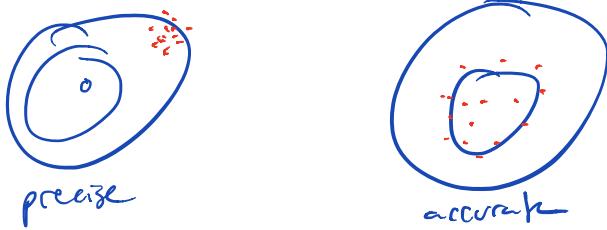
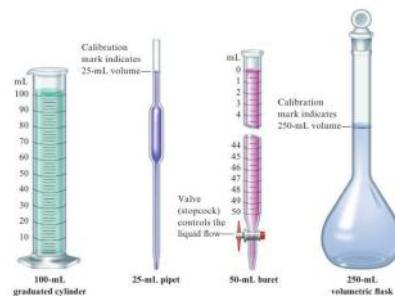


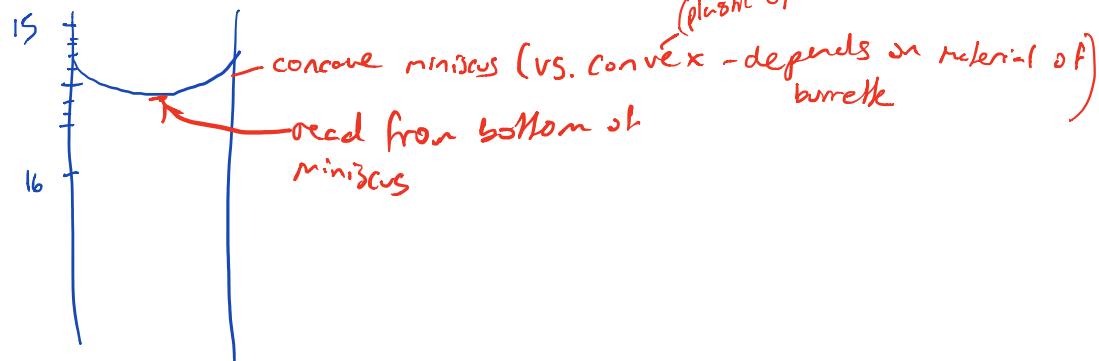
- Units
- Prefixes
- Accuracy vs precision
 - Accuracy: degree of agreement between the particular measurement and the real value
 - Precision: degree of agreement amongst several measurements
 - Better to be precise because it means you're consistent in your error and then you can just find the source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



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



Significant Figures



Certain digits / Sig Figs

- **Certain digits:** say data was 15.48, 15.45, 15.49: the certain digits would be 15.4
 - 1 5 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)

0.004005400
 ↓
 sig figs

Examples:

1. 478 (3)
2. 6.01 (3)
3. 0.825 (3)
4. 0.043 (2)
5. 1.310×10^4 (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. $4.56 \times 1.4 = 6.38 \sim 6.4$
 ↓ ↓

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

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

Ex/ 12.11
 ↓
 $\begin{array}{r} 12.0 \\ + 1.013 \\ \hline 13.123 \end{array} \sim 13.1$

Ex/ $21 - 13.8 = 7.2 \sim 7$

→ round to the nearest even no.
 Ex/ 34.5 ~ 34

3. Multiple Operations

Ex/ $A \times B = C$
 $C \times D = E$
 $\underline{\quad}$
 $A = 3.66$
 $B = 8.45$
 $D = 2.11$

$$\begin{aligned} 3.66 \times 8.45 &= 30.9 \\ 30.9 \times 2.11 &= 65.2 \\ E &= 65.2 \end{aligned}$$

use this approach

Ex/ $\frac{29.837 - 29.241}{32.064}$ ① FIRST DO ADDITION/SUBTRACTION ② $\frac{0.596}{32.064} = \frac{1.86 \times 10^{-2}}{3.52 \times 10^{-3}}$

$$\begin{array}{r} 29.837 \\ - 29.241 \\ \hline 0.596 \end{array}$$

$$\text{ex/ } \begin{array}{r} 732.11 + 6.3 \\ \hline 760.00 \end{array} \quad \begin{array}{r} 732.11 \\ 6.3 \\ \hline 738.41 \end{array} \rightarrow 738.4 (\text{q})$$

**Addition
Subtraction
first*

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

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

$$\begin{array}{r} 6.78 \\ \times 5.903 \\ \hline 0.479 \end{array}$$

$$= 19.1767009 \sim 19.2$$

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

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

Need to keep same
 no. of sig figs
 &
 convert to same exponent
 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)

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

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

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

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

UNIT FACTORS

$$25.5 \text{ in} \rightarrow \text{cm}$$

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

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

25.50 in \rightarrow cm exact
 25.50 in $\times \frac{2.54 \text{ cm}}{1 \text{ in}}$ no. = 64.80

How many sec in a year?

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

$$\approx 31,536,000 \text{ s}$$

Temperatures

Celsius - kelvin

$$T_c = T_k - 273.15$$

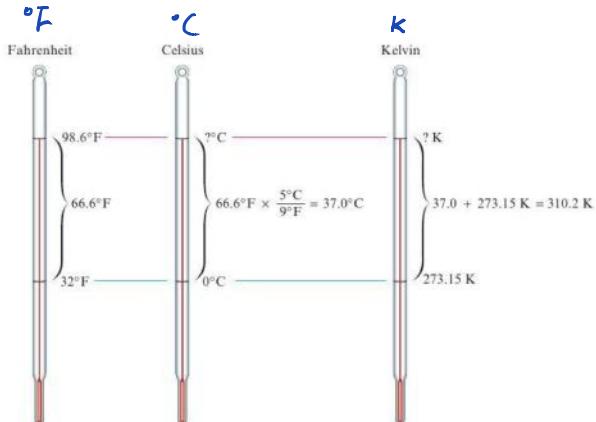
$$T_k = T_c + 273.15$$

Celsius - Fahrenheit

$$\frac{100^\circ}{180^\circ} = \frac{5^\circ C}{9^\circ F}$$

$$T_c = (T_f - 32^\circ F) \times \frac{5^\circ C}{9^\circ F}$$

$$T_f = T_c \times \frac{9^\circ F}{5^\circ C} + 32^\circ F$$



normal body temp
↓

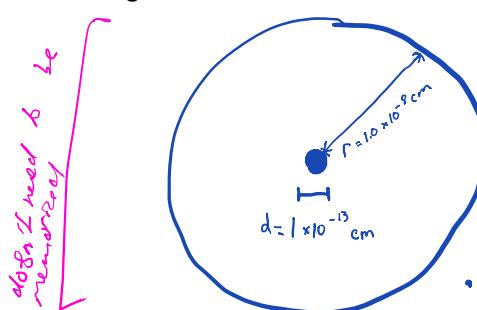
$$ex/ 98.6^\circ F \rightarrow ^\circ C$$

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

$$T_c \approx 37^\circ C$$

Atomic Structure

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



nucleus: distance to orbiting electron

• size of ping pong ball: 500 m

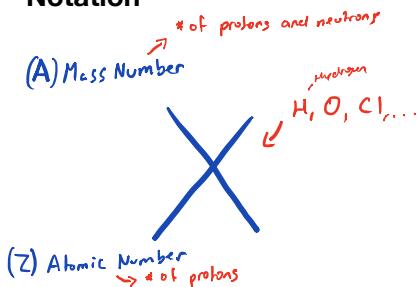
• $d_{\text{Nucleus}}^{\text{diameter}} = 1.6 \times 10^{-14} \text{ m}$

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

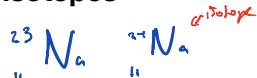
Must have been huge force to displace the nucleus (nuclear energy), force even higher for proton

	Mass	Charge	
Electron	$9.11 \times 10^{-31} \text{ g}$	-1	$\pm 1 = 1.6 \times 10^{-19} \text{ C}$
Proton	$1.67 \times 10^{-24} \text{ g}$	+1	charge is relative to Coulomb
Neutron	$1.67 \times 10^{-24} \text{ g}$	0	

Notation



Isotopes

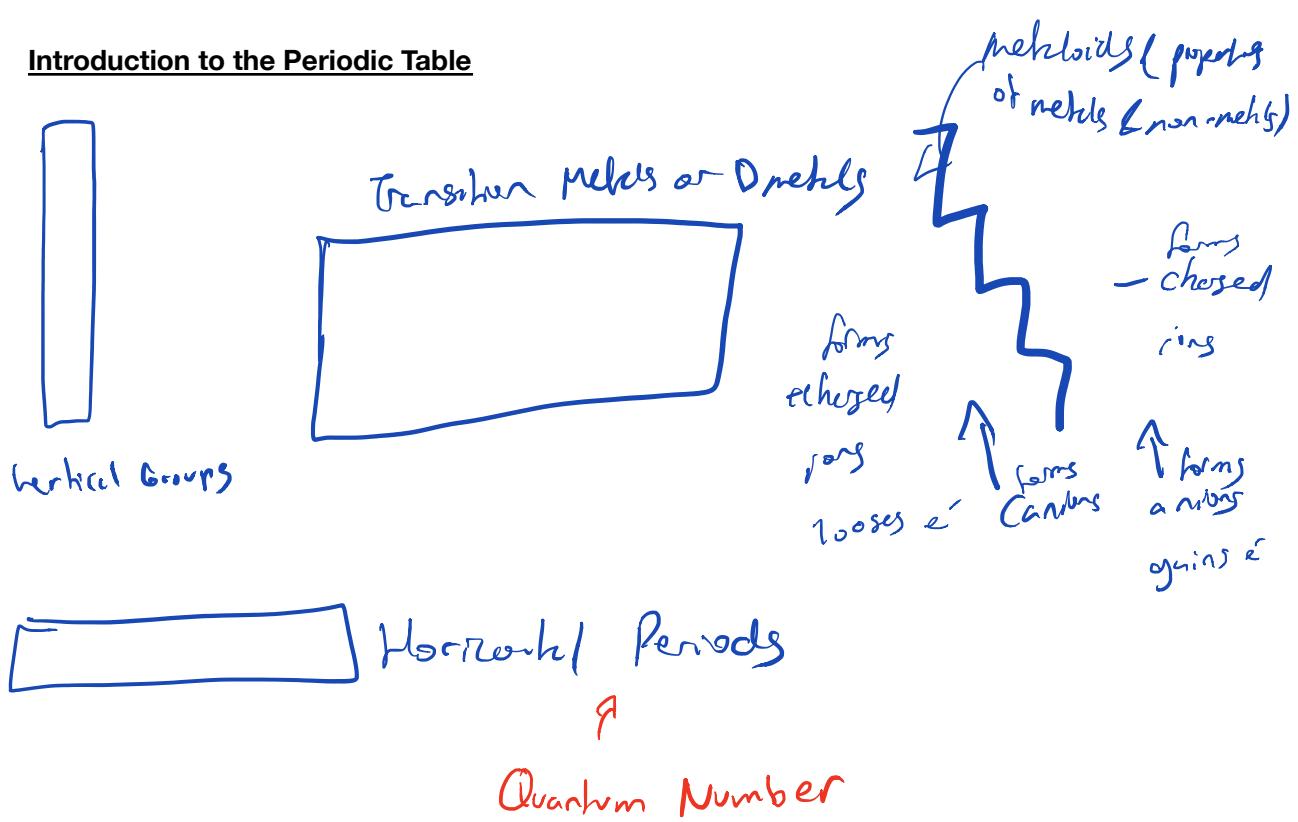


- Neutrons are not relevant in chemistry (that's physics), in chemistry we're interested in the electrons
- Very difficult to separate isotopes from each other
 - Need to use difference in mass
 - Separate Uranium 235 from Uranium 238
 - First need to enrich the percentage of U 235
 - Ex. Effusion: make it in gaseous form by adding Fluorine, 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) $^{24}_{12} \text{Mg}$	b) $^{24}_{12} \text{Mg}^{2+}$	c) $^{59}_{27} \text{Co}^{3+}$	d) $^{59}_{27} \text{Co}^{2+}$	e) $^{75}_{34} \text{Se}^{2-}$. becomes positively charged by loss e ⁻
P 12	12	27	27	34	" " negatively by gain e ⁻
N 12	12	32	32	45	
E 12	10	24	25	36	

Introduction to the Periodic Table



Physical Prop. most
Metals: Conduct electricity well, shiny

Physical properties of non-metals cannot be generalized

* In 2 weeks - Quiz

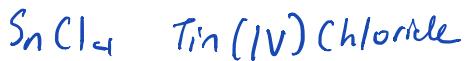
Nomenclature

Binary Ionic Compound (1st 2 groups) Type I
ex/ $\text{Na}^+ \text{Cl}^-$ ← anion ends in "ide"
Sodium chloride

Anions
 C^{4-} CARBIDE
 B^{5-} BORIDE

* Compound needs to be neutral

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



Polyatomic Ions



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



* 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^- Hypochlorite
= less than

ClO_2^- Chlorite

ClO_3^- Chlorate

ClO_4^- Perchlorate
= greater than

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

Na HCO_3 Sodium Hydrogen Carbonate

Na NO_2 Ammonium 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

$\text{HF}_{(\text{aq})}$ Hydrofluoric acid needs to be aq., dissolved
in water

$\text{HF}_{(\text{g})}$ Hydrogen fluoride

* contains oxygen:

NO_2^- Nitrite

HNO_2 Nitro - ois acid

NO_3^- Nitrate

HNO_3 Nitric acid

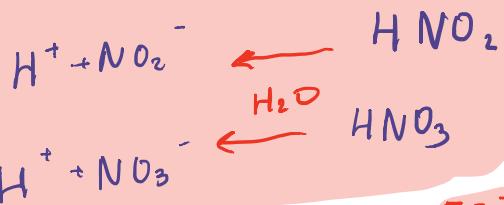
e.g. HClO Hypochlorous acid

HClO_2 Chlorous acid

HClO_3 Chloric acid

HClO_4 Perchloric acid

DISSOCIATION



Strong vs weak acid [?]*

(Common Strong Acids)

HCl

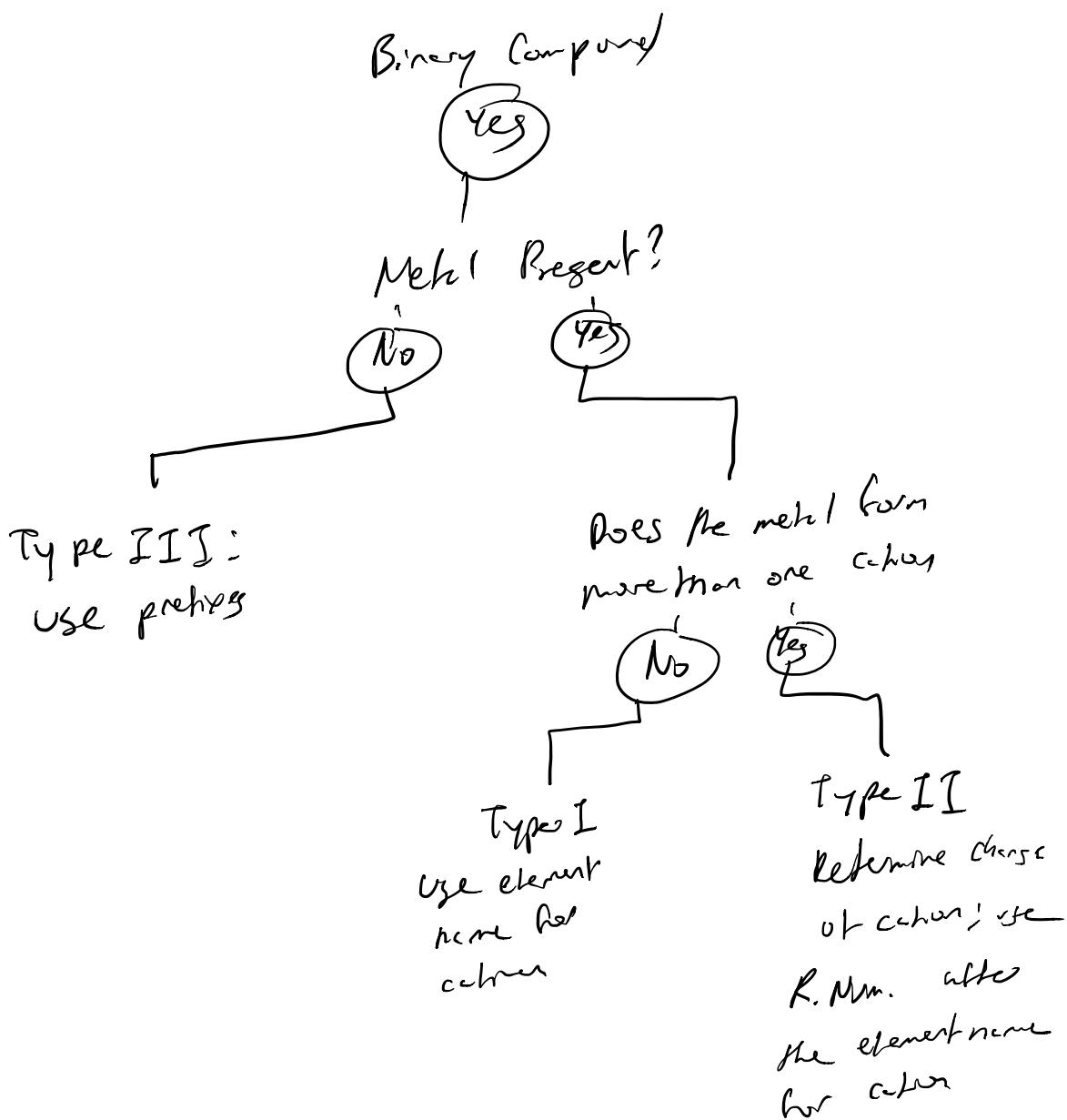
HBr

HI

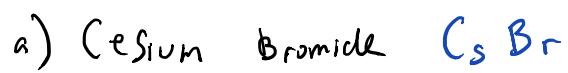
H_2SO_4

HNO_3

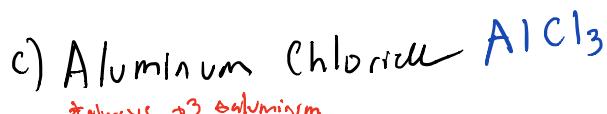
stronger acid $\Rightarrow \text{HClO}_4$



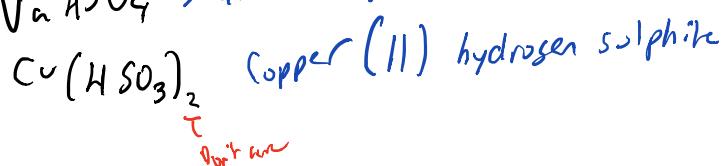
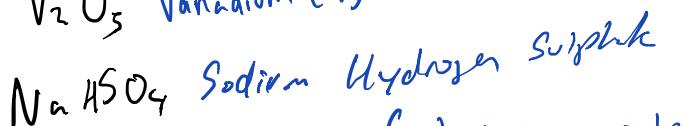
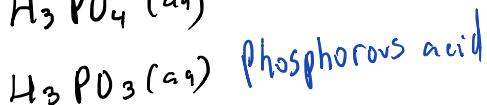
Write formulas for the following compounds



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



Name the following compounds:



Stoichiometry

Atomic Masses

- Carbon 12 (C^{12}) is used as a reference
 - Assumed that C^{12} has 12 atomic mass units
- 1 amu \approx Mass of proton or neutron (1.6710×10^{-24})
- Can measure using a specific machine
 - Shine electron beam and element loses 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: $12.011 \rightarrow 1.11\% \text{ of } C^{13} \text{ and } 98.89\% \text{ of } C^{12}$
- $$\left(\frac{1.11}{100} \cdot 13 \text{ amu} \right) + \left(\frac{98.89}{100} \cdot 12 \text{ amu} \right) = 12.011$$
- Some elements that don't have isotopes still have a mass that is not an integer
 - Due to mass defect

Mol

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

Avogadro's number

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

*

Ex/ Computer chip
5.68 mg Si
Atoms of Si?

$$\begin{aligned} & 5.68 \text{ mg Si} \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol Si}}{28.08 \text{ g Si}} \times \frac{6.02 \times 10^{23} \text{ Si atoms}}{1 \text{ mol Si}} \\ & = 1.22 \times 10^{20} \text{ Si atoms} \end{aligned}$$

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

Ex/ calculate the mass (g) of 2.23 mol of Nitrogen molecules (N_2)

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

MOLECULAR MASS vs
mass of a single molecule
expressed in amu
 CH_4

$$\begin{aligned} 1 \text{ C-atom: } & 12.011 \text{ amu} \\ 4 \text{ H-atoms: } & 4 \times 1.008 \text{ amu} \\ & \underline{16.045 \text{ amu}} \end{aligned}$$

MOLAR MASS
mass of one mole of molecules(atoms)
expressed in
 CH_4

$$\begin{aligned} 1 \text{ mol C-atom: } & 12.011 \text{ g} \\ 4 \text{ mol H-atoms: } & \frac{4 \times 1.008 \text{ g}}{16.045 \text{ g}} \end{aligned}$$

$\text{C}_2\text{H}_{14}\text{O}_2$: Isopentyl acetate (bees release it, responsible for smell of bananas)

1 mg / sting

* of $\text{C}_2\text{H}_{14}\text{O}_2$ molecules/sting
* of C - Atoms/sting

Molar mass

$$7\text{C}: 7 \times 12.011 \text{ g}$$

$$14\text{H}: 14 \times 1.008 \text{ g}$$

$$2\text{O}: 2 \times 15.999 \text{ g}$$

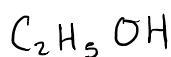
$$\underline{130.186 \text{ g}}$$

$$1 \text{ mg} \times \frac{1 \text{ g } \text{C}_2\text{H}_{14}\text{O}_2}{10^3 \text{ mg}} \times \frac{1 \text{ mol } \text{C}_2\text{H}_{14}\text{O}_2}{130.186 \text{ g } \text{C}_2\text{H}_{14}\text{O}_2} = 8 \times 10^{-9} \text{ mol of } \text{C}_2\text{H}_{14}\text{O}_2$$

$$8 \times 10^{-9} \text{ mol} \times \frac{6.02 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 5 \times 10^{15} \text{ C}_2\text{H}_{14}\text{O}_2 \text{ molecules}$$

$$5 \times 10^{15} \text{ C}_2\text{H}_{14}\text{O}_2 \text{ molecules} \times \frac{7 \text{ C-atoms}}{1 \text{ molecule}} = 3.5 \times 10^{16} \text{ C-atoms}$$

% Composition of Compounds



Assume 1 mol

$$2\text{C}: 2 \times 12.011$$

$$6\text{H}: 6 \times 1.008$$

$$1\text{O}: 15.999$$

$$\underline{46.069 \text{ g}}$$

$$\% \text{C} = \frac{\text{mass of C in a mole}}{\text{molar mass}} \times 100 = \frac{24.022 \text{ g H}}{46.069 \text{ g}} \times 100 = 52.144 \%$$

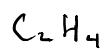
$$\% \text{H} = \frac{6 \times 1.008 \text{ g H}}{46.069 \text{ g}} \times 100 = 13.13\%$$

$$\% \text{O} = \dots \approx 34.728\% \text{ O}$$

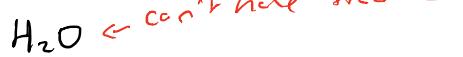
EMPIRICAL FORMULA

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

MOLECULAR FORMULA



EMPIRICAL FORMULA



Empirical Formula Worksheet

$$1) \text{Fe} : 1.34 \text{ g} \quad 2) 1.34 \text{ g Fe} \times \frac{1 \text{ mol Fe}}{55.8 \text{ g Fe}} = 0.0240 \text{ mol}$$

$$\begin{array}{r} 1.34 \text{ g} \\ - 1.34 \text{ g} \\ \hline 0.58 \text{ g} \end{array}$$

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

* Empirical = Molecular for Ionic compounds

$$3) \frac{0.0240}{0.0240} = 1 \rightarrow 1 \times 2 = 2$$

$$0.036 / 0.0240 = 1.5 \rightarrow 1.5 \times 2 = 3 \Rightarrow \text{Fe}_2\text{O}_3$$

* organic compounds are usually formed with Carbon & Hydrogen

2) Combustion Analysis

* Nitrogen
can't be collected

$$0.01156 \text{ g} - \text{Compound} \quad 6) \text{CO}_2: 0.1638 \text{ g CO}_2 \times \frac{12.01 \text{ g C}}{44.009 \text{ g CO}_2} = 0.04470 \text{ g C}$$

$$0.1638 \text{ g CO}_2 \quad \underline{\text{H}_2\text{O}: 0.1676 \text{ g H}_2\text{O} \times \frac{2 \times 1.008 \text{ g H}}{18.015 \text{ g H}_2\text{O}} = 0.01867 \text{ g H}}$$

$$7) \text{N: } 0.01156 - (0.04470 \text{ g C} + 0.01867 \text{ g H}) = 0.05225 \text{ g N}$$

$$0.04470 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 0.00372 \text{ mol C} / 0.00372 = 1 \text{ mol C}$$

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

$$0.05225 \text{ g N} \times \frac{1 \text{ mol N}}{14.007 \text{ g N}} = 0.00372 \text{ mol N} / 0.00372 = 1 \text{ mol N}$$

$(\text{CH}_5\text{N})_x$ requires further steps
this means it represents
the empirical formula

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

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

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

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 CO₂ and 0.1676 g of H₂O are collected. Determine the empirical formula of the compound.
- 3) The compounds called chlorofluorocarbons or "freons" have proved to be very valuable as refrigerants 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.

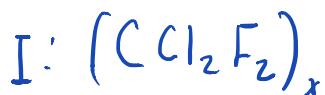
- 4) A 1.35 g sample of a substance containing C, H, N, and O was burned in oxygen and produced 0.810 g of H₂O and 1.32 g of CO₂. In a separate reaction, all the nitrogen in 0.735 g of the substance was converted to ammonia (NH₃). This gave 0.284 g of ammonia. Determine the empirical formula of the substance.
- 5) A hydrated compound has an analysis of 18.29 % Ca, 32.37 % Cl and 49.34 % H₂O. What is the molecular formula of this compound?

3. Assume 100g

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

$$58.6 \text{ g Cl} \times \frac{1 \text{ mol Cl}}{35.45 \text{ g Cl}} = 1.65 \text{ mol} / 0.820 = 2$$

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

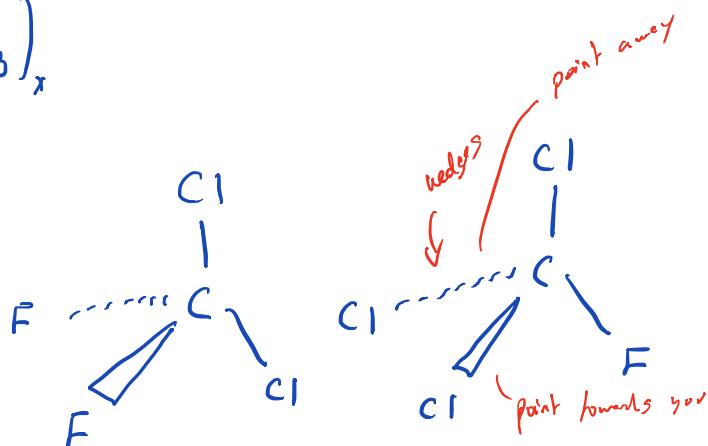


II Assume 100 g

$$11.5 \text{ g Cl} \times \frac{1 \text{ mol Cl}}{35.45 \text{ g Cl}} = 0.96 / 0.96 = 1$$

$$33.9 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 0.96 / 0.96 = 1$$

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



* Oxygen cannot be obtained from Combustion analysis
 since addition O_2 was introduced in the experiment
 \rightarrow would have to be obtained from difference of masses

4. TWO SAMPLES

$$\underline{\text{H}_2\text{O}} : 0.810 \text{ g H}_2\text{O} \times \frac{2 \times 1.008 \text{ g H}}{18.015 \text{ g H}_2\text{O}} = 0.09065 \text{ g H}$$

$$\% \text{ H} = \frac{0.09065 \text{ g H}}{1.35 \text{ g sample}} \times 100 = 6.71\% \text{ H}$$

$$\underline{\text{CO}_2} : 1.32 \text{ g CO}_2 \times \frac{12.011 \text{ g C}}{44.009 \text{ g CO}_2} = 0.360 \text{ g C}$$

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

$$\underline{\text{NH}_3} : 0.284 \text{ g NH}_3 \times \frac{14.007 \text{ g N}}{17.031 \text{ g NH}_3} = 0.234 \text{ g N}$$

doesn't vary from sample to sample

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

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

100 g

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

$$26.7 \text{ g C} \times \frac{1 \text{ mol C}}{12.011 \text{ g C}} = 2.22 \text{ mol C} / 2.18 = 1$$

$$31.8 \text{ g N} \times \frac{1 \text{ mol N}}{14.007 \text{ g N}} = 2.27 \text{ mol N} / 2.18 = 1$$

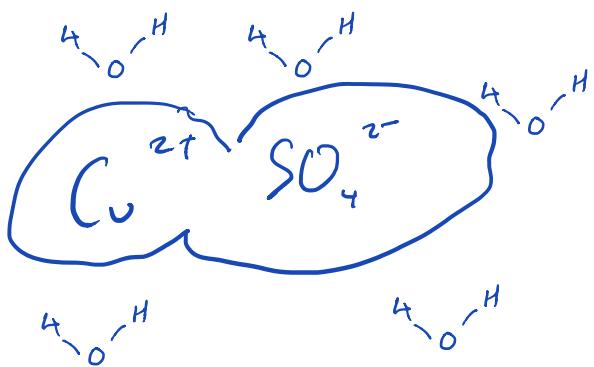
$$34.8 \text{ g O} \times \frac{1 \text{ mol O}}{15.999 \text{ g O}} = 2.18 \text{ mol O} / 2.18 = 1$$



HYDRATED COMPOUNDS



On average, there will be 5 H_2O s around the $CuSO_4$



Called Copper (II) sulfate pentahydrate

5. 100g

$$18.245 \text{ g Ca} \times \frac{1 \text{ mol Ca}}{40.095 \text{ g Ca}} = 0.4563 \text{ mol Ca} / 0.4563 = 1$$

$$32.375 \text{ g Cl} \times \frac{1 \text{ mol Cl}}{35.455 \text{ g Cl}} = 0.9131 \text{ mol Cl} / 0.4563 = 2$$

$$49.345 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.025 \text{ g H}_2\text{O}} = 2.738 \text{ mol H}_2\text{O} / 0.4563 = 6$$

Don't care about

H_2O , just

H_2O in hydrated
compounds

In ionic compounds, empirical \rightarrow molecular
formula



Calcium Chloride hexa hydrate