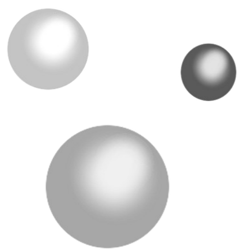
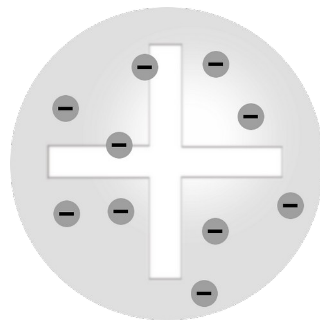
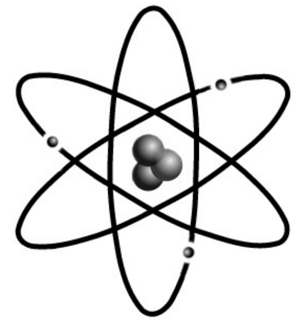
The structure of the atom (an introduction)

1814 to 1819	1903	1911
J. Dalton	J.J. Thomson	E. Rutherford
		
Atoms of a given element are identical in size, mass and properties	**An atom is made of charged particles**	**An atom has a nucleus (probably positive, with high mass)**
Dalton as first to calculate the relative atomic masses of the elements Atoms are extremely small particles that cannot be created, or destroyed. Law of multiple proportions: Atoms combine in simple whole-number ratios to form chemical compounds.	Had worked on the electron: knows that the electron is a sub-particle of the atom “plum pudding” model where negatively-charged "plums" are embedded in a positively-charged "pudding". “+” = “−” so that an atom would be electrically neutral 1906: has showed that hydrogen has only one electron.	Nuclear atom model could explain the deflection of “α particles” (α particle =He-4 nucleus) An atom has a nucleus (+) of high mass surrounded by electrons.

J. Dalton (1819):	All atoms of a given element are identical (based on their chemical behavior)
D. Mendeleev (1865):	Classification of the element (according to their mass and their chemical properties)
J.J. Thomson (1903)	Electrons are present in all atoms
H. Moseley (1913)	All the atom of a given element have the same Atomic number (the proton was not discovered yet but it was a strong hypothesis)
E. Rutherford (1917)	Discovery of the proton (nuclei) (Presence of hydrogen nucleus in other atom)
J. Chadwick (1932):	Discovery of the neutron (isotope explanation).

Modern concept of the atomic structure

particle	symbol	charge	mass
electron	e^-	-1	9.11×10^{-31} kg
proton	p^+	$+1$	1.673×10^{-27} kg
neutron	n^o	0	1.675×10^{-27} kg

Note: The charges of +1 or −1 are symbolic to show that the charges are balanced in an atom. The actual value of the electric charge carried by a single proton or electron is 1.602×10^{-19} coulombs. It is called the elementary charge (q_e) discovered by Mulliken in 1909 from its famous oil drop experiment.

Mass ratio p^+/e^- = 1836. The nucleus is responsible for 99.97% of the mass of the atom.

An atom is mostly open space
Nucleus: 10^{-15} m if atom = football field, then nucleus size = ant head
Atom: 10^{-10} m

All atoms are composed of e^-, p^+, n^o.

Q. Why different atoms have different chemical properties?
A. because of the arrangement of the electrons (therefore, the number of p^+)

Representation of an atom, ion and isotope

$^{A}_{Z}X$ were:
A = mass number ($p^+ + n^o$)
Z = atomic number (p^+)
X = Symbol of the element

Ex:Lithium-7 is: $^{7}_{3}Li$ oxygen-16 is: $^{16}_{8}O$

Atom: any atom having the same number of proton and electron (charge = 0)
Isotope: two atom with the same number of p^+ but different number of n^o ($^{12}_{6}C$, $^{14}_{6}C$)

Sodium-23 = $^{23}_{11}Na$ Both 11 protons = same chemical properties.
Sodium-24 = $^{24}_{11}Na$ However, different number of neutrons (or atomic masses).

Exercise: Write the symbol (AZX) for the silver atom that has 61 neutrons

Silver: Ag, Z = 47 Mass number = 47 proton + 61 neutrons = 108

Therefore: $^{108}_{47}Ag$

The atomic masses of the elements shown in the periodic table are averages of their stable isotope. Therefore, their proportions may vary in nature. 21 elements do not have stable natural isotopes. In this case, their masses can be known with greater precision.

In nature, most elements are a mixture of isotopes:

Symbol	In nature / %	P^+	e^-	n^o
${}^{12}_{6}C$	98.89	6	6	6
${}^{13}_{6}C$	1.11	6	6	7
${}^{14}_{6}C$	1×10^{-7}	6	6	8

12 g/mol (exact) x 98.89% + 13.00 g/mol x 1.11% = 12.011 g/mol

Ion: Species with a different number of proton and electrons
(atom = zero net charge, $p^+ = e^-$)

Positive ion = cation
Negative ion = anion.

Chemical properties of an atom (neutral) are different from the one of an ion (charge)

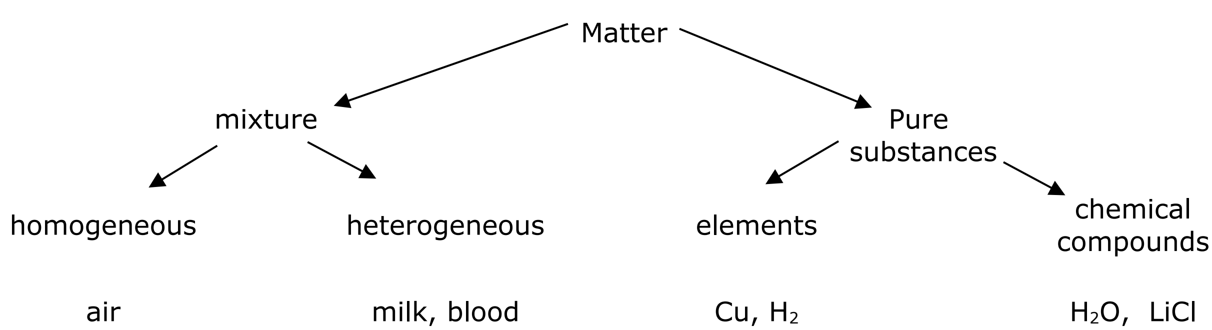
Net charge of an ion = $(p^+) - (e^-)$.

Exercise: Write the symbol (${}^{A}{}_{Z}X$) of lithium-7 that has lost an electron:
$P^+ = 3$, $e^- = 2$: net charge = +1 ${}^{7}_{3}Li^+$

1. Complete the following table (symbol ${}^{A}_{Z}X^{charge}$)

Symbol	proton	neutron	electron	net charge
${}^{41}_{20}Ca^{2+}$	______	______	______	______
______	42	55	______	0
${}^{\_\_}_{\_\_}S^{2-}$		17	______	______

Compounds and mixtures



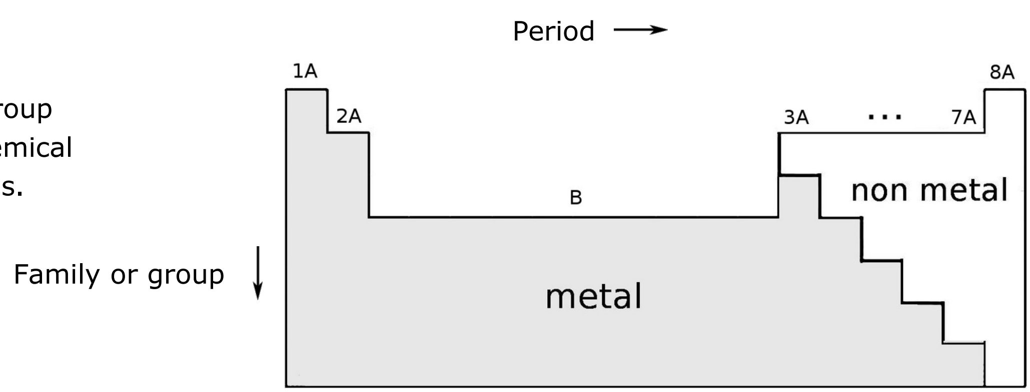
The periodic table (a very brief introduction)

Elements

Periodic: elements are arranged in a “repetitive pattern”
similar chemical behavior every 8 elements = periodicity = periodic table

1862 L. Meyer (28 elements): arranged by valence (6 families) + increasing mass.
1869 D. Mendeleev (65 elements known): **arranged by chemical properties**
He was able to predict the properties of several as-yet-undiscovered elements.
1913 A. van den Broek arranged the element by nuclear charge.
(confirmed by H. Moseley)
1913 E. Rutherford coined the word "atomic number" for nuclear charge
1932 Chadwick, discovery of the neutron, explain the odd position of some atoms in the periodic table.
1961 IUPAC: Carbon-12 is used as the standard for calculating the mass of the elements.
2019 = 250 anniversary of the periodic table: 118 elements.

Elements in a group have similar chemical properties.



3/4 of the elements are metals (metal-non metal “stair” separation)

1A alkali metal (reaction = +1 ion) Highly reactive metals
2A alkaline earth (reaction = +2 ion)
B = transition elements (multivalence ions +1, +2, +3 … +7)

Non metal
7A halogen highly reactive non metal (reaction = formation of a −1 ion)
8A noble gas non reactive compound

Native element (free in nature): H_2, O_2, N_2, C, S_8, Cu, Ag, Au, Pt, all the noble gases.

The majority of elements occur in nature as chemical combination with other elements

Iron: Fe_2O_3, Aluminum: $Al(OH)_3$, Lithium: Li_2CO_3

In conclusion

(Dalton)

- All matter is composed of atoms
- Atom: the smallest body that retains the unique identity of an element
- Atom can not be transformed by chemical reaction
- Each atom of an element have the same number of proton and electrons (but not necessarily the same atomic mass: neutron)
- Compounds are composed by two or more elements in specific ratio.

Name of the elements to learn in Chemistry SN1

	1A	2A	3B	4B	5B	6B	7B	8B	9B	10B	1B	2B	3A	4A	5A	6A	7A	8A
1	1 H hydrogen																	2 He helium
2	3 Li lithium	4 Be beryllium											5 B boron	6 C carbon	7 N nitrogen	8 O oxygen	9 F fluorine	10 Ne neon
3	11 Na sodium	12 Mg magnesium											13 Al aluminum	14 Si silicon	15 P phosphorous	16 S sulfur	17 Cl chlorine	18 Ar argon
4	19 K potassium	20 Ca calcium	21 Sc scandium	22 Ti titanium	23 V vanadium	24 Cr chromium	25 Mn manganese	26 Fe iron	27 Co cobalt	28 Ni nickel	29 Cu copper	30 Zn zinc	31 Ga gallium	32 Ge germanium	33 As arsenic	34 Se selenium	35 Br bromine	36 Kr krypton
5	37 Rb rubidium	38 Sr strontium	39 Y	40 Zr	41 Nb	42 Mo molybdenum	43 Tc	44 Ru	45 Rh	46 Pd palladium	47 Ag silver	48 Cd cadmium	49 In	50 Sn tin	51 Sb antimony	52 Te	53 I iodine	54 Xe xenon
6	55 Cs cesium	56 Ba barium	57 La * lanthanide	72 Hf	73 Ta	74 W tungsten	75 Re	76 Os	77 Ir	78 Pt platinum	79 Au gold	80 Hg mercury	81 Tl	82 Pb lead	83 Bi bismuth	84 Po	85 At	86 Rn radon
7	87 Fr francium	88 Ra radium	89 Ac° actinide	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

*Lanthanides	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
°Actinides	90 Th	91 Pa	92 U uranium	93 Np	94 Pu plutonium	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Introduction to bonding

Chemical bond: electron interactions between two atoms

Transferring electron = ionic compound   crystal
Sharing electron = covalent compound   molecules

Ionic compounds

Simplest binary ionic compound = metal + non metal

Metal loses electron(s) = cation +
Non-metal gain electron(s) = anion −

Bond = Electrostatic forces

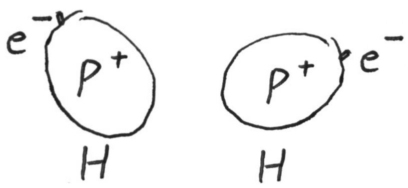
$$2Na(s) + Cl_2(g) \longrightarrow 2\ NaCl(s)$$

Coulomb Law $\text{Force} \propto \dfrac{(+\ \text{charge})\times(-\ \text{charge})}{\text{distance}^2}$

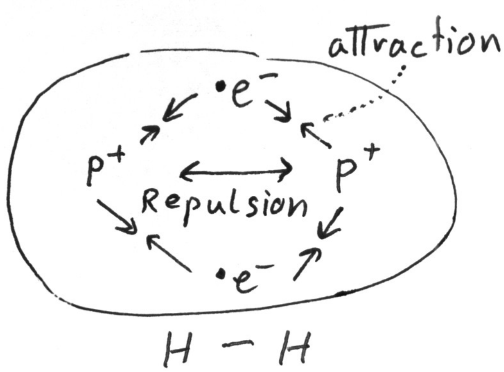
Covalent compounds

Covalent compounds = sharing electrons
Usually occurs between two non-metals

Simplest one: Hydrogen molecule



2 hydrogen atoms



one H_2 molecule

COVALENT BOND: The electrons no longer "belong" to a particular H atom. The two electrons are shared by the two nuclei. Net attraction > Net repulsion

Case: N_2, O_2, halogen: F_2, Cl_2, etc.
Covalent bonding: provide another way for atoms to attain the same number of electrons as the nearest noble gas.

Chemical formula (element symbol with numerical subscript)

Hydrogen peroxide: H_2O_2

Empirical formula: HO

Relative number of atom of each element in the compound.

Always used to describe ionic compounds.

Molecular formula: H_2O_2

Actual number of atoms in a molecule

Used to identify covalent compounds (molecule)

The lowercase 2 indicate that only preceding atom is multiplied by this number.

Ex: SO_3 = 1 sulfur and 3 oxygen atoms in this molecule

$(NH_4)_2S$ = 2 ammonium ion or 2 x (NH_4) and one sulfur atom.

Structural formula: H−O−O−H

actual position of the bonds in the molecule.

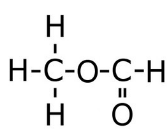
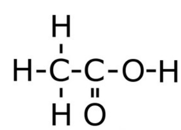
For hydrogen peroxide, the structural formula is:

The structural formula is used in organic chemistry, to know how the atoms are combined together in the molecule.

Example: write the empirical, molecular and structural formulas for acetic acid

Empirical formula: CH_2O

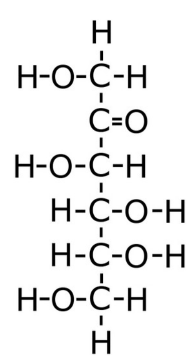
Molecular formula: $C_2H_4O_2$

Structural formula:  obviously  is another molecule.

Another example: the sugar fructose:

Fructose: $C_6H_{12}O_6$

The empirical or molecular formulas are inappropriate to correctly describe this molecule.



Fischer representation of d-Fructose

Naming compound. An introduction

Provide a name for the following compounds

1. CO_2 : Carbon dioxide (covalent, name the number of atoms)
   Ex: SO_2 and SO_3 also exist

2. H_2O : water: covalent compound with trivial names
   (NH_3: ammonia, CH_4: methane)

3. OMg or MgO : Metal first, non metal second
   Therefore, MgO = magnesium oxide

4. $MgBr_2$: Magnesium bromide
   ionic compound (metal + non-metal)
   MgBr or $MgBr_3$ do not exist!

5. FeO : iron(II)oxide. Oxygen ion always −2, therefore Fe = +2
   Fe_2O_3 : iron(III)oxide since Fe = +3

6. H_3PO_4 : no metal but ionic compound (oxyanion PO_4^{3-} = phosphate)
   Therefore: hydrogen phosphate
   NO_3^- = nitrate, SO_4^{2-} = sulfate, CO_3^{2-} = carbonate

7. $CuCl_2{\cdot}5H_2O$: copper(II)chloride pentahydrate

Compounds to know by heart:

formula	systematic name	use
$AgNO_3$	silver nitrate	to make mirror
$CaCO_3$	calcium carbonate	chalk, marble
$BaSO_4$	barium sulfate	medical x-rays
$AlPO_4$	aluminum phosphate	self-rising flour
$LiClO_4$	lithium perchlorate	firework, source of oxygen aerospace.