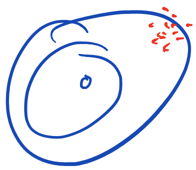
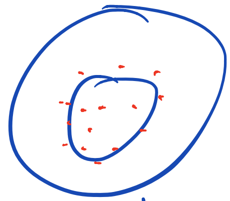
- Units
- Prefixes
- Accuracy vs precision
    - Accuracy: degree of agreement between the particular measurement and the real value
    - Precision: degree of agreement amongst several measurements
    - Better to be precise because it means you're consistent in your error and then you can just find the source of error

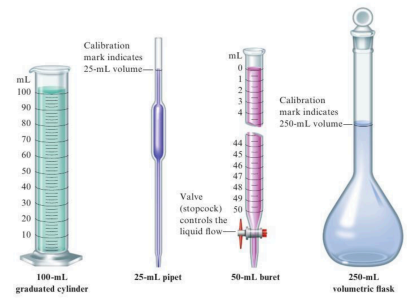


precise

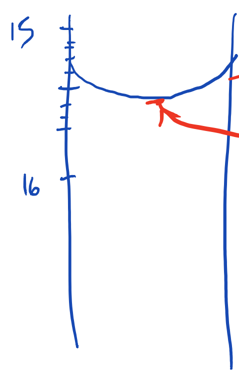


accurate

- Graduated cylinders (100 ml)
- Pipette (25 ml)
- Burrette (titration?) (50 ml)
- Volumetric flask (prepare and store solutions (250 ml)



Significant Figures



concave miniscus (vs. convex - depends on material of burette) (plastic cylinder or mercury)

read from bottom of miniscus

Certain digits / Sig Figs

- **Certain digits:** say data was (15.48, 15.45, 15.49): the certain digits would be 15.4

estimated digits

- Result (in terms of sig figs) = all the certain digits + 1 estimated/uncertain digit
    - This would allow us to determine the type of apparatus used

*Very important to use sig figs in the lab, not as much in assignments

Rules for Sig Figs

- **non-zero integers (4578)** always count as sig figs
- **Captive zeros (405)** always count as sig figs
- **Leading zeros (0.0315)** never count as sig figs
- **Trailing zeros** count as sig figs if the number in question has a decimal point

- Ex/ 1.520 - 4 sig figs, 3500 - 2 sig figs, 3500. - 4 sig figs
- **Exact numbers** are assumed to have an infinite amount of sig figs (# of students in a classroom, # of fans in a classroom)

$0.00\underbrace{4005400}_{\text{sig figs}}$

Examples:

1. 478 (3)
2. 6.01 (3)
3. 0.825 (3)
4. 0.043 (2)
5. 1.310×10^{22} (4)
6. 7000 (1)
7. 10. (2)

Operations with sig figs

1. **Multiplication / Division:** Final answers should have as many sig figs as the least precise measurement
   A. Ex. $\underset{(3)}{4.56} \times \underset{(2)}{1.4} = 6.38 \sim 6.4$

   B. $\dfrac{1.05 \times 10^{-3}}{6.135} = 1.71 \times 10^{-4}$

2. **Addition / Subtraction:** Final answer should have as many decimal places* as the least precise measurement (need to round up for 6+, round down for 4-), for 5: → either round up → round to the nearest even no. ex/ 34.5 ~ 34

ex/
12.11
18.0
1.013
31.123 ~ 31.1

ex/ 21 − 13.8 = 7.2 ~ 7

3. **Multiple Operations**

ex/ A × B = C
C × D = E

A = 3.66
B = 8.45
D = 2.11

3.66 × 8.45 = 30.9
30.9 × 2.11 = 65.2
E = 65.2

$\boxed{\begin{array}{l} 3.66 \times 8.45 = 30.927 \\ 30.927 \times 2.11 = 65.25597 \\ E = 65.3 \end{array}}$ – use this approach

ex/ $\dfrac{29.837 - 29.241}{32.064}$ ① FIRST DO ADDITION/SUBTRACTION

29.837
− 29.241
0.596

② $\dfrac{0.596}{32.064} = 1.86 \times 10^{-2}$ (3 sig figs) ex/ $\frac{732.11 + 6.3}{760.00}$

$$\begin{array}{r} 732.11 \\ 6.3 \\ \hline 738.41 \end{array} \rightarrow 738.4(1)$$

$\frac{738.41}{760.00} = 0.9716$

* Addition subtraction first

ex/ $6.78 \times 5.903 \times (5.489 - 5.01)$

" $\times$ 0.479

$= 19.1707009 \sim 19.2$

ex/ $1.22 \times 10^{-2} + 34.5 \times 10^{-3} + 1.04 \times 10^{-4} = ?$

$1.22 \times 10^{-2} + 3.45 \times 10^{-2} + 0.0104 \times 10^{-2}$

need to keep same no. of sig figs & $\underbrace{\text{convert to same exponent}}_{\text{just for add/sub}}$

Dimensional Analysis

1 in = 2.54 cm <-- conversion factor (assumed to be exact numbers, therefore assumed to have an infinite amount of sig figs)

1 in = 2.54 cm

$\frac{1 \text{ in}}{2.54 \text{ cm}} = 1$

$\frac{1 \text{ in}}{1 \text{ in}} = \frac{2.54 \text{ cm}}{1 \text{ in}}$

$1 = \frac{2.54 \text{ cm}}{1 \text{ in}}$

UNIT FACTORS

25.5 in → cm

$25.5 \cancel{\text{in}} \times \frac{2.54 \text{ cm}}{1 \cancel{\text{in}}} = 64.8 \text{ cm}$

inches need to be in the denominator to cancel out, cm needs to be on the numerator

25.50 in → cm

$25.50 \text{ in} \times \frac{2.54 \text{ cm}}{1 \text{ in}} = 64.80$

exact no.

How meny sec in a year?

$$1 \text{ year} \times \frac{365 \cancel{\text{days}}}{1 \text{ year}} \times \frac{24 \cancel{h}}{\cancel{\text{day}}} \times \frac{60 \cancel{\text{min}}}{1 \cancel{h}} \times \frac{60 s}{\cancel{\text{min}}}$$

$= 31\ 536\ 000\ s$

Temperatures

Celcius - kelvin

Tc = Tk - 273.15

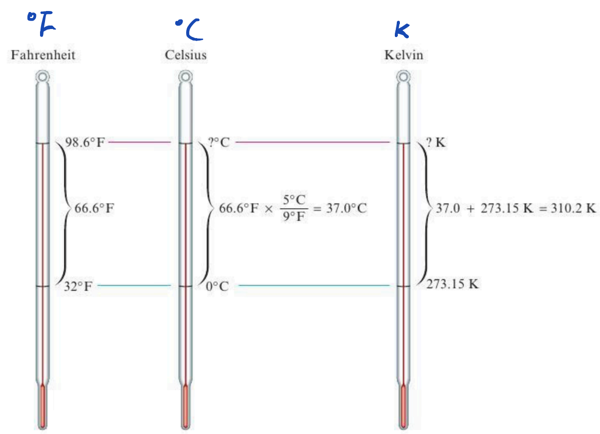
Tk = Tc + 273.15

Celcius - Ferehheit

$\frac{100°}{180°} = \frac{5°C}{9°F}$

$$T_c = (T_F - 32°F) \times \frac{5°C}{9°F}$$

$$T_F = T_c \times \frac{9°F}{5°C} + 32°F$$



normal body temp

ex/ 98.6 F° → °C

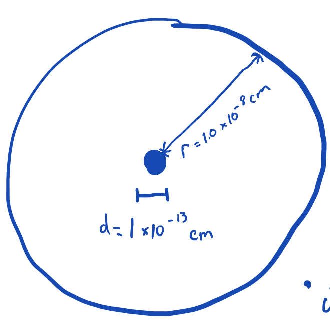
$$T_c = (98.6°F - 32°F) \times \frac{5°C}{9°F}$$

$T_c = 37°C$

Atomic Structure

• Nucleus composed of Proton and Neutron (except hydrogen, doesn't have neutron) and electron orbiting around it

dosn I need to be memorized



nucleus : distance to orbitting electron

• Size of ping pong ball ! 500 m

diameter

• $d_{Nucleus} = 1.6 \times 10^{14}$ g/ml

• mass of ping pong ball : 2.5 billion tons with density of nucleus

Must have been huge force to displace the nucleus (nuclear energy), force even higher for proton

	Mass	Charge
Electron	9.11×10^{-28} g	-1
Proton	1.67×10^{-24} g	+1
Neutron	1.67×10^{-24} g	0

$\boxed{\pm 1 = 1.6 \times 10^{-19} C}$

charge is relative to columb

Notation

\# of protons and neutrons

(A) Mass Number

hydrogen

H, O, Cl, ...

X

(Z) Atomic Number

→ # of protons

Isotopes

$^{23}_{11}Na$ $^{24}_{11}Na$ ← isotope

- Neutrons are not relevant in chemistry (that's physics), in chemistry were interested in the electrons
- Very difficult to separate isotopes from each other
  - Need to use difference in mass
  - Separate Uranium 235 from Uranium 238
    - First need to enrich the percentage of U 235
    - Ex. Effusion: make it in gaseous form by adding Florine, drill holes between the gases and a vacuum. Difference in masses = difference in velocity, when you collect the smaller gas will be more concentrated than prior

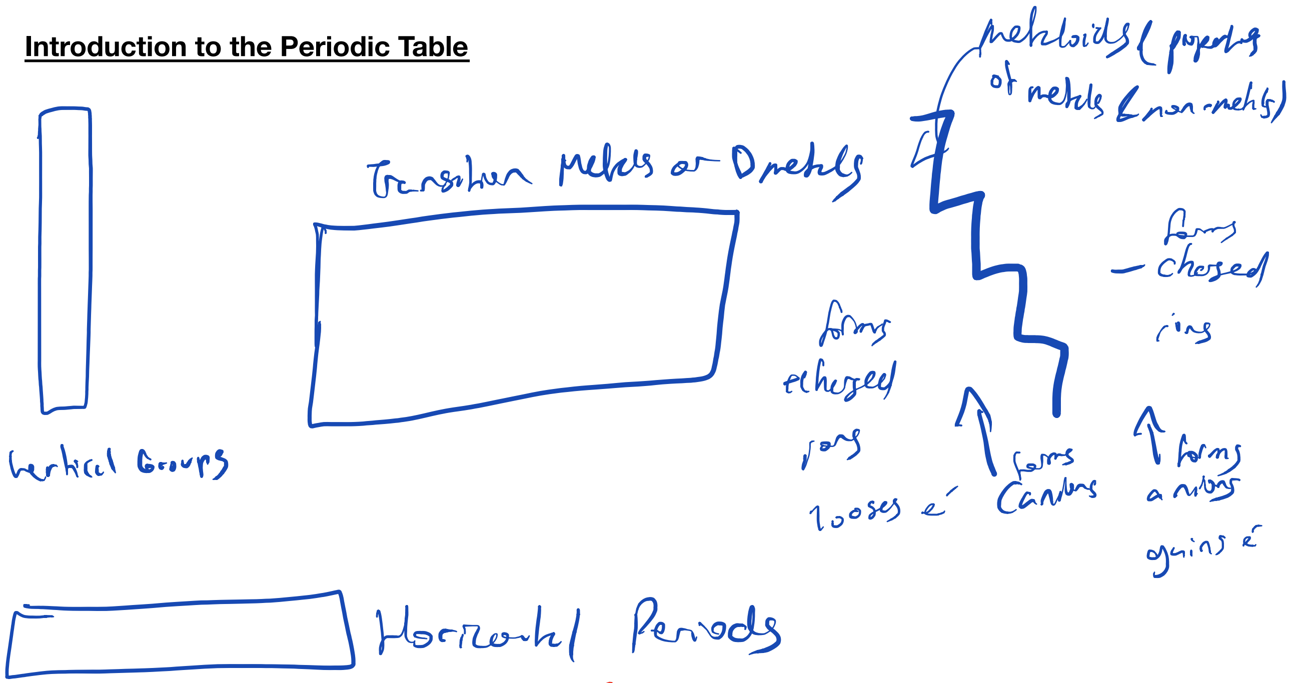
How many protons, neutrons and electrons are in each of the following ions or atoms?

	a) $^{24}_{12}Mg$	b) $^{24}_{12}Mg^{2+}$	c) $^{59}_{27}Co^{3+}$	d) $^{59}_{27}Co^{2+}$	e) $^{79}_{34}Se^{2-}$
P	12	12	27	27	34
N	12	12	32	32	45
E	12	10	24	25	36

· becomes positively charged by less e^-

· " " negatively " by extra e^-

Introduction to the Periodic Table



Quantum Number

Physical Prop.

Metals: Conduct electricity well, most shiny

Physical properties of non-metals cannot be generalized

* In 2 weeks - Quiz

Nomenclature

Binary Ionic Compound (1st 2 groups) Type I

ex/ Na^+Cl^- ← anion ends in "ide"

Sodium cloride

Anions

C^{4-} CARBIDE

B^{5-} BORIDE

* Compound needs to be neutral

Binary... Type II - USE ROMAN NUMERALS (transition & even post-transition metals)

ex/ $\overset{+2}{Fe}Cl_2$ Iron (II) chloride

$\overset{+3}{Fe}Cl_3$ Iron (III) chloride

ex/ $CuCl$ Copper (I) Chloride

HgO Mercury (II) Oxide

Fe_2O_3 Iron (III) Oxide

MnO_2 Manganese (IV) Oxide

$SnCl_4$ Tin (IV) Chloride

Fe_3O_4

$CoBr_2$ Cobalt (II) Bromide

Al_2O_3 Aluminium Oxide

$CrCl_3$ Chromium (III) Chloride

Polyatomic Ions

NO_2^- NITR-**ITE**

SO_3^{2-} SULPH-**ITE**

NO_3^- NITR-**ATE**

SO_4^{2-} SULPH-**ATE**

used to be $^{-2}$, add H^1, now $^{-1}$

HSO_3^{-1} Hydrogen Sulphite (Bisulfite)

HSO_4^- Hydrogen Sulfate

*Need to memorize all chemical names & polyatomic ions

• add : O_2^- superoxide

$S_2O_3^{2-}$ Thiosulfate   *Normally group #7

$C_2O_4^{2-}$ Oxalate

OCN^- Cyanate

SCN^- Thiocyanate

ClO^- $\underbrace{\text{hypo}}_{=\text{less than}}$chlorite

ClO_2^- Chlor<u>ite</u>

ClO_3^- Chlor<u>ate</u>

ClO_4^- $\underbrace{\text{per}}_{=\text{greater than}}$chlorate

ex/

Na_2SO_4 Sodium sulphate

Na_2SO_3 Sodium Sulfite

$NaOCl$ Sodium Hypochlorite

$CsClO_4$ Cesium Perchlorate

$Fe(NO_3)_3$ Iron (III) Nitrate

Na_2CO_3 Sodium Carbonate

$NaHCO_3$ Sodium Hydrogen Carbonate

$NaNO_2$ Amonium Nitrite

BINARY COVALENT COMPOUNDS

*mono never used for first term

ex/ N_2O dinitrogen monoxide

NO nitrogen monoxide

NO_2 nitrogen dioxide

N_2O_3 dinitrogen trioxide

N_2O_4 dinitrogen tetroxide

N_2O_5 dinitrogen pentoxide

ex/ PCl_5 phosphorus pentachloride

SO_3 Sodium tetroxide

Nb_2O_5 Niobium (V) Oxide Ionic compound

ACIDS

= one or more H^+ ions attached to an anion

*If the anion does not contain oxygen, the acid is named with the prefix hydro- and the suffix -ic

$HF_{(aq)}$ Hydroflori c acid *Needs to be aq, dissolved in water

$HF_{(g)}$ Hydrogen Floride

* contains oxygen:

NO_2^- Nitrite HNO_2 Nitr-ous acid

NO_3^- Nitrate HNO_3 Nitr-ic acid

ex/ $HClO$ Hypochloous acid

$HClO_2$ Chlorous acid

$HClO_3$ chloric acid

$HClO_4$ perchloric acid

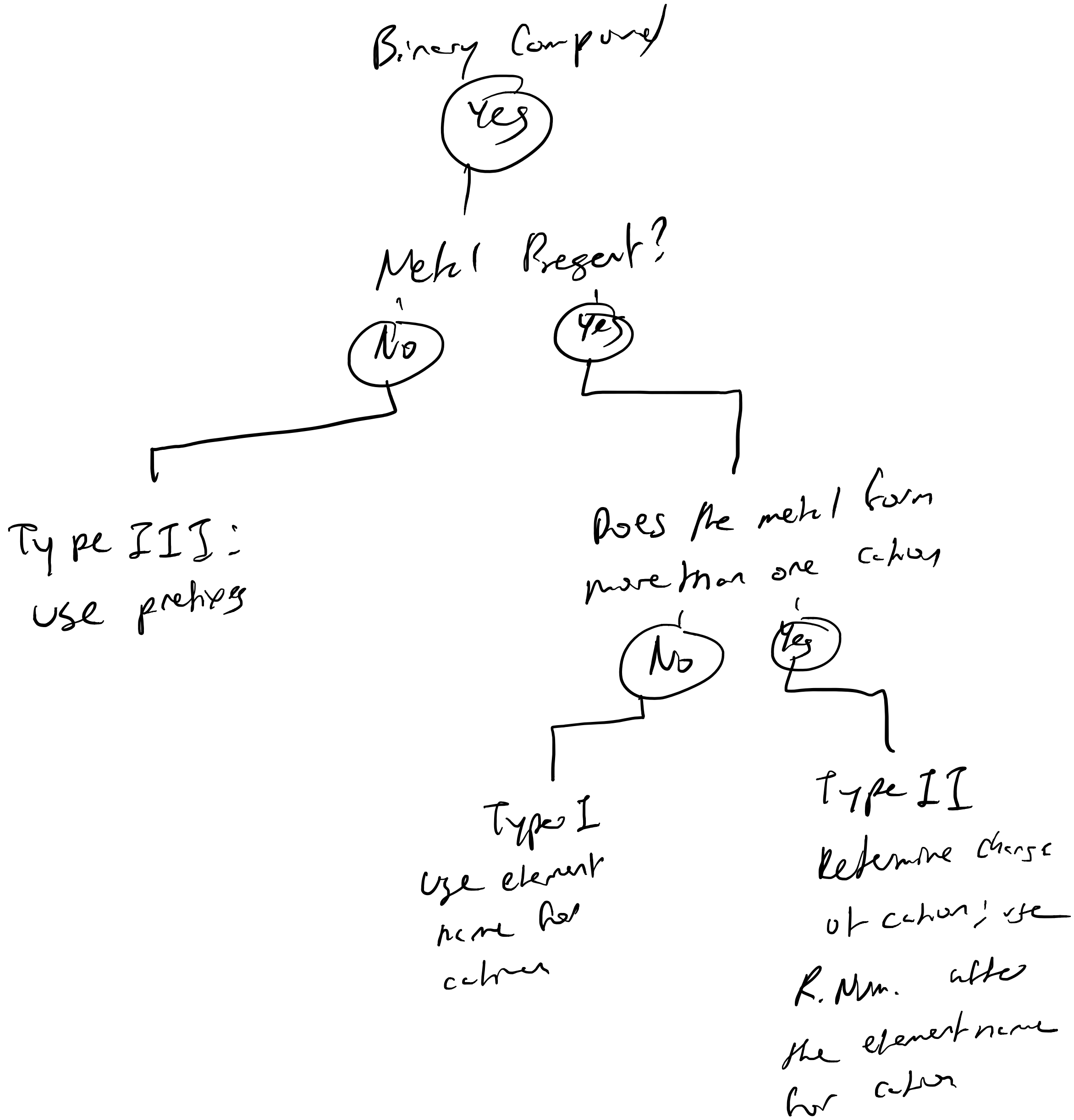
DISSOCIATION

$H^+ + NO_2^- \leftarrow HNO_2$

$H^+ + NO_3^- \xleftarrow{H_2O} HNO_3$

strong vs weak acid [?]*

Common Strong Acids	
HCl	
HBr	
HI	
H_2SO_4	
HNO_3	
strongest acid → $HClO_4$	


Binary Compound
Yes
Metal Present?
No
Yes
Type III: use prefixes
Does the metal form more than one cation
No
Yes
Type I
Use element name for cation
Type II
Determine charge of cation; use R.Num. after the element name for cation

Write Formulas for the following Compounds

*reverse, if Br is group 7, Cs must be gr. I

a) Cesium Bromide $CsBr$

b) Barium Sulfate $BaSO_4$

c) Aluminum Chloride $AlCl_3$

*always +3 aluminum

d) Chlorine Monoxide ClO

e) Silicon Tetrachloride $SiCl_4$

f) Chlorine Trifluoride ClF_3

g) Beryllium oxide BeO

Name the following compounds:

$HNO_{3(aq)}$ Nitric acid

$HNO_{2(aq)}$ Nitrous acid

$H_3PO_{4(aq)}$ Phosphoric acid

$H_3PO_{3(aq)}$ Phosphorous acid

V_2O_5 Vanadium (V) oxide

$NaHSO_4$ Sodium Hydrogen Sulphate

$Cu(HSO_3)_2$ Copper (II) hydrogen sulphite

Don't care

Stoichiometry

Atomic Masses

- Carbon 12 (C12) is used as a reference
  - Assumed that ^{12}C has 12 atomic mass units
- 1 amu ≈ Mass of proton or neutron (1.6710 x 10^{-24})
- Can measure using a specific machine
  - Shine electron beam and element looses electron (now cation) - positively charged
  - Element has its own magnetic field, is accelerated, angle it is shot at is proportional to mass
- Mass represents the average of isotopes in nature: 12.011 --> 1.11% of 13-C and 98.89% of 12-C

$$\left(\frac{1.11}{100} \cdot 13\,amu\right) + \left(\frac{98.89}{100} \cdot 12\,amu\right) = 12.011$$

- Some elements that don't have isotopes still have a mass that is not an integer
  - Due to mass defect

Mol

$N_A = 6.02214 \times 10^{23}$: Number of atoms in exactly 12 grams of ^{12}C

^Avogadro's number

$$\underbrace{1.67 \times 10^{-24}\,amu}_{\text{mass of } p^+ \text{ or } n^0 \text{ in amu}} \cdot 6.02 \times 10^{23}\,atoms = 1.0\,g$$

*

ex/ Computer chip
5.68 mg Si
Atoms of Si?

$$5.68\,\cancel{mg}\,Si \times \frac{1\,\cancel{g}}{1000\,\cancel{mg}} \times \frac{1\,mol\,\cancel{Si}}{28.08\,\cancel{g\,Si}} \times \frac{6.02 \times 10^{23}\,Si\,atoms}{1\,\cancel{mol\,Si}}$$

$= 1.22 \times 10^{20}$ Si atoms

^ atomic mass should be taken with as many # of sig figs to never limit the # of sig figs in the final answer

ex/ Calculate the mass (g) of 2.23 mol of Nitrogen molecules (N_2)

$$2.23\,mol\,N_2 \times \frac{28.014\,g\,N_2}{1\,mol\,N_2}$$

MOLECULAR MASS vs **MOLAR MASS**

mass of a single molecule expressed in amu

CH_4

1 C-atom : 12.011 amu
4 H-atoms : 4 x 1.008 amu
16.043 amu

mass of one mole of molecules (atoms) expressed in g

CH_4

1 mol C-atom : 12.011 g
4 moles H-atoms : 4 x 1.008 g
16.043 g

ex/ $C_2 H_{14} O_2$: Isopentyl acetate (bees release it, responsible for smell of bananas)

$\overset{\text{micro gram}}{1 mg}$ / sting

\# of $C_2H_{14}O_2$ molecules / sting

\# of C - Atoms / sting

Molar mass

7 C : 7 x 12.011 g

14 H : 14 x 1.008 g

2 O : 2 x 15.999 g

130.186 g

$$1 \cancel{mg} \times \frac{1g\ C_2H_{14}O_2}{10^6\ \cancel{mg}} \times \frac{1\ mol\ C_2H_{14}O_2}{130.186\ g\ C_2H_{14}O_2} = \overset{7.68 \times 10^{-9}}{8 \times 10^{-9}}\ mol\ of\ C_7H_{14}O_2$$

$$\overset{7.68 \times 10^{-9}}{8 \times 10^{-9}}\ \cancel{mol} \times \frac{6.02 \times 10^{23}\ molecules}{1\ \cancel{mol}} = \overset{4.62 \times 10^{15}}{5 \times 10^{15}}\ C_7H_{14}O_2\ molecules$$

$$\overset{4.62 \times 10^{15}}{5 \times 10^{15}}\ C_2H_{14}O_2\ molecules\ \frac{7\ C\text{-atoms}}{molecule} = \overset{3.2 \times 10^{16} \rightarrow 3 \times 10^{16}}{4 \times 10^{16}}\ C\text{-atoms}$$

% Composition of Compounds

C_2H_5OH

Assume 1 mol

2 C : 2 x 12.011

6 H : 6 x 1.008

1 O : 15.999

46.069 g

$$\% C = \frac{mass\ of\ C\ in\ a\ mole}{molar\ mass} \times 100 = \frac{6 \times 1.008\ g\ H}{46.069\ g} \times 100 = 52.144\%$$

$$\% H = \frac{6 \times 1.008\ g\ H}{46.069\ g} \times 100 = 13.13\%$$

$$\% O = \ldots = 34.728\%\ O$$

EMPIRICAL FORMULA

= Smallest whole number ratio of numbers of atoms in a molecule

MOLECULAR FORMULA	EMPIRICAL FORMULA
H_2O_2	HO
C_2H_4	CH_2
H_2O	H_2O ← can't have fractions

Empirical Formula Worksheet

1) ① Fe : 1.34 g

O : 1.92 g − 1.34 g = 0.58 g

② $1.34\text{ g Fe} \times \dfrac{1\text{ mol Fe}}{55.8\text{ g Fe}} = 0.0240\text{ mol}$

$0.58\text{ g O} \times \dfrac{1\text{ mol O}}{16.0} = 0.036\text{ mol}$

* Empirical = Molecular Form. for Ionic compounds

divide by smallest one

③ $0.0240 / 0.0240 = 1 \rightarrow 1\times2 = 2$

$0.036 / 0.0240 = 1.5 \rightarrow 1.5\times2 = 3$

$\Rightarrow Fe_2O_3$

*organic compounds are usually formed with Carbon & Hydrogen

2) **Combustion Analysis***

0.01156 g - compound

0.1638 g CO_2

0.1676 g H_2O

* Nitrogen can't be collected

for review

CO_2 : $0.1638\text{ g } CO_2 \times \dfrac{12.011\text{ g C}}{44.009\text{ g } CO_2} = 0.04470\text{ g C}$

H_2O : $0.1676\text{ g } H_2O \times \dfrac{2\times1.008\text{ g H}}{18.01\text{ g } H_2O} = 0.01867\text{ g H}$

g N : $0.01156 - (0.04470\text{ g C} + 0.01867\text{ g H}) = 0.0522\text{ g N}$

$0.04470\text{ g C} \times \dfrac{1\text{ mol C}}{12.011\text{ g C}} = 0.00372\text{ mol C} / 0.00372 = 1\text{ mol C}$

$0.01867\text{ g H} \times \dfrac{1\text{ mol H}}{1.008\text{ g H}} = 0.0185\text{ mol H} / 0.00372 = 5\text{ mol H}$

$0.0522\text{ g N} \times \dfrac{1\text{ mol N}}{14.007\text{ g N}} = 0.00372\text{ mol N} / 0.00372 = 1\text{ mol N}$

$(CH_5N)_x$ ← requires molar mass

this means it represents the empirical formula

$$X = \frac{\text{molar mass}}{\text{empirical formula mass}}$$

molar mass = 62.12 g   empirical formula mass: 12.017 + ... = 31.06

$$\frac{62.12}{31.06} = 2$$

needs to
be integer/
close to integer

EMPIRICAL FORMULA

1) The mass of a piece of iron is 1.34 g. Exposed to oxygen under conditions in which oxygen combines with all of the iron to form a pure oxide of iron, the final mass increases to 1.92 g. Find the empirical formula of the compound.

2) When 0.1156 g of a certain compound containing C, H, and N is reacted with oxygen 0.1638 g of CO_2 and 0.1676 g of H_2O are collected.
Determine the empirical formula of the compound.

3) The compounds called chloroflurocarbons or "freons" have proved to be very valuable as refrigirants and cleaning agents for circuit boards. Unfortunately, in the atmosphere these compounds produce chlorine atoms that catalyze the decomposition of the ozone that protects the earth from ultra-violet radiation. Two of these compounds have the mass percentages:

	% C	% Cl	% F
I	9.93	58.6	31.4
II	11.5	33.9	54.6

Determine the empirical formulas of these compounds.

4) A 1.35 g sample of a substance containing C, H, N, and O was burned in oxygen and produced 0.810 g of H_2O and 1.32 g of CO_2.
In a separate reaction, all the nitogen in 0.735 g of the substance was converted to ammonia (NH_3). This gave 0.284 g of ammonia.
Determine the empirical formula of the substance.

5) A hydrated compound has an analysis of 18.29 % Ca, 32.37 % Cl and 49.34 % H_2O. What is the molecular formula of this compound?

3. Assume 100g

I

$9.93\ g\ \cancel{C} \times \frac{1\ mol\ C}{12.011\ g\ C} = 0.820\ mol / 0.820 = 1$

$58.6\ g\ Cl \times \frac{1\ mol\ Cl}{4\ \ C} = 1.65\ mol / 0.80 = 2$

$31.4\ g\ F \times \frac{1\ mol\ F}{19.00\ g} = 1.65\ mol / 0.820 = 2$

I: $(CCl_2F_2)_x$

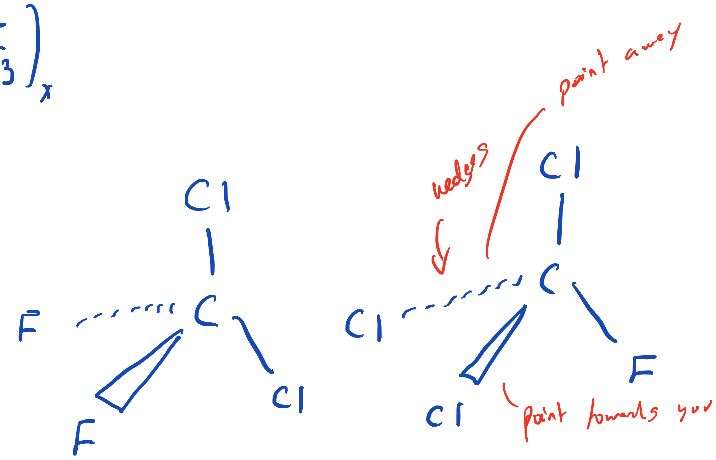
II **Assume 100 g**

$11.5\ \cancel{g\ C} \times \frac{1\ mol}{12.011\ \cancel{g\ C}} = 0.96 / 0.96 = 1$

$33.9\ \cancel{g\ Cl} \times \frac{1\ mol\ Cl}{35.45\ \cancel{g\ Cl}} = 0.96 / 0.96 = 1$

$54.6\ \cancel{g\ F} \times \frac{1\ mol\ F}{19.00\ \cancel{g\ F}} = 2.87 / 0.96 = 3$

I: $(CClF_3)_x$



* Oxygen cannot be obtained from Combustion analysis since addition O_2 was introduced in the experiment

→ Would have to be obtained from difference of masses

4. TWO SAMPLES

H_2O : $0.810\ \cancel{g\ H_2O} \times \dfrac{2 \times 1.008\ g\ H}{18.015\ \cancel{g\ H_2O}} = 0.0906\ g\ H$

$\%H = \dfrac{0.0906\ g\ H}{1.35\ g\ sample} \times 100 = 6.71\%\ H$

CO_2 : $1.32\ \cancel{g\ CO_2} \times \dfrac{12.011\ g\ C}{44.009\ \cancel{g\ CO_2}} = 0.360\ g\ C$

$\%C = \dfrac{0.360\ g\ C}{1.35\ g\ sample} \times 100 = 26.7\%\ C$

NH_3 : $0.284\ g\ NH_3 \times \dfrac{14.007\ g\ N}{17.031\ g\ NH_3} = 0.234\ g\ N$

doesn't vary from sample to sample

$\%N = \dfrac{0.234\ g}{0.735\ g\ sample} \times 100 = 31.8\%\ N$

$\%O = 100 - (6.71 + 26.7 + 31.8) = 34.8\%$

100 g

$6.71\ \cancel{g\ H} \times \dfrac{1\ mol\ H}{1.008\ \cancel{g\ H}} = 6.66\ mol\ H\ /2.18 = 3$

$26.7\ \cancel{g\ C} \times \dfrac{1\ mol\ C}{12.011\ \cancel{g\ C}} = 2.22\ mol\ C\ /2.18 = 1$

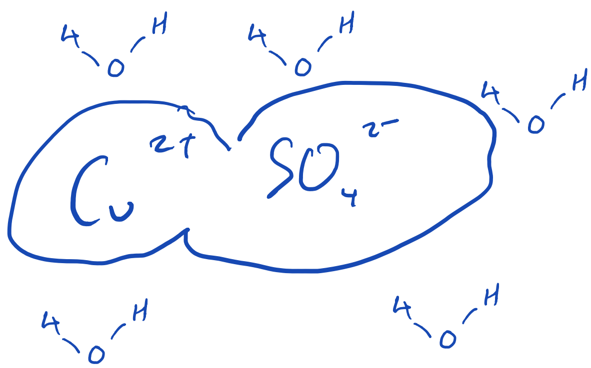
$31.8\ \cancel{g\ N} \times \dfrac{1\ mol\ N}{14.007\ \cancel{g\ N}} = 2.27\ mol\ N\ /2.18 = 1$

$34.8\ \cancel{g\ O} \times \dfrac{1\ mol\ O}{15.999\ \cancel{g\ O}} = 2.18\ mol\ O\ /2.18 = 1$

$(CH_3NO)_x$

HYDRATED COMPOUNDS

$CuSO_4 \times 5H_2O$ — On average, there will be 5 H_2Os around the $CuSO_4$



Called Copper (II) sulfate pentahydrate

5. 100 g

$18.29\,g\,Ca \times \frac{1\,mol\,Ca}{40.09\,g\,Ca} = 0.4563\,mol\,Ca / 0.4563 = 1$

$32.37\,g\,Cl \times \frac{1\,mol\,Cl}{35.45\,g\,Cl} = 0.9131\,mol\,Cl / 0.4563 = 2$

$49.34\,g\,H_2O \times \frac{1\,mol\,H_2O}{18.02\,g\,H_2O} = 2.738\,mol\,H_2O / 0.4563 = 6$

Don't care about H & O, just H_2O in hydrated compounds

In ionic compounds, empirical = molecular formula

$CaCl_2 \times 6H_2O$

Calcium Chloride hexahydrate