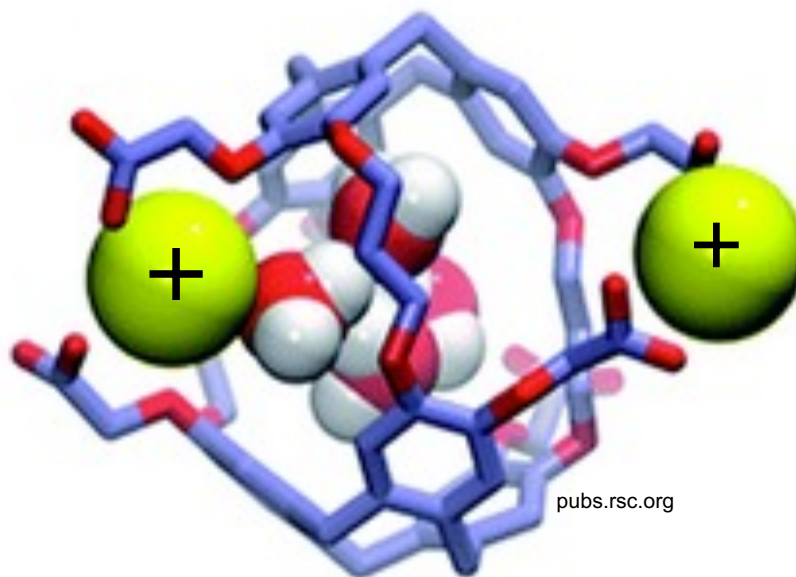


Chapter 2:

Atoms and the Periodic Table



Atomic Theory of Matter: Dalton (1808)²

1. All matter is composed of tiny particles called atoms
2. All atoms of a given element are identical, but atoms of different elements differ in size, mass, & chemical properties

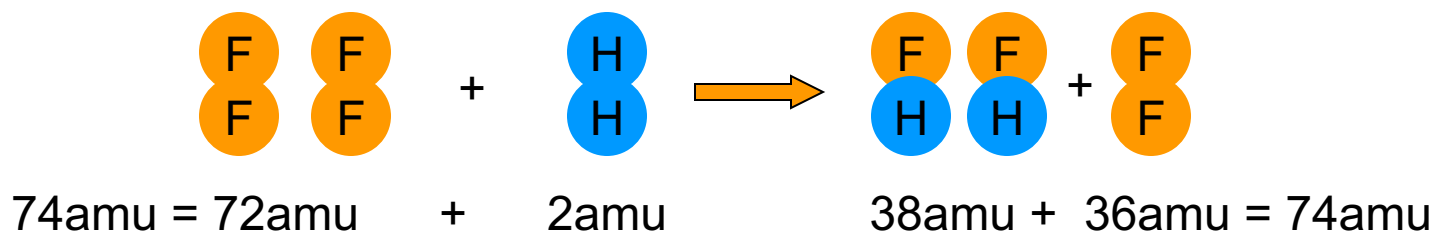


Fluorine atom: 18 amu



Hydrogen atom: 1 amu

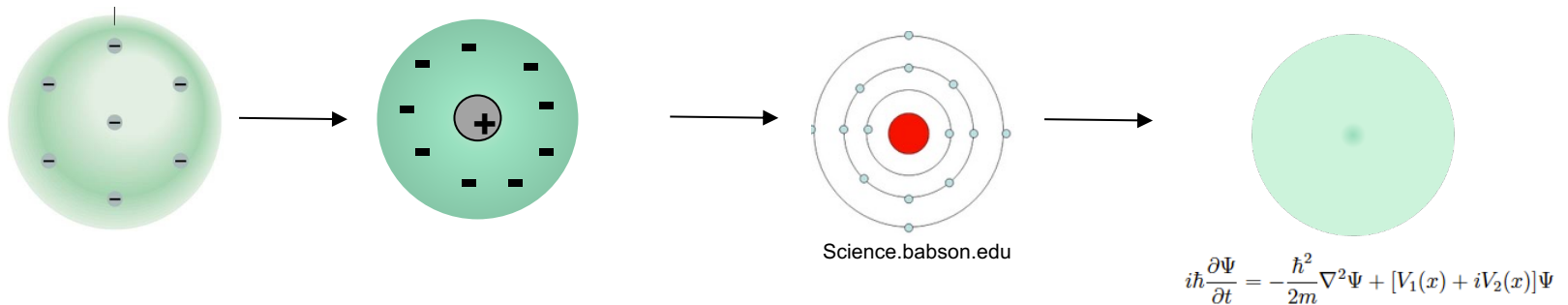
3. Compounds are formed when atoms of different elements combine in fixed proportions.



4. A chemical reaction involves atomic rearrangement.
No atoms are created or destroyed!!!

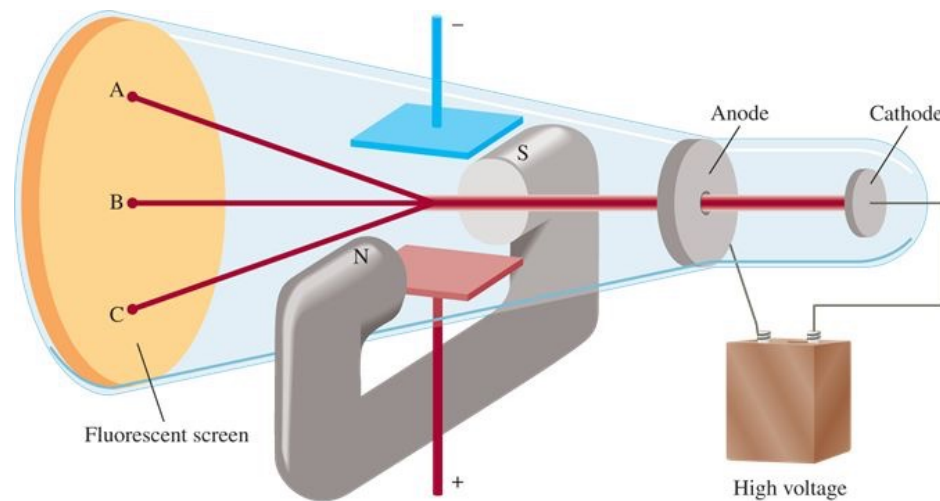
Structure of the Atom

What's on the inside?!?



The Electron and Cathode Rays (1890's)

Electricity causes ray to be deflected in a vacuum
Few molecules: minimal molecular interference
Applied magnetic field or electric field deflects ray



Ray is attracted to positively (+) charged anode, so it must be made of negatively (-) charged particles
Atom not smallest piece of matter – had charged “things” inside!

Millikan Oil Drop Experiment

Determination of charge and mass of electron

JJ Thompson:

Ratio of cathode ray particle's charge to mass

$$= -1.76 \times 10^8 \text{ C/g}$$

Negatively charged particle is called an **electron**

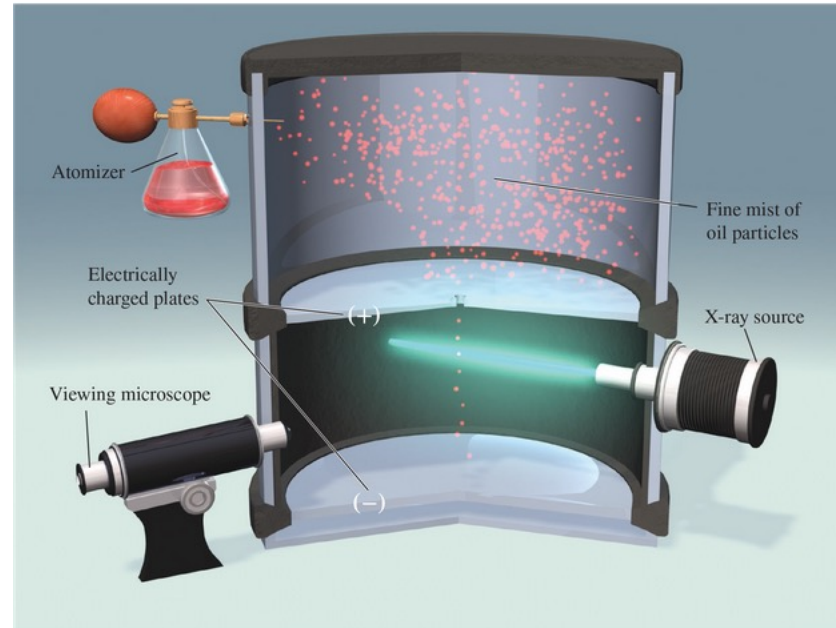
Robert Millikan

Charge on an electron:

$$e = -1.602 \times 10^{-19} \text{ C}$$

Mass of an electron:

$$m_e = 9.10 \times 10^{-28} \text{ g}$$



Amount of electricity needed to suspend particle = charge on particle

Discovery of The Nucleus

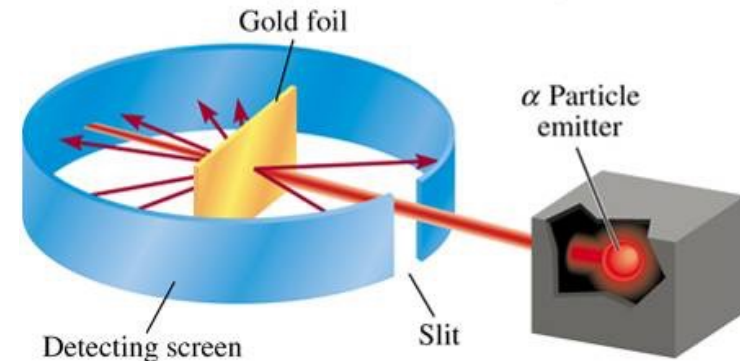


J. J. Thomson's Plum Pudding Model

- Positively charged sphere with electrons imbedded inside
- Like a Ball of Chocolate Chip Cookie Dough

Rutherford's Experiments

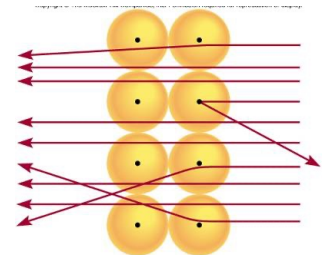
- Shot α particles through gold foil



Results:

- Most hit detector w/ no interference (empty space!)
- Some deflected from straight line: Charge interference
- A few reflected back toward emitter
 - Hit something small & positive in center

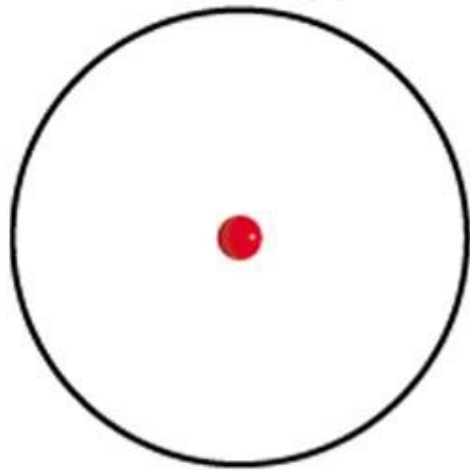
Nucleus!



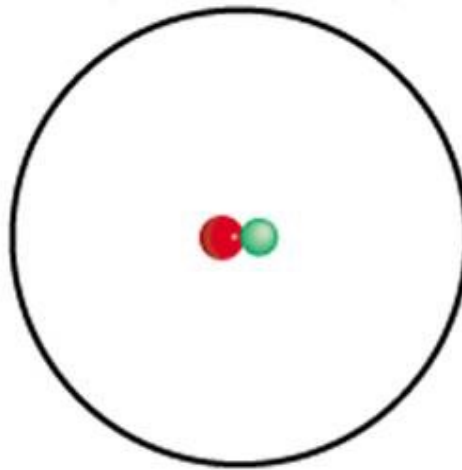
Neutrons

Subatomic particle with same mass as proton

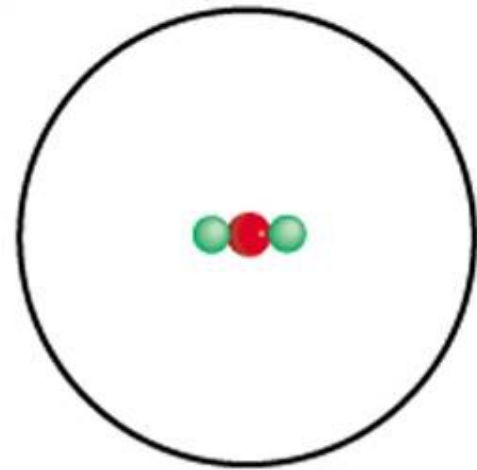
- Discovered by James Chadwick
- Located in nucleus
- No charge – accounts for extra mass of isotopes
- Change in mass, no change in chemical properties
- Needed for stability of nucleus – larger nuclei need more neutrons



Hydrogen



Deuterium



Tritium

The Atom and Sub-Atomic Particles

✚ Protons ✚

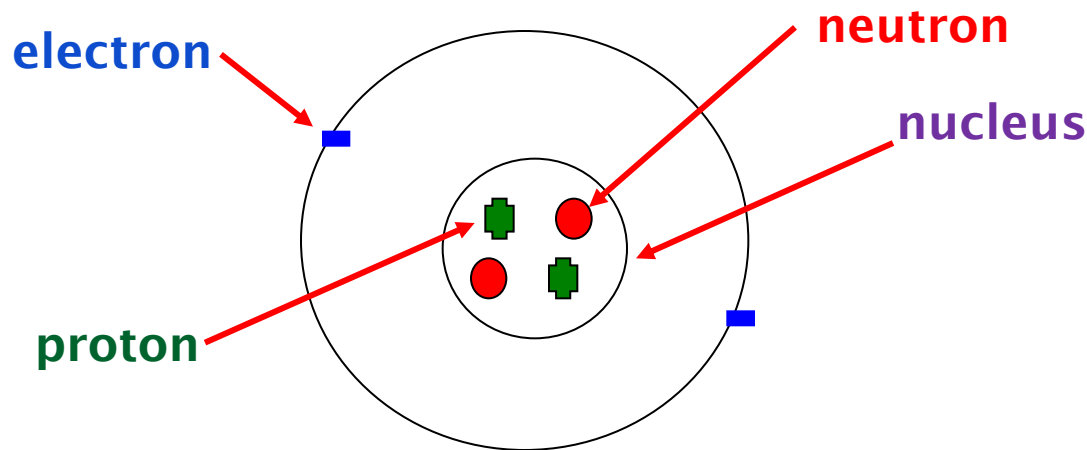
large, positively charged particles in small central nucleus

- Electrons -

tiny, negatively charged particles in cloud around nucleus

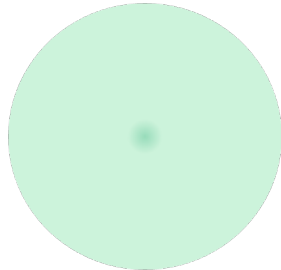
● Neutrons ●

large, neutral particles in nucleus



- Elements are not electrically charged
- Must have equal numbers of protons & electrons

Modern View of the Atom



$$i\hbar \frac{\partial \Psi}{\partial t} = -\frac{\hbar^2}{2m} \nabla^2 \Psi + [V_1(x) + iV_2(x)] \Psi$$

- Protons (p⁺) & Neutrons (n⁰) in nucleus
- Electrons (e⁻) in “cloud” around nucleus
 - Exist in mathematically defined energy levels
 - Highest energy level – electrons can travel furthest away from nucleus
 - Electrons in highest energy level are called valence electrons
 - Chemical reactions and bonding most often involve valence electrons.
 - Max number of valence electrons is 8 (an octet)
 - 8 valence electrons is stable (don't want to react)

Atomic Symbols

Atomic Number (Z)

protons in a nucleus

Determines element identity

Located lower left on symbol

- can also be used to
determine # electrons in
uncharged atom

Mass Number (A)

protons + # neutrons

Determines isotope identity

Located upper left on symbol

- use to determine # neutrons!

General Form



Actual Element

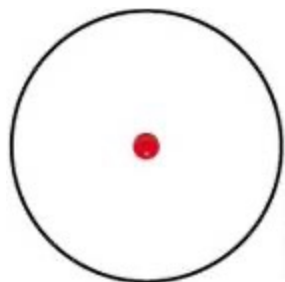


Isotopes

Elements with the same number of protons and electrons, but differing number of neutrons

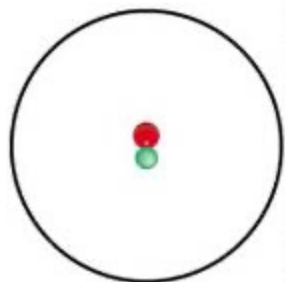
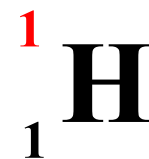
Used in chemistry for structure identification or to follow a particular molecule through a reaction

Example: hydrogen and deuterium



Water, H₂O

H has 1 proton and 0 neutrons
Most abundant



Heavy water, D₂O

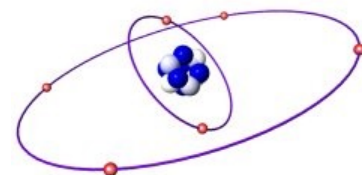
D (deuterium) has 1 proton & 1 neutron
Occurs 1/6700 molecules



Average Atomic Mass

Atomic Mass: Mass of an atom in atomic mass units

1 amu = 1/12 of the mass of 1 C-12 atom
 → The mass of a ^{12}C atom = 12 amu
 = 1.661×10^{-24} g
 = mass 1 proton or 1 neutron

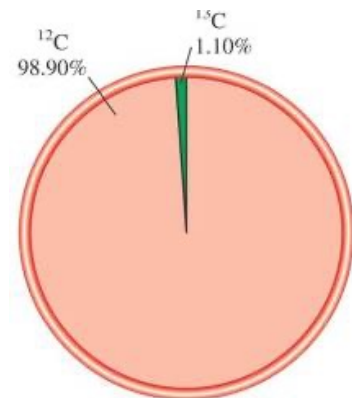


Naturally occurring carbon is a mixture of isotopes

$^{12}_6\text{C}$ 98.90% 6 protons 6 neutrons 12.000 amu

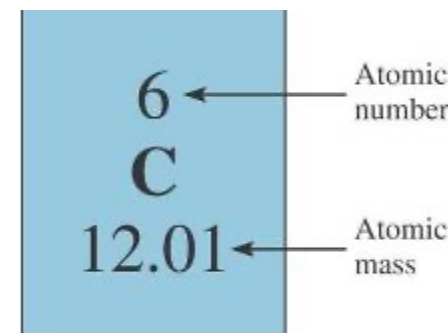
$^{13}_6\text{C}$ 1.100% 6 protons 7 neutrons 13.003 amu

$^{14}_6\text{C}$ $\sim 10^{-12}$ 6 protons 8 neutrons 14.003 amu
 (C-14 is unstable)



Atomic mass of naturally occurring carbon:

$(0.9890 \times 12.000 \text{ amu}) + (0.0110 \times 13.003 \text{ amu})$
 = Atomic Mass of C = 12.01 amu



Average Atomic Mass

Calculate the average atomic mass of lead if the isotopes of lead have the following masses and percentages:

^{204}Pb : 203.97043amu, 1.4%

^{206}Pb : 205.947465amu, 24.1%

^{207}Pb : 206.975897amu, 22.1%

^{208}Pb : 207.976652amu, 52.4%

Los Alamos National Laboratory Chemistry Division

Periodic Table of the Elements

1A 1 H hydrogen 1.008	2A 4 Be beryllium 9.012	3B 11 Na sodium 22.99	4B 20 Ca calcium 40.08	5B 22 Ti titanium 47.88	6B 23 V vanadium 50.94	7B 24 Cr chromium 52.00	8B 25 Mn manganese 54.94	8B 26 Fe iron 55.85	8B 27 Co cobalt 58.93	8B 28 Ni nickel 58.69	11B 29 Cu copper 63.55	12B 30 Zn zinc 65.39	13A 5 B boron 10.81	14A 6 C carbon 12.01	15A 7 N nitrogen 14.01	16A 8 O oxygen 16.00	17A 9 F fluorine 19.00	8A 2 He helium 4.003	10 Ne neon 20.18	18 Ar argon 39.95	36 Kr krypton 83.79	54 Xe xenon 131.3	86 Rn radon (222)																																																																																																																																																																																																																																																																																																																																																																																																																																																														
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 95.96	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	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	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.9	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 200.5	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 Ru ruthenium (261)	105 Rh rhodium (268)	106 Pd palladium (271)	107 Ag silver (278)	108 Cd cadmium (277)	109 In indium (284)	110 Sn tin (283)	111 Sb antimony (280)	112 Te tellurium (285)	113 I iodine (284)	114 Xe xenon (289)	115 Po polonium (288)	116 At astatine (293)	117 Rn radon (294)	118 Uuo ununoctium (294)	119 Uuh ununium (295)	120 Uuq ununium (296)	121 Uub ununium (297)	122 Uut ununium (298)	123 Uuq ununium (299)	124 Uub ununium (301)	125 Uut ununium (302)	126 Uuq ununium (304)	127 Uub ununium (306)	128 Uut ununium (307)	129 Uuq ununium (309)	130 Uub ununium (310)	131 Uut ununium (312)	132 Uuq ununium (315)	133 Uub ununium (318)	134 Uut ununium (319)	135 Uuq ununium (321)	136 Uub ununium (323)	137 Uut ununium (325)	138 Uuq ununium (327)	139 Uub ununium (329)	140 Uut ununium (331)	141 Uuq ununium (333)	142 Uub ununium (335)	143 Uut ununium (337)	144 Uuq ununium (339)	145 Uub ununium (341)	146 Uut ununium (343)	147 Uuq ununium (345)	148 Uub ununium (347)	149 Uut ununium (349)	150 Uuq ununium (351)	151 Uub ununium (353)	152 Uut ununium (355)	153 Uuq ununium (357)	154 Uub ununium (359)	155 Uut ununium (361)	156 Uuq ununium (363)	157 Uub ununium (365)	158 Uut ununium (367)	159 Uuq ununium (369)	160 Uub ununium (371)	161 Uut ununium (373)	162 Uuq ununium (375)	163 Uub ununium (377)	164 Uut ununium (379)	165 Uuq ununium (381)	166 Uub ununium (383)	167 Uut ununium (385)	168 Uuq ununium (387)	169 Uub ununium (389)	170 Uut ununium (391)	171 Uuq ununium (393)	172 Uub ununium (395)	173 Uut ununium (397)	174 Uuq ununium (399)	175 Uub ununium (401)	176 Uut ununium (403)	177 Uuq ununium (405)	178 Uub ununium (407)	179 Uut ununium (409)	180 Uuq ununium (411)	181 Uub ununium (413)	182 Uut ununium (415)	183 Uuq ununium (417)	184 Uub ununium (419)	185 Uut ununium (421)	186 Uuq ununium (423)	187 Uub ununium (425)	188 Uut ununium (427)	189 Uuq ununium (429)	190 Uub ununium (431)	191 Uut ununium (433)	192 Uuq ununium (435)	193 Uub ununium (437)	194 Uut ununium (439)	195 Uuq ununium (441)	196 Uub ununium (443)	197 Uut ununium (445)	198 Uuq ununium (447)	199 Uub ununium (449)	200 Uut ununium (451)	201 Uuq ununium (453)	202 Uub ununium (455)	203 Uut ununium (457)	204 Uuq ununium (459)	205 Uub ununium (461)	206 Uut ununium (463)	207 Uuq ununium (465)	208 Uub ununium (467)	209 Uut ununium (469)	210 Uuq ununium (471)	211 Uub ununium (473)	212 Uut ununium (475)	213 Uuq ununium (477)	214 Uub ununium (479)	215 Uut ununium (481)	216 Uuq ununium (483)	217 Uub ununium (485)	218 Uut ununium (487)	219 Uuq ununium (489)	220 Uub ununium (491)	221 Uut ununium (493)	222 Uuq ununium (495)	223 Uub ununium (497)	224 Uut ununium (499)	225 Uuq ununium (501)	226 Uub ununium (503)	227 Uut ununium (505)	228 Uuq ununium (507)	229 Uub ununium (509)	230 Uut ununium (511)	231 Uuq ununium (513)	232 Uub ununium (515)	233 Uut ununium (517)	234 Uuq ununium (519)	235 Uub ununium (521)	236 Uut ununium (523)	237 Uuq ununium (525)	238 Uub ununium 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(799)	375 Uuq ununium (801)	376 Uub ununium (803)	377 Uut ununium (805)	378 Uuq ununium (807)	379 Uub ununium (809)	380 Uut ununium (811)	381 Uuq ununium (813)	382 Uub ununium (815)	383 Uut ununium (817)	384 Uuq ununium (819)	385 Uub ununium (821)	386 Uut ununium (823)	387 Uuq ununium (825)	388 Uub ununium (827)	389 Uut ununium (829)	390 Uuq ununium (831)	391 Uub ununium (833)	392 Uut ununium (835)	393 Uuq ununium (837)	394 Uub ununium (839)	395 Uut ununium (841)	396 Uuq ununium (843)	397 Uub ununium (845)	398 Uut ununium (847)	399 Uuq ununium (849)	400 Uub ununium (851)	401 Uut ununium (853)	402 Uuq ununium (855)	403 Uub ununium (857)	404 Uut ununium (859)	405 Uuq ununium (861)	406 Uub ununium (863)	407 Uut ununium (865)	408 Uuq ununium (867)	409 Uub ununium (869)	410 Uut ununium (871)	411 Uuq ununium (873)	412 Uub ununium (875)	413 Uut ununium (877)	414 Uuq ununium (879)	415 Uub ununium (881)	416 Uut ununium (883)	417 Uuq ununium (885)	418 Uub ununium (887)	419 Uut ununium (889)	420 Uuq ununium (891)	421 Uub ununium (893)	422 Uut ununium (895)	423 Uuq ununium (897)	424 Uub ununium (899)	425 Uut ununium (901)	426 Uuq ununium (903)	427 Uub ununium (905)	428 Uut ununium (907)	429 Uuq ununium (909)	430 Uub ununium (911)	431 Uut ununium (913)	432 Uuq ununium (915)	433 Uub ununium (917)	434 Uut ununium (919)	435 Uuq ununium (921)	436 Uub ununium (923)	437 Uut ununium (925)	438 Uuq ununium (927)	439 Uub ununium (929)	440 Uut ununium (931)	441 Uuq ununium (933)	442 Uub ununium (935)	443 Uut ununium (937)	444 Uuq ununium (939)	445 Uub ununium (941)	446 Uut ununium (943)	447 Uuq ununium (945)	448 Uub ununium (947)	449 Uut ununium (949)	450 Uuq ununium (951)	451 Uub ununium (953)	452 Uut ununium (955)	453 Uuq ununium (957)	454 Uub ununium (959)	455 Uut ununium (961)	456 Uuq ununium (963)	457 Uub ununium (965)	458 Uut ununium (967)	459 Uuq ununium (969)	460 Uub ununium (971)	461 Uut ununium (973)	462 Uuq ununium (975)	463 Uub ununium (977)	464 Uut ununium (979)	465 Uuq ununium (981)	466 Uub ununium (983)	467 Uut ununium (985)	468 Uuq ununium (987)	469 Uub ununium (989)	470 Uut ununium (991)	471 Uuq ununium (993)	472 Uub ununium (995)	473 Uut ununium (997)	474 Uuq ununium (999)	475 Uub ununium (1001)	476 Uut ununium (1003)	477 Uuq ununium (1005)	478 Uub ununium (1007)	479 Uut ununium (1009)	480 Uuq ununium (1011)	481 Uub ununium (1013)	482 Uut ununium (1015)	483 Uuq ununium (1017)	484 Uub ununium (1019)	485 Uut ununium (1021)	486 Uuq ununium (1023)	487 Uub ununium (1025)	488 Uut ununium (1027)	489 Uuq ununium (1029)	490 Uub ununium (1031)	491 Uut ununium (1033)	492 Uuq ununium (1035)	493 Uub ununium (1037)	494 Uut ununium (1039)	495 Uuq ununium (1041)	496 Uub ununium (1043)	497 Uut ununium (1045)	498 Uuq ununium (1047)	499 Uub ununium (1049)	500 Uut ununium (1051)	501 Uuq ununium (1053)	502 Uub ununium (1055)	503 Uut ununium (1057)	504 Uuq ununium (1059)	505 Uub ununium (1061)	506 Uut ununium (1063)	507 Uuq ununium (1065)	508 Uub ununium (1067)	509 Uut ununium (1069)	510 Uuq ununium (1071)	511 Uub ununium (1073)	512 Uut ununium (1075)	513 Uuq ununium (1077)	514 Uub ununium (1079)	515 Uut ununium (1081)	516 Uuq ununium (1083)	517 Uub ununium (1085)	518 Uut ununium (1087)	519 Uuq ununium (1089)	520 Uub ununium (1091)	521 Uut ununium (1093)	522 Uuq ununium (1095)	523 Uub ununium (1097)	524 Uut ununium (1099)	525 Uuq ununium (1101)	526 Uub ununium (1103)	527 Uut ununium (1105)	528 Uuq ununium (1107)	529 Uub ununium (1109)	530 Uut ununium (1111)	531 Uuq ununium (1113)	532 Uub ununium (1115)	533 Uut ununium (1117)	534 Uuq ununium (1119)	535 Uub ununium (1121)	536 Uut ununium (1123)	537 Uuq ununium (1125)	538 Uub ununium (1127)	539 Uut ununium (1129)	540 Uuq ununium (1131)	541 Uub ununium (1133)	542 Uut ununium (1135)	543 Uuq ununium (1137)	544 Uub ununium (1139)	545 Uut ununium (1141)	546 Uuq ununium (1143)	547 Uub ununium (1145)	548 Uut ununium (1147)	549 Uuq ununium (1149)	550 Uub ununium (1151)	551 Uut ununium (1153)	552 Uuq ununium (1155)	553 Uub ununium (1157)	554 Uut ununium (1159)	555 Uuq ununium (1161)	556 Uub ununium (1163)	557 Uut ununium (1165)	558 Uuq ununium (1167)	559 Uub ununium (1169)	560 Uut ununium (1171)	561 Uuq ununium (1173)	562 Uub ununium (1175)	563 Uut ununium (1177)	564 Uuq ununium (1179)	565 Uub ununium (1181)	566 Uut ununium (1183)	567 Uuq ununium (1185)	568 Uub ununium (1187)	569 Uut ununium (1189)	570 Uuq unun

The Modern Periodic Table

Arranged by Atomic Number

Arranged by Atomic Number																		18 8A
1 1A H	2 2A He											13 3A B	14 4A C	15 5A N	16 6A O	17 7A F	18 8A Ne	
3 Li	4 Be											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
11 Na	12 Mg	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr	
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe	
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn	
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112	(113)	114	(115)	116	(117)	(118)	

	Metals
	Metalloids
	Nonmetals

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
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Green	Metals	Ductile, malleable, conductive, positive ionic charge
Blue	Nonmetals	Brittle solids, often gases or liquids, negative charge
Pink	Metalloids	Properties of both metals and nonmetals

Columns are called **groups** or **families** – contain elements with similar characteristics

Rows are also called **periods** –

Reference: R.D. Vocke, Jr., *Atomic Weights of the Elements*, **1997**, National Institute of Standards and Technology. Parentheses () indicate the mass number of the most stable isotope.

Some Groups in the Periodic Table

Alkali Metals

- Group 1A
- +1 charge
- Highly reactive



Alkali Earth Metals

- Group 2A
- +2 charge
- Reactive



Halogens

- Group 7A
- -1 charge
- Highly reactive if single atoms
- Diatomic molecules



Periodic Table of the Elements

Legend:

- Alkali metals
- Alkaline earth metals
- Lanthanides
- Actinides
- Transition metals
- Unknown properties
- Post-transition metals
- Metalloids
- Other nonmetals
- Halogens
- Noble gases

SOURCES: National Institute of Standards and Technology, International Union of Pure and Applied Chemistry

Metalloids

- Some characteristics of metals, some of nonmetals
- semiconductors



Silicon (Si)

Transition metals

- Center of table
- Varying (+) charge
- Use Roman numerals



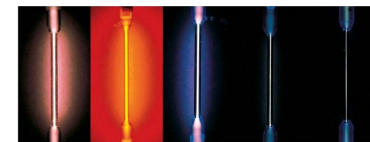
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Lanthanides & Actinides

- Bottom of table
- Very reactive
- + charge
- Often radioactive

Noble Gases

- Group 8A
- + charge (if charged)
- Inert (least reactive)



Elements you should be familiar with by the end of this course:

(Name & Symbol)

First 4 rows of periodic table

Including 1st row of transition metals

Additional elements

Ag: Silver Pb: Lead

I: Iodine Hg: Mercury

(A Periodic Table with both names & symbols will be provided in this class, but you may be expected to know these in future chemistry courses.)



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1 IA																	18 VIIIA
1 H Hydrogen 1.00794	2 He Helium 4.00260																
3 Li Lithium 6.941	4 Be Beryllium 9.01218	5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984	10 Ne Neon 20.180										
11 Na Sodium 22.9898	12 Mg Magnesium 24.305	13 Al Aluminum 26.9815	14 Si Silicon 28.0855	15 P Phosphorus 30.9738	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948										
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.9559	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.9059	40 Zr Zirconium 91.224	41 Nb Niobium 92.9064	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.60	53 I Iodine 126.904	54 Xe Xenon 131.29
55 Cs Cesium 132.905	56 Ba Barium 137.33	57* La Lanthanum 138.906	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.078	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89** Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (264)	108 Hs Hassium (265)	109 Mt Meitnerium (268)									



21
Sc
Scandium
44.9559

Atomic Number
Element Symbol
Atomic Weight

Reference: R.D. Vocke, Jr., *Atomic Weights of the Elements*, 1997, National Institute of Standards and Technology.
Parentheses () indicate the mass number of the most stable isotope.

* Lanthanide Series

58* Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.97
90** Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	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)

** Actinide Series

The Mole – like a dozen but a lot more!

20

Mole

of atoms in 12.00g of C-12

Avogadro's number (N_a)

- # particles in 1 mole
- $N_a = 6.022 \times 10^{23}$ particles/mol
- Determined experimentally – so does impact sig figs!

Similar to the word "dozen"

- Makes numbers more manageable



1 Mole of each substance

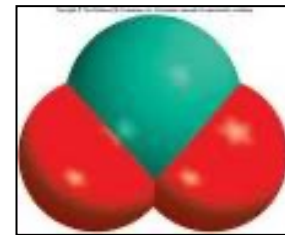
For most chemicals, a mole is an amount that can be measured in a lab (using a balance, etc.)
(Atoms are too small to measure on a balance)

$$\text{C-12: } \frac{12.00\text{g}}{1\text{mole}} \times \frac{1\text{mole}}{6.022 \times 10^{23} \text{ atoms}} = 1.993 \times 10^{-23} \text{ g / 1 atom}$$

Molar Mass

The mass of one mole of a substance

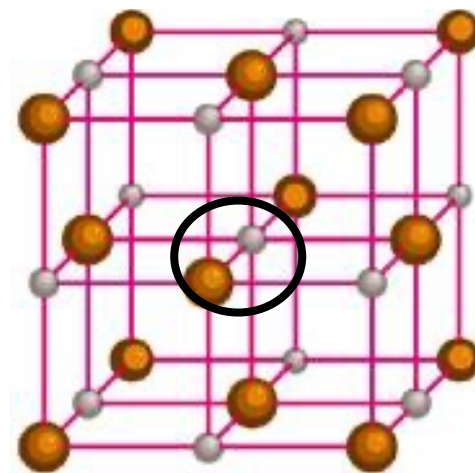
- Equal to AMU, but in units of g/mol



SO₂ - molecule

To calculate for a compound:

- Find atomic mass of each element
→ located on Periodic table (often below symbol)
- Multiply atomic mass of element by subscript, then add all elements together.
- Molecular mass: mass of molecule
→ include every atom
- Formula mass: mass of ions in a salt
→ use smallest ratio



NaCl – ionic compound

Examples:

$$1 \text{ mol Na} = 22.99 \text{ g/mol}$$

$$1 \text{ mol SO}_2 = 64.07 \text{ g/mol}$$

$$1 \text{ mole NaCl} = 58.44 \text{ g/mol}$$

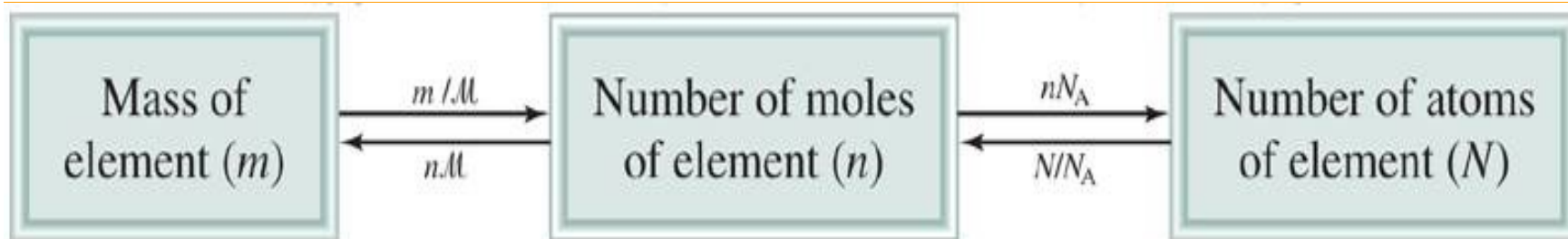
Mole-based Calculations

(Mass/Mole/Particle Conversions)

Molar Mass (M): grams/mol – from Periodic Table!

Avogadro's Number N_a : 6.022×10^{23} particles/mol

$$10.0 \text{ g}_C \times \frac{1 \text{ mol}_C}{12.0 \text{ g}_C} = 0.833 \text{ mol}_C \times \frac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol}_C} = 5.01 \times 10^{23} \text{ atoms}$$



$$10.0 \text{ g}_C = \frac{12.0 \text{ g}_C}{1 \text{ mol}_C} \times 0.833 \text{ mol}_C = \frac{1 \text{ mol}_C}{6.02 \times 10^{23} \text{ atoms}} \times 5.01 \times 10^{23} \text{ atoms}$$

moles $\rightarrow$ mass

What is the mass, in grams, of 0.287 mol Na? (6.60 g)

mass $\rightarrow$ # moles

How many moles are there in 38.65 g of Ag? (0.3583 mol)

moles $\rightarrow$ # particles

How many atoms are in 2.6 moles of Sulfur? (1.6×10^{24} atoms)

particles $\rightarrow$ # moles ($\rightarrow$ grams!)

If you have 2.5×10^{22} atoms of gold, how many moles do you have?

How many grams do you have? (0.042mol, 8.2g)

grams $\rightarrow$ # particles

If you have 78.56 g of copper, how many atoms do you have?

(1.236mol, 7.445×10^{23} atoms)