Periodic Table
Structure of Elements
Isotopes
Nuclid Symbols

Chapter 2.3 Modern Atomic Theory

Because atoms are so small we developed a new unit of mass. → atomic mass unit (amu).

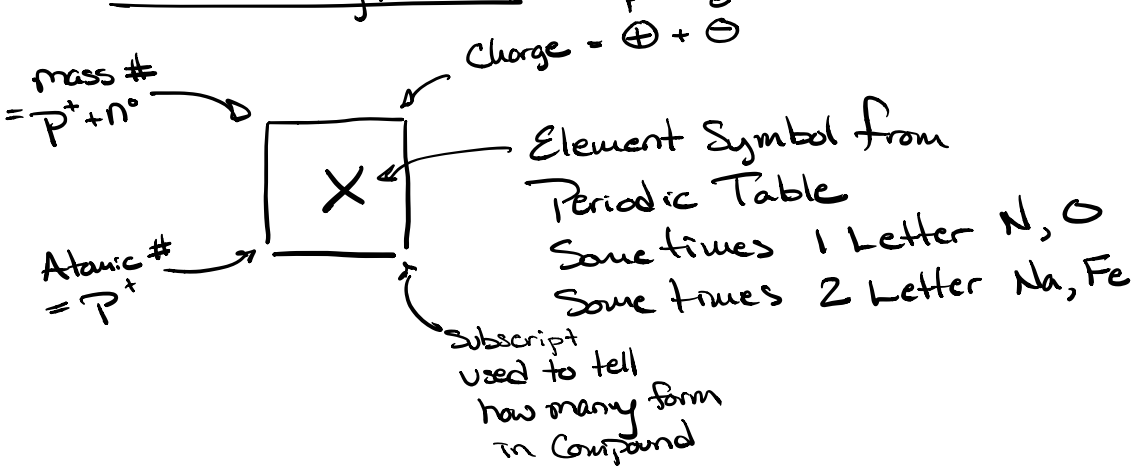
$C_{atom} = 2 \times 10^{-23}$ grams

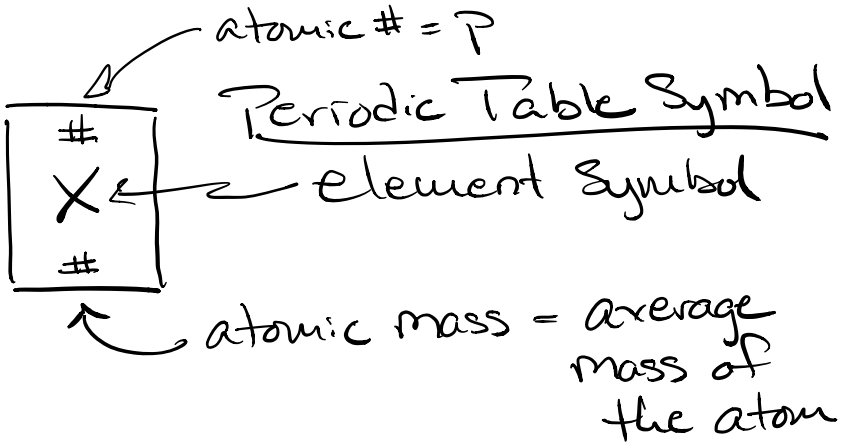
Define amu = $\frac{1}{12}$ mass of ^{12}C atom

$1\ amu = 1.6605 \times 10^{-24}$ grams

↪ do not need to memorize

Nuclid Symbol





Istope = Relationship between two or more atoms that have the same number of protons but different neutrons.
A very close family member

H = Hydrogen

mass # = p+n

atomic # = p

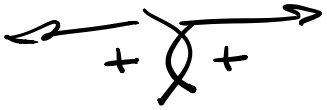
	$^{1}_{1}H$	$^{2}_{1}H$	$^{3}_{1}H$
$\#p^+$	1	1	1
$\#n^\circ$	mass # - #p 1-1=0	2-1=1	3-1=2
amu	1 amu	2 amu	3 amu

p ≈ n ≈ 1amu

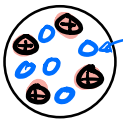
* # of e^- is not given, but is equal to the # of p for neutral atoms.

Why are there isotopes?

Why do some have different #'s of neutrons?

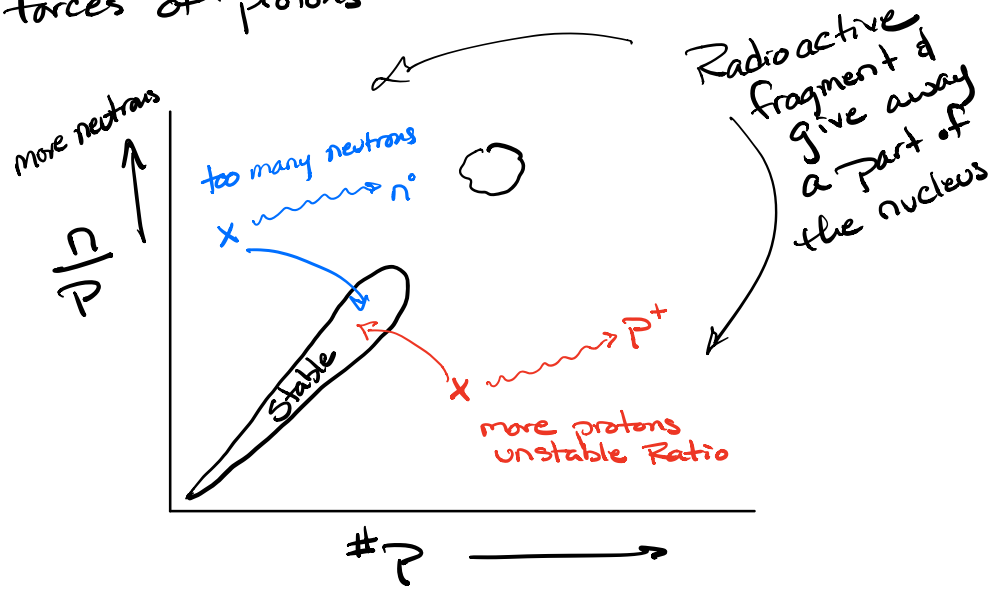


Conflict



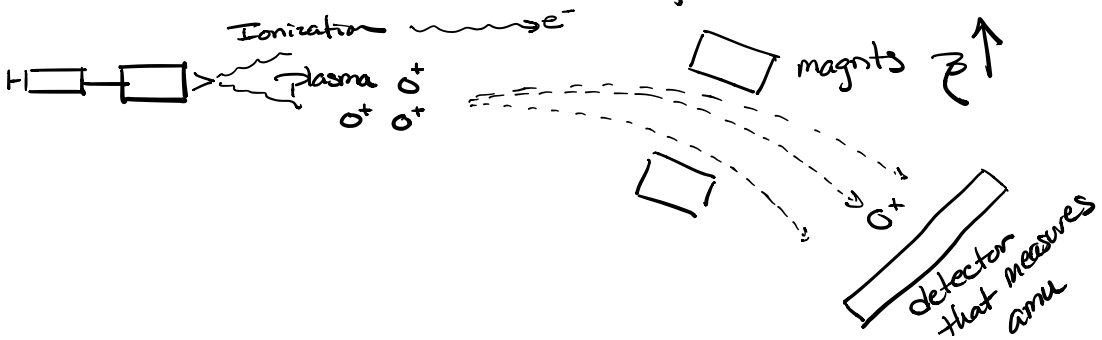
Repel very Strongly

Job of neutrons is to decrease the repulsive forces of protons



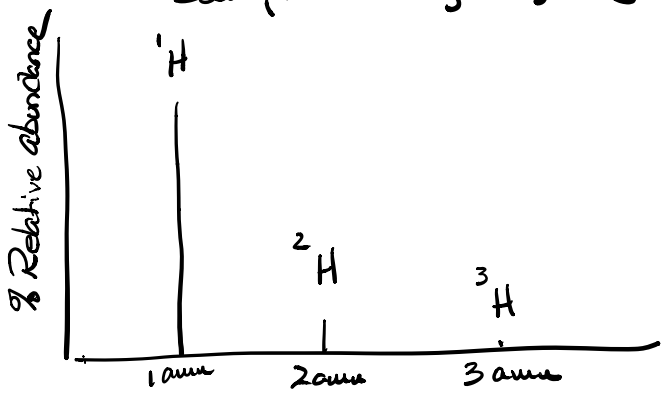
How do we measure Isotopes?

Instrument called mass Spectrometer



Mass Spec

Sample = hydrogen gas



^1H	99.9850 %	Hydrogen
^2H	0.0150 %	Deuterium
^3H	0.0000 %	Tritium

Pb

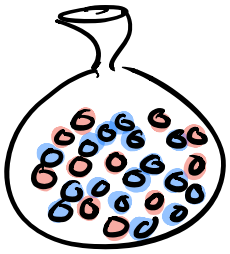
$^{204}_{82}Pb$	$^{206}_{82}Pb$	$^{207}_{82}Pb$	$^{208}_{82}Pb$
1.40%	24.1%	22.1%	52.4%
204 amu	206 amu	207 amu	208 amu

^{82}Pb

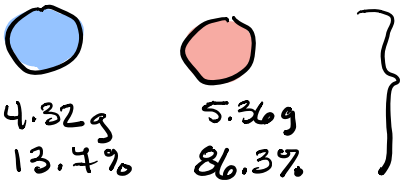
207.20 ← average amu for lead

Weighted Average

marble factory



← ~ 100 marbles / bag

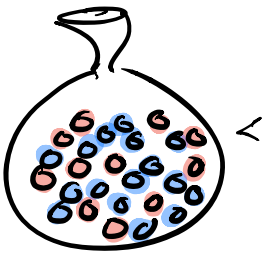


$$4.32\text{ g blue} \times \frac{13.7\text{ g blue}}{100\text{ g Ave}} = 0.59184\text{ g}$$

$$5.36\text{ g Red} \times \frac{86.3\text{ g Red}}{100\text{ g Ave}} = +\ 4.62568\text{ g}$$

$$5.21752\text{ g}$$

= 5.22 g Ave Marble mass



100 marbles

= 100 × 5.22g = 522g on Average

Ex Oxygen

	$^{16}_{8}O$	$^{17}_{8}O$	$^{18}_{8}O$
%	99.762%	0.0380%	0.200%
	15.995 amu	16.999 amu	17.999 amu

Calculate the average amu for oxygen

^{16}O $15.995\ \text{amu} \times \frac{99.762\ ^{16}O}{100\ \text{oxygen atoms}} = 15.9569319\ \text{amu}$

^{17}O $16.999\ \text{amu} \times \frac{0.0380\ ^{17}O}{100\ \text{oxygen atoms}} = 0.00645962\ \text{amu}$

^{18}O $17.999\ \text{amu} \times \frac{0.200\ \text{amu}\ ^{18}O}{100\ \text{oxygen atoms}} = 0.035998\ \text{amu}$

$+$

15.99938952

$= 15.999\ \text{amu}$ ✓ for an average oxygen atom

Periodic Table mass for Oxygen

$= 15.9994\,O$

$= 15.999\ \text{amu}$ ✓

1 1A																	18 8A
1 H Hydrogen 1.008	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.30	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.84	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.41	31 Ga Gallium 69.72	32 Ge Germanium 72.64	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
55 Cs Cesium 132.9	56 Ba Barium 137.3		72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.8	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)		104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (272)	112 Cn Copernicium (285)	113 Nh Nihonium (284)	114 Fl Flerovium (289)	115 Mc Moscovium (288)	116 Lv Livermorium (289)	117 Ts Tennessine	118 Og Oganesson
Lanthanides			57 La Lanthanum 138.9	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.2	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
Actinides			89 Ac Actinium (227)	90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

average mass of element = Weighted Average of the isotopes = amu per atom

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Values rounded to four significant figures

Chapter 2.4 ⇒ The Mole

The mole is a unit similar to a dozen

1 dozen = 12 things

1 dozen eggs = 12 eggs

1 dozen rocks = 12 rock

1 mole = 6.022×10^{23} things

1 mole eggs = 6.022×10^{23} eggs

Original definition:

1 mole = number of carbon atoms in 12g of ^{12}C isotope. = 6.022×10^{23} atoms

^{12}C $6p^+$
$6n^\circ$
12amu

New Definition mole = Exactly $6.02214076 \times 10^{23}$

Mole is call Avagodro's Number

Symbole of mole = N_A N_a Sodium

$6.022140\,76 \times 10^{23}$ exact

Memorize ⟹ 6.022×10^{23} 4 SF because rounded

Ex

How many eggs are in 3.72 dozen ?

$$3.72 \text{ dozen eggs} \times \frac{12 \text{ eggs}}{1 \text{ dozen eggs}} = 44.64 \text{ eggs}$$

(12 exact; 3.72 has 3 SF)

$= 44.6$ eggs

How Carbon atoms are in 3.72 moles of Carbon?

moles $\xrightarrow{6.022\times10^{23} = 1 \text{ mole}}$ Carbon atoms

$$3.72 \text{ mole Carbon} \times \frac{6.022\times10^{23} \text{ atoms Carbon}}{1 \text{ mole Carbon}} = 2.240184 \times 10^{24}$$

(3.72 has 3 SF; 6.022×10^{23} has 4 SF)

$= 2.24 \times 10^{24}$ Carbon atoms

1 mole things = 6.022×10^{23} things

1 mole atoms = 6.022×10^{23} atoms

1 mole molecules = 6.022×10^{23} molecules

1 mole Shoes = 6.022×10^{23} shoes

How many grams does exactly 1 mole of ^{12}Carbon Weigh?

1 mole $\xrightarrow{①}$ # atoms $\xrightarrow{②}$ # amu $\xrightarrow{③}$ grams

① 1 mole = 6.022×10^{23}

② 1 ^{12}C atom = 12 amu

③ 1 amu = 1.6606×10^{-24} g

$$1 \text{ mole } {}^{12}\text{C atoms} \times \frac{6.022 \times 10^{23} \text{ } {}^{12}\text{C atoms}}{1 \text{ mole } {}^{12}\text{C atoms}} \times \frac{12 \text{ amu}}{1 \text{ } {}^{12}\text{C atom}} \times \frac{1.6606 \times 10^{-24} \text{ g}}{1 \text{ amu}} =$$

(exact; ④; def; 5 SF)

12.000015984 g

= 12.00 g

mass# $p^+ + n^\circ$

$^{12}_{6}C$ = 12 amu / atom

12.00 g / 1 mole atoms

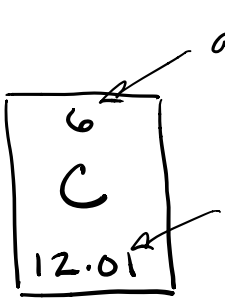
??? same ???

Linked by ^{12}C

Inverse

$$1 \text{ mole } {}^{12}C \text{ atoms} \times \frac{6.022 \times 10^{23} \ {}^{12}C \text{ atoms}}{1 \text{ mol } {}^{12}C \text{ atoms}} \times \frac{12 \text{ amu}}{1 \ {}^{12}C \text{ atom}} \times \frac{1.66606 \times 10^{-24} \text{ g}}{1 \text{ amu}} =$$

$$\frac{1}{6.022 \times 10^{23}} = 1.66606 \times 10^{-24}$$



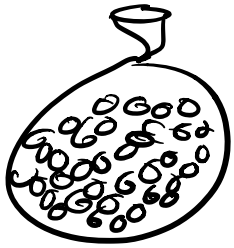
Both atomic mass in amu

amu / atom

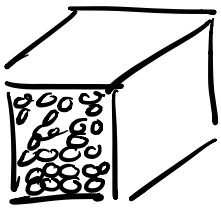
Molar Mass

g / mole atoms

g 6.022×10^{23} atoms weigh



Marble bag
Average weight of marble
Count marbles by weighing the bag.



Sample of Carbon
Weigh Sample 132.36 g
Average mass of Carbon 12.01 g/mole

"Count" Carbon atoms in Sample

Calculate

g Carbon ⟶ mole C ⟶ C atoms

$$132.36\,\text{g Carbon} \times \frac{1\ \text{mole Carbon}}{12.01\,\text{g Carbon}} \times \frac{6.022\times10^{23}\ \text{atoms Carbon}}{1\ \text{mole Carbon}} =$$

$$= 6.636735387\times10^{24}\ \text{Carbon atoms}$$

$$= 6.637\times10^{24}\ \text{Carbon atoms}$$