GENERAL CHEMISTRY

"What hopes and fears does this scientific method imply for mankind? I do not think that this is the right way to put the question. Whatever this tool in the hand of man will produce depends entirely on the nature of the goals alive in this mankind. Once the goals exist, scientific method furnishes means to realize them. Yet it cannot furnish the very goals. The scientific method itself would not have led anywhere, it would not even have been born without a passionate striving for clear understanding."

– Albert Einstein –

The Scientific Method

The Steps in the Scientific Method

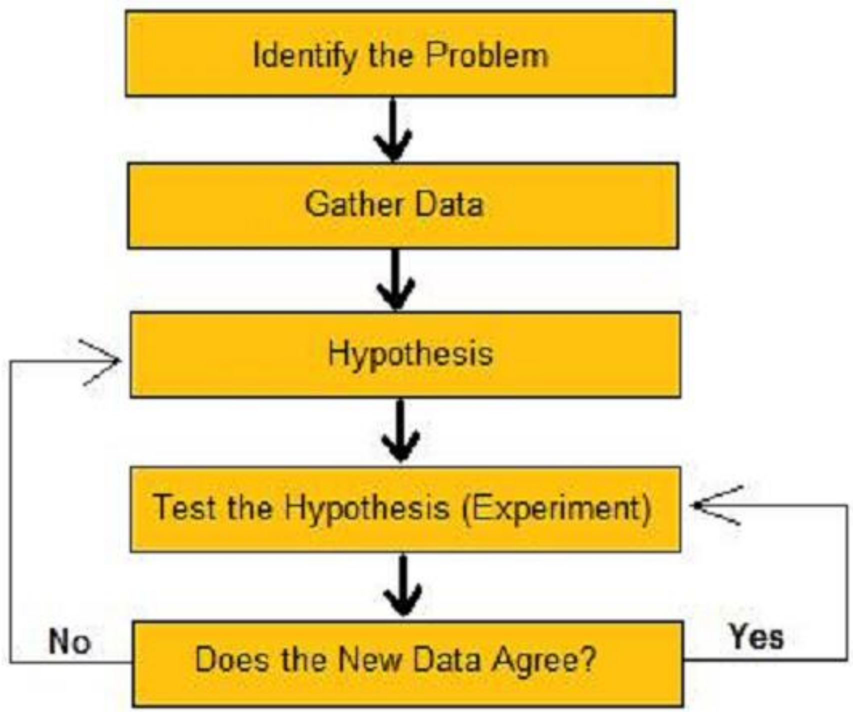
Step 1: Identify the problem or phenomenon that needs explaining. This is sometimes referred to as "defining the problem." This activity helps limit the field of observations.

Step 2: Gather and organize data on the problem. This step is also known as "making observations."

Step 3: Suggest a possible solution or explanation. A suggested solution is called a hypothesis.

Step 4: Test the hypothesis by making new observations. If the new observations support the hypothesis, you accept the hypothesis for further testing.

Step 5: If the new observations do not agree with your hypothesis, you discard the hypothesis, add the new data to your observations list, and return to step 3.



An Example of the Scientific Method

READING MATERIAL

Suppose you are required to maintain a large campfire and you are completely unfamiliar with the property of objects that makes them combustible (able to burn). The first step in the scientific method is to define the problem. What property of objects make them combustible? The next step is to gather data on the problem. So, you begin to collect objects at random and put them into the fire. You must keep good records of what objects were tried and whether or not they burned. Here's a list of organized data (observations).

Will Burn	**Won't Burn**
tree limbs	rocks
chair legs	bricks
pencils	marbles
baseball bat	hubcaps

The list of organized observations helps because now you can collect only the items on the "will burn" list and not waste the effort of dragging items that won't burn back to the fire. However, you would soon use up all the items on the "will burn" list and it is necessary to guess what property the "will burn" objects have that cause them to burn. If you had that answer, you could bring objects that may not be on the "will burn" list but that have the "will burn" property and keep the fire going.

The third step in the scientific method is to suggest a hypothesis. Your guess about what property the "will burn" objects have that makes them combustible is a hypothesis. Suppose you notice that all the items on the "will burn" list are cylindrical in shape and therefore, you hypothesize that "cylindrical objects burn". The fourth step in the scientific method is to test your hypothesis. To test this hypothesis, you go out and collect a group of objects that are cylindrical including iron pipes, soda bottles, broom handles, and tin cans. When these cylindrical objects are placed in the fire and most of them don't burn, you realize your hypothesis is not supported by these new observations.

The new observations are the test , and your hypothesis has failed the test.When the new observations fail to support your hypothesis, you reject your original hypothesis, add your new data to the table, and make a new hypothesis based on the updated observations list. In the schematic diagram of the scientific method, a failed test returns the scientist to step 3, make a new hypothesis .

Will Burn	**Won't Burn**
tree limbs	rocks
chair legs	bricks
pencils	marbles
baseball bat	hubcaps
broom handle	iron pipes
	soda bottles
	tin cans

Suppose your new hypothesis is "wooden objects burn." You will find this hypothesis more satisfactory since all the wooden object you try will burn. Your confidence will grow that you have discovered a "law of nature." Even with your somewhat successful theory, you might be ignoring a large stack of old car tires, objects made of fabric or paper, or perhaps containers of petroleum. You can see that even though you are quite satisfied with your theory because it does the job you want it to do, you actually do not have a complete statement on the property of objects that make them burn. So it is with science.

You can see from this example that the "solution" does not become what we think of as a "fact," but rather becomes a tentatively accepted theory which must undergo continuous testing and perhaps adjustment . No matter how long a tentative explanation has been accepted, it can be discarded at any time if contradictory observations are found. As long as the theory is consistent with all observations, scientists will continue to use it. When a theory is contradicted by observations, it is discarded and replaced. Even though the terms hypothesis, theory, and fact are used somewhat carelessly at times, a theory will continue to be used while it is useful and will be called into question when contradictory evidence is found. Theories never become facts.

There is a common generalization about theories, which says that "theories are much easier to disprove than to prove." The common example given is a hypothesis that "all swans are white." You may observe a thousand white swans and every observation of a white swan supports your hypothesis, but it only takes a single observation of a black swan to disprove the hypothesis. To be an acceptable scientific hypothesis, observations that disprove the hypothesis must be possible. That is, if every conceivable observation supports the hypothesis, then it is not an acceptable scientific hypothesis. To be a scientific hypothesis, it must be possible to refute the concept.

IMPORTANCE OF CHEMISTRY

Why do we study chemistry?

Chemistry is the science that studies the composition and changes in composition of the substances around us.

The science of the composition, structure, properties, and reactions of matter.

Chemistry is a Science of Materials

Ancient Materials Versus Modern Materials

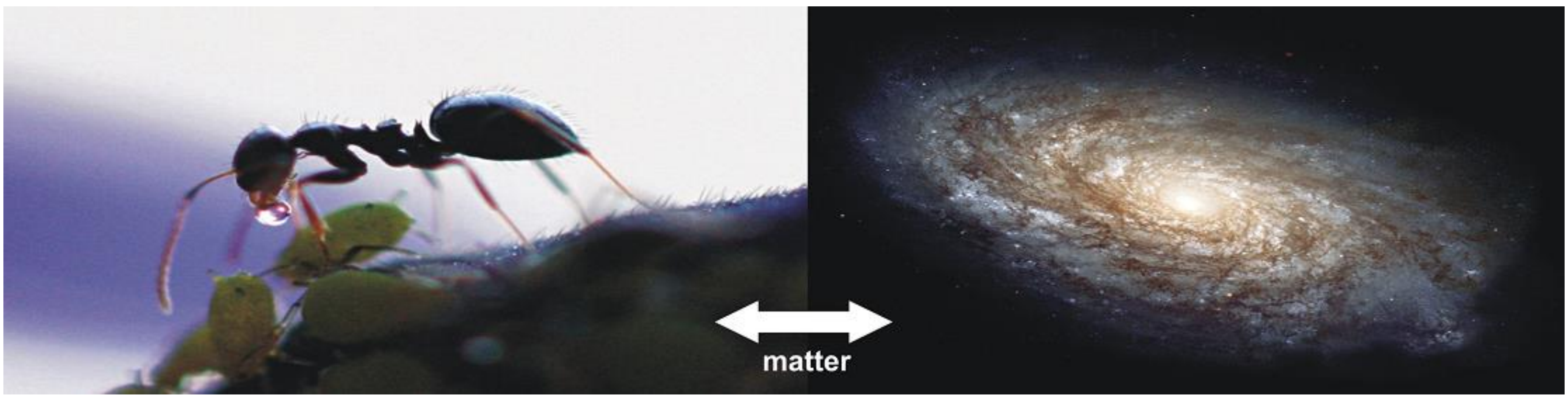
Ancient bronze artifacts

Some common household items made of plastic.

- Chemists Study the Properties of Matter
- Chemists Study of How and Why Matter Changes
- Chemists Study the Interchange of Matter and Energy

MATTER : anything that has mass and volume

- **matter is anything that occupies space and has weight.**
- **obviously, the matter around you is not all the same.**



Physical States of Matter

(1) Solids. Solids have a definite shape and volume. Examples of solids are books, rocks, pieces of steel, and sand.

(2) Liquids. Liquids have a definite volume but indefinite shape. That is, they take the shape of their container. Water, mercury, alcohol, and oils are liquids.

(3) Gases. Gases have neither a definite shape nor a definite volume.
They assume not only the shape of their container, but also the volume of their container. Gases may be expanded or compressed to fit the container in which they are being placed. Therefore, the air in an automobile tire would, if released, expand to fill a large weather balloon.

Properties of Matter.

- Matter possesses two types of properties, : physical and chemical
- Characteristics such as smell, color, shape, freezing point, boiling point, and solubility are said to be physical properties of matter.
- Energy content, reactions with other substances, and chemical reactions due to light, heat, and electricity are said to be chemical properties of matter.
- From the physical and chemical properties exhibited by a substance, it is possible to isolate, identify, and classify the particular substance.

Classification of Pure Matter

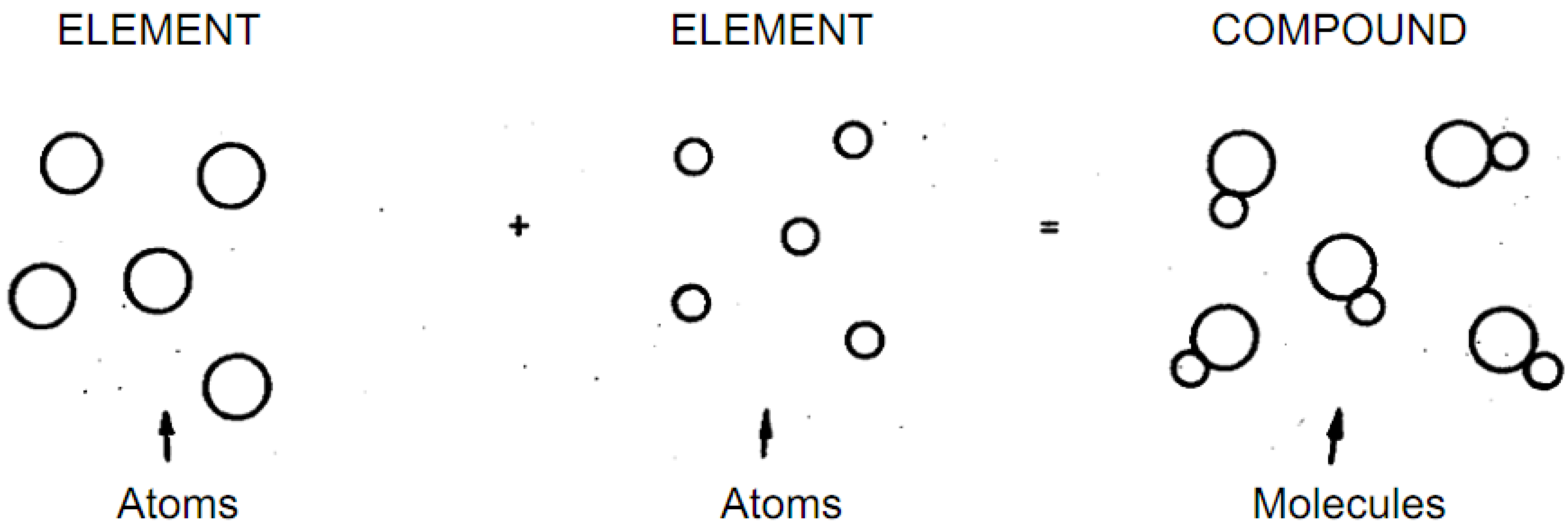
- **Matter that cannot be separated into two or more types of matter by physical means is called <u>pure matter</u>.**
- **Pure matter consists of two types: <u>*elements and compounds*</u>.**

Elements (원소)

- Elements are substances that cannot be separated into two or more types of matter by physical or chemical methods.
- Another way to say this is that elements consist of only one type of atom.
- An atom is a chemical building block and can be defined as the smallest part of an element that remains unchanged during any chemical reaction and exhibits or displays the chemical properties of that element.
- Examples of common elements are oxygen, gold, iron, mercury, hydrogen, and carbon.

Compounds (화합물)

- **Compounds are composed of two or more elements chemically combined.**
- **Compounds are substances that have been <u>purified by physical means</u>, but not by chemical methods.**
- **They can be separated into two or more types of matter by chemical methods because their basic unit, the molecule, is a combination of two or more types of atoms.**
- **A molecule is composed of two or more atoms and is the <u>smallest part of a compound</u> that can exist and still <u>retain the chemical properties</u> of that compound.**


ELEMENT
+
ELEMENT
=
COMPOUND
Atoms
Atoms
Molecules

	ELEMENT	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT
	Actinium	Ac	89	227
*	Aluminum	Al	13	26.9815
	Americium	Am	95	243
	Antimony	Sb	51	121.75
	Argon	Ar	18	39.948
*	Arsenic	As	33	74.9216
	Astatine	At	85	210
*	Barium	Ba	56	137.34
	Berkelium	Bk	97	247
	Beryllium	Be	4	9.0122
*	Bismuth	Bi	83	208.980
*	Boron	B	5	10.811
*	Bromine	Br	35`	79.909
	Cadmium	Cd	48	112.40
*	Calcium	Ca	20	40.08
	Californium	Cf	98	249

* Denotes elements most common to medicine.

	ELEMENT	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT
*	Carbon	C	6	12.01115
	Cerium	Ce	58	140.12
	Cesium	Cs	55	132.905
*	Chlorine	Cl	17	35.453
	Chromium	Cr	24	51.996
*	Cobalt	Co	27	58.9332
*	Copper	Cu	29	63.54
	Curium	Cm	96	247
	Dysprosium	Dy	66	162.50
	Einsteinium	Es	99	254
	Erbium	Er	68	167.26
	Europium	Eu	63	151.96
	Fermium	Fm	100	253
*	Fluorine	F	9	18.9984
	Francium	Fr	87	223
	Gadolinium	Gd	64	157.25
	Gallium	Ga	31	69.72
	Germanium	Ge	32	72.59
*	Gold	Au	79	196.967
	Hafnium	Hf	72	178.49
	Helium	He	2	4.006
	Holmium	Ho	67	164.930
*	Hydrogen	H	1	1.00797
	Indium	In	49	114.82
*	Iodine	I	53	126.9044
	Iridium	Ir	77	192.2
*	Iron	Fe	26	55.847
	Krypton	Kr	36	83.80
	Kurchatovium	Ku	104	257
	Lanthanum	La	57	138.91
	Lawrencium	Lw	103	257
*	Lead	Pb	82	207.19
*	Lithium	Li	3	6.939
	Lutetium	Lu	71	174.97

	ELEMENT	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT
*	Magnesium	Mg	12	24.312
*	Manganese	Mn	25	54.9380
	Mendelevium	Md, Mv	101	256
*	Mercury	Hg	80	200.59
	Molybdenum	Mo	42	95.94
	Neodymium	Nd	60	144.24
	Neon	Ne	10	20.183
	Neptunium	Np	93	237
	Nickel	Ni	28	58.71
	Niobium	Nb, Cb	41	92.906
*	Nitrogen	N	7	14.0067
	Nobelium	No	102	254
	Osmium	Os	76	190.2
*	Oxygen	O	8	15.9994
	Palladium	Pd	46	106.4
*	Phosphorus	P	15	30.9738
	Platinum	Pt	78	195.09
	Plutonium	Pu	94	242
	Polonium	Po	84	210
*	Potassium	K	19	39.102
	Praseodymium	Pr	59	140.907
	Promethium	Pm	61	147
	Protactinium	Pa	91	231
*	Radium	Ra	88	226
	Radon	Rn	86	222
	Rhenium	Re	75	186.2
	Rhodium	Rh	45	102.905
	Rubidium	Rb	37	85.47
	Ruthenium	Ru	44	101.07
	Samarium	Sm	62	150.35
	Scandium	Sc	21	44.956
*	Selenium	Se	34	78.96
*	Silicon	Si	14	28.086
*	Silver	Ag	47	107.870

	ELEMENT	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT
*	Sodium	Na	11	22.9898
*	Strontium	Sr	38	87.62
*	Sulfur	S	16	32.064
	Tantalum	Ta	73	180.948
	Technetium	Tc	43	99
	Tellurium	Te	52	127.60
	Terbium	Tb	65	158.924
	Thallium	Tl	81	204.37
	Thorium	Th	90	232.038
	Thulium	Tm	69	168.934
	Tin	Sn	50	118.69
	Titanium	Ti	22	47.90
	Tungsten	W	74	183.85
	Uranium	U	92	238.03
	Vanadium	V	23	50.942
	Xenon	Xe	54	131.30
	Ytterbium	Yb	70	173.04
	Yttrium	Y	39	88.905
*	Zinc	Zn	30	65.37
	Zirconium	Zr	40	91.22

Elements, symbols, atomic numbers, and atomic Weights in alphabetical order

Classification of Mixed Matter

(1) Homogeneous mixtures

- **Mixtures that are uniform throughout are called homogeneous**
- **An example of a homogeneous mixture is a solution of sugar in water.**
- **Any small part of this solution would exhibit the same properties as any other small part; therefore, it would be uniform throughout the mixture.**

(2) Heterogeneous mixtures

- **Mixtures that are not uniform are called heterogeneous.**
- **An example of a heterogeneous mixture is a mixture of water and oil.**
- **If a small sample is taken, it may not be the same as another small sample taken from elsewhere in the mixture.**
- **This is because oil and water do not mix well--they give a nonuniform mixture.**

ATOMIC STRUCTURE

- **Early scientists felt that all matter must be built from some *basic unit*, just as a wall may be constructed from a basic unit, the brick.**
- **In trying to find this basic unit, they separated matter by all the methods (chemical and physical) available to them until they could not separate it any further.**
- **They felt this separation must result in the building block of matter, which they called the *atom* (from the Greek word for indivisible).**
- **They also observed that the basic units or atoms for various elements differed in their properties, as iron was certainly different from carbon.**

ATOMIC STRUCTURE

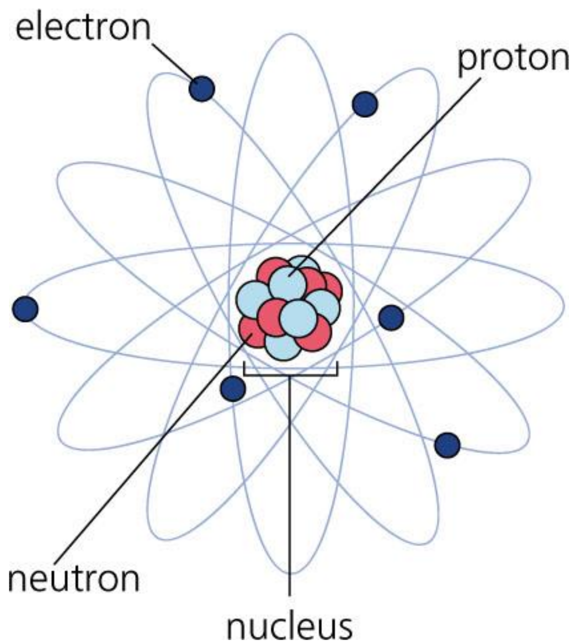
- **This led them to try to find the structure of the atom**
- **The difficulty of this problem can be seen when you consider that one cubic centimeter of gold contains as many as 59,000,000,000,000,000,000,000 atoms.**
- **The atom is so small that it defies conception.**
- **Through ingenious methods, particularly in the last 100 years, we have discovered many facts about this tiny particle, which enables us to understand many of the changes that occur around us.**

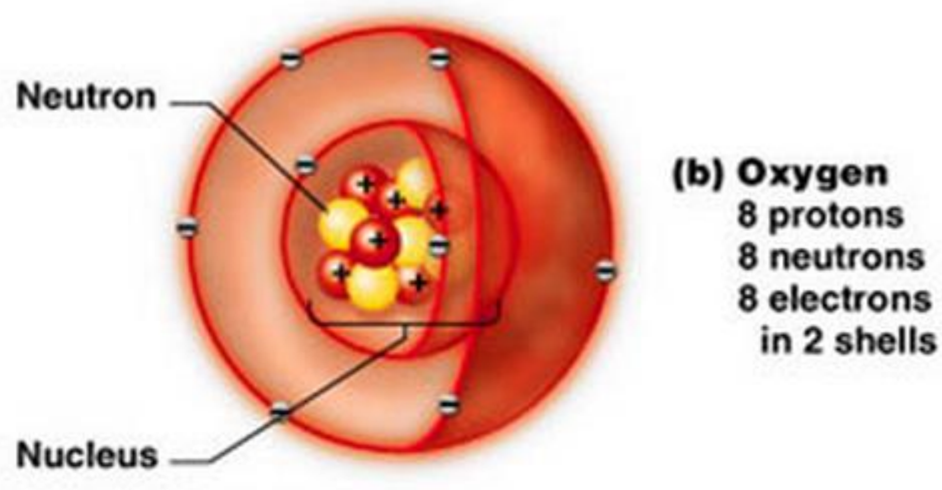
a. Atomic Model.

- In order for us to picture what an atom looks like, we can use a description with which most people are familiar--the solar system model.
- In this model, the atom is thought of as a tiny solar system in which there is a central core (like the sun) with other particles traveling in circular paths or orbits (like the planets).
- While more complex and exact models have been developed, this is the best approximation for general use.

b. The Nucleus.

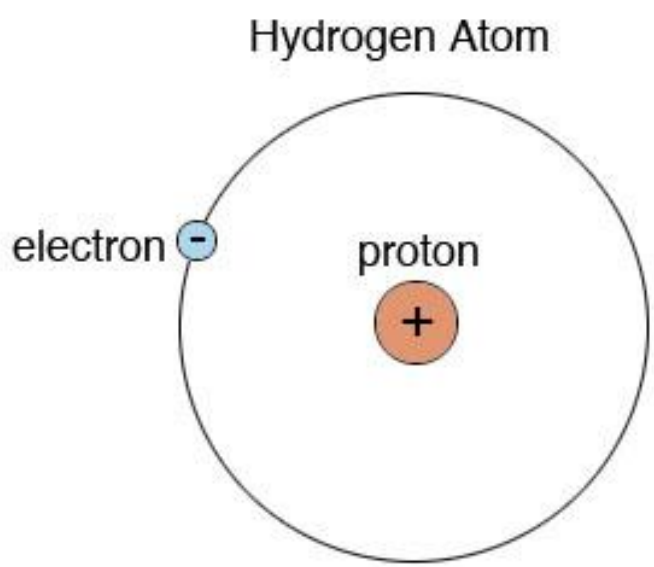
- The central core from the solar system model is called the
- nucleus (which is derived from the Latin word nucis meaning nut or kernel). The
- nucleus contains two types of particles, the proton and the neutron.





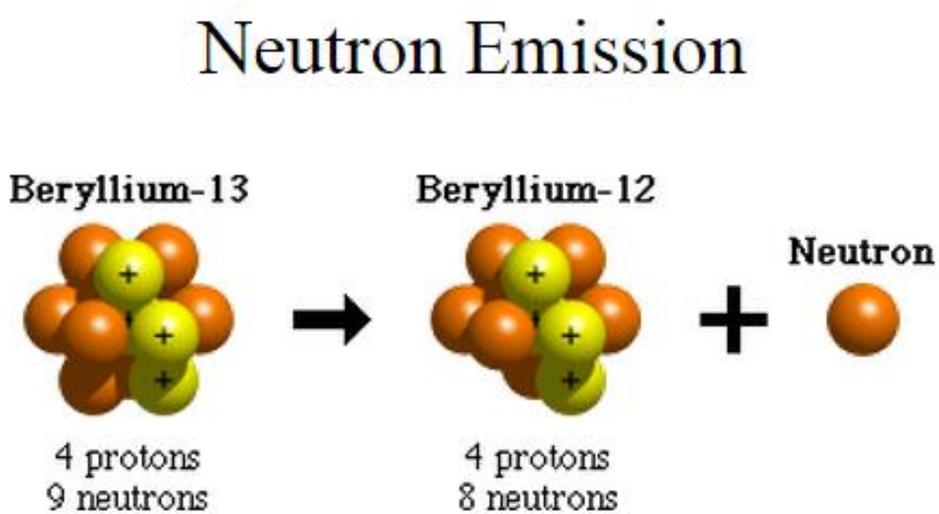
(1) The proton

- **The proton is a particle that has a mass (or weight) of one amu (atomic mass unit) and a positive one (+1) electrical charge.**
- **The symbol for the proton is p, p+ or H+.**



(2)The neutron

- **The neutron has a mass of one amu (atomic mass unit) but has no electrical charge; that is, it is a neutral particle.**
- **In an atom that has more than one proton, the positive charges tend to repel each other.**
- **The neutrons serve to bind the protons so that this electrical repulsion does not cause them to fly off into space.**
- **The symbol for the neutron is n.**



(3) Atomic number and atomic weight

- **Two important figures commonly used when discussing an atom are its *atomic number* and its *atomic weight*.**

  - ✓ **Atomic number. The atomic number of an atom is equal to the number of protons in the nucleus of the atom. For example, a carbon atom has six protons in its nucleus; therefore, the atomic number of carbon is six.**

  - ✓ **Atomic weight. The atomic weight of an atom is equal to the number of protons in the nucleus of the atom (one amu each) plus the number of neutrons in the nucleus of the atom (one amu each). Therefore, a carbon atom with six protons and six neutrons has an atomic weight of 12.**

c. The Outer Structure.

- The particles that orbit the nucleus (as the planets orbit the sun) are called electrons.
- These particles have an electrical charge of negative one (-1), but their mass is so small that it is considered to be zero.
- Actually, the mass of the electron is 1/1837 of the mass of a proton, but the mass, which contributes to the atom is so small that it is not important.
- The symbol for the electrons is e- or -.

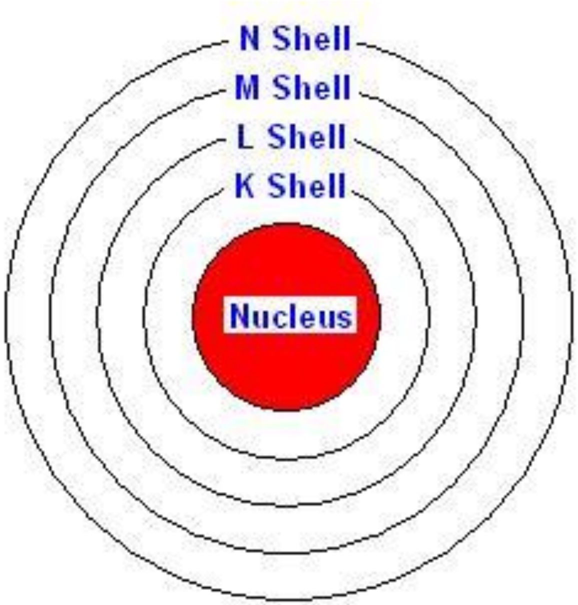
(1)Electron configuration.

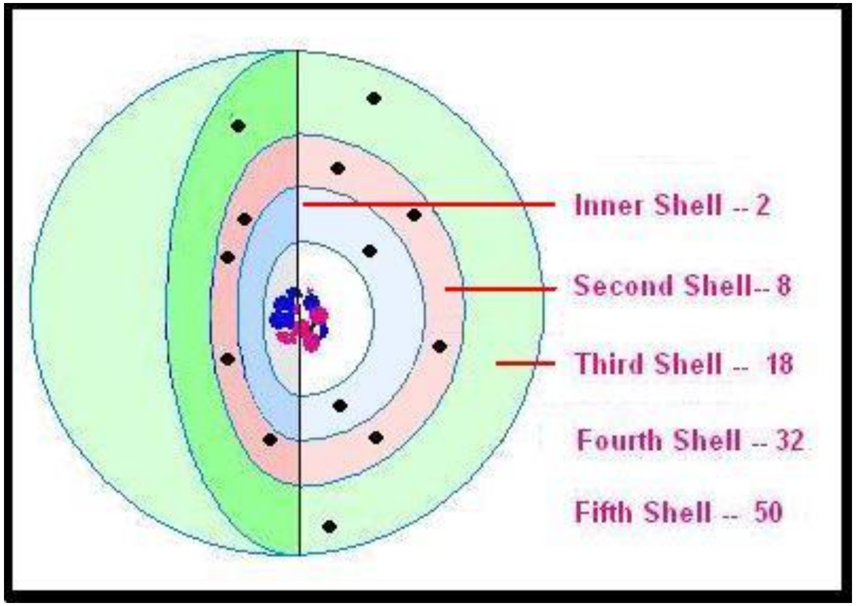
- **Since we may have many electrons going around the nucleus, It might appear that there could be a collision of electrons.**
- **Collisions do not occur because the electrons are located in orbits, which are different distances from the nucleus and because of the repulsion between like charges.**
- **The number of electrons and their locations are called the electron configuration.**
- **This electron configuration is different for each element.**

(2)Electron shell.

- **The term electron shell (or energy level) describes where electrons are located (i.e., a specific region around the nucleus).**
- **Since electrons can be forced to leave their atoms, the term energy level indicated the amount of energy required to remove the electrons from the various levels or shells.**
- **A nucleus can have seven shells, but more chemicals of medicinal importance contain electrons in the first four, which are labeled the K, L, M, and N shells.**

- **The K shell is the closest to the nucleus and the N shell is the farthest from the nucleus**





First four electron shells

- **These shells contain different numbers of electrons.**
- **The maximum number each shell can hold is equal to $2N^2$, where N is the number of the shell (K=1, L=2, M=3, and so forth.).**
- **Thus, the maximum number of electrons that each of the first four shells can hold Is:**

$$K = 2(1^2) = 2$$

$$L = 2(2^2) = 8$$

$$N = 2(3^2) = 18$$

$$N = 2(4^2) = 32$$

(3)Number of electrons

- **What determines the number of electrons an atom will contain? For an atom to exist freely in nature, it must be electrically neutral (without a charge).**
- **There are two particles in an atom that have charges-the proton, which is positive, and the electron, which is negative.**
- **For electrical neutrality, the sum of the charges must be zero.**
- **In other words, the number of electrons (negative charges) must equal the number of protons (positive charges).**

d. Atomic Structure of Elements.

- **As previously stated, each element consists of a single type of atom.**
- **Since <u>all atoms</u> consist of the three basic particles we have just discussed (except hydrogen, which usually has no neutrons), the only ways in which elements can differ are atomic number (the number of protons) and atomic weight, (the number of protons and neutrons).**

- **There are over 106 different elements which scientists know to have a different atomic number and atomic weight.**
- **These elements have a large assortment of properties.**
- **Two elements are liquids at room temperature, eleven are gases, and all others are solids.**

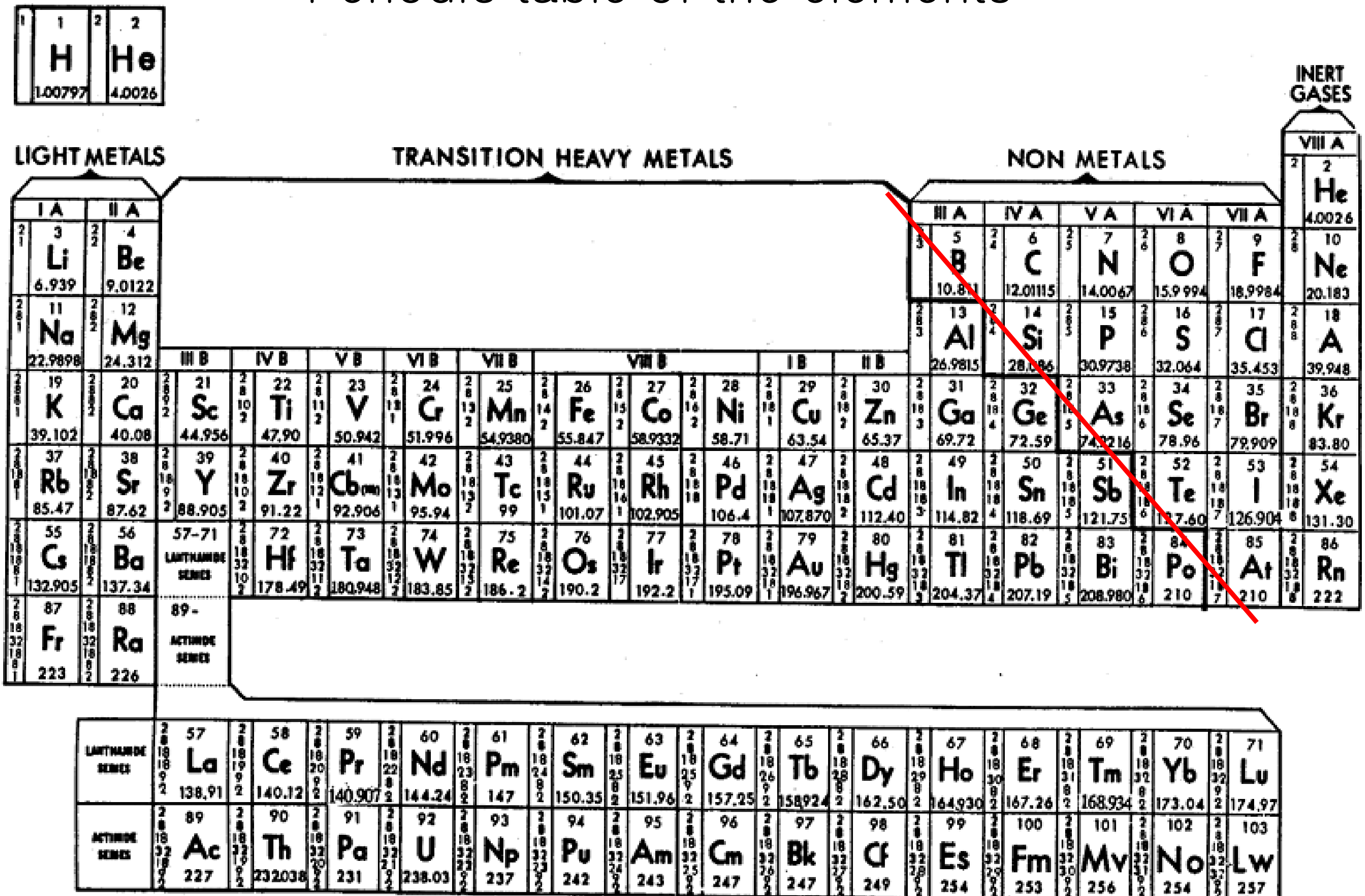
e. Periodic Law.

- **While investigating the properties of the elements, scientists discovered an interesting fact that is now called the periodic law.**
- **This law states that the properties of the elements are periodic functions of the atomic number.**
- **As the atomic number increases, the properties of the elements repeat themselves at regular intervals.**

f. Periodic Table.

- **The periodic law allowed the scientists to group together the elements that had similar properties and form a systematic table of the elements.**
- **This table is the periodic table**
- **The vertical columns are called groups, and the horizontal rows are called periods.**
- **This table contains a lot of information that we will not generally use; however, we are concerned with the basic information we can obtain about the elements.**

Periodic table of the elements



Periodic Table

Representative Elements | *d*-Transition Elements | Representative Elements | Noble Gases

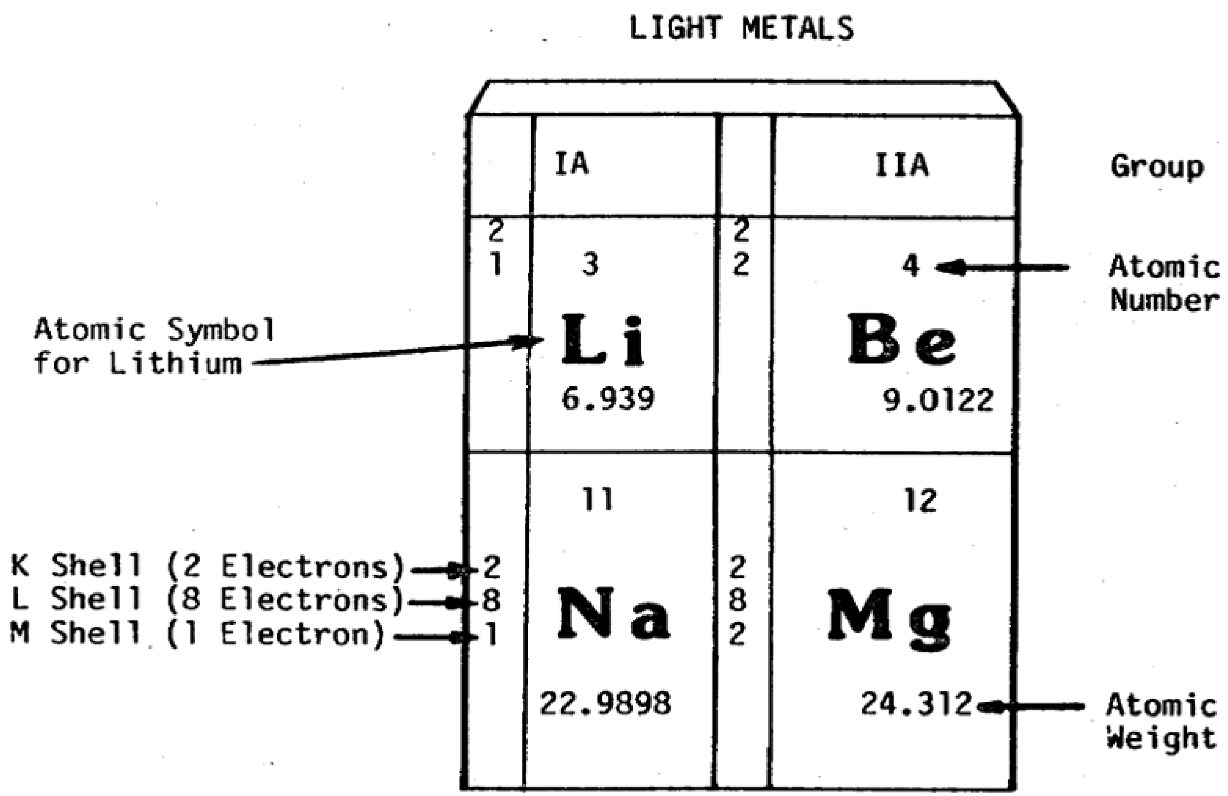
Group numbers

Period number, highest occupied electron level

Period	1 1A ns^1	2 2A ns^2	3	4	5	6	7	8	9	10	11	12	13 3A ns^2np^1	14 4A ns^2np^2	15 5A ns^2np^3	16 6A ns^2np^4	17 7A ns^2np^5	18 8A ns^2np^6
1	1 H $1s^1$																	2 He $1s^2$
2	3 Li $2s^1$	4 Be $2s^2$											5 B $2s^22p^1$	6 C $2s^22p^2$	7 N $2s^22p^3$	8 O $2s^22p^4$	9 F $2s^22p^5$	10 Ne $2s^22p^6$
3	11 Na $3s^1$	12 Mg $3s^2$											13 Al $3s^23p^1$	14 Si $3s^23p^2$	15 P $3s^23p^3$	16 S $3s^23p^4$	17 Cl $3s^23p^5$	18 Ar $3s^23p^6$
4	19 K $4s^1$	20 Ca $4s^2$	21 Sc $4s^23d^1$	22 Ti $4s^23d^2$	23 V $4s^23d^3$	24 Cr $4s^13d^5$	25 Mn $4s^23d^5$	26 Fe $4s^23d^6$	27 Co $4s^23d^7$	28 Ni $4s^23d^8$	29 Cu $4s^13d^{10}$	30 Zn $4s^23d^{10}$	31 Ga $4s^24p^1$	32 Ge $4s^24p^2$	33 As $4s^24p^3$	34 Se $4s^24p^4$	35 Br $4s^24p^5$	36 Kr $4s^24p^6$
5	37 Rb $5s^1$	38 Sr $5s^2$	39 Y $5s^24d^1$	40 Zr $5s^24d^2$	41 Nb $5s^14d^4$	42 Mo $5s^14d^5$	43 Tc $5s^14d^6$	44 Ru $5s^14d^7$	45 Rh $5s^14d^8$	46 Pd $4d^{10}$	47 Ag $5s^14d^{10}$	48 Cd $5s^24d^{10}$	49 In $5s^25p^1$	50 Sn $5s^25p^2$	51 Sb $5s^25p^3$	52 Te $5s^25p^4$	53 I $5s^25p^5$	54 Xe $5s^25p^6$
6	55 Cs $6s^1$	56 Ba $6s^2$	57 La* $6s^25d^1$	72 Hf $4f^{14}6s^25d^2$	73 Ta $6s^25d^3$	74 W $6s^25d^4$	75 Re $6s^25d^5$	76 Os $6s^25d^6$	77 Ir $6s^25d^7$	78 Pt $6s^15d^9$	79 Au $6s^15d^{10}$	80 Hg $6s^25d^{10}$	81 Tl $6s^26p^1$	82 Pb $6s^26p^2$	83 Bi $6s^26p^3$	84 Po $6s^26p^4$	85 At $6s^26p^5$	86 Rn $6s^26p^6$
7	87 Fr $7s^1$	88 Ra $7s^2$	89 Ac** $7s^26d^1$	104 Rf $7s^26d^2$	105 Db $7s^26d^3$	106 Sg $7s^26d^4$	107 Bh $7s^26d^5$	108 Hs $7s^26d^6$	109 Mt $7s^26d^7$	110 Uun $7s^26d^8$	111 Uuu $7s^16d^{10}$	112 Uub $7s^26d^{10}$						

f-Transition Elements

*Lanthanides	58 Ce $6s^24f^15d^1$	59 Pr $6s^24f^35d^0$	60 Nd $6s^24f^45d^0$	61 Pm $6s^24f^55d^0$	62 Sm $6s^24f^65d^0$	63 Eu $6s^24f^75d^0$	64 Gd $6s^24f^75d^1$	65 Tb $6s^24f^95d^0$	66 Dy $6s^24f^{10}5d^0$	67 Ho $6s^24f^{11}5d^0$	68 Er $6s^24f^{12}5d^0$	69 Tm $6s^24f^{13}5d^0$	70 Yb $6s^24f^{14}5d^0$	71 Lu $6s^24f^{14}5d^1$
**Actinides	90 Th $7s^25f^06d^2$	91 Pa $7s^25f^26d^1$	92 U $7s^25f^36d^1$	93 Np $7s^25f^46d^1$	94 Pu $7s^25f^66d^0$	95 Am $7s^25f^76d^0$	96 Cm $7s^25f^76d^1$	97 Bk $7s^25f^96d^0$	98 Cf $7s^25f^{10}6d^0$	99 Es $7s^25f^{11}6d^0$	100 Fm $7s^25f^{12}6d^0$	101 Md $7s^25f^{13}6d^0$	102 No $7s^25f^{14}6d^0$	103 Lr $7s^25f^{14}6d^1$



Identifying the components of the periodic table


Time for
Q&A