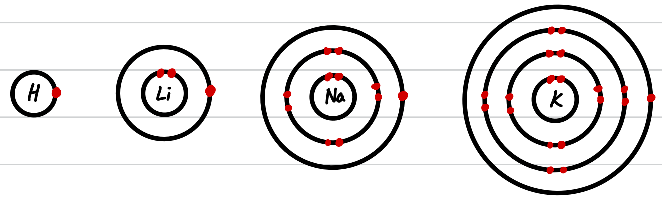
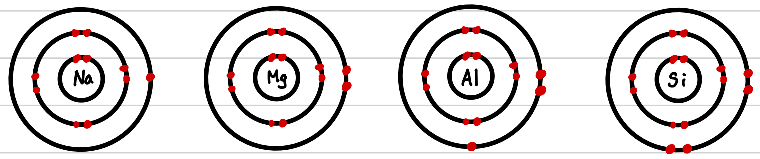
Periodic Table of Elements

Group - vertical column
↳ all elements have same number of valence electrons
ex: group 1 all have 1 outer e^-



↳ group # = number of valence e^- (before Ca)
* groups 13-17 treat as 3-7
* group 18 all full outer shell

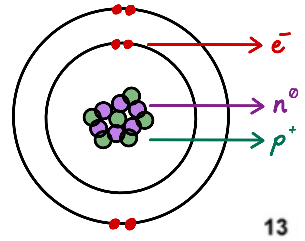
Period - horizontal row
↳ all elements have same number of electron shells
ex: period 3 all have 3 electron shells



↳ period # = number of electron shells (before Ca)
↳ # elements in each period = max # of electrons in each shell

period 1 = 2 e^- max   3 = 8 e^- max
2 = 8 e^- max   4 = 18 e^- max

Chemical name ← carbon
chemical symbol ← C
6 → **atomic number**: number of protons (p^+) in nucleus
ex: carbon has 6 p^+
12.01 → **relative atomic mass** (A_r): average mass of the atom (nucleus only)
*electrons (e^-) not considered as too light (0.0005)
A_r = protons + neutrons (n^0)



1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hydrogen 1 H 1.01																		Helium 2 He 4.00
Lithium 3 Li 6.94	Beryllium 4 Be 9.01												Boron 5 B 10.81	Carbon 6 C 12.01	Nitrogen 7 N 14.01	Oxygen 8 O 16.00	Fluorine 9 F 19.00	Neon 10 Ne 20.18
Sodium 11 Na 22.99	Magnesium 12 Mg 24.31												Aluminum 13 Al 26.98	Silicon 14 Si 28.09	Phosphorus 15 P 30.97	Sulfur 16 S 32.07	Chlorine 17 Cl 35.45	Argon 18 Ar 39.95
Potassium 19 K 39.10	Calcium 20 Ca 40.08		Scandium 21 Sc 44.96	Titanium 22 Ti 47.88	Vanadium 23 V 50.94	Chromium 24 Cr 52.00	Manganese 25 Mn 54.94	Iron 26 Fe 55.85	Cobalt 27 Co 58.93	Nickel 28 Ni 58.69	Copper 29 Cu 63.55	Zinc 30 Zn 65.39	Gallium 31 Ga 69.72	Germanium 32 Ge 72.61	Arsenic 33 As 74.92	Selenium 34 Se 78.96	Bromine 35 Br 79.90	Krypton 36 Kr 83.80
Rubidium 37 Rb 85.47	Strontium 38 Sr 87.62		Yttrium 39 Y 88.91	Zirconium 40 Zr 91.22	Niobium 41 Nb 92.91	Molybdenum 42 Mo 95.94	Technetium 43 Tc (98)	Ruthenium 44 Ru 101.07	Rhodium 45 Rh 102.91	Palladium 46 Pd 106.42	Silver 47 Ag 107.87	Cadmium 48 Cd 112.41	Indium 49 In 114.82	Tin 50 Sn 118.71	Antimony 51 Sb 121.76	Tellurium 52 Te 127.60	Iodine 53 I 126.90	Xenon 54 Xe 131.29
Cesium 55 Cs 132.91	Barium 56 Ba 137.33	57-70 *	Lutetium 71 Lu 174.97	Hafnium 72 Hf 178.49	Tantalum 73 Ta 180.95	Tungsten 74 W 183.84	Rhenium 75 Re 186.21	Osmium 76 Os 190.23	Iridium 77 Ir 192.22	Platinum 78 Pt 195.08	Gold 79 Au 196.97	Mercury 80 Hg 200.59	Thallium 81 Tl 204.38	Lead 82 Pb 207.20	Bismuth 83 Bi 208.98	Polonium 84 Po (209)	Astatine 85 At (210)	Radon 86 Rn (222)
Francium 87 Fr (223)	Radium 88 Ra (226)	89-102 **	Lawrencium 103 Lr (262)	Rutherfordium 104 Rf (267)	Dubnium 105 Db (268)	Seaborgium 106 Sg (271)	Bohrium 107 Bh (272)	Hassium 108 Hs (270)	Meitnerium 109 Mt (276)	Darmstadtium 110 Ds (281)	Roentgenium 111 Rg (280)	Copernicium 112 Cn (285)	Ununtrium 113 Uut (284)	Ununquadium 114 Uuq (289)	Ununpentium 115 Uup (288)	Ununhexium 116 Uuh (293)	Ununseptium 117 Uus (294?)	Ununoctium 118 Uuo (294)

*lanthanides	Lanthanum 57 La 138.91	Cerium 58 Ce 140.12	Praseodymium 59 Pr 140.91	Neodymium 60 Nd 144.24	Promethium 61 Pm (145)	Samarium 62 Sm 150.36	Europium 63 Eu 151.97	Gadolinium 64 Gd 157.25	Terbium 65 Tb 158.93	Dysprosium 66 Dy 162.50	Holmium 67 Ho 164.93	Erbium 68 Er 167.26	Thulium 69 Tm 168.93	Ytterbium 70 Yb 173.04
**actinides	Actinium 89 Ac (227)	Thorium 90 Th 232.04	Protactinium 91 Pa 231.04	Uranium 92 U 238.03	Neptunium 93 Np (237)	Plutonium 94 Pu (244)	Americium 95 Am (243)	Curium 96 Cm (247)	Berkelium 97 Bk (247)	Californium 98 Cf (251)	Einsteinium 99 Es (252)	Fermium 100 Fm (257)	Mendelevium 101 Md (258)	Nobelium 102 No (259)

Synthetic man-made elements, not naturally-occuring

Non-metals mainly undergo covalent bonding but also ionic bonding with metals
general properties: poor electrical/thermal conductors, dull, brittle, low m.p./b.p.
mainly gas at room temp (some l and s)

Metals mainly undergo metallic bonding but also ionic bonding with non-metals
general properties: good electrical/thermal conductors, shiny, malleable, high m.p./b.p.
nearly all solid at room temp (only Hg is not - is l)

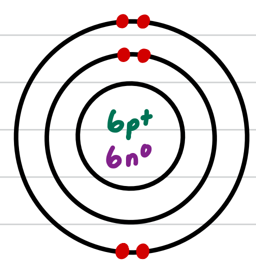
Metalloids mainly undergo covalent bonding with non-metals (but also ionic bonding)

Drawing atomic diagrams

↳ determine p^+ : atomic number
↳ determine e^- : same as atomic number (as atoms on table are neutral)
↳ determine n^0 : atomic mass - atomic number
↳ determine number of shells : period number

ex: carbon
p^+ = 6
e^- = 6
n^0 = 12.01 - 6
= 6
shells = 2^{nd} period
= 2 shells

C



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Chemical Bonding

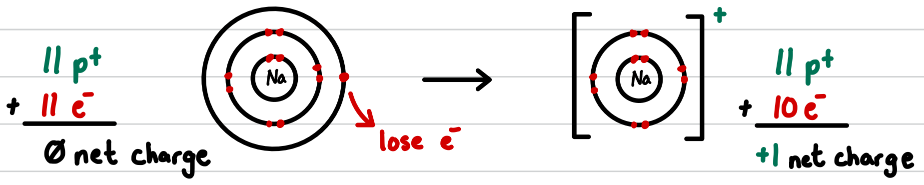
ion: a charged atom. Can be positive (cation) or negative (anion)

↳ cations are formed by an atom losing 1 or more electrons

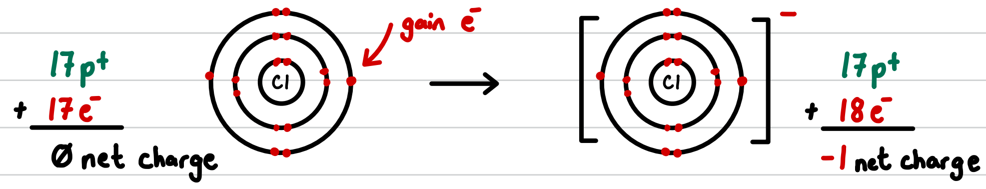
↳ anions are formed by an atom gaining 1 or more electrons

↳ typically, ions are formed because atoms 'seek' to have a full valence shell to become more stable

ex: Sodium has one valence e^-.
it can either lose 1 or gain 7. Easier to lose 1



ex: Chlorine has seven valence e^-.
it can either gain 1 or lose 7. Easier to gain 1



↳ can predict what ion an atom will make by examining their group number:

Group 1 = 1 valence
∴ will lose 1 ∴ 1^+

Group 2 = 2^+
Group 13 (3) = 3^+

Group 14 (4) = mainly covalent
Group 15 (5) = 3^-

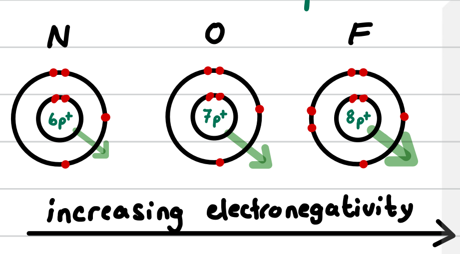
Group 16 (6) = 2^-
Group 17 (7) = 1^-

Group 18 (8) = already full
no charge

electronegativity: the tendency of a nucleus to attract bonding electrons. i.e. the more it attracts, the more electronegative

↳ depends on number of protons in nucleus

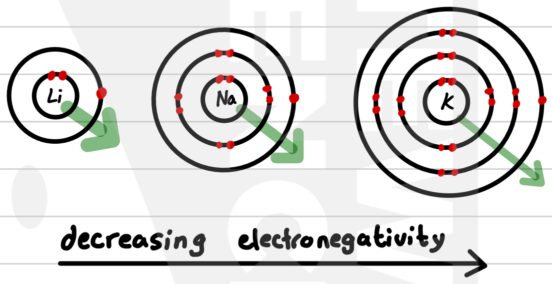
ex:



more protons
mean stronger pull

↳ depends on distance between nucleus and bonding electrons

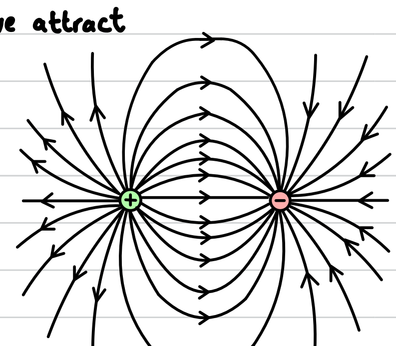
ex:



greater distance
means weaker
attractive force

★ if the difference between electronegativities is very large (>1.4 on Pauling scale), one atom will pull an electron from another

Ionic bonding: electrostatic force of attraction between negative and positive ions. *recall: positive and negative attract



metals tend to have a small number (< half of their max) valence electrons
low electronegativity → tend to donate or remove their outer electron(s)
→ causing full inner shell to become its valence shell ∴ becoming cations (+)

non-metals tend to have a large number (> half of their max) valence electrons
high electronegativity → tend to recieve or accept their outer electron(s)
→ causing valence to become full ∴ becoming anions (−)

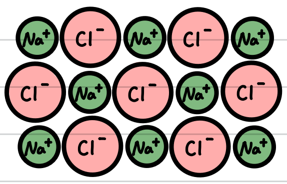
↳ can predict the chemical formula of ionic compound by determining ionic charge of each element and crossing them
*metal first, non-metal second (suffix 'ide')

ex: potassium + nitrogen
K (1+) N (3−)
K_3N
potassium nitride

ex: magnesium + chlorine
Mg (2+) Cl (1−)
$MgCl_2$
magnesium chloride

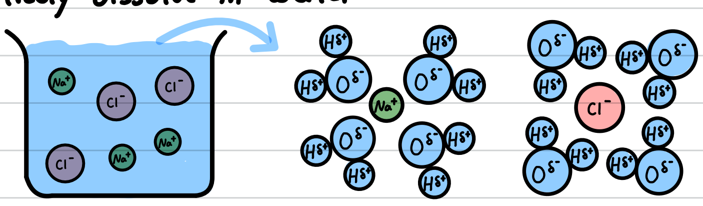
ex: beryllium + sulfur
Be (2+) S (2−)
Be_2S_2 → BeS (reduce to lowest common terms)
beryllium sulfide

↳ as solids, ionic compounds bond as lattice



☑ brittle: layers shift and break off
☑ insulator: no free charges, cannot flow

↳ freely dissolve in water

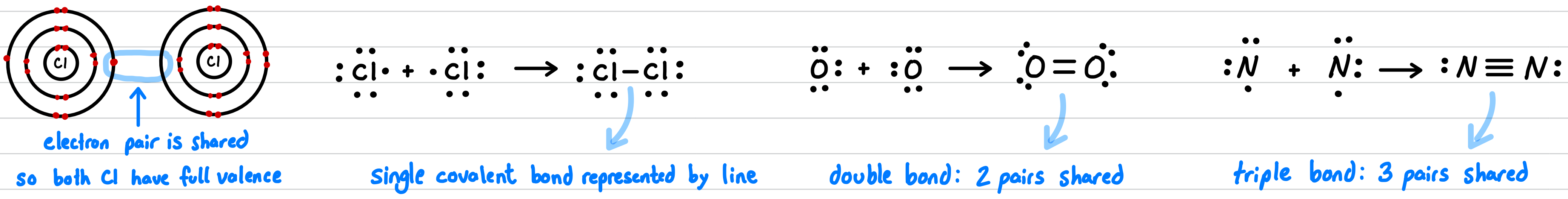


☑ disassociate
☑ conduct electricity as free ions

★ if the difference between electronegativities is small (0 - 0.4 on Pauling scale), electrons will be equally shared between atoms

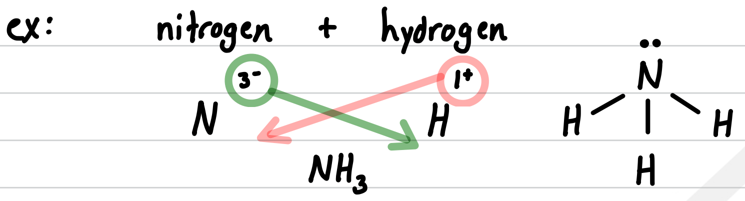
covalent bonding: electrostatic attraction between positive nuclei and a shared pair of electrons

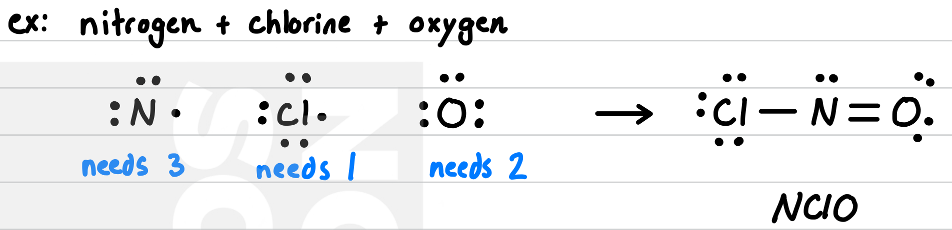
↳ tend to occur between non-metals as they have a larger valency and hold onto their electrons (high electronegativity)



↳ can predict chemical formula of covalent compound similarly to ionic

↳ determine number of bonds by drawing





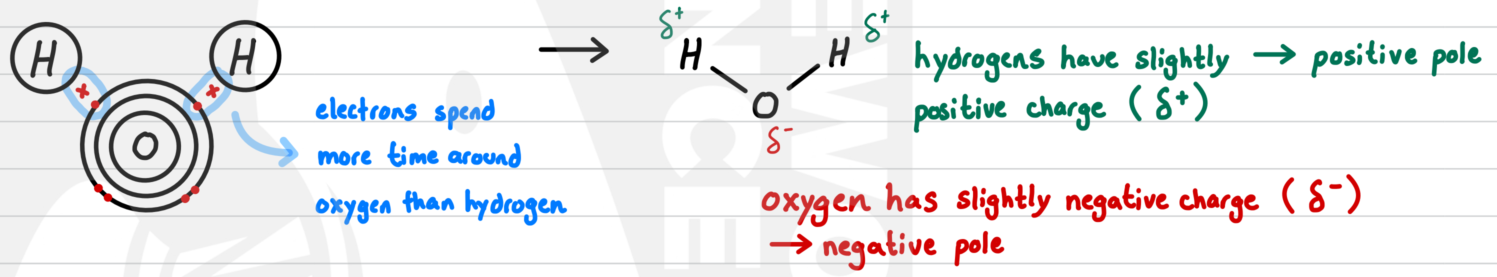
★ if the difference between electronegativities is moderately large (> 0.4 > 1.7 on Pauling scale) electrons will be shared unevenly

Polar covalent bonding: the unequal sharing of electrons leading to partial charges in a molecule (polarity)

ex: hydrogen + oxygen →

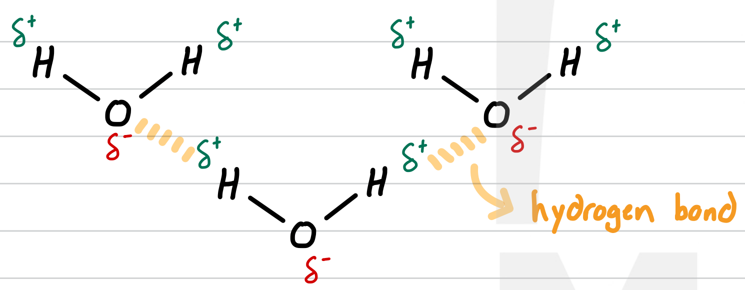
↓ electroneg. ∴ ↓ pull

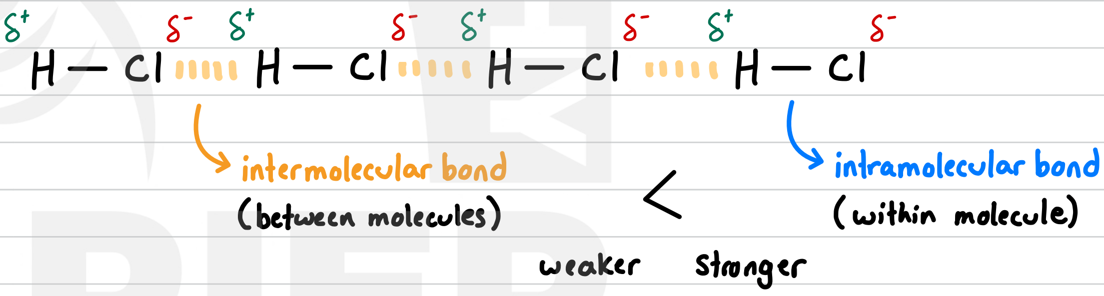
↑ electroneg. ∴ ↑ pull



↳ two polar molecules will attract one another with intermolecular bonding

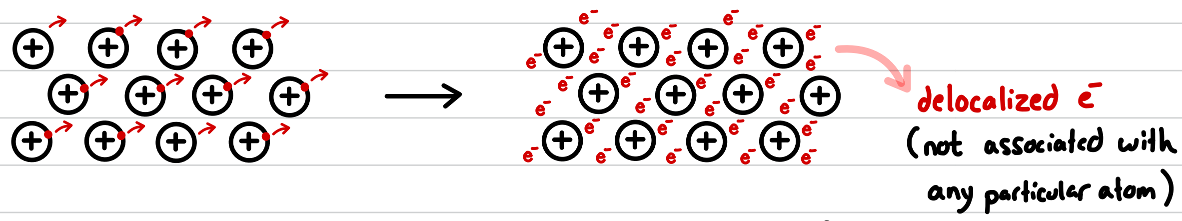
Hydrogen bonding: electrostatic attraction between partially positive hydrogen (δ⁺) and a partially negative atom (δ⁻)





★ if a group of identical atoms with low electronegativities (metals) are together, they will all shed their valence electrons

Metallic bonding: electrostatic attraction between the positive nuclei and negative delocalized electrons in a metal

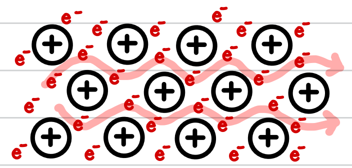


metals have a weak hold on few valence electrons ∴ will release them

the positive nuclei of metal atoms will be held together by their attraction to the 'sea' of delocalized e⁻ in a lattice

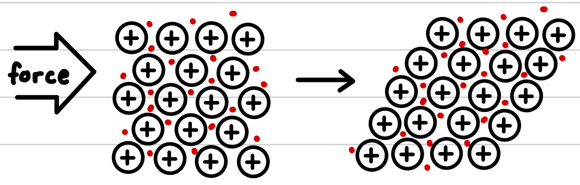
leads to metallic properties:

↳ good electrical and thermal conductor



delocalized e⁻ free to move and can transfer heat (energy) and charge easily

↳ malleable



layers slide past each other and remain bonded

Balancing chemical equations

Law of conservation of mass: matter cannot be created or destroyed

∴ the number / mass of atoms reacting must be equal to those in products

reactants		product	
$A + B_2$	$\longrightarrow$	AB	✗ not balanced
	1 A 1 2 B 1		less "B" in product than reactant - matter has been destroyed
$2A + B_2$	$\longrightarrow$	$2AB$	✓ balanced
	2 ~~1~~ A ~~1~~ 2 2 B ~~1~~ 2		coefficient means 2x molecule AB

Steps to solving some equations

(i) Single displacement $(A + BC \rightarrow AC + B)$

1- balance anion: $Ni + 2AgNO_3 \rightarrow Ni(NO_3)_2 + Ag$ 2 ~~1~~ NO_3 2

2- balance cation: $Ni + 2AgNO_3 \rightarrow Ni(NO_3)_2 + 2Ag$ 2 Ag ~~1~~ 2

(ii) neutralization (base + acid → H_2O + salt)

1- balance cation: $3Ca(OH)_2 + H_3PO_4 \rightarrow H_2O + Ca_3(PO_4)_2$ 3 ~~1~~ Ca 3

2- balance anion: $3Ca(OH)_2 + 2H_3PO_4 \rightarrow H_2O + Ca_3(PO_4)_2$ 2 ~~1~~ PO_4 2

3- balance hydrogen: $3Ca(OH)_2 + 2H_3PO_4 \rightarrow 6H_2O + Ca_3(PO_4)_2$ 12   12 ÷ 2

(iii) combustion $(C_xH_y + O_2 \rightarrow H_2O + CO_2)$

1- balance carbon: $C_6H_{14} + O_2 \rightarrow H_2O + 6CO_2$ 6 C ~~1~~ 6

2- balance hydrogen: $C_6H_{14} + O_2 \rightarrow 7H_2O + 6CO_2$ 14 H ~~2~~ 14

3- balance oxygen: $C_6H_{14} + \frac{19}{2}O_2 \rightarrow 7H_2O + 6CO_2$ 2 O 19

4- 2x: $2C_6H_{14} + 19O_2 \rightarrow 14H_2O + 12CO_2$

Tips and Tricks

* if a polyatomic ion is present in both reactants and products, treat as an atom and balance
* save oxygen and hydrogen until the end
* double check all coefficients are in lowest terms
* double check each individual atom is balanced

(iv) really ugly / difficult equation - algebra!

1- assign variables: $aS + bHNO_3 \rightarrow cH_2SO_4 + dNO_2 + eH_2O$

2- setup equations:

S $a = c$
H $b = 2c + 2e$
N $b = d$
O $3b = 4c + 2d + e$

3- let one variable = 1 and substitute: $b = 1$ ∴ $d = 1$

S $a = c$
H $1 = 2c + 2e$
N $1 = 1$
O $3(1) = 4c + 2(1) + e$
$1 = 4c + e$

4- substitute equations:

$4c + e = 2c + 2e$
$2c = e$

$1 = 2c + 2(2c)$
$1 = 6c$
$1/6 = c$ ∴ $1/6 = a$

$1 = 2(1/6) + 2e$
$\frac{1 - 1/3}{2} = \frac{2e}{2}$
$1/3 = e$

5- substitute variables as intiger coefficients

$\frac{1}{6}S + 1HNO_3 \rightarrow \frac{1}{6}H_2SO_4 + 1NO_2 + \frac{1}{3}H_2O$ ×6

$1S + 6HNO_3 \rightarrow 1H_2SO_4 + 6NO_2 + 2H_2O$

Atomic, Molecular, and Molar Mass

atomic mass (A_r): mass of a single atom in undefined mass units (u)

molecular mass (M_r): mass of a single molecule in undefined mass units (u)

calculating M_r

Ex: $(NH_4)_2SO_4$ = 2(N) + 8(H) + S + 4(O)
= 2(14.01) + 8(1.01) + 32.07 + 4(16.00)
= 28.02 + 8.08 + 32.07 + 64
= **132.17 u**

(×2)

molar mass (M): mass of 1 mole (n) of a single molecule (g/mol)

↳ 6.02×10^{23} A quantity, like "dozen" Unit: mol

Average Atomic Mass and Isotopic Abundance

Isotopes: two or more types of atoms that have the same atomic number but have different number of neutrons and ∴ mass

ex:

	Carbon - 12	Carbon - 13	Carbon - 14
p^+	6	6	6
n^0	6	7	8

← all same element, C, but different mass

Average atomic mass: the weighted average mass of the atoms in a naturally-occuring sample of the element

Example problems

(i) ~ determining average atomic mass from isotopic abundance ~
Calculate the average atomic mass of sulfur if 95.00% of all S atoms have a mass of 31.972 u, 0.76% has a mass of 32.971 and 4.22% have a mass of 33.967u.

1- divide abundances by 100 $\frac{95.00\%}{100} = 0.95$ $\frac{0.76\%}{100} = 0.0076$ $\frac{4.22\%}{100} = 0.0422$

2- multiply by mass and add together 0.95(31.972) + 0.0076(32.971) + 0.0422(33.967) = **32.06 u**

(ii) ~ determine percent abundance from average atomic mass ~
Naturally-occuring europium (Eu) consists of two isotopes with a mass of 151 and 153.
If the average atomic mass of Europium is 151.97 u, what are the abundances?

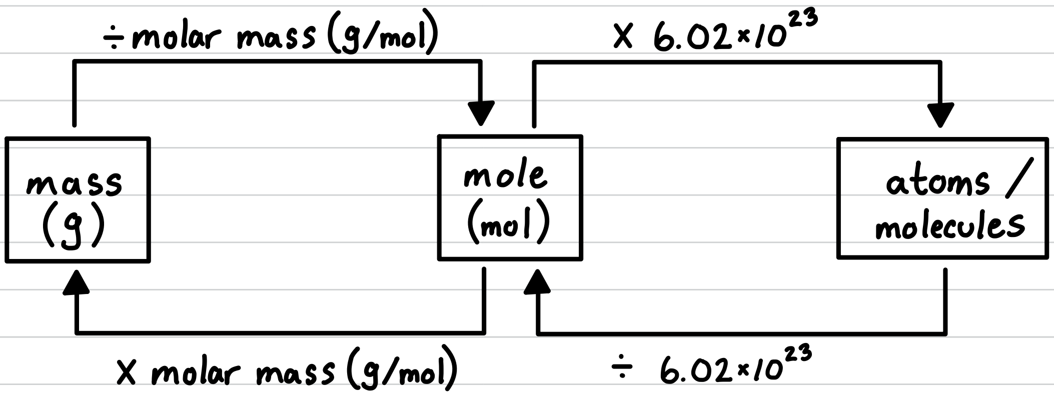
1- setup equation $(x)(151) + (1-x)(153) = 151.97$

2- expand and solve for x
$151x + 153 - 153x = 151.97$
$-2x = -1.03$
$x = 0.515$

3- calculate %
Eu-151 = 0.515(100)
= **51.5%**
Eu-153 = 100 - 51.5
= **48.5%**

Molar Conversions

~ if you know the amount of moles of a substance, you can determine its mass in (g) and vice-versa ~



Dimensional analysis

to cancel units, divide by them
↳ move in a diagonal manner

$g \times \frac{mol}{g} \times \frac{molecule}{mol}$	$molecule \times \frac{mol}{molecule} \times \frac{g}{mol}$

Example problems

(i) ~ mass ⟶ moles ~

10.6 grams of $AgNO_3$ is how many moles?

$$10.6\,g\,AgNO_3 \times \frac{mol}{169.87\,g} = 0.0624\ mol$$

(ii) ~ moles ⟶ mass ~

how many grams are in 2.4 moles of sulfur?

$$2.4\,mol\,S \times \frac{32.07\,g}{mol} = 76.97\,g$$

(iii) ~ mass ⟶ atoms ~

how many atoms are their in 8.7g of argon?

$$8.7\,g\,Ar \times \frac{mol}{39.95\,g} \times \frac{6.02\times10^{23}\ atoms}{mol} = 1.311\times10^{23}\ atoms$$

(iv) ~ molecules ⟶ mass ~

what is the mass of 9.4×10^{25} molecules of H_2?

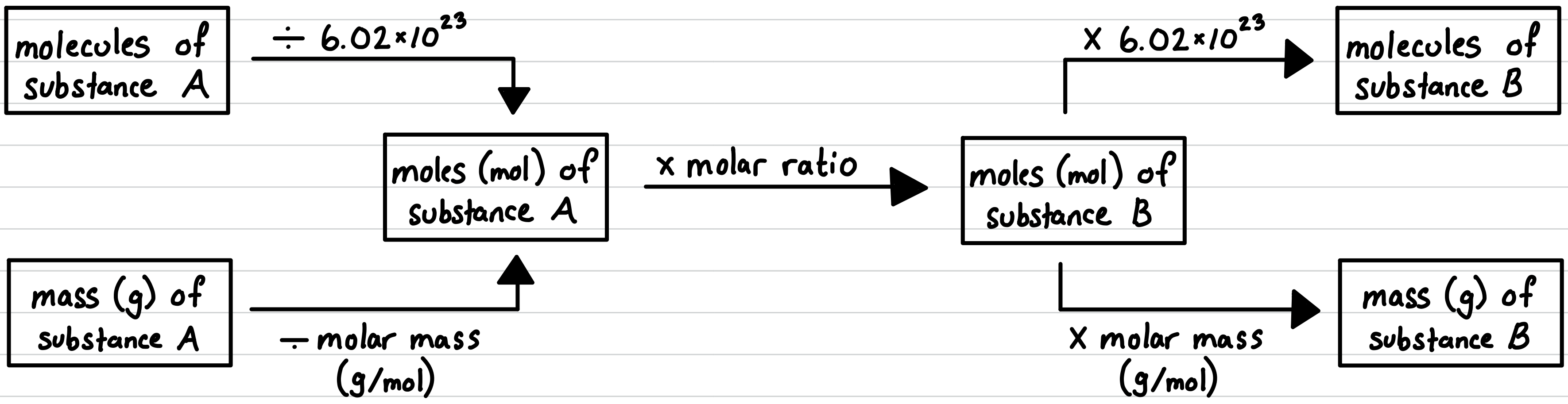
$$9.4\times10^{25}\ molecules \times \frac{mol}{6.02\times10^{23}\ molecules} \times \frac{2.02\ g}{mol} = 315.42\,g$$

(v) ~ mass ⟶ atoms in molecule ~

how many atoms of hydrogen are there in 2.3 grams of NH_4SO_2?

$$2.3\,g\,NH_4SO_2 \times \frac{mol}{82.12\,g} \times \frac{6.02\times10^{23}\ molecules}{mol} \times \frac{4\ \text{atoms of } H}{1\ \text{molecule of } NH_4SO_2} = 6.74\times10^{22}\ atoms$$

Using a balanced chemical equation, we can convert between different reactants and products



Example problems

(i) ~ converting mass of one substance to mass of another ~

Aluminum oxide is decomposed using electricity to produce Aluminum and oxygen gas, O_2.
What mass of Al metal can be produced from 125g of aluminum oxide?

1- write a chemical equation $Al_2O_3 \longrightarrow Al + O_2$

2- balance the equation $2Al_2O_3 \longrightarrow 4Al + 3O_2$

4 2 Al 1 4
6 3 O 2 6

3- write information underneath $2Al_2O_3 \longrightarrow 4Al + 3O_2$
125g ?g

4- convert mass to mol $125g\ Al_2O_3 \times \frac{mol}{101.96\ g} = 1.226\ mol$

5- convert mol of one substance to the needed substance $1.226\ mol\ Al_2O_3 \times \frac{4\ mol\ Al}{2\ mol\ Al_2O_3} = 2.452\ mol\ Al$

6- convert mol to mass $2.452\ mol\ Al \times \frac{26.98\ g}{mol} = 66.15g\ Al$

(ii) ~ converting mass of one substance to atoms of another ~

Nitrogen gas, N_2 and sodium are produced in an automobile air bag. It is generated by the decomposition of sodium azide, NaN_3.
How many atoms of Na are produced when 80.0g of N_2 are generated in this reaction?

1- write a chemical equation $NaN_3 \longrightarrow N_2 + Na$

2- balance the equation $2NaN_3 \longrightarrow 3N_2 + 2Na$

2 1 Na 1 2
6 3 N 2 6

3- write information underneath $2NaN_3 \longrightarrow 3N_2 + 2Na$
80.0g ?

4- convert mass to mol $80.0g\ N_2 \times \frac{mol}{28.02\ g} = 2.855\ mol$

5- convert mol of one substance to the needed substance $2.855\ mol\ N_2 \times \frac{2\ mol\ Na}{3\ mol\ N_2} = 1.903\ mol\ Na$

6- convert mol to atoms $1.903\ mol\ Na \times \frac{6.02\times10^{23}\ molecules}{mol} = 1.146\times10^{24}$ atoms of Na