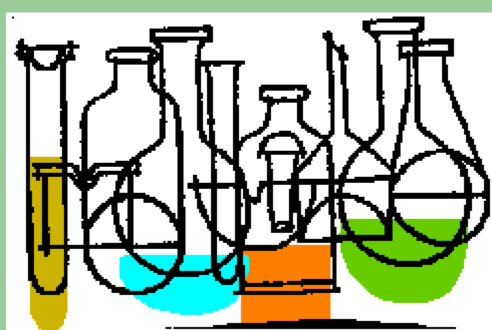
CHEMISTRY BASIS

A prelude to AMD 101



Bruce Golden
WPCAMR

If all the students who slept through lectures were laid end to end, they'd all be a lot more comfortable.

http://amrclearinghouse.org

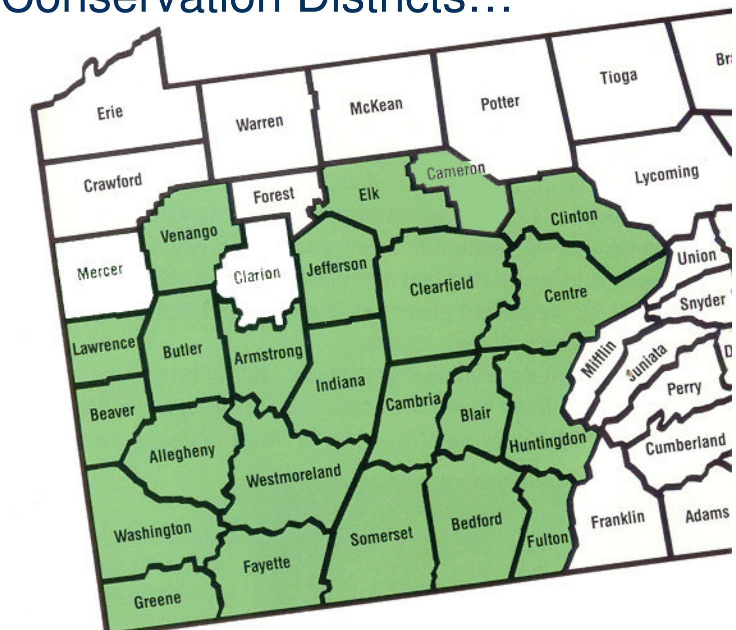
Western PA Coalition for Abandoned Mine Reclamation

WPCAMR
Western Pennsylvania Coalition for Abandoned Mine Reclamation

- A helping hand to watershed groups grappling with the legacy of problems from abandoned coal mining.

Funded by Department of Environmental Protection 319 NPS Program

Serving 23 counties in cooperation with Conservation Districts…



… and over 80 watershed groups in western PA

C-SAW

Consortium for Scientific Assistance to Watersheds

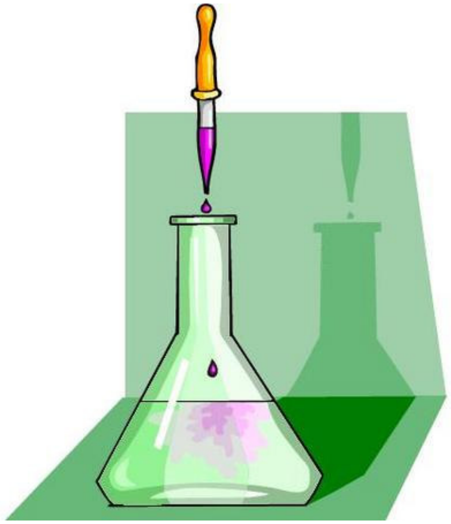
Funding for
AMD 101
provided by

Consortium for Scientific Assistance to Watersheds (C-SAW) is a team of specialists who provide eligible watershed groups or local project sponsors Program Management and Scientific Technical Assistance through the Pennsylvania Department of Environmental Protection's (PADEP) Growing Greener Program. The service is at no cost to eligible groups.

http://pa.water.usgs.gov/csaw/

Part 1

Chemistry Basics



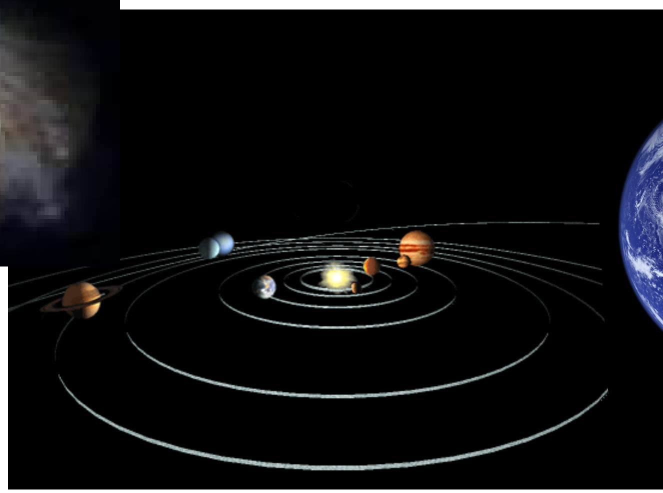
Chemistry

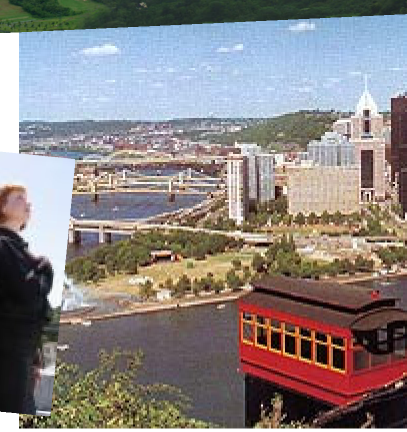
- ***Chemistry*** is the science in which substances are examined to find out what they are made of, how they act under different conditions, and how they are combined or separated to/from other substances.

- To understand chemistry, an appreciation of atoms and atomic theory is fundamental.

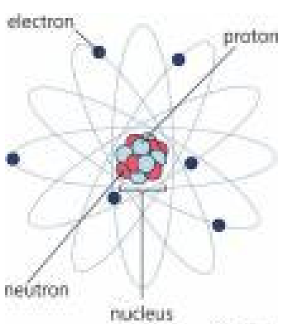
Atoms

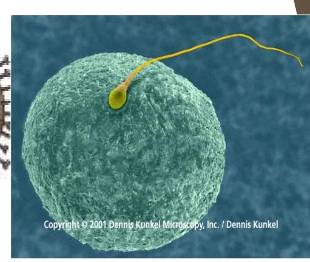
The building blocks for almost everything





http://library.thinkquest.org/C005775/Knocking/physicalworld.html



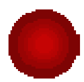


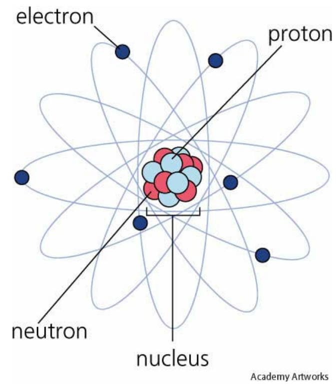
Caption: Human egg (oocyte) and sperm (spermatozoon).
File Name: 97990A
Category: Medical
Type of Image: SEM
Magnification: egg x260, sperm x560 (Based on an image size of 1 inch in the narrow dimension)

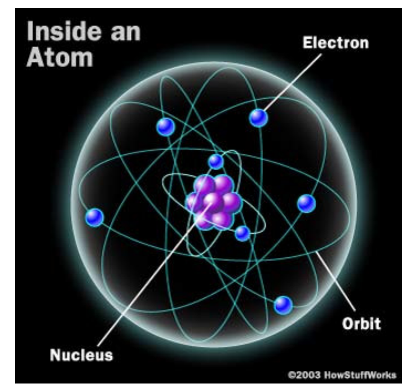
Atoms – simplified model

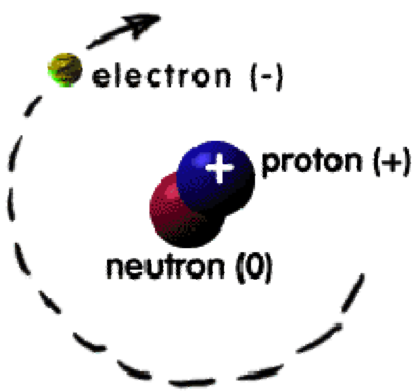
- Simplified model of atoms –
  - *like tiny solar systems*
  - At the center is a dense *nucleus* comprised of (a) positively charged *protons*, and (b) uncharged *neutrons*
  - The nucleus is surrounded by orbits of negatively charged *electrons*.
  - For atoms, the number of electrons(-) in orbits around the nucleus equals the number of protons(+) in the nucleus for an atom (by definition).
    - The sum of positive and negative charges = zero .

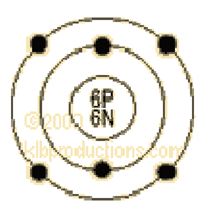
Atoms - visuals

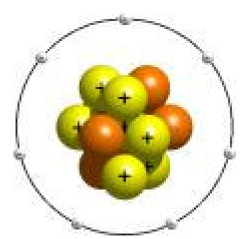


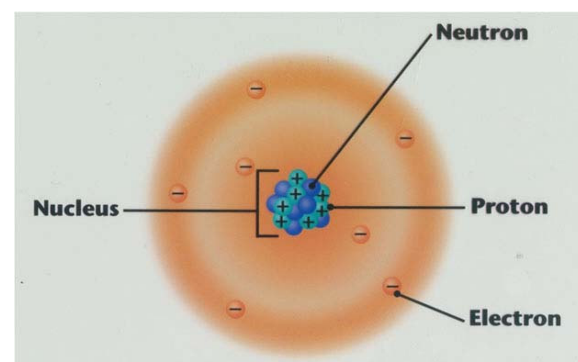












Atoms

- Compared to electrons, protons and neutrons of the nucleus are very much larger
  - (proton/electron mass ratio is 1836, neutron/electron mass ratio is 1838)
- Nucleus comprises virtually all of an atom’s mass
  - (can neglect electron mass)
- An atom is virtually all empty space
  - (although rarely depicted that way)


nucleus
electron
To home plate
Web Images Groups News Froogle Local New! Desktop more »
pittsburgh
Search
Search the map
Find businesses
Get directions
e.g., "hotels near lax" or "10 market st, san francisco"
Help
Local
Link to this page
Map
Satellite
Hybrid
1000 ft
200 m
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Atoms – element definition

- *Elements* are collections of atoms, where each atom in the collection has the same number of protons.
- An atom is the simplest form of an element.
  - Although they're not really the same, the terms elements and atoms are often used interchangeably.

Atoms – quite a variety

- 90 different naturally occurring elements have been discovered on Earth
- Another ~25 elements have been created artificially

Atoms - Protons and Atomic Number

- One kind of an atom (or element) is distinguished from another kind *by* *the number of protons* in its nucleus
- The number of protons defines the kind of atom
- *Atomic number* is name given to the number of protons in the nucleus.
- Each element has a single atomic number associated with it.
- Atomic number is the most important feature in determining the properties of an element.

Atoms – the Element Hydrogen

The element Hydrogen (chemical symbol H) has the simplest of all kinds of atoms

- 1 proton (Atomic number 1)
- 0 neutrons

Full disclosure

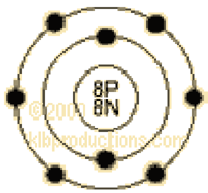
- 2 naturally occurring isotopes
- 99.99% of H atoms have ***<u>no</u>*** neutrons (the only element with this property)
- 0.01% have a single neutron

- 1 electron

Atoms – the Element Oxygen

The element Oxygen (chemical symbol O)

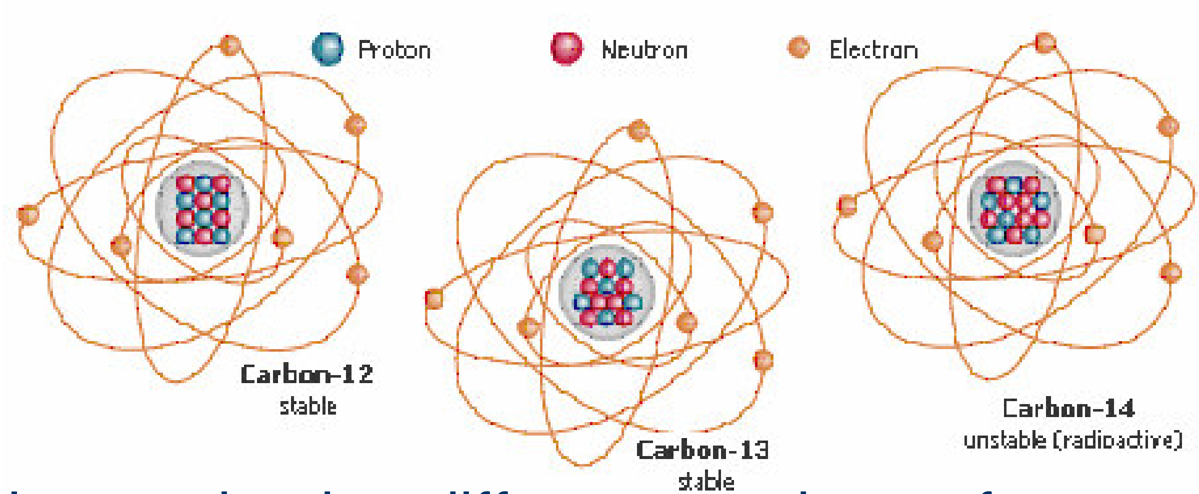
- 8 protons (Atomic number 8)
- 8 neutrons
  - Full disclosure
    - 2 naturally occurring isotopes
    - 99.96% of Oxygen atoms have 8 neutrons
    - 0.04% have 9 neutrons
- 8 electrons



Atoms – neutrons and isotopes

All atoms of an element may not all have the same number of neutrons, even though the number of protons is equal.

The element carbon (Atomic Number 6) can have atoms with 6, 7, or 8 neutrons.



- Atoms of an element having different numbers of neutrons are called *isotopes* *(also called nuclides)*.
- There is virtually no difference in the chemical behavior of isotopes of an element.

Atoms – Atomic Weight

- The sum of protons + neutrons for a given isotope is the *Mass Number*.
    - The isotope of carbon having 7 neutrons has a Mass Number of 13 (= 6 + 7)
- A similar (*and important*) term is *Atomic Weight* .
- *Atomic Weight* is the average of mass numbers for naturally occurring isotopes of an element, taking into account the isotopes' relative abundances.
- Atomic weights for all elements are readily available

Atoms – the nucleus doesn't change

- In chemistry, we can assume the

  nucleus of an atom never, ever changes.

  - The nuclei of the vast majority of atoms have remained unchanged from their creation in stars billions of years ago.
  - The nucleus of an atom can be altered, but only through rather extraordinary means.
    - nuclear reactor, nuclear bomb, particle accelerators, radioactivity

- The number of neutrons and protons in a given atom is immutable.

- Electrons are quite another story.
- Much of what happens in chemistry has to do with what happens with the electrons of atoms.

Atoms – electrons & energy levels

- As atoms become more complex (with increasing Atomic Number) so does the electronic structure of atoms.
- Electrons are populated in atoms in a very systematic way. *(A lesson for another day.)*
- As more electrons are added, they fill distinct energy levels (or shells).
- The outer electrons have higher energy levels than do the inner ones.

Atoms – valence electrons

- The outermost electrons (or highest energy level electrons) are mainly responsible for the chemical properties of atoms.
- These “outer shell” electrons are called *valence* electrons.
- Valence electrons are where the action happens.
- The inner electrons can be thought of as unchangable and don’t contribute much to the properties of atoms.

Atoms – Periodic Table

- The *Periodic Table of the Elements* is a systematic classification of elements by atomic number and by number of valence electrons
- This classification shows atoms with similar properties in groups.
- Other valuable information is usually displayed.
  - Atomic Weight
- The Periodic Table is one of chemistry's most fundamental and important tools.

Elements involved in AMD Chemistry

Periodic Table of the Elements 2005

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.01																	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.41	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (270)	109 Mt (268)	110 Ds (281)	111 Rg (272)							

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

Molecular Research Institute

Elements of interest (for AMD)

Element	Symbol	At.No.	Atomic Wt.
• Hydrogen	H	1	1.01
• Carbon	C	6	12.01
• Oxygen	O	8	16.00
• Aluminum	Al	13	26.98
• Sulfur	S	16	32.07
• Calcium	Ca	20	40.08
• Manganese	Mn	25	54.94
• Iron	Fe	26	55.85

Ions – proton / electron inequality

- Atoms are capable of either gaining or loosing an electron(s)
- An atom that either gains or looses an electron(s) will:
  - No longer have equal numbers of protons and electrons
  - No longer be electrically neutral; it will have a net charge
  - No longer be a called an atom, but an *ion.*

Example:
A hydrogen atom that's lost it's electron
*is a **hydrogen ion (H^+)***

- Each element has its own propensity of gaining or loosing an electron.
- Valence (outer) electrons are the ones gained or lost

Ions - cations and anions

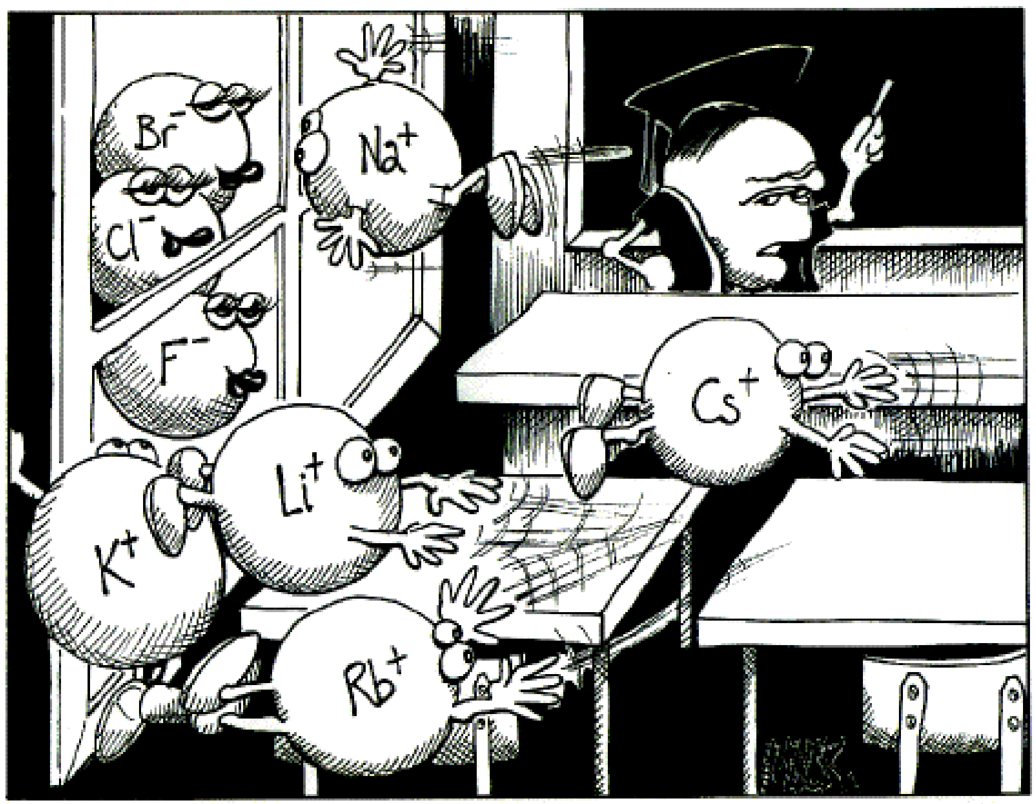
- Ions with a positve charge are also called *cations* (pronounced *kat-ions*).
- Cations with a +1 charge have lost 1 electron, with a +2 charge have lost 2 electrons.
  - Examples: H^{+} Fe^{2+} Fe^{3+} Al^{3+} Ca^{2+} Na^{+}
- Ions with a negative charge are also called *anions* (pronounced *an-ions*).
- Anions with a -1 charge have gained 1 electron, with a -2 charge have gained 2 electrons.
  - Examples: F^{-} Cl^{-} Br^{-}

Ions – rules of attraction

- Positive (+) ions attract negative (-) ions
  - Anions attract cations (and *vise versa*)

- Ionic attraction is one way that atoms can ***bond*** with each other.
  - Table salt is an example:
  - Sodium cations (Na^+) and chlorine anions (Cl^-) are boned to each other by ionic attraction in forming the molecule sodium chloride (NaCl)

Ionic attraction – irresistible?



"Perhaps one of you gentlemen would mind telling me just what it is outside the window that you find so attractive...?"

Molecules

A *molecule*

- is a group of atoms bound tightly together by inter-atomic bonds (resulting from interactions of valence electrons).
- is the smallest unit of a substance that shows all the chemical properties of that substance.
- can contain atoms of the same element or atoms of different elements.
  - $\mathbf{H_2}$ hydrogen molecule, $\mathbf{O_2}$ oxygen molecule
  - $\mathbf{H_2O}$ water, $\mathbf{CO_2}$ carbon dioxide, $\mathbf{CH_4}$ methane
  - $\mathbf{H_2SO_4}$ sulfuric acid

Molecular Weight

- ***Molecular weight*** is the sum of atomic weights of each atom comprising the molecule
  - Calculation for **H_2O**
    - H 2 x 1.01 = 2.02
    - O 1 x 16.00 = 16.00
    - MW $_{water}$ = **18.02**

Atomic Weights	
Hydrogen	1.01
Oxygen	16.00

- We'll see later the molecular weight is also the number of grams in a mole of a compound.

Molecular formulas

Molecule	M.W.	Name
O_2	16	Oxygen
H_2O	18	Water
FeS_2	120	Iron sulfide (*Pyrite*)
$Fe(OH)_3$	107	Ferric Hydroxide (*Yellow Boy*)
Fe_2O_3	160	Iron Oxide
H_2SO_4	98	Sulfuric Acid
CO_2	44	Carbon Dioxide
H_2CO_3	62	Carbonic Acid
$CaCO_3$	100	Calcium Carbonate (*Limestone*)
$Al(OH)_3$	46	Aluminum Hydroxide

Compounds

- A <u>*compound*</u> is a collection of molecules, all of the same kind.
- An <u>atom is to an element</u> as a <u>molecule is to a compound</u>.

Complex Ions

- A *complex ion* is similar to a molecule (having 2 or more constituent atoms) but where the group of atoms has either lost or gained electron(s), leaving the collective group of atoms with either a net positive or negative charge.

Complex ions

Ion	MW	Name
OH^-	17	hydroxide
SO_4^{2-}	96	sulfate
CO_3^{2-}	60	carbonate
HCO_3^-	61	bicarbonate

Bonding

- Individual pairs of atoms in a molecule are strongly held together by chemical bonds.
- The bonding occurs between pairs of atoms by interactions of the atoms' outermost (valence) electrons.
- 2 main categories of bonding: Ionic & Covalent
- *Ionic Bonding*
  - Electron(s) from one atom are transferred to the other.
  - The attractive force of the resulting opposite charges bind the atoms together.
  - Atom pairs whose electronic structure are the most dissimilar are the ones that are most likely to enter into this relationship.
- *Covalent Bonding*
  - Electrons are shared between atoms.
  - Each atom has a hold on the electrons, binding the atoms together.
  - Atom pairs whose electronic structure are the most similar are the ones that are most likely to enter into this relationship.

Mole - sort of like a dozen but a lot bigger

- Chemists often approach situations on the basis of number of atoms or molecules involved.
- Atoms and molecules are way too small to deal with individually… need a more convenient way.
- A *mole* is a collection of a 6.022×10^{23} things (usually atoms or molecules)
  - Like a dozen is a collection of 12 things (eggs or donuts)
- *Avagadro's number* is 6.022×10^{23}
- That number was constructed so that one mole of molecules will equal its molecular weight in grams.
  - There are Avagadro's number of protons in 1 gram
  - One mole of water molecules has a mass of 18 grams
- If we know the mass of something and know what kind of molecule makes it up (assuming all one kind), we can always figure out the number of moles.

$$36\ g\ H_2O \times (1\ mole\ H_2O / 18\ g\ H_2O) = 2\ moles\ H_2O$$

Avagadro’s Number

HUGE

- 602,200,000,000,000,000,000,000
- That’s .6 trillion trillion
- Or .6 million million million million
- One big honkin’ number

Chemical Reactions

- occur when atoms or molecules rearrange to form products with new properties.
- Plants and animals are literal chemical factories driven by chemical reactions.
- Our modern quality of life depends on producing and transforming substances through chemical reactions.

Reactions

- A *Chemical Reaction* is the process by which atoms or groups of atoms are redistributed (rearranged), resulting in a change in the molecular composition of substances.
- The properties of the products of the reaction may show no similarity to those of the original reacting compounds.
- Because a reaction only rearranges atoms, there is no change in the total mass. This is known as the law of *Conservation of Mass.*

Chemical equations describe reactions

- A chemical equation symbolizes the reactants and products of a reaction.

$$H_2 + O_2 \rightarrow H_2O$$

reactants → *products*

(consumed) *(produced)*

- The equation must balance the number and kinds of atoms on both the reactant and product sides.

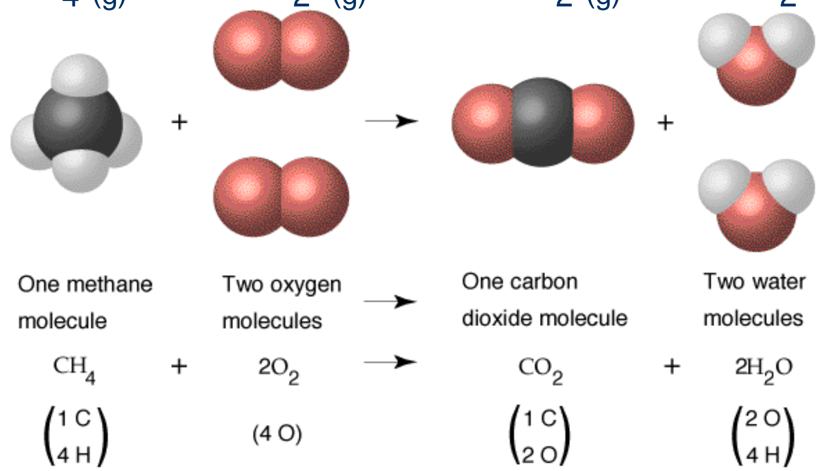
$$2H_2 + O_2 \rightarrow 2H_2O$$

- The state of matter is usually indicated.

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$$

Reactions – when natural gas burns

- Combustion of methane
  - $CH_{4\,(g)} + 2\,O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2\,H_2O_{(g)}$



  - Methane (CH_4) gas reacts with oxygen (O_2) gas to form the gas carbon dioxide (CO_2) and water (H_2O) vapor
  - 1 molecule of methane and 2 molecules of oxygen react to form one molecule of carbon dioxide and two molecules of water
  - 1 mole of methane and two moles of oxygen are consumed in producing one mole of carbon dioxide and two moles of water

Reactions - symbology

- *(s)* solid phase
- *(l)* liquid phase
- *(g)* gas phase
- *(aq)* aqueous… dissolved in water
- $\rightarrow$ read as "reacts to form" (in the direction indicated)
- $\leftrightharpoons$ means the reaction is capable of proceeding in either direction (left to right or right to left)
- A number preceding a reactant or product indicates the number of atoms/molecules/ions involved in the reaction
  - A *balanced reaction* indicates that reactants and products have equal numbers of atoms for each element involved, which obey the law of conservation of mass.

Atoms Review

An **atom** is a submicroscopic structure found in all ordinary matter. It is the smallest unit of an element to retain all the chemical properties of that element. The word *atom* originally meant the smallest possible particle of matter, not further divisible. Later, the objects that had been called atoms were found to be further divisible into smaller subatomic particles, but the word atom nonetheless continues to refer to them.

Most atoms are composed of three types of massive subatomic particles which govern their external properties:

- electrons, which have a negative charge and are the least massive of the three;
- protons, which have a positive charge and are about 1836 times more massive than electrons; and
- neutrons, which have no charge and are about 1838 times more massive than electrons.

Together, protons and neutrons form the nucleus of an atom, which is surrounded by the electrons.

An atom's size is defined by the electrons' paths (or orbitals) around the nucleus. The modern view of an atom is a nucleus surrounded by a cloud where the electrons can be found. Most of an atom is empty space with almost all of the mass concentrated in the protons and neutrons of the nucleus.

Atoms Review

Atoms can differ in the number of each of the subatomic particles they contain. The number of protons in the nucleus (also known as the atomic number) distnguishes one element from another. Atoms of the same element have the same number of protons, but can differ in the number of neutrons, in which case they are called isotopes of that element. With the exception of hydrogen atom, the number of neutrons will be at least equal to the number of protons.

Atoms are electrostatically neutral (having a charge of zero) if they have an equal number of protons and electrons.

Atoms whose number of protons don't equal the number of electrons are called ions and have a net charge. Atoms deficient in electrons have a net positive charge and are also called cations. Atoms having a surplus of electrons have a net negative charge and are also called anions.

Electrons that are furthest from the nucleus are less tightly bound to the atom and are relatively easily transferred to other nearby atoms or even shared between atoms.

Atoms are the fundamental building blocks of chemistry, and are conserved in chemical reactions meaning the atoms are merely rearraged, not lost or gained. Atoms are able to bond into molecules and other types of chemical compounds. Molecules are made up of multiple atoms; for example, a molecule of water is a combination of two hydrogen and one oxygen atom.

Ninety elements are known to occur in nature, and 22 more have been made artificially. Out of this limited number of elements, all the millions of known substances are made.

States of Matter

- *Solid* – a solid is a collection of molecules and/or atoms (particles) which touch each other and are rigidly held together by attractive forces. Solids have a definite shape and volume.
- *Liquid* - a collection of particles which touch each other, but where attractive forces are not strong enough to keep them from moving around releative to each other. Liquids have a definite volume and take the shape of their container.
- *Gas* - a collection of particles which are completely separated from one another. The attractive forces between them are extremely small and are insufficient to hold gases in a definite shape or volume. Gases expand freely to fill their containers.

Solutions

- *Solutions* are homogeneous (uniform) mixtures of two or more substances.
- The substance present in largest quantity usually is called the *solvent*,
- The substance present in smallest quantity is called the *solute*.
- The most common solvent is liquid water, although a solvent can be a gas, liquid, or solid.
- A solution with water as the solvent is called an *aqueous solution*.
- The solute can be a gas, liquid, or solid.
- Sugar water is an example of a solid solute (sugar) dissolved in a liquid solvent (water).
- Carbonated water is an example of a gas solute (carbon dioxide) dissolved in a liquid solvent (water). Oxygen is another example of a dissolved gas.

Dissolve

- Dissolution
- Solubility
- Some liquids, such as water and alcohol, can dissolve in each other in any proportion. If sugar is dissolved in water, however, new sugar added to the solution above a certain amount will not dissolve any more; the solution is then called saturated. The solubility of a compound in a given solvent at a given temperature and pressure thus is defined as the maximum amount of that compound that can be dissolved in the solution. Solubility increases with the increasing temperature of the solvent for most substances. For some substances, such as gases or the organic salts of calcium, solubility in a liquid increases with a lowering of temperature.

Concentration

- The amount of dissolved material in a solution is called the concentration and can be expressed in units, such as grams per liter or ounces per gallon.
- The use of parts per million (ppm) is common when the amount of solute is very small.
- Lab reports for AMD water mostly use the unit of concentration of milligrams (of solute) per liter (mg/L) (which is numerically equivalent to ppm.)
- For chemical purposes, expressing concentration in terms of the number of molecules (or ions) in solution is often preferable. Moles per liter is called the Molar concentration.

Precipitation

- **precipitation** is a process in which a solid is separated from liquid. In a suspension such as sand in water the solid spontaneously precipitates (settles out, falls out) by gravity on standing.
- The solid may also be formed as the result of a chemical reaction.

Acids

- An *acid* is a compound that contributes hydrogen ions to water.
- An aqueous solution is *acidic* if it has a greater concentration of hydrogen ions (H^+) than does pure water.
- About pure water

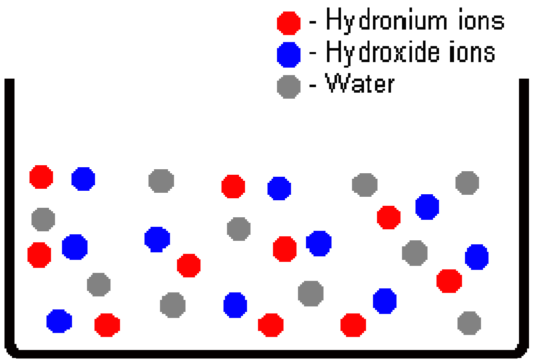
  $[H^+]_{\text{pure water}} = 1.0 \times 10^{-7}$ M at 25C; $pH_{\text{pure water}} = 7$

  $[H^+]_{\text{pure water}} = [OH^-]_{\text{pure water}}$
- A solution becomes more acidic as its H^+ concentration $[H^+]$ increases
- The addition of an acid will increase H^+ concentration $[H^+]$

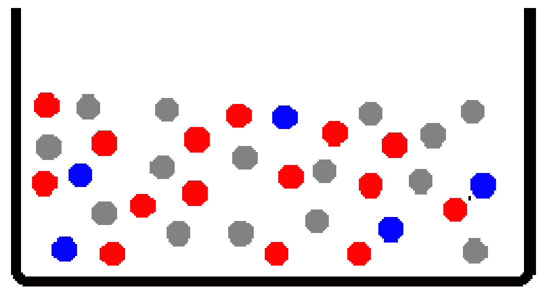
Properties of Acids

- conduct electricity
- taste sour
- "neutralize" bases
- turn litmus red
- react with many metals

Acids



Pure Water
$[H^+] = [OH^-]$



Acidic Solution
$[H+] > [OH-]$

Bases

- A ***base*** is a compound that contributes hydroxide ions (OH^-) to water.
- An aqueous solution is ***basic*** (or ***alkaline***) if it has a greater concentration of hydroxide ions (OH^-) than does pure water.

  $[OH^-]_{pure\ water} = 1.0 \times 10^{-7}$ M at 25C;   pH=7

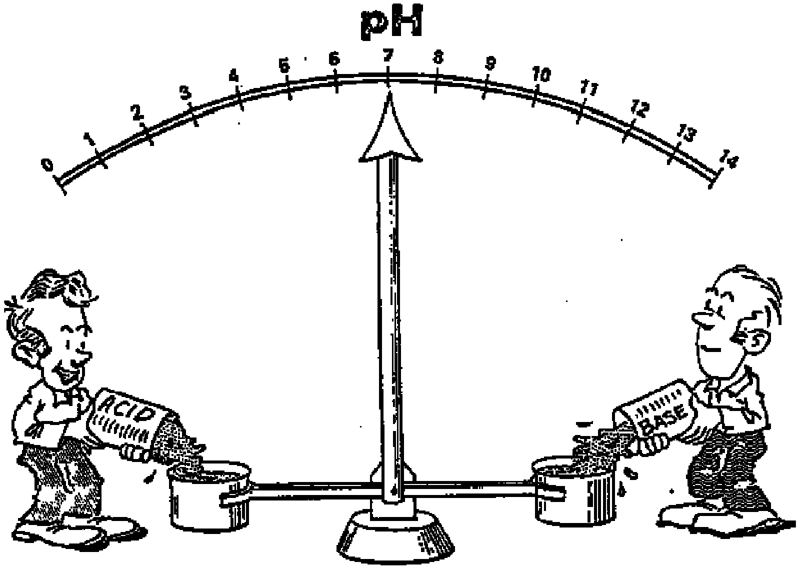
  $[H^+]_{pure\ water} = [OH^-]_{pure\ water}$
- The solution becomes more basic (or alkaline) as the OH^- concentration increases.
- The addition of a base will increase hydroxide ion (OH^-) concentration $[OH^-]$

Properties of bases

- conduct electricity
- taste bitter
- "neutralize" acids
- turn litmus blue
- feel slippery

Neutralization

- TUMS (a base) for an acid stomach
- When acids and bases combine, they neutralize each other
- $H^+ + OH^- \rightarrow H_2O$
- H^+ and OH^- are in perfect balance at pH = 7



pH - Background

- Water is one of the most important of all substances on earth
- One of it’s most important properties is hydrogen ion concentration $[H^+]$
- Almost all life is sensitive in some way to $[H^+]$, so it’s very important to be able to measure it.
- Even absolutely pure water will have a certain amount of H^+ because of a small tendency of water to split into H^+ and OH^- ions.

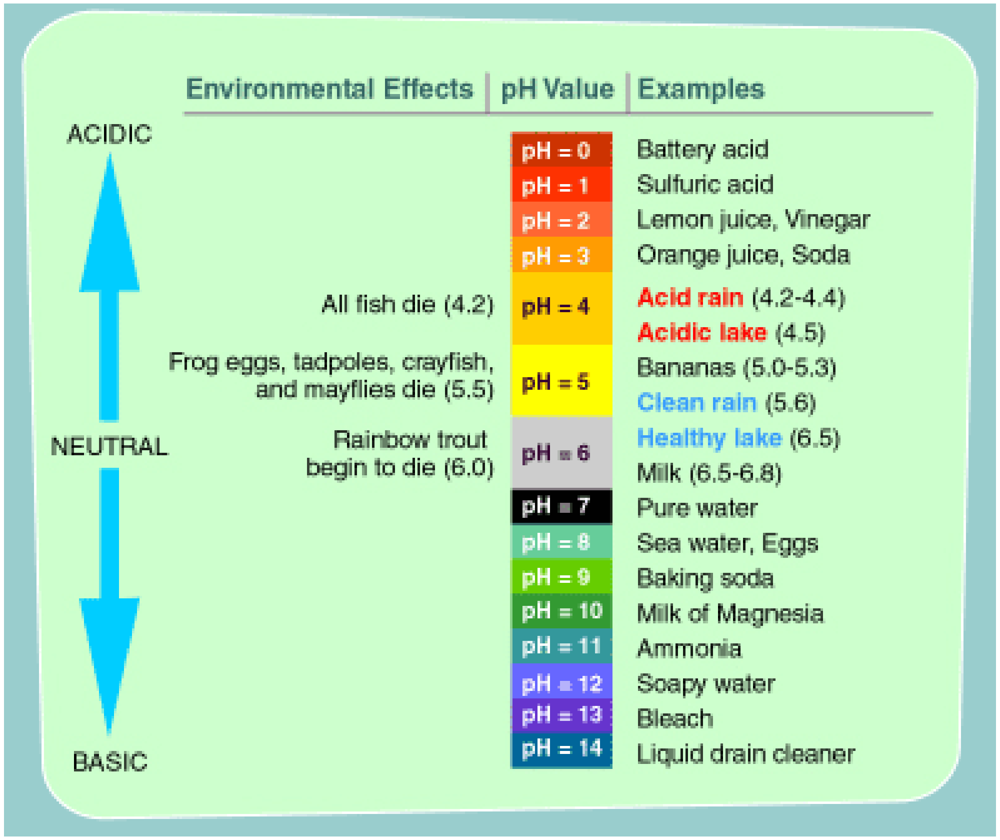
pH – necessity is mother of invention

- The measurable dynamic range of hydrogen ion concentrations in water can vary from the smallest to the largest by over 100 trillion times! (and that's conservative!)
- The largest concentration we might be interested in is over 100,000,000,000,000 times larger than the smallest.
- That's like Bill Gates picking up pennies on the street!
- This huge dynamic range of concentrations presented some problems in presenting data.
- Chemists devised a way of being able to compress the large dynamic range into a more manageable range by inventing the pH scale.

pH

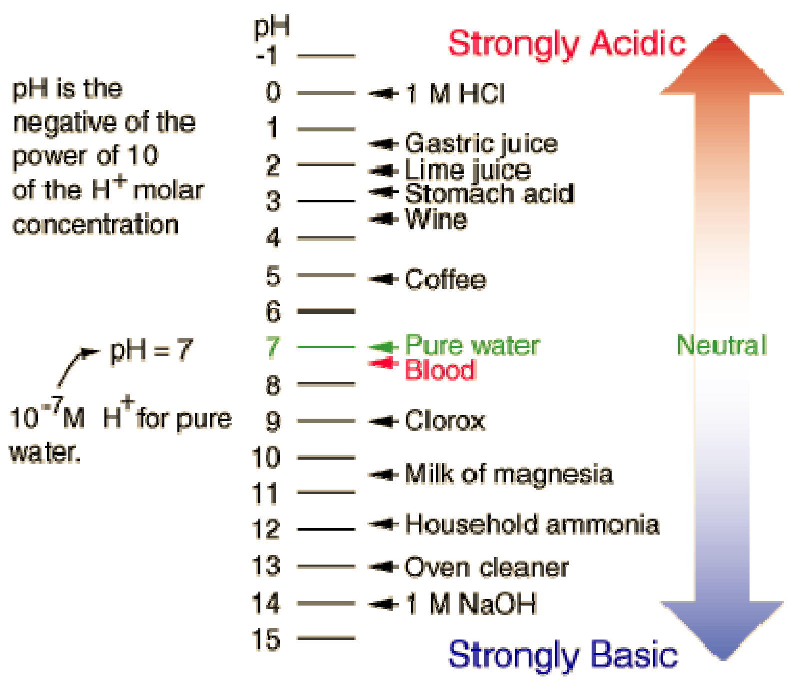
pH	$[H^+]$ decimal form	$[H^+]$ scientific notation	$[OH^-]$ decimal form	$[OH^-]$ scientific notation	
0	1	1×10^{0}	0.00000000000001	1×10^{-14}	very acidic
1	0.1	1×10^{-1}	0.0000000000001	1×10^{-13}	quite acidic
2	0.01	1×10^{-2}	0.000000000001	1×10^{-12}	quite acidic
3	0.001	1×10^{-3}	0.00000000001	1×10^{-11}	moderately acidic
4	0.0001	1×10^{-4}	0.0000000001	1×10^{-10}	moderately acidic
5	0.00001	1×10^{-5}	0.000000001	1×10^{-9}	mildly acidic
6	0.000001	1×10^{-6}	0.00000001	1×10^{-8}	mildly acidic
7	0.0000001	1×10^{-7}	0.0000001	1×10^{-7}	pure water, neutral
8	0.00000001	1×10^{-8}	0.000001	1×10^{-6}	mildly basic
9	0.000000001	1×10^{-9}	0.00001	1×10^{-5}	mildly basic
10	0.0000000001	1×10^{-10}	0.0001	1×10^{-4}	moderately basic
11	0.00000000001	1×10^{-11}	0.001	1×10^{-3}	moderately basic
12	0.000000000001	1×10^{-12}	0.01	1×10^{-2}	quite basic
13	0.0000000000001	1×10^{-13}	0.1	1×10^{-1}	quite basic
14	0.00000000000001	1×10^{-14}	1	1×10^{0}	very basic

pH – the simple description



Concentration of Hydrogen ions compared to distilled water		Examples of solutions at this pH
10,000,000	pH= 0	Battery acid, Strong Hydrofluoric Acid
1,000,000	pH = 1	Hydrochloric acid secreted by stomach lining
100,000	pH = 2	Lemon Juice, Gastric Acid Vineger
10,000	pH = 3	Grapefruit, Orange Juice, Soda
1,000	pH = 4	Acid rain Tomato Juice
100	pH = 5	Soft drinking water Black Coffee
10	pH = 6	Urine Saliva
1	pH = 7	"Pure" water
1/10	pH = 8	Sea water
1/100	pH = 9	Baking soda
1/1,000	pH = 10	Great Salt Lake Milk of Magnesia
1/10,000	pH = 11	Ammonia solution
1/100,000	pH = 12	Soapy water
1/1,000,000	pH =13	Bleaches Oven cleaner
1/10,000,000	pH = 14	Liquid drain cleaner

pH – the simple description



pH – what it is and what it isn't

- pH is a measure of hydrogen ion concentration
- pH is related to the hydrogen ion concentration
- For every pH value there is a unique hydrogen ion concentration, and *vice versa*

$$pH = -\log [H^+]; \qquad [H^+] = 10^{-pH}$$

- pH is NOT the hydrogen ion concentration
- pH only applies to water solutions
- pH is a mathematical invention of convenience

Why pH 7 for pure water?

- Water has an inherent, yet small tendency to split (dissociate) into H^+ and OH^- ions.
- While the vast majority of water molecules will remain as water molecules, a small number will dissociate.

$$H2O \rightleftharpoons H^+ + OH^-$$

- For absolutely pure water at 25°C, the *measured* $[H^+]$ is 0.0000001 M; (pH = 7)

Only if you're really interested

- The dissociation of water is described by the reaction

$$H2O \rightleftharpoons H^+ + OH^-$$

- The tendency of water to dissociate can be described mathematically by the following formula

$$K_w = [H^+] [OH^-]$$

where K_w is known as the dissociation constant of water.

- *For pure water* the only source of H^+ and OH^- is the dissociation reaction above, which implies that $[OH^-]$ is equal to $[H^+]$ in pure water. Therefore, a value for K_w can be calculated as follows:

$$K_w = (1 \text{ x } 10^{-7})\ (1 \text{ x } 10^{-7})$$
$$K_w = 1 \text{ x } 10^{-14}$$

pH tutor

Enter [H+] here

Enter **hydrogen ion concentration** $[H^+]$ =	0.001	M
can also be expressed as	1.00E-03	M
The definition of pH is	*$pH = -log_{10} [H^+]$*	
The log_{10} of 1.00E-03 is	-3.00	
so $-log_{10}$ of [H+] (*its* ***pH***) is	3.00	S.U.

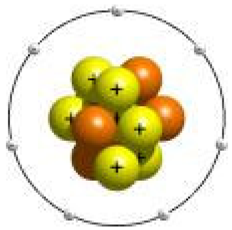
Working the other way….. from pH back to [H+]

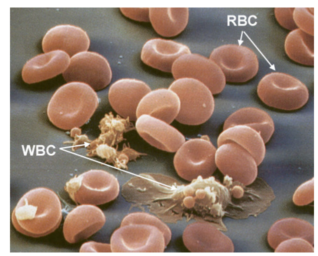
Since	*$[H^+] = 10^{-pH}$*	
$[H^+] = 10^{-}$	3.00	
So, $[H^+]$ =	0.001	M
can also be expressed as	1.00E-03	M

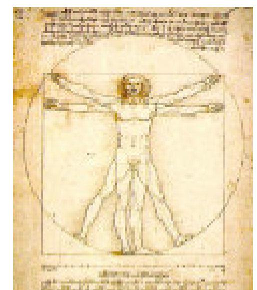
Recommended Web Sites

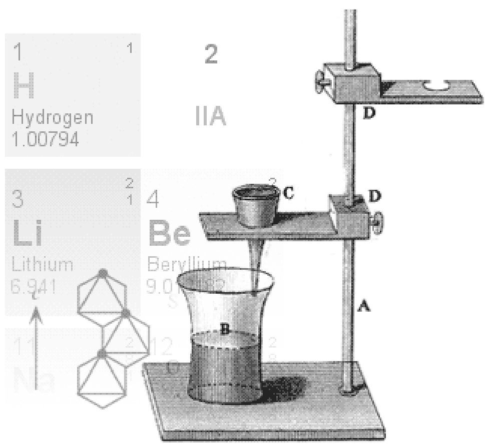
- Virtual ChemBook
  http://www.elmhurst.edu/~chm/vchembook/
- *msn* Encarta
  http://encarta.msn.com/encyclopedia_762504460/Chemistry.html
- Chemistrycoach.com
  http://www.chemistrycoach.com/
- EnvironmentalChemistry.com
  http://environmentalchemistry.com
- AMRClearinghouse.org
  http://amrclearinghouse.org
- Chem4Kids
  http://www.chem4kids.com
- HyperPhysics
  http://hyperphysics.phy-astr.gsu.edu/hbase/chemical/chemcon.html

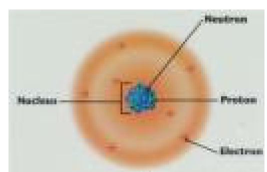
The End




RBC
WBC




1
H
Hydrogen
1.00794
2
IIA
3
Li
Lithium
6.941
4
Be
Beryllium
D
C
D
B
A


Neutron
Nucleus
Proton
Electron