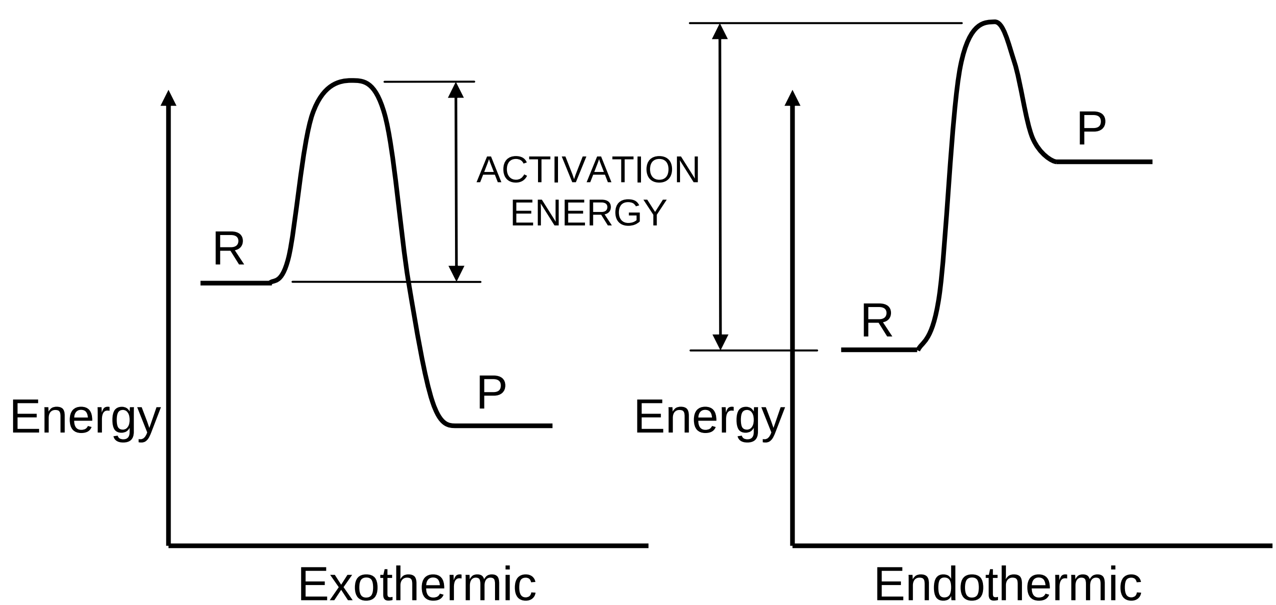




- ***Energy Changes***

<u>endothermic</u> change	<u>exothermic</u> change
system absorbs heat	system releases heat
-- beaker feels cold	-- beaker feels hot

water boiling	ENDO
paper burning	EXO
steam condensing	EXO
CO_2 subliming	ENDO
water freezing	EXO
ice melting	ENDO



The Mole

Atoms are so small, it is impossible to count them by the dozens, thousands, or even millions. To count atoms, we use the concept of the mole.

1 mole of atoms = 602,000,000,000,000,000,000,000 atoms

That is, 1 mole of atoms = 6.02×10^{23} atoms

- ***How Big is 6.02×10^{23}?***

6.02×10^{23} marbles would cover the entire Earth (including the oceans) to a depth of 2 miles.

6.02×10^{23} \$1 bills stacked face-to-face would stretch from the Sun to Pluto and back 7.5 million times. It takes light 9,500 years to travel that far.

For any element on the Periodic Table, one mole of that element (i.e., 6.02×10^{23} atoms of that element) has a mass in grams equal to the decimal number on the Table for that element.

- ***Island Diagram Problems***

1. How many moles is 3.79 x 10^{25} atoms of zinc?

$$\text{X mol Zn} = 3.79 \times 10^{25}\ \text{at. Zn}\left(\frac{1\ \text{mol Zn}}{6.02 \times 10^{23}\ \text{at. Zn}}\right) = 63.0\ \text{mol Zn}$$

2. How many atoms is 0.68 moles of zinc?

$$\text{X at. Zn} = 0.68\ \text{mol Zn}\left(\frac{6.02 \times 10^{23}\ \text{at. Zn}}{1\ \text{mol Zn}}\right) = 4.1 \times 10^{23}\ \text{at. Zn}$$

3. How many grams is 5.69 moles of uranium?

$$\text{X g U} = 5.69\ \text{mol U}\left(\frac{238\ \text{g U}}{1\ \text{mol U}}\right) = 1.35 \times 10^{3}\ \text{g U}$$

4. How many grams is 2.65 x 10^{23} atoms of neon?

$$\text{X g Ne} = 2.65 \times 10^{23}\ \text{at. Ne}\left(\frac{1\ \text{mol Ne}}{6.02 \times 10^{23}\ \text{at. Ne}}\right)\left(\frac{20.2\ \text{g Ne}}{1\ \text{mol Ne}}\right) = 8.9\ \text{g Ne}$$

5. How many atoms is 421 g of promethium?

$$\text{X at. Pm} = 421\ \text{g Pm}\left(\frac{1\ \text{mol Pm}}{145\ \text{g Pm}}\right)\left(\frac{6.02 \times 10^{23}\ \text{at. Pm}}{1\ \text{mol Pm}}\right) = 1.75 \times 10^{24}\ \text{at. Pm}$$