Introduction to Chemistry: Physico-Chemical Perspectives

Student Learning Outcomes

Upon completion of this Introductory Primer, the **properly prepared student** will be able to successfully explain, define, list and apply the introductory physicochemical concepts in this document as demonstrated by examination **at an average score of 75%**.

Specifically, the properly prepared student will be able to:

1) Define chemistry;
2) Define and give examples of properties;
3) Differentiate between chemical and physical properties;
4) Define, illustrate and give examples of Newton's three laws;
5) Be able to list, define and give examples of the five states of matter;
6) Be able to define nuclear fission and nuclear fusion;
7) Be able to calculate the edge length of a solid;
8) Be able to use the Pythagorean theory to determine ionic radii distances;
9) Briefly define what an ion is; what a cation is; what an anion is;
10) Illustrate and superficially explain the 14 Bravais Lattices for solids;
11) Define superfluidity and superconductivity;
12) Give examples of fermions and bosons;
13) Count atoms in any of the Bravais Lattices, including a hexagonal arrangement of atoms;
14) Define elements, compounds and mixtures; homoatomic and hetero atomic mono-atomic and poly-atomic;
15) Differentiate between mass and weight;
16) Complete a blank periodic table with the correct elemental symbols in order up to element 106;
17) Give the correct name of the first 106 elements in the periodic table when procided with the elemental symbol[s];
18) Match simple chemical formulas with their correct names;
19) Define and differentiate between static and current electricity;
20) State and define the four laws of electrostatics;
21) Explain the difference between electrical circuits in series or parallel; by extension, the same for blood vessels;
22) Define and illustrate the phenomenon of Piezoelectricity;
23) Define electron, proton and neutron;
24) Calculate net forces (F_{net}) between objects;
25) Define the Law of Definite Proportions and the Law of Conservation of Mass and give an example, thereof;

at an average score of 75% on the assessment tool.

Chemistry is the study of the portion of nature that deals with substances, their compositions and structures and their abilities to be changed into other substances.

Chemistry is the root science for understanding and applying medicine, dentistry, chiropractic medicine, botany, physiology, nutrition, pharmacology, nursing, microbiology, dental hygiene health sciences and biochemistry.

Properties

A property is any characteristic of something that we can use to identify and recognize it when we see it, again.

A chemical property is a property that causes a substance to change into another substance. A chemical reaction is the change of one substance into another that is observable.

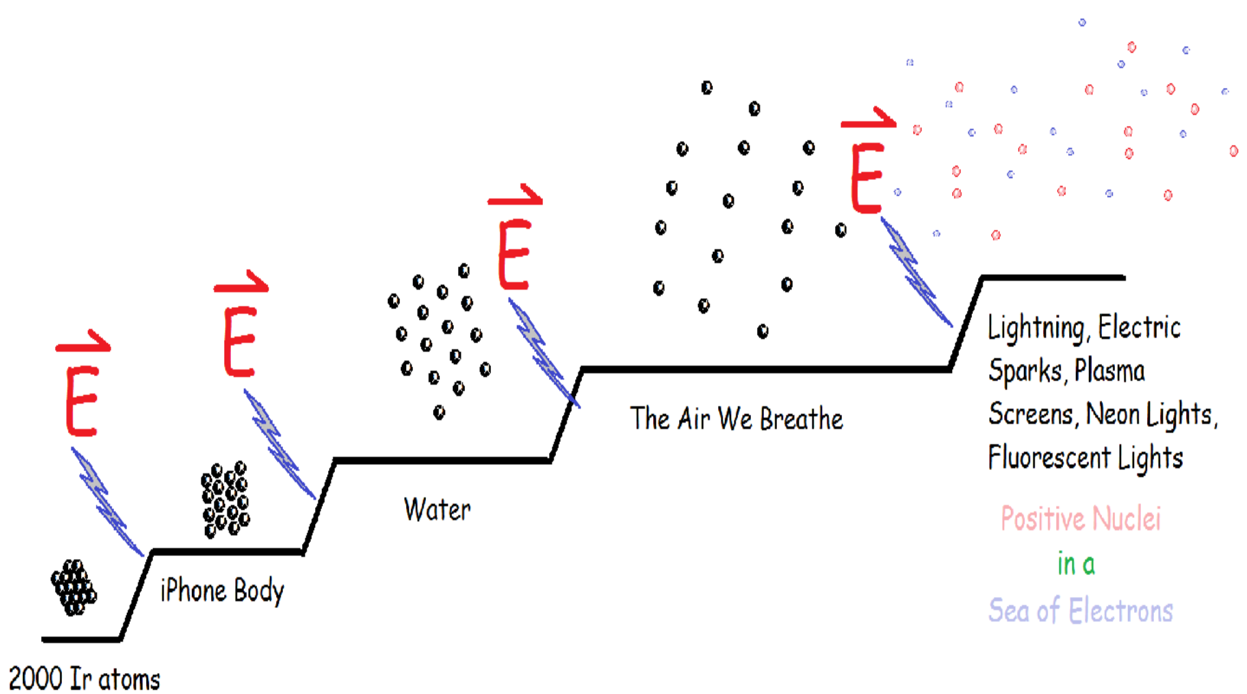
Physical properties include things like color, height, weight – something that can be observed without changing an object into something different.

Physical quantities are properties to which a numerical value and a unit is assigned, e.g., height -- 5.75 feet. The numerical value is 5.75; the unit is feet. The UNIT in a physical quantity is just as important as the number -- the physical quantity is a number TIMES a unit.

A measurement is an operation by which an unknown physical quantity is compared with one that is known.

Matter

Matter is anything that occupies space and has mass. There are five states of matter we'll eventually explore: Bose-Einstein Condensates, Solids, Liquids, Gases and Plasma, in sequence from left to right in the graphic, below.



Mass is a measurement of the amount of matter in an object.

Weight is a measurement of the gravitational force acting on an object.

Inertia is the inherent resistance to any kind of change in motion.

Mass, weight and inertia are related through Newton's second law: force is equal to the product of mass and acceleration.

A large mass has a large inertia. A large mass, though, does NOT necessarily mean having a large weight, e.g., your weight on earth is 6 times that on the moon. Your mass hasn't changed, though.

Newton's First Law of Motion: INERTIA

A body at rest will remain at rest unless acted upon by outside forces. A body in motion will remain in motion unless acted upon by outside forces. SUMMARY: An object tends to resist a change in motion.

Why does a sledge hammer have more inertia than a reflex hammer? It's more <u>***MASS***</u>IVE!

MASS is the amount of matter present and is NOT equal to weight. Wt is a <u>FORCE</u> and = (mass) * (g), where

(g = acceleration due to gravity)

Inertia (p) equals mass (m) times (*) velocity (v) or:

$p = m v$

Application:

Car wreck: car stops and person is ejected; Baby sitting in parent's lap crushed between parent and dashboard in wreck; Organs slamming into the skeletal system.

Newton's Second Law: Force

A force (F) is defined as a push or a pull capable of causing a change in an object's state of motion. All forces, though, do NOT cause motion, e.g., pushing on a floor, tug of war with no net movement – this is called "<u>net force of zero</u>"

Gravity is involved in force – we call it weight and report it in pounds, ounces or in Newtons (1 N = 0.225 pounds).

ACCELERATION (a)

$F = m a$

In the direction of motion

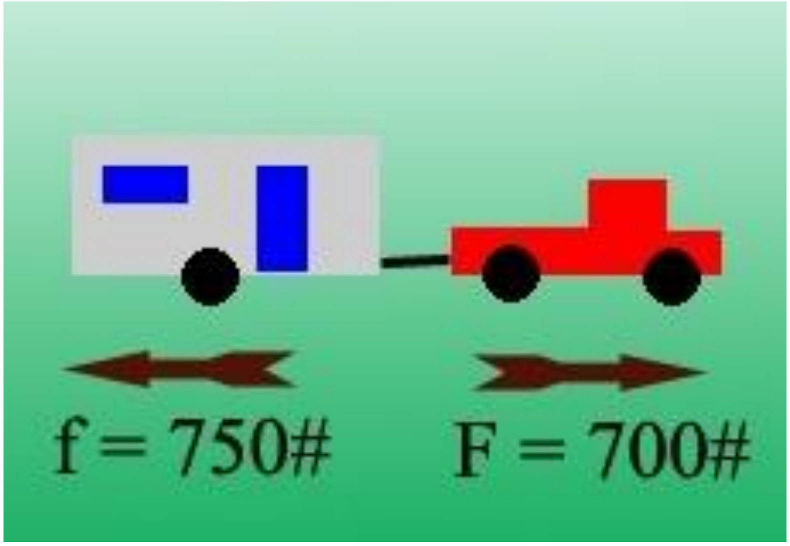
$Wt = m g$

M = mass and g = gravitational attraction

In the direction of motion

The force opposite to the direction of motion is friction: $F_{net} = F – f$

Where F = applied force and f = frictional force and F_{net} = the net force



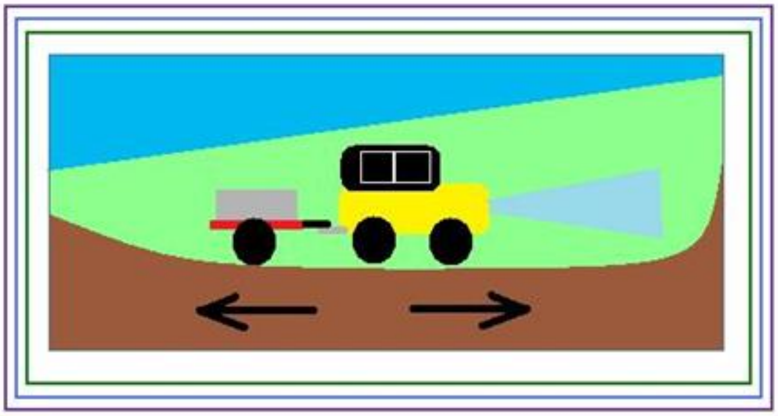
Example

$F_{net} = F - f$

If a truck is pulling with a force of 700# and the force of friction is 750#, are the truck and trailer moving? What is the F_{net}?

If a jeep is pulling with an F_{net} of 400# and the force of friction is 350#, are the truck and trailer moving? What is the force with which the jeep is pulling?

Newton's Third Law:
INTERACTION

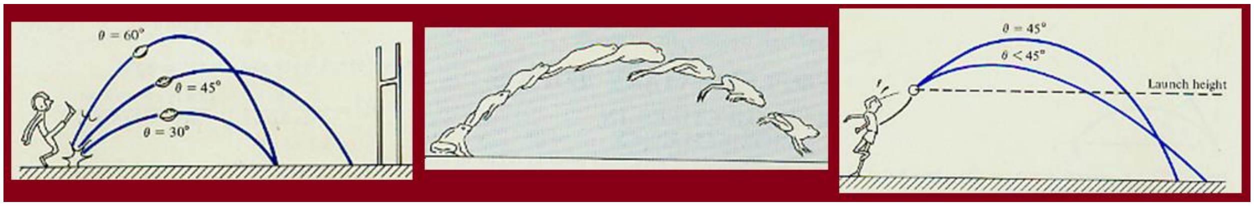


When a force is exerted ON an object, an equal and opposite force is exerted BY the object. Example: kick a football with 10# of force and the football exerts a 10# force on your foot. SUMMARIZED: for every action, there is an equal and opposite reaction. E.g., Cars and cement/concrete dividers – car hits it and the divider exerts an equal and opposite force on the car.

SUMMARIZED: for every action, there is an equal and opposite reaction.

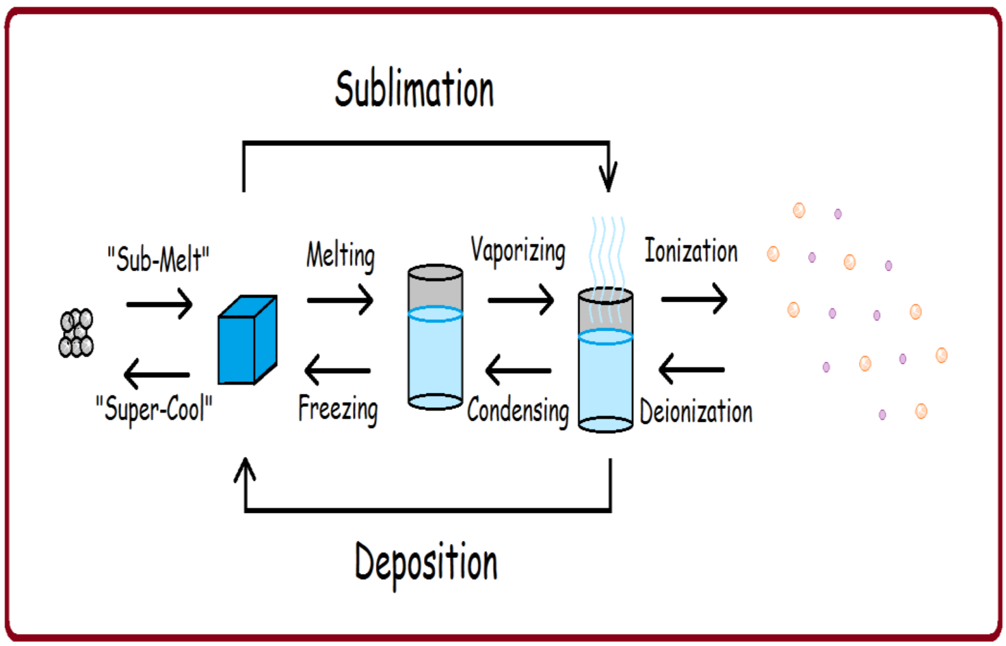
Projectile Motion

Projectiles = kicked or thrown balls, jumping animals and objects dropped from windows.



Projectiles = kicked or thrown balls (immediately above left: steep angles or shallow angles are used by football players to for short kicks; middle angles are used for distance); tennis players hitting a ball above the ground know to alter their angles, too (above right), jumping animals (above center) jumping frogs know that a 45 degree angle gets them leaped the farthest) and objects dropped from windows.

Five Phases of Matter



Bose Einstein Condensates – BEC's

Fermions	half-integral spin	only one per state	Examples: electrons, protons, neutrons, quarks, neutrinos
Bosons	integral spin	Many can occupy the same state	Examples: photons, ^{4}He atoms, gluons

Bosons have intrinsic angular momenta in integral units of *h*/(2p). For instance the spin of a photon is either +1 or -1 and the spin of a ^{4}He atom is always zero. Many bosons can occupy a single quantum state. This allows them to behave collectively and is responsible for the behavior of lasers and superfluid helium. [http://www.pa.msu.edu/courses/1997spring/phy232/lectures/atomic/bosons.html]

Only one fermion can exist in a given quantum state. This is known as the Pauli exclusion principle (more on this in another chapter). Fermions tend to avoid each other, for which reason each electron in a group occupies a separate quantum state (indicated by different quantum numbers – more coming on this in another chapter).

In contrast, an unlimited number of bosons can have the same energy state and share a single quantum state.

Any object which is comprised of an even number of fermions is a boson, while any particle which is comprised of an odd number of fermions is a fermion. For example, a proton is made of three quarks, hence it is a fermion. A ^{4}He atom is made of 2 protons, 2 neutrons and 2 electrons, hence it is a boson.

Gluons are the exchange particles for the color force between quarks, analogous to the exchange of photons in the electromagnetic force between two charged particles. The gluon can be considered to be the fundamental exchange particle underlying the strong interaction between protons and neutrons in a nucleus. You'll get more on this in your physics courses in the future.
[http://www.pa.msu.edu/courses/1997spring/phy232/lectures/atomic/bosons.html, http://www.britannica.com/EBchecked/topic/74640/Bose-Einstein-condensate-BEC, http://hyperphysics.phy-astr.gsu.edu/hbase/particles/expar.html]

Bose-Einstein condensate (BEC), is a state of matter in which separate atoms or subatomic particles, cooled to near absolute zero (1995, Cornell and Wiemann (shared 2001 Nobel Prize in Physics), cooled a gas of rubidium atoms to 1.7×10^{-7} K above absolute zero), coalesce into a single quantum mechanical entity—that is, one that can be described by a wave function—on a near-macroscopic scale. [http://www.britannica.com/EBchecked/topic/74640/Bose-Einstein-condensate-BEC]

BEC theory traces back to 1924, when Bose considered how groups of photons behave. Photons belong to one of the two classes of elementary or submicroscopic particles defined by whether their quantum spin is a non-negative integer (0, 1, 2, …). These are called bosons, which includes photons, whose spin is 1; or an odd half integer (1/2, 3/2, …) and these are called fermions, which includes electrons, whose spin is 1/2. [http://www.britannica.com/EBchecked/topic/74640/Bose-Einstein-condensate-BEC]

BECs are related to two remarkable low-temperature phenomena:

- superfluidity, in which each of the helium isotopes ^{3}He and ^{4}He forms a liquid that flows with zero friction;

and

- superconductivity, in which electrons move through a material with zero electrical resistance.

^{4}He atoms are bosons, and although ^{3}He atoms and electrons are fermions, they can also undergo Bose condensation if they pair up with opposite spins to form boson-like states with zero net spin. He is an unusual noble gas. [http://www.britannica.com/EBchecked/topic/74640/Bose-Einstein-condensate-BEC]

The most intriguing property of BECs is that they can slow down light. In 1998 Lene Hau of Harvard University and her colleagues slowed light traveling through a BEC from its speed in vacuum of 3×10^8 meters per second to a mere 17 meters per second, or about 38 miles per hour.

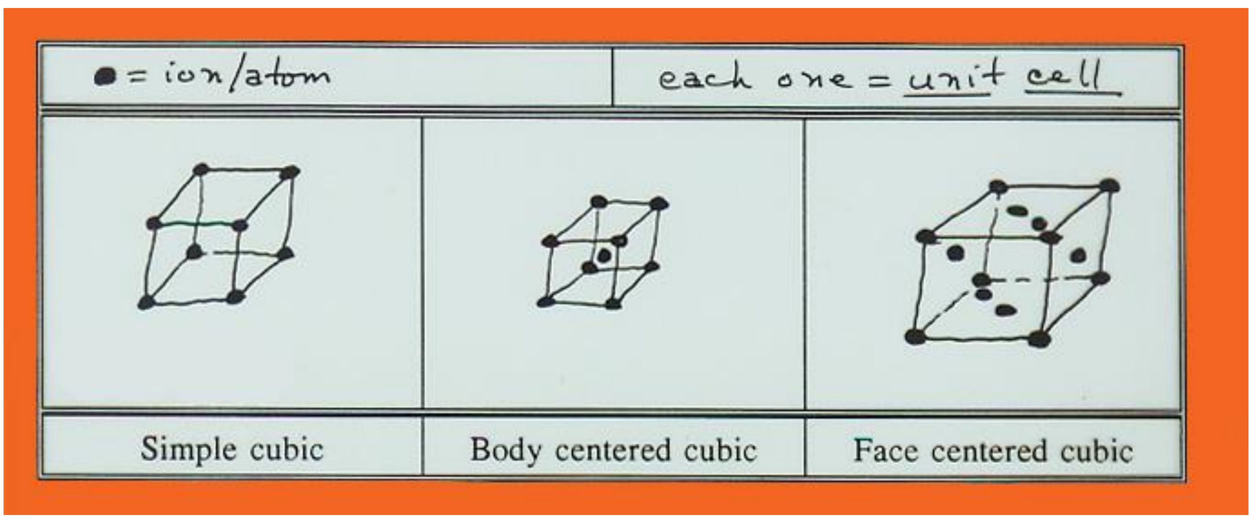
Since then, Hau and others have completely halted and stored a light pulse within a BEC, later releasing the light unchanged or sending it to a second BEC. These manipulations hold promise for new types of light-based telecommunications, optical storage of data, and quantum computing, though the low-temperature requirements of BECs offer practical difficulties. [http://www.britannica.com/EBchecked/topic/74640/Bose-Einstein-condensate-BEC]

The Solid State

Solids have a definite, fixed shape and volume. The atoms in a solid occupy fixed positions in a crystal lattice.

How Do We Use Lattices?

There are 14 Bravais Lattices and Rules for Using Them.



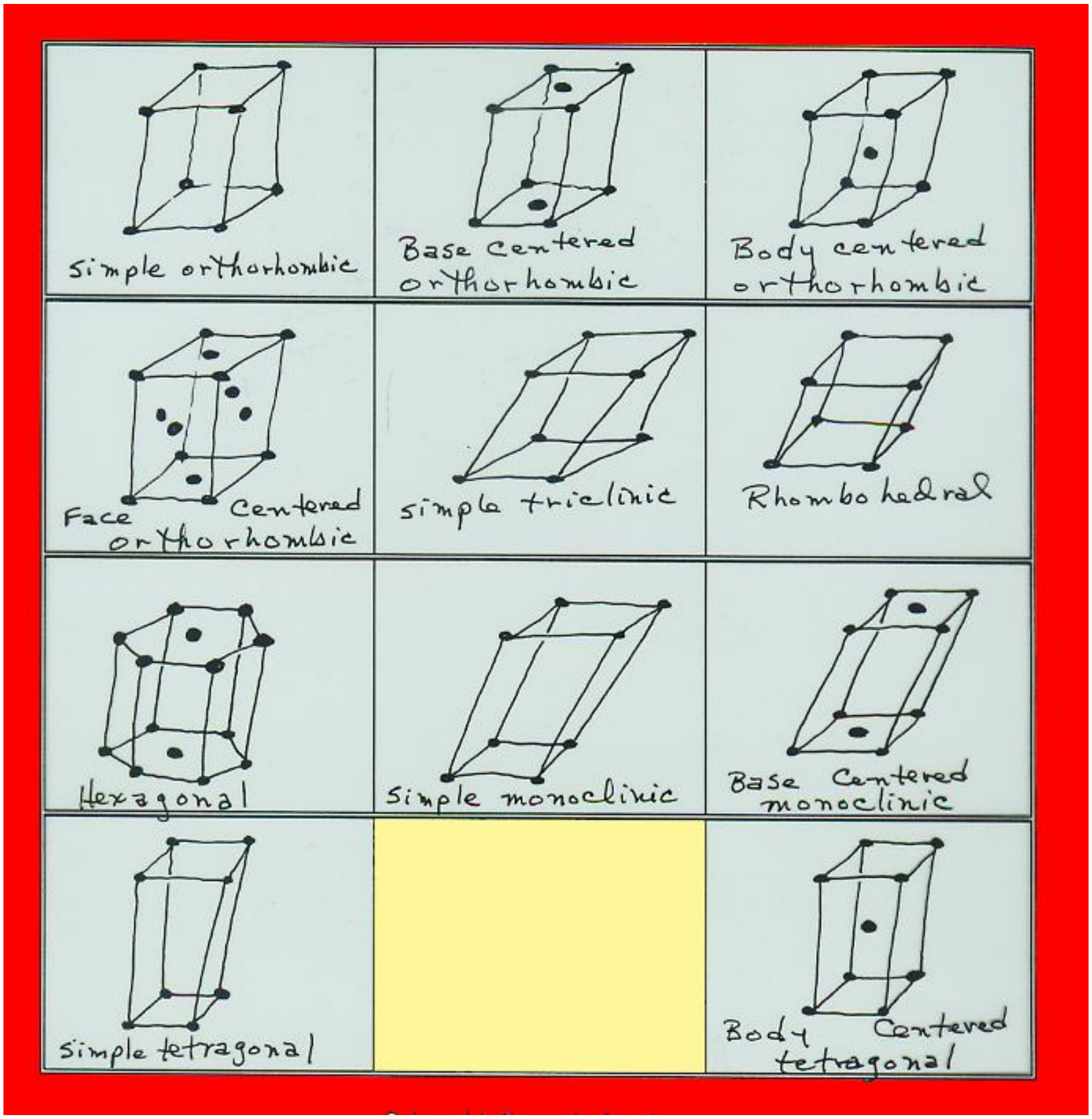
Three Examples, above.

Rules for Counting Atoms in Unit Cells:

1. Corner atoms are shared with 8 unit cells, therefore, each corner is worth 1/8 of an atom at each corner UNLESS in hexagon, then = 1/6
2. Edge atoms are shared with 4 unit cells, therefore, each edge = ¼ of an atom at each edge
3. Face-centered atoms are shared with 2 unit cells, therefore, each face = ½ of each atom at each face

4. Body centered atoms are shared with 1 unit cell, therefore each body = 1 full portion of each atom in "body"

The Other 11 Bravais Lattices



Different compounds which crystallize in the same structure are called ISOMORPHOUS

- Examples
  - NaF, KCl, CaS all have the same crystalline structure as NaCl

$SrCl_2$, ZrO_2 and CdF_2 all have the same crystalline structure as CaF_2

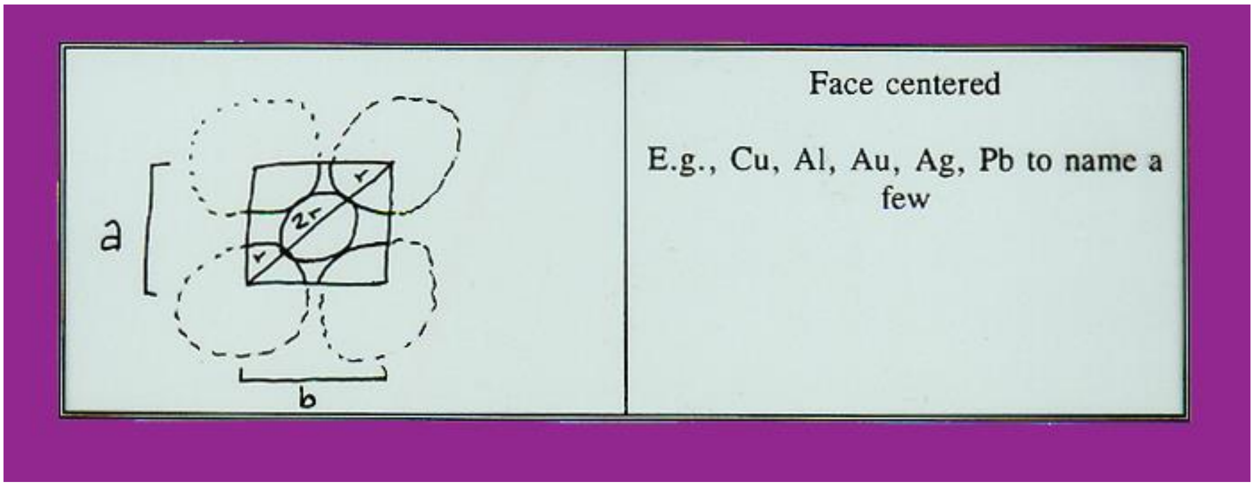
Compounds that have 2 or more crystalline structures due to different conditions undergo POLYMORPHISM

Examples

- Low temperature $CaCO_3$ is rhombohedral and called calcite
- High temperature $CaCO_3$ is orthorhombic and called aragnonite

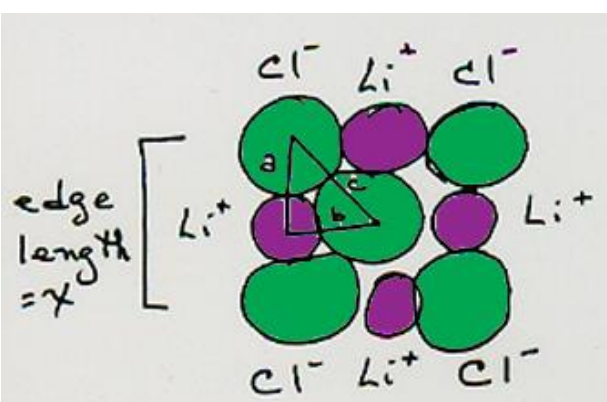
The crystalline structure of any lattice is determined by X-Ray Diffraction (more in CHEM 122).

How Do We Calculate/Determine Lattice Edge Length “a”?



Pythagoras Revisited

$$a^2 + b^2 = c^2$$
$$where \quad a = a, b = a, \; and \; c = 4r \; (r = atomic \; radius)$$
$$if \; we \; know \; "a", can \; solve \; for \; atomic \; or \; ionic \; radius \; of \; substance:$$
$$a^2 + a^2 = (4r)^2$$
$$2a^2 = 4^2 * r^2$$
$$r = \sqrt{\frac{2a^2}{4^2}} = \left(\frac{a}{4}\right)\sqrt{2}$$
$$or, \; r = 0.354 \; a$$



Knowing the edge length of a unit cell, we may then calculate the ionic radii. E.g., Calculate the ionic radius for Li^+ if LiCl (face centered) edge length = 0.514 nm; assume anion-anion contact. An ion is an atom or molecule with a net electric charge due to the loss or gain of one or more electrons. A cation is positively charged and an anion is negatively charged. Ionization is discussed in more detail in a future chapter.

$$a = \frac{x}{2} = \frac{0.514}{2} = 0.257 \;\; nm \;\; (Li^+ \rightarrow Cl^-)$$

$$b = \frac{x}{2} = \frac{0.514}{2} = 0.257 \;\; nm \;\; (Li^+ \rightarrow Cl^-)$$

$$How \;\; get \;\; Cl^- \rightarrow Cl^- ???$$

$$c^2 = a^2 + b^2$$

$$c = \sqrt{(a^2 + b^2)} \; = \; \sqrt{(0.257)^2 + (0.257)^2}$$

$$c \; = \; 0.363 \;\; nm \; = \; ionic \;\; DIAMETER \quad (Cl^- \rightarrow Cl^-)$$

$$ionic \;\; radius \;\; of \;\; Cl^- \; = \; \frac{0.363}{2} = 0.182 \;\; nm$$

If center to center between Li^+ and Cl^- is 0.257 nm, can calculate the Li^+ ionic radius:

$$Li^+ \; \rightarrow \; Cl^- \; = \; 0.257 \;\; nm$$

$$Cl^- \;\; radius \; = \; 0.182$$

$$\therefore$$

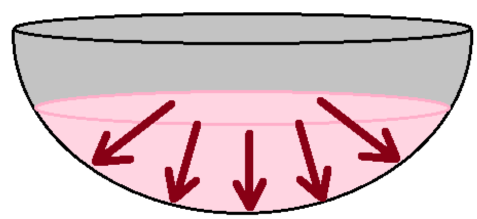
$$0.257 \;\; nm \; - \; 0.182 \;\; nm \; = \; 0.075 \;\; nm \; = \; Li^+ \;\; radius$$

Liquids

A liquid is the only state with a definite volume but no fixed shape.

Hydrostatic Pressure

A liquid can flow, assume the shape of a container, and, if placed in a sealed container, will distribute applied pressure evenly to every surface in the container.



Liquids are covered in greater detail in a later chapter.

Gases

A gas is a compressible fluid. Not only will a gas conform to the shape of its container but it will also expand to fill the container.

A liquid may be converted to a gas (or vapor) by heating at constant pressure to the boiling point.

Gases are covered in greater detail in a later chapter.

Plasma

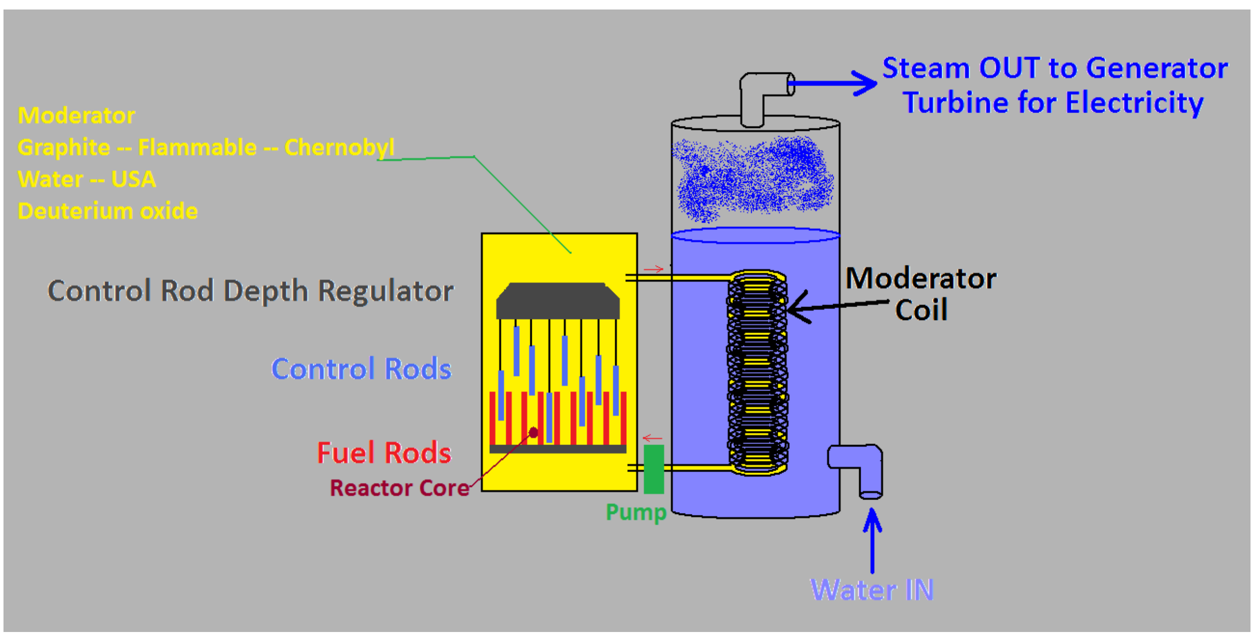
Plasma is the fourth state of matter. Simply stated, a plasma is an ionized gas, a gas into which sufficient energy is provided to free electrons from atoms or molecules and to allow both species, ions and electrons, to coexist. A gas is usually converted to a plasma in one of two ways, either from a huge voltage difference between two points, or by exposing it to extremely high temperatures.

Like a gas, plasma does not have a definite shape or volume. Unlike gases, plasmas are electrically conductive, produce magnetic fields and electric currents, and respond strongly to electromagnetic forces. Positively charged nuclei swim in a "sea" of freely-moving disassociated electrons, similar to the way such charges exist in conductive metal. To discuss plasmas, we need to have a fundamental understanding of some nuclear chemistry.

Elementary Definitions in Nuclear Chemistry

- Nuclear fission is defined as splitting a heavy nucleus into lighter nuclei.
- Nuclear fusion is defined as the combination of light nuclei to make a heavy nucleus.

Fission Nuclear Reactor



Control Rods are made from neutron absorbing metals: Cd and B. Too few neutrons in the raector core and reaction dies out. Too many neutrons and get core overheating: the core melts down and maybe thermonuclear explosion (SAFETY SYSTEMS!)

Moderator: slows neutrons to most appropriate Energy for ^{235}U fission initiation

Fission Rate Regulation

To Increase Fission Rate, raise control rods in core; To Decrease Fission Rate, lower control rods in core. When rods are full "IN" the core, shuts down reactor.

Fuel Rods

Are enriched from 0.7% to 3.0% used with water because increased numbers of neutrons combine with hydrogen ($^1H_1$ = protium; $^2H_1$ = deuterium; $^3H_1$ = tritium) instead of uranium:

$$ {}_{1}^{1}H + {}_{0}^{1}n \rightarrow {}_{1}^{2}H = \underline{\underline{D}} $$

D_2O is more efficient because neutrons do NOT combine well with deuterium. Therefore, D_2O reactor runs on the cheaper 0.7% fuel pellets (in the rods; UO_2) … BUT, D costs money to make, hence 6 of one and a half dozen of the other.

Fusion

Greatest success for fusion, though, so far, is the hydrogen bomb (H-bomb): Lithium-6-deuteride: $^6Li^2H$ or ^6LiD

The energy from the fission portion of the 2-step reaction is in the form of γ emissions.

$$ Fission : \ {}_{3}^{6}Li + {}_{0}^{1}n \rightarrow {}_{2}^{4}He + {}_{1}^{3}H + 4.8\,MeV \quad STEP\ 1 $$

$$ Fusion : \ {}_{1}^{2}H + {}_{1}^{3}H \rightarrow {}_{2}^{4}He + {}_{0}^{1}n + 17.6\,MeV \quad STEP\ 2 $$

$$ {}_{3}^{6}Li + {}_{1}^{2}H \rightarrow 2\ {}_{2}^{4}He + 22.4\,MeV \quad TOTAL $$

Two Staged Reactions: This energy is used to "drive" the second reaction to completion.

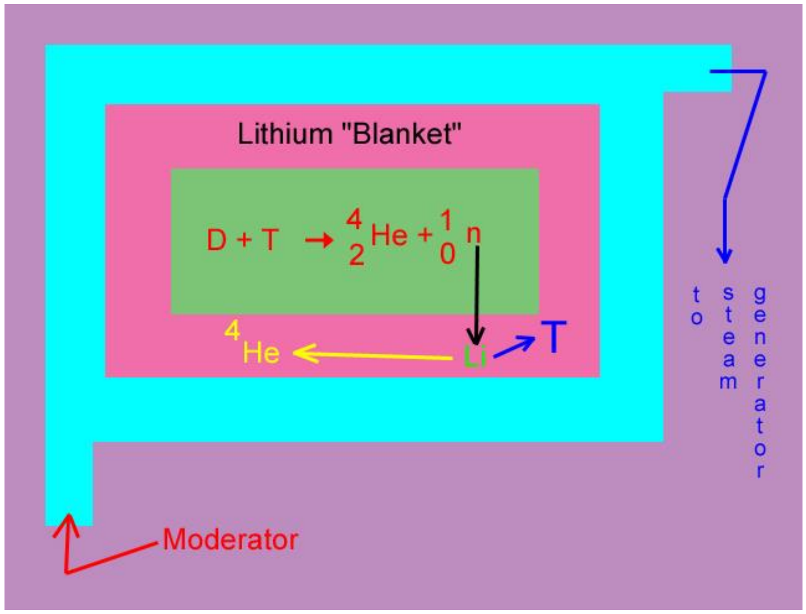
FUSION

Combination of light nuclides to form heavy nuclides – are THERMONUCLEAR REACTIONS because they only occur at high temperature. "Cold Fusion" was reported a number of years ago – it was not reproducible. Indeed some have suggested that it "worked" due to an impurity in the system. Recently, lasers are playing a role in cold fusion and that may be a key to developing fusion reactors.

FUSION REACTORS: best so far seems to be:

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n + 17.6\,MeV$$

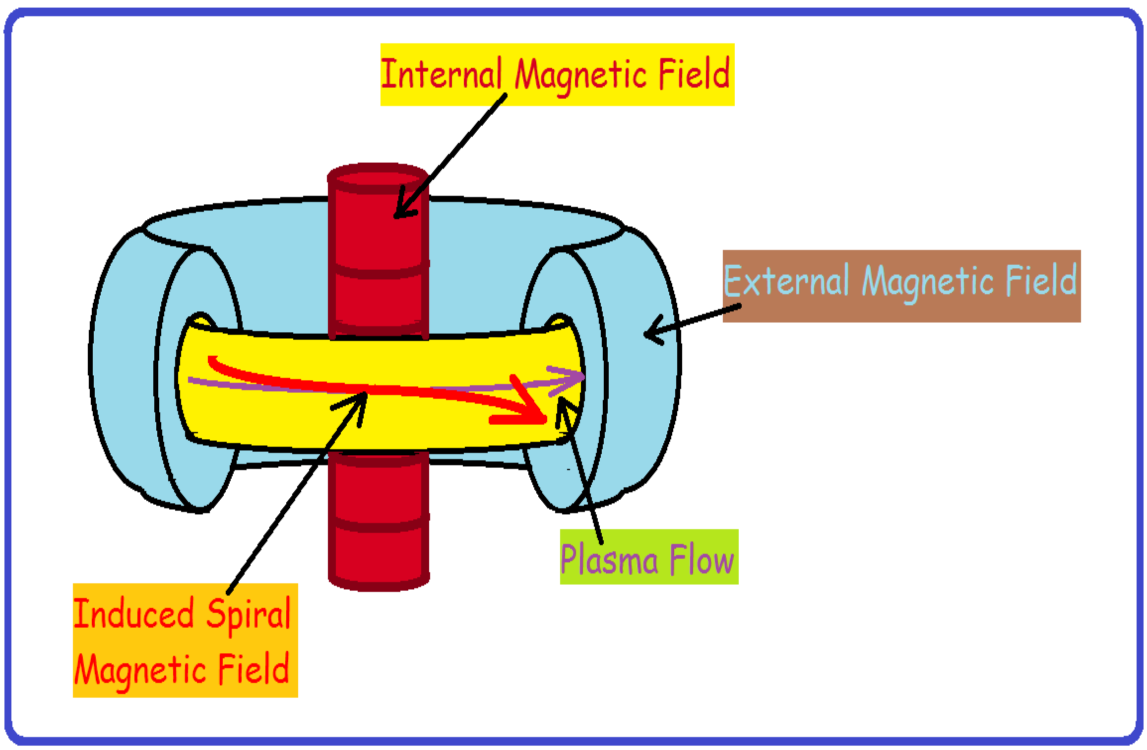
This reaction requires an energy of activation of 10 keV, but the energy obtained is 17.6 **M**eV (e.g., 10 lbs of TNT = 2.6114476363552E+20 MeV)! Fusion reaction products do NOT produce waste with long half lives.



Li Blanket Tritium Production PROBLEM

T is very rare – how do we make more? With Li! Wrap Deuterium (D or ^{2}H) and Tritium (T or ^{3}H) in a Li “blanket”.

BIG Problem: the temperature required to run the D+T reaction in the Li blanket is $2*10^{8}$ K. At this temperature, matter is present as PLASMA: gas made up of separated electrons and positively charged nuclei. How do you confine this “plasma”? It vaporizes everything solid known to man!



Magnets Confine the Plasma (Image above)

This answer was reached in response to learning that magnetic fields are known to restrict the motion of charged particles in space.

Matter, Mass and Conservation

Matter may be subdivided into several categories.

- In Mixtures, proportions of the components may vary.
  - Properties vary with the composition. Mixtures may be separated physically into 2 or more pure substances.
- Pure substances have a constant composition.
  - They have a fixed set of properties and can not be separated into simpler substances. Pure substances may be elements (e.g., carbon, oxygen, hydrogen, nitrogen, neon, argon) or compounds (water, sugar, salt, plaster of Paris, phenol).

Homogeneous matter is matter that has the same properties throughout the sample.

Heterogeneous matter is matter with properties that are not the same throughout the sample, e.g., fruit salad, pizza, wood and lasagna.

Solutions are homogeneous mixtures of 2 or more substances, e.g., sugar water, gasoline, gold alloy and salt water.

- Elements are pure substances made up of **HOMO**atomic molecules.
  - Elements can not be chemically subdivided into simpler substances.
- Compounds are those made up of **HETERO**atomic molecules.
  - Compounds can be chemically subdivided into simpler substances.
  - Compounds are products of chemical subdivisions and produce either elements or simpler compounds.

Elements	Compounds	Mixtures
These are substances that can not be broken down into anything simpler, yet are stable.	These are made from 2 or more elements.	These occur by blending two or more compounds or elements in any relative amounts.

The table, below, illustrates these latter two definitions:

Element (HOMOatomic)	Compound (HETEROatomic)	Compound (HETEROatomic)
X-X O-O = O_2 = Oxygen	X-O-X H-O-H = H_2O = Water	X-O-Z-Q C-H-H-H-H-N-N-O = CH_4N_2O = Urea

Monoatomic molecules are molecules that contain only a single atom. Homoatomic molecules are molecules that contain only one kind of atom. Heteroatomic molecules are molecules that contain 2 or more kinds of atoms. Polyatomic molecules are molecules that contain 2 or more atoms. The table, below, graphically illustrates these new terms:

Monoatomic	Homoatomic	Heteroatomic
	Polyatomic, also	Polyatomic, also
X Ca = Calcium	X-X-X-X-X-X-X O-O-O = O_3 = Ozone	X-O-Q NH_4OH = ammonium hydroxide

All matter gives rise to the Law of Definite Proportion: the elements in specific compounds are combined in the same proportion by mass, e.g.:

Water (H_2O) at the simplest:	Methanol (CH_3OH) at the simplest:	Glucose ($C_6H_{12}O_6$) at the simplest:
1.0 g hydrogen and 8 g oxygen = 9.0 g water	3 g carbon, 1 g hydrogen and 4 g oxygen = 8 g methanol	6 g carbon, 1 g hydrogen and 8 g oxygen = 15 g glucose

Elemental symbols [is] are [a] symbols assigned to an element based on the name of the element. These symbols are represented by either one capital letter or one capital letter followed by a lower case letter:

One capital letter		One capital letter and one lower case letter	
B = boron	O = oxygen	Ag = silver	He = helium
C = carbon	P = phosphorus	Au = gold	Ne = neon
F = fluorine	S = sulfur	Pt = platinum	Ar = argon
H = hydrogen	U = uranium	Hg = mercury	Tc = technetium
I = iodine	V = vanadium	Mg = magnesium	Fe = iron
K = potassium	W = tungsten	Ca = calcium	Co = cobalt
N = nitrogen	Y = yttrium	Be = beryllium	Mn = manganese

Compound formulas are symbols for the molecule of compounds, consisting of the symbols of the atoms found in the molecule.

Atoms present in numbers greater than one have a number indicated by a subscript (number behind and below that atom):

HCl = hydrochloric acid	H_2SO_4 = sulfuric acid	HNO_3 = nitric acid	H_3PO_4 = phosphoric acid
NaOH = sodium hydroxide	KOH = potassium hydroxide	$CaCO_3$ = calcium carbonate	Li_2CO_3 = lithium carbonate
$HC_2H_3O_2$ = acetic acid	$Al(OH)_3$ = aluminum hydroxide	$C_6H_{12}O_6$ = glucose	CH_4N_2O = urea
Na_3PO_4 = sodium phosphate	Al_2S_3 = aluminum sulfide		CaC_2O_4 = calcium oxalate

When mixtures are blended, this is a physical change. A physical change is defined any change without a chemical reaction. A chemical reaction is an event in which substances change into other substances:

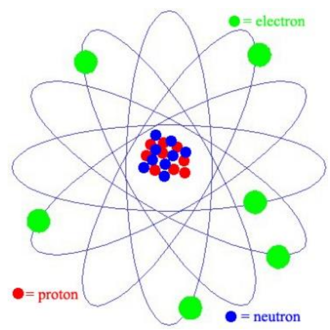
Reactants	→	Products
$H_2O_2 + Fe^{3+}$	→	$H_2O + O_2$
$Na + H_2O$	→	$NaOH + H_2$
$C + S + KNO_3$	→	BOOM!
$H_2 + O_2$ + spark	→	H_2O*
Urea + H_2O	→	"ice pack"#

*This is an exothermic reaction (a reaction that generates and gives off heat). #This is an endothermic reaction (a reaction that absorbs heat and feels cold).

All chemical reactions follow the Law of Conservation of Mass. This Law says that mass is neither gained nor lost in a chemical reaction, i.e., mass is conserved. Staying with our earlier examples from the Law of Definite Proportions:

Reactants	→	Products
1.01 g H + 8 g O	→	9.01 g H_2O
3 g C + 1 g H + 4 g O	→	8 g CH_3OH
6 g C + 1 g H + 8 g O	→	15 g $C_6H_{12}O_6$
6 g C + 1 g H + 8 g O	→	15 g $HC_2H_3O_2$ (HOAc is slang)

The Atom: A Q&D Intro



Atoms of the same element have the same average mass. Those of different elements have different average masses. Atom comes from "atomos" which means "not cuttable". Atoms consist of protons, neutrons and electrons:

Atoms		
Protons	Neutrons	Electrons
Positively charged; located in the nucleus of an atom; we write it as either p or p^+	Have no charge; found in the nucleus; written as n	Negatively charged; in the energy shells/orbitals around the nucleus; written as e^-
In an element, the number of protons = the number of electrons; the number of protons is also equal to the atomic number of that element.	Effects atomic mass.	Has no effect on atomic mass; in elements, the number of electrons equals the number of protons.
The number of protons + the number of neutrons = the atomic mass		

Electricity and The Atomic Nature of "Things"

Electrostatics = study of fixed or stationary, electric charges. Static electricity is the most common form we encounter. Electric charges = $\pm$. Smallest units = electrons (-) and protons (+). Have equal magnitude with opposite signs.

Remember: Static electricity is an excess of electric charge trapped on the surface of an object. The charge remains until it is allowed to escape to an object with a weaker or opposite electrical charge, such as the ground, by means of an electric current or electrical discharge.

Static electricity is named in contrast with current electricity, which flows through wires or other conductors and transmits energy.

Electrons

May travel from atom to atom: Protons don't. Discussions of electricity, then, rely on negative charges. An object is electrified if it has excess or missing electrons. How lose or gain electrons? Touch sock feet on carpet; Using a magnet to induce an electrical current.

Four Laws of Electrostatics

1) Law of Electrical Charges
2) Law of Electrification
3) Law of Electric Charge Distribution
4) Law of Electric Charge Concentration

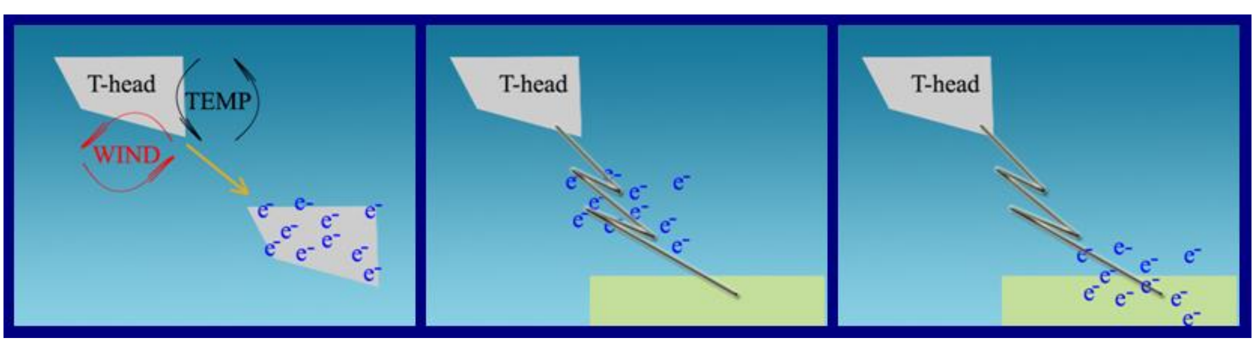
Law of Electrical Charges -- #1

Unlike charges attract; Like charges repel; The force of attraction or repulsion is the electrostatic force.

Law of Electrification -- #2

Electrification occurs because of the movement of negative electric charges. When a negatively charged object is in contact with an electrically neutral object, charges are transferred to the neutral object. If the transfer is sufficiently violent, makes a spark – of interest is the strap in "booties" for OR – was to reduce sparking by grounding person so patient wouldn't blow up on the table

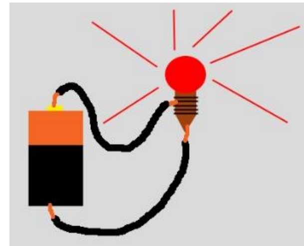
Thundercloud Example



Electron movement = lightning. CAN occur between clouds. USUALLY between clouds and earth.

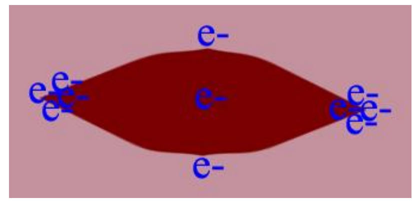
Law of Electric Charge Distribution -- #3

A diffuse non-conductor object (cloud) has charges distributed throughout the object. A conductor (Cu wire) has excess electrons over its outer surface:



Law of Electric Charge Concentration -- #4

Electric charges are concentrated along the sharpest curvature of a surface:

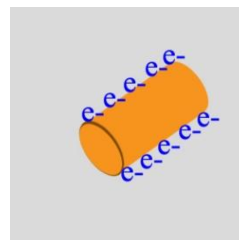


Electrodynamics

We recognize electrodynamic phenomena as electricity. The flow of electrons along a wire is the electric current. Any material through which electrons easily flow is called a conductor.

Electric Circuits

Electrons flow along the outer wire surface. The wire can be modified to resist the flow in certain regions. When resistance (Ω) is controlled and conductor is in a closed path, you've got an electric circuit. Current is measured in amperes (amps; I in equations). The electrical potential is measured in volts (V). Resistance is measured in ohms (Ω; R in equations). Ohm's Law is written as V = I R

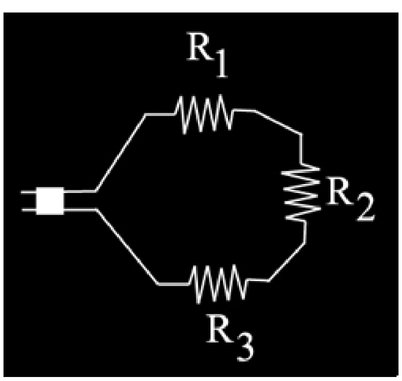


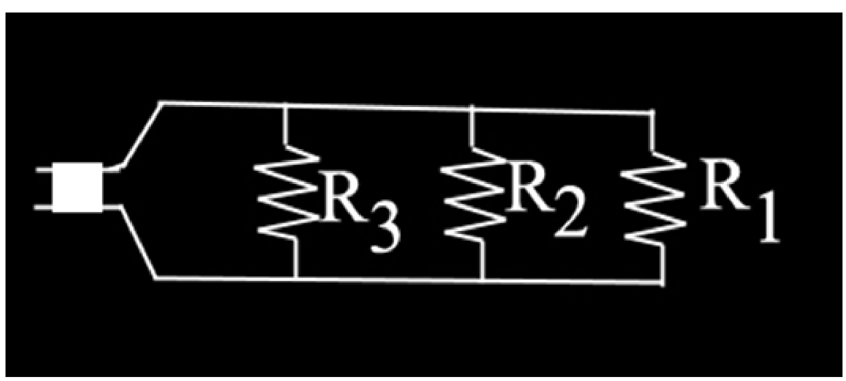
Electric Power

$P = I\,V = I^2\,R$

1 kW = 1000 Watts; 1kWh = 1000 watts used in one hour

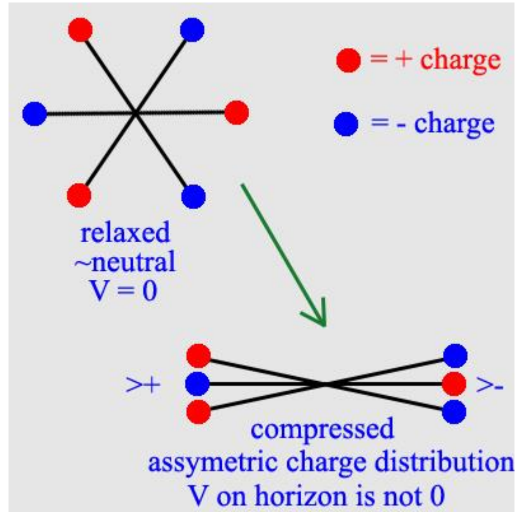
Electrical Circuits





Series (left) – set up like X-mas lights: one goes out, they all go out – Greatest Ω (resistance to electron flow), least electron flow.

Parallel (right) – one goes out, the rest stay on – Least Ω, greatest electron flow (conductance).



Blood Vessels

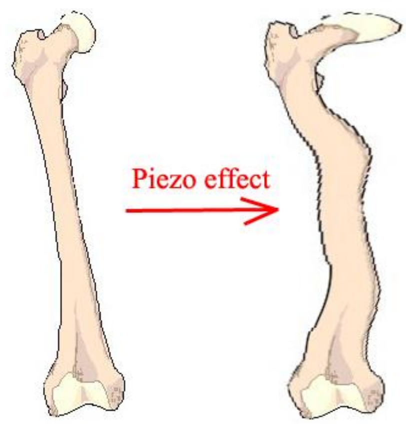
Is also why circulatory system is set up in parallel – it's most flow with the least amount of resistance.

Piezo Electric Effect

Piezoelectricity = pressure electricity. We know it from BBQ grills with the propane "starter". 1st discovered in quartz and tourmaline. Found in tendon, dentin, aorta, trachea, elastin and BONE!

The effect is the ability of a mineral or crystal to acquire opposing electrical charges on opposing surfaces when bending, stretching or compression is applied to the crystal. The effect is caused by displacing ionic charges within a crystal structure – the magnitude of the charge is usually proportional to the amount of stress applied. Think "pop rocks"!

Piezo – Bone



This stress effect causes osteoblasts (immature bone cells) to secrete osteoid (a protein that permits Ca salt precipitation on/in it) to make/remodel new bone.