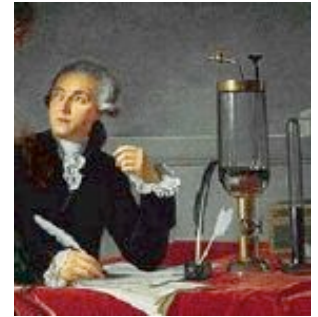


AP Chemistry

Zumdahl Ch 2

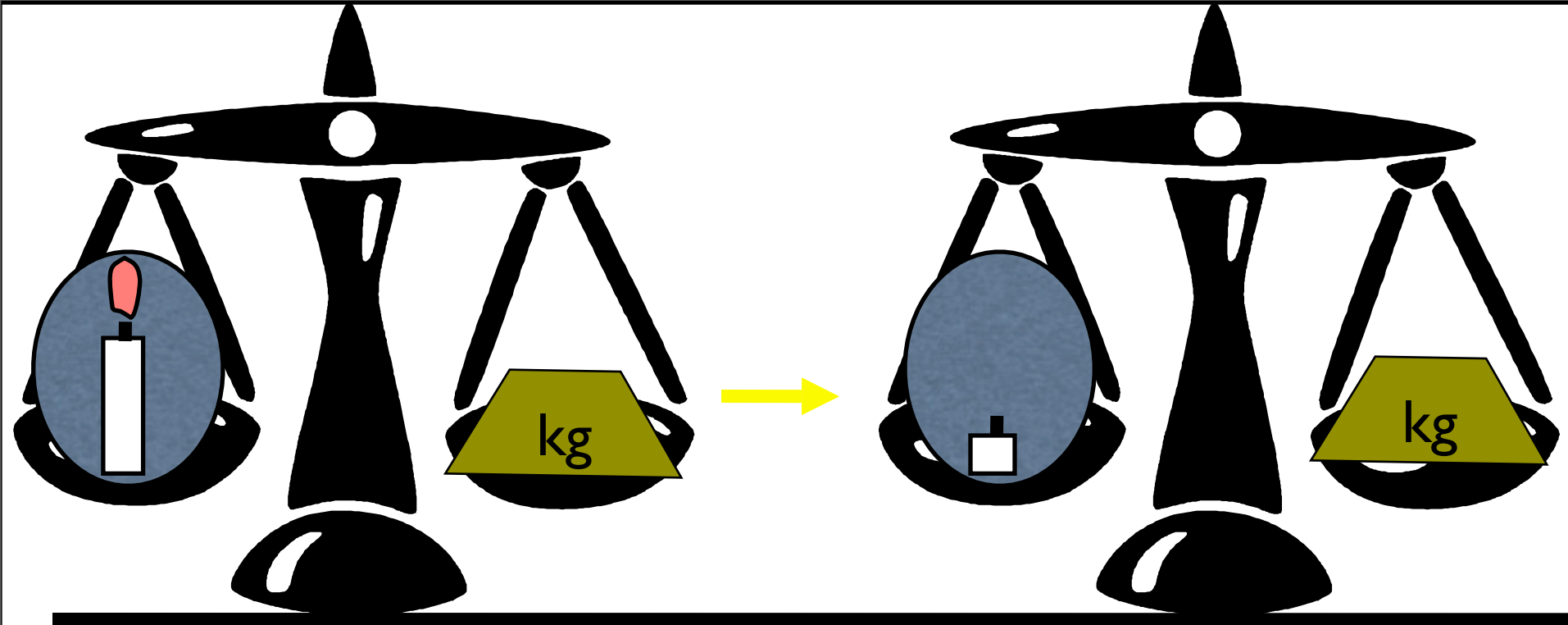
Atoms, Molecules, and Ions

Law of Conservation of Mass

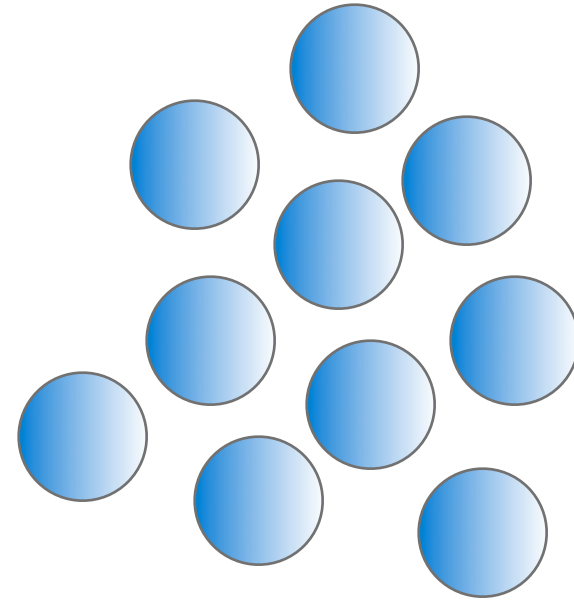
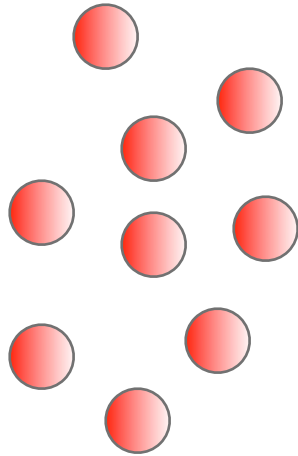


- ✓ Discovered by Antoine Lavoisier late 1700's.
- ✓ Mass is neither created nor destroyed

Law of Conservation of Mass (cont)



Dalton's Atomic Theory (1808)



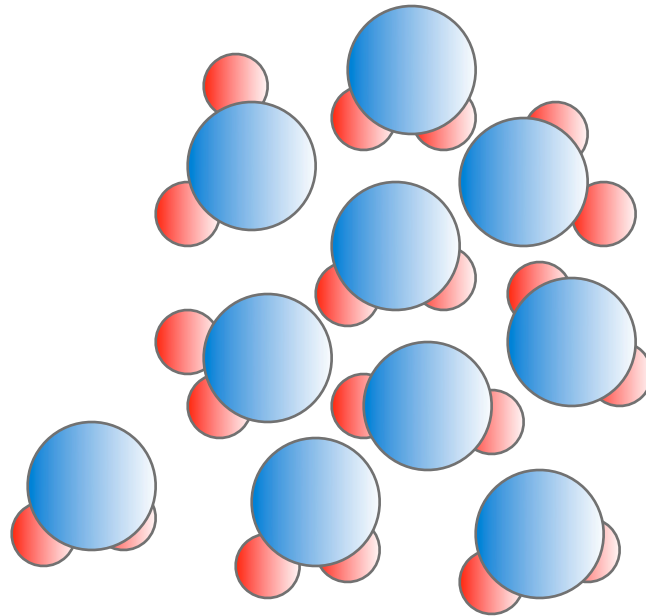
Atoms of Element X

Atoms of Element Y

- ① Each element is made up of tiny particles called atoms.
- ② The atoms of a given element are identical; the atoms of different elements are different in some fundamental way or ways.

Dalton's Atomic Theory

(continued)

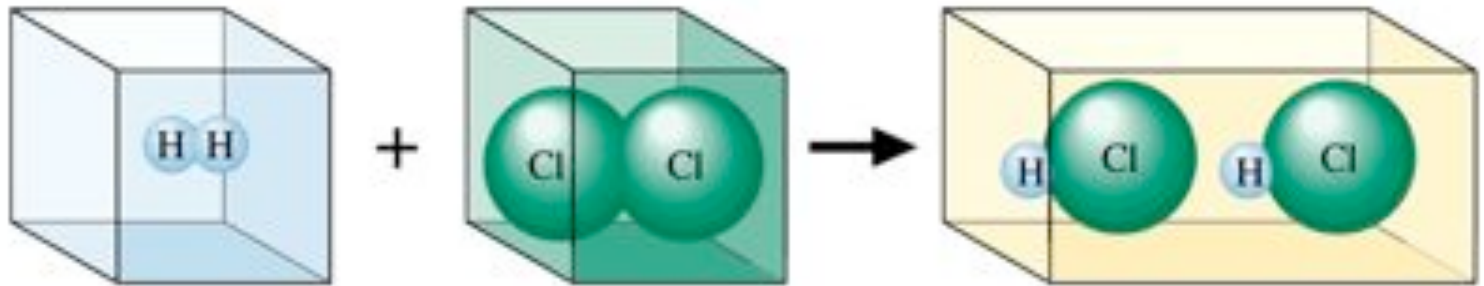
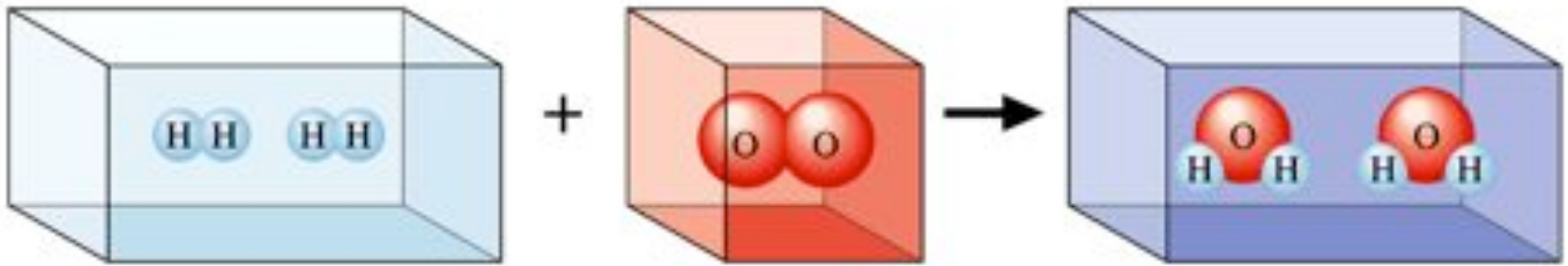


Compound of Elements **X** and **Y**

- ③ Chemical compounds are formed when atoms combine with each other. A given compound always has the same relative numbers and types of atoms.

Dalton's Atomic Theory

(continued)



- 4 Chemical reactions involve reorganization of the atoms - changes in the way they are bound together. The atoms themselves are not changed in a chemical reaction.

Avogadro's Hypothesis

At the same temperature and pressure, equal volumes of different **gases** contain the same number of particles.

- 5 liters of Argon
- 5 liters of Xenon
- Same number of particles!

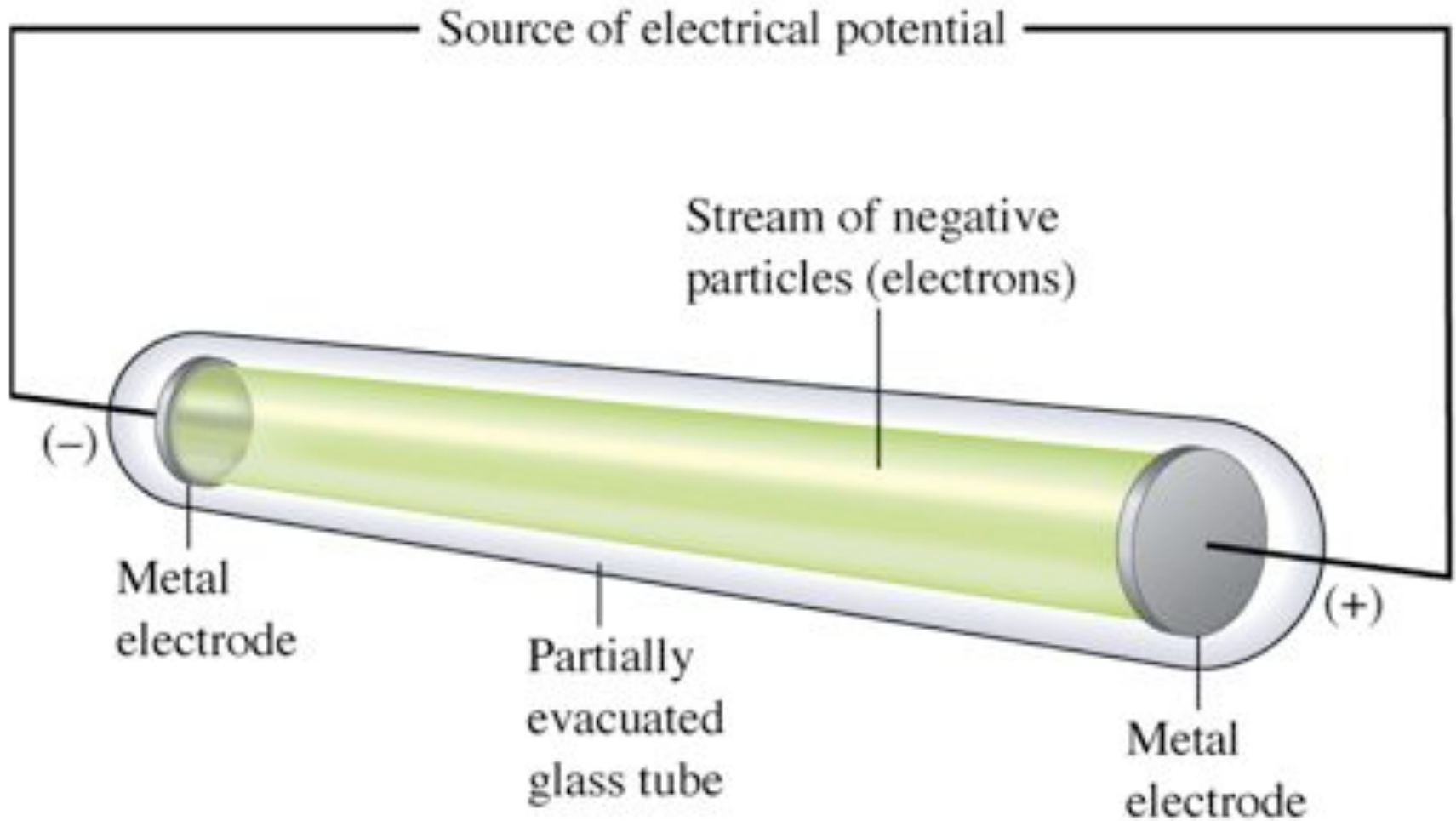
Say the 5 L of Xenon has a mass 3.3x that of the Ar. What might that tell you about the mass of individual Ar atoms vs. Xe atoms?

Early Experiments to Characterize the Atom

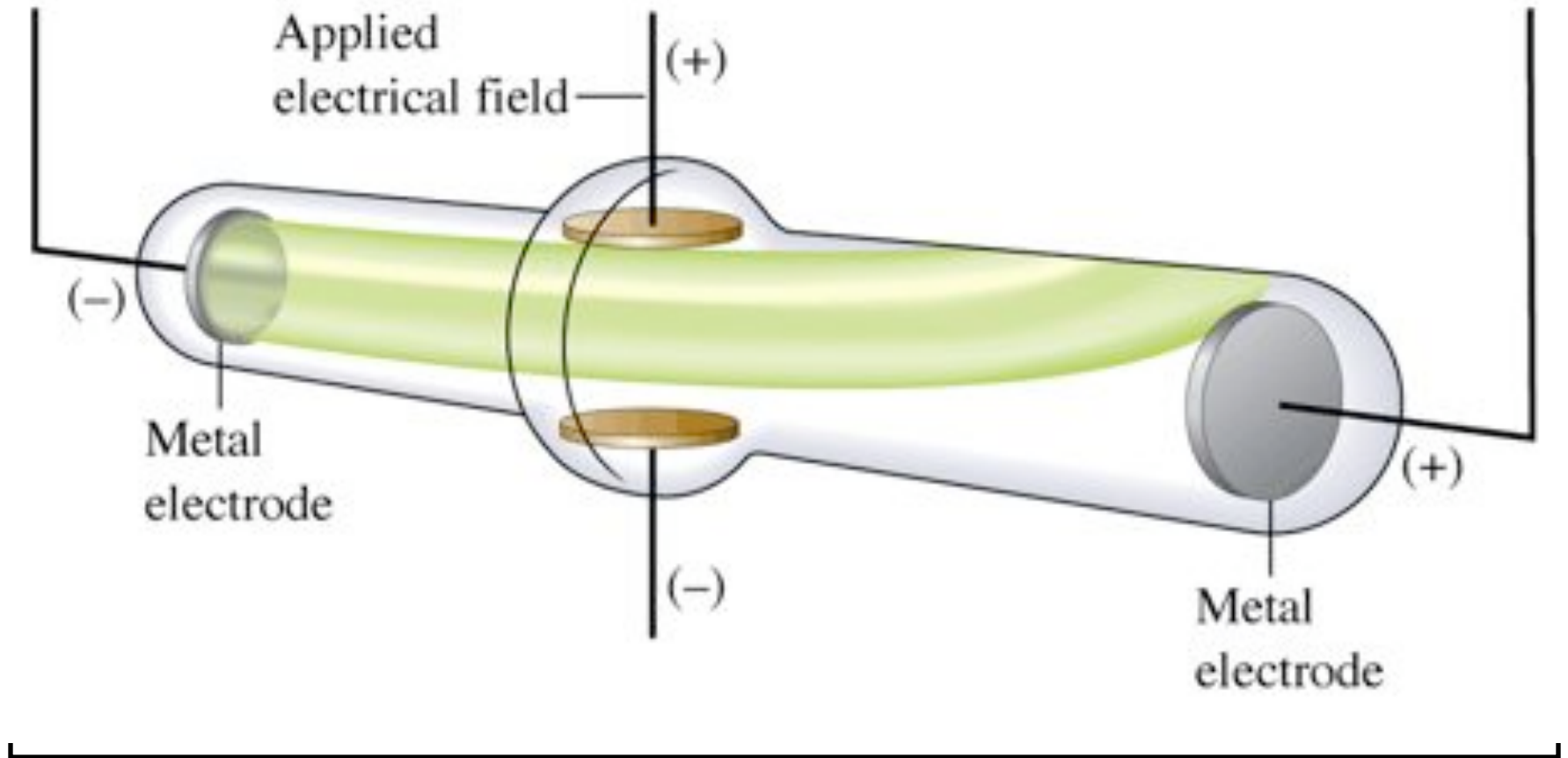
- ★ J. J. Thomson - postulated the existence of electrons, the first sub-atomic particles, using cathode ray tubes.



J.J. Thomson's Cathode Ray Expt

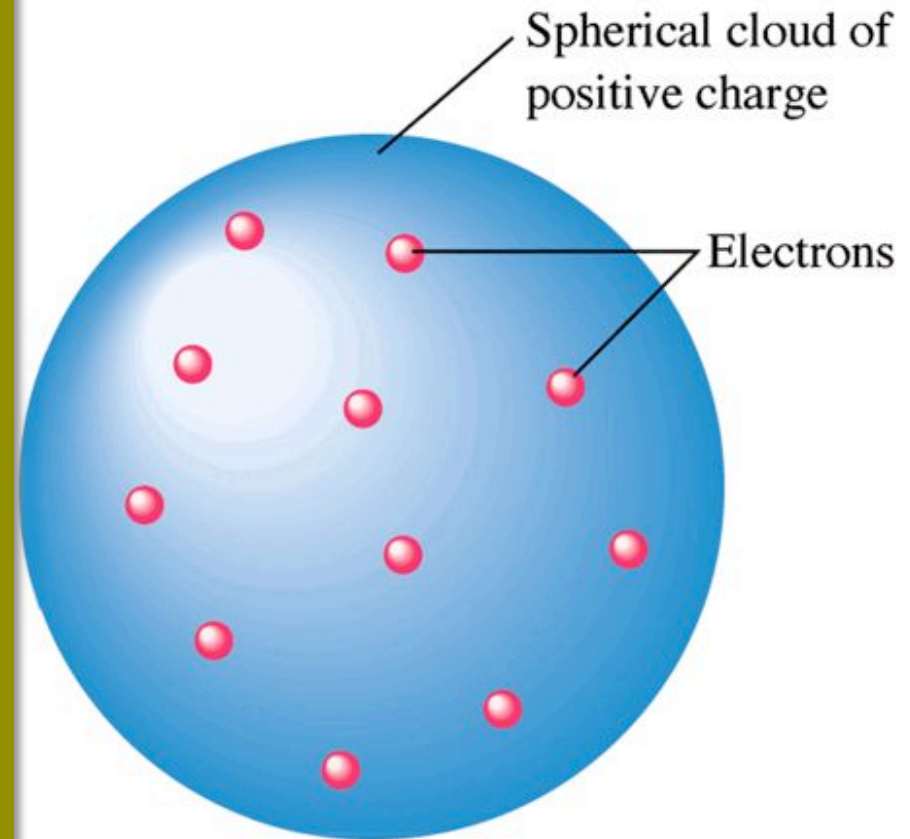


Charge to Mass Ratio (e/m_e)



Thomson's Model of the Atom

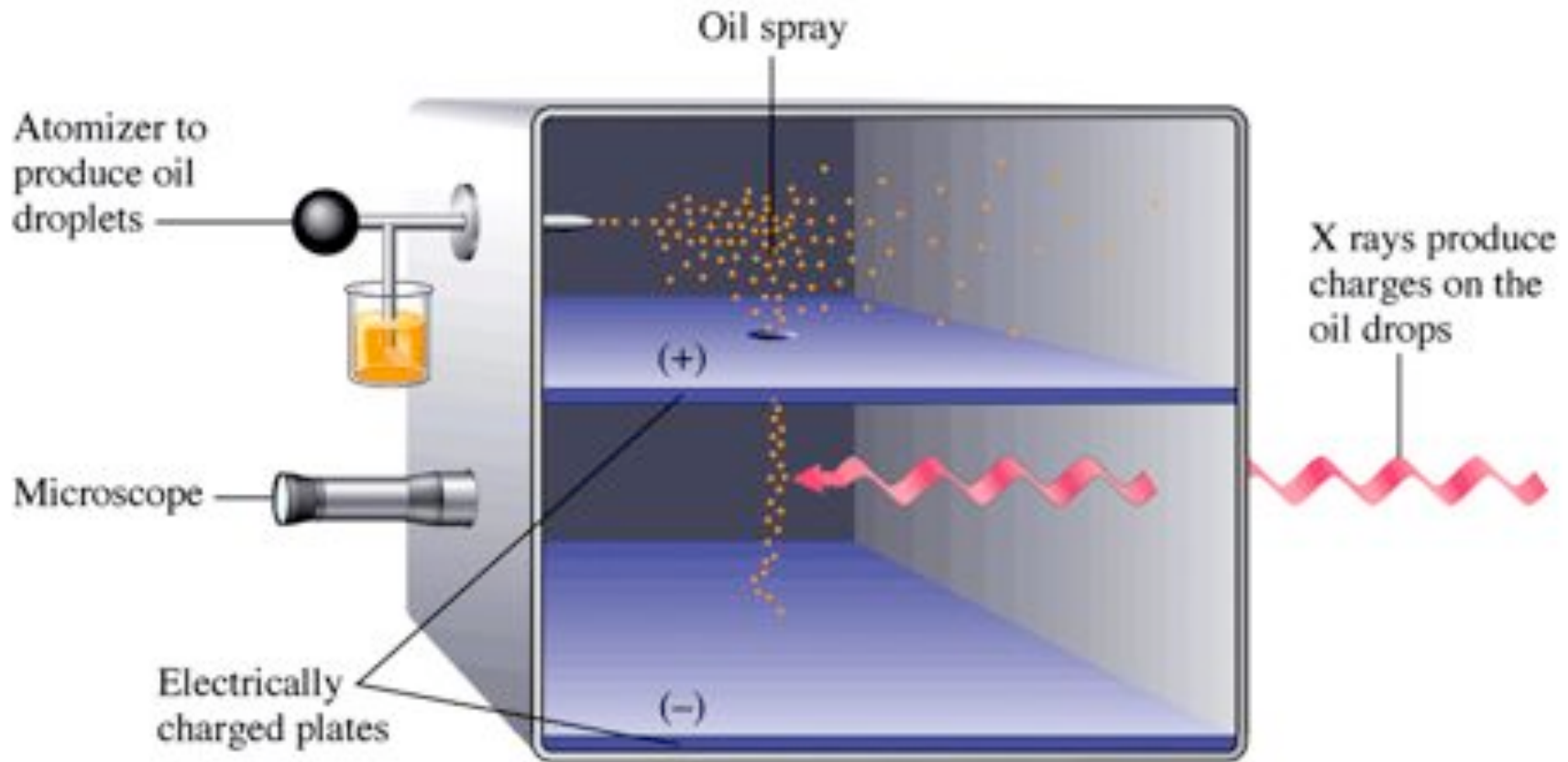
Known: electrons are negatively charged but atoms are neutral. And like charges repel. So...



Model called plum pudding, raisin bun, watermelon seed, etc.

Millikan Oil Drop Expt

Determines the charge of the e^-

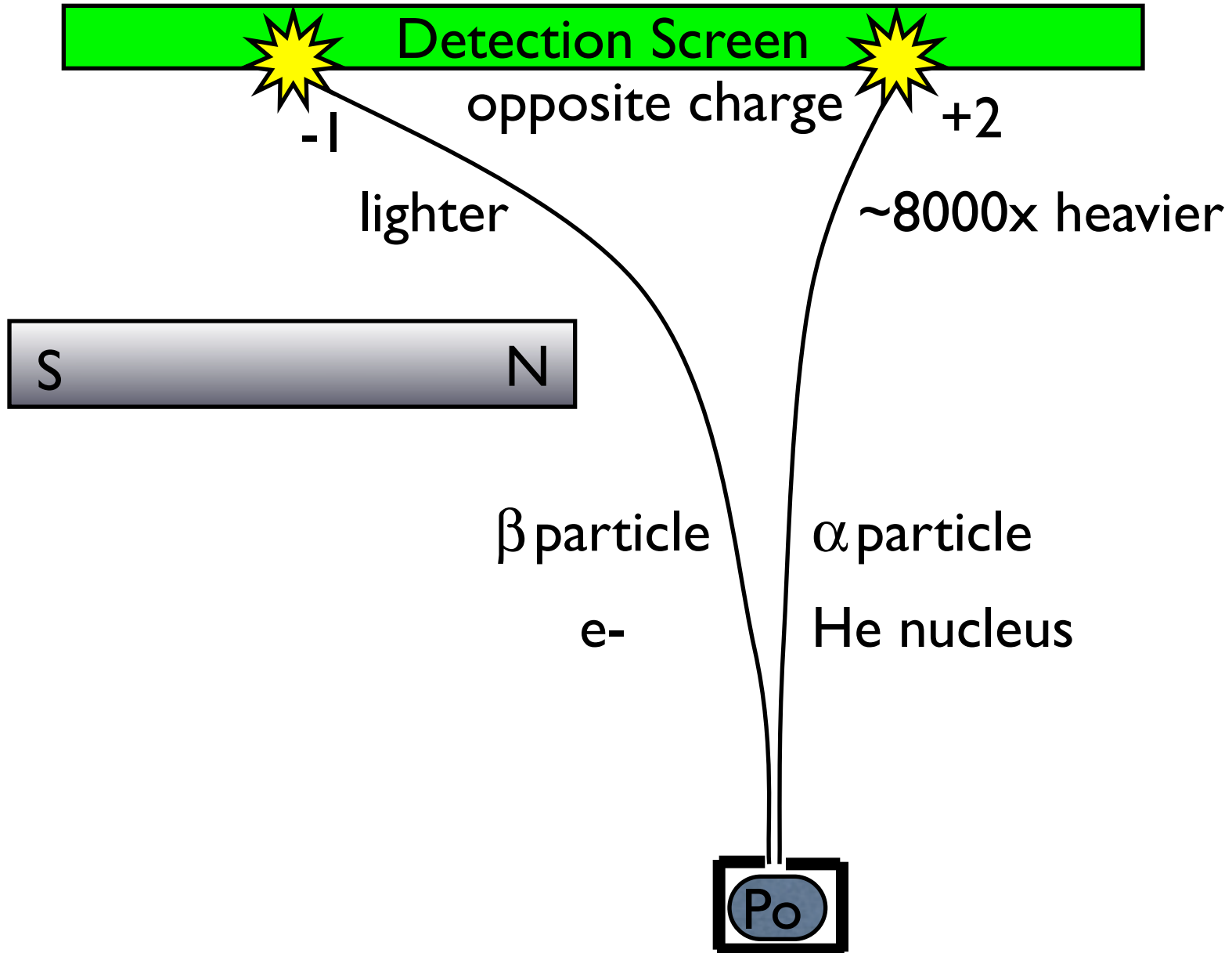


Early Experiments to Characterize the Atom

★ Ernest Rutherford



Rutherford Discovers 2 Types of Particles

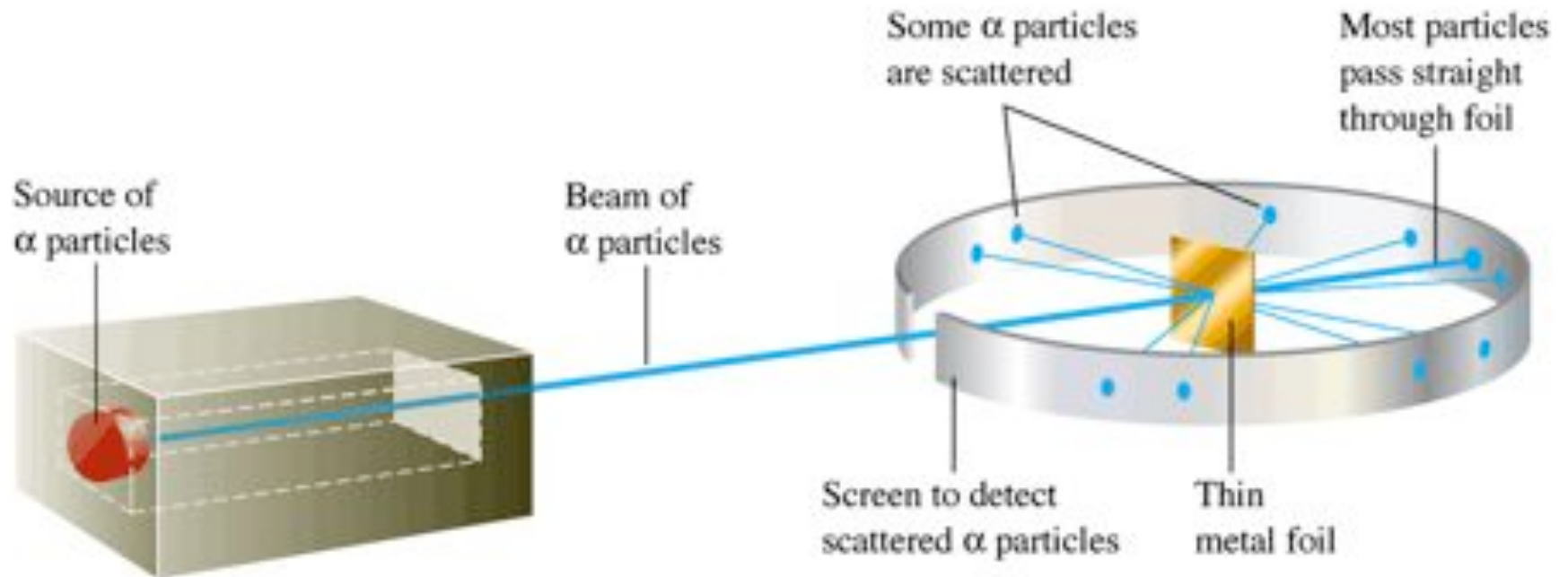


Radioactivity

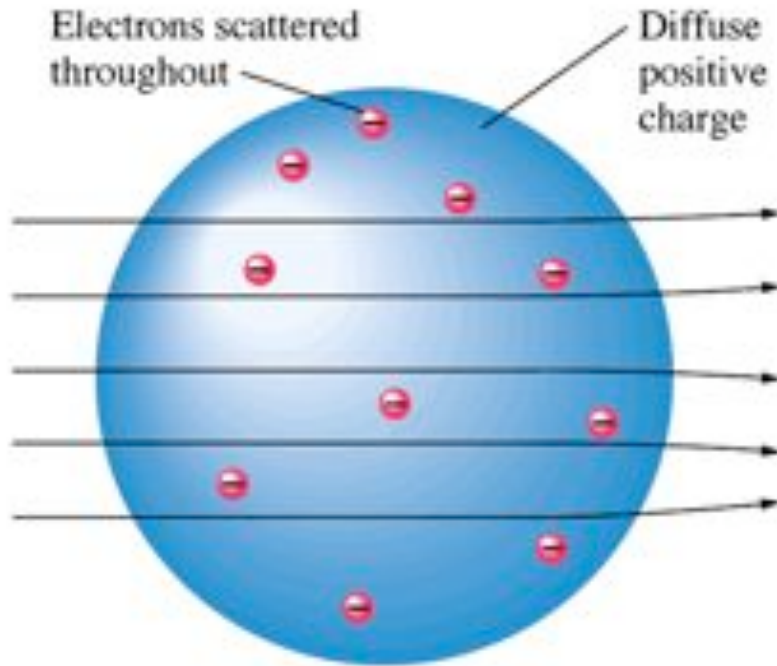
Rutherford coined the terms

- Alpha particle
 - $\alpha = 2 p^+$ and $2 n^0 =$ one He nucleus
- Beta particle
 - $\beta =$ an electron = a “cathode ray”
- Gamma ray
 - $\gamma =$ high-energy light

Rutherford's Gold Foil Expt



What Rutherford Expected vs. Found

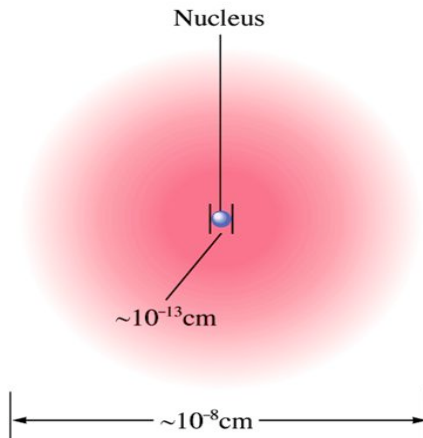


(a)

★ Rutherford's model: **planetary model** - atoms contain a dense nucleus and electrons travel around the nucleus at a "large" distance. Atom is mostly empty space.

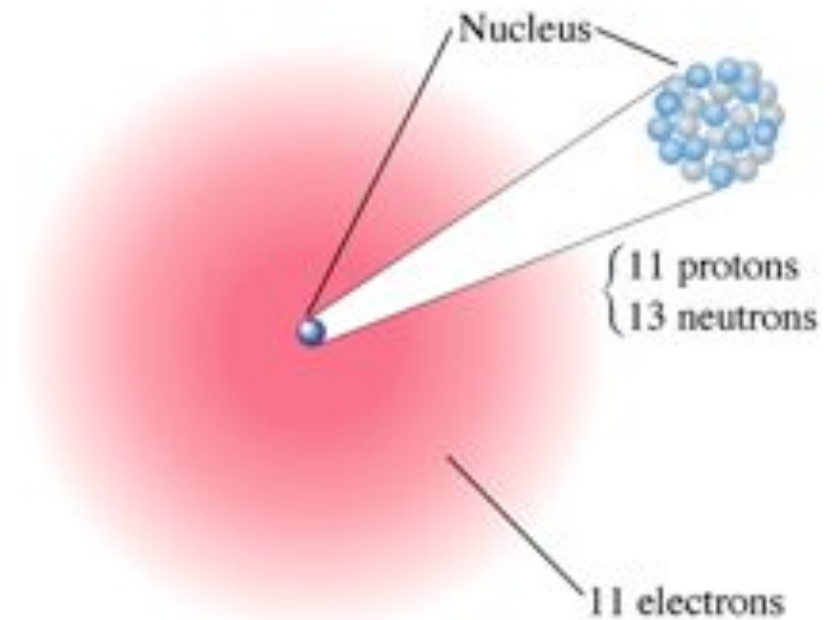
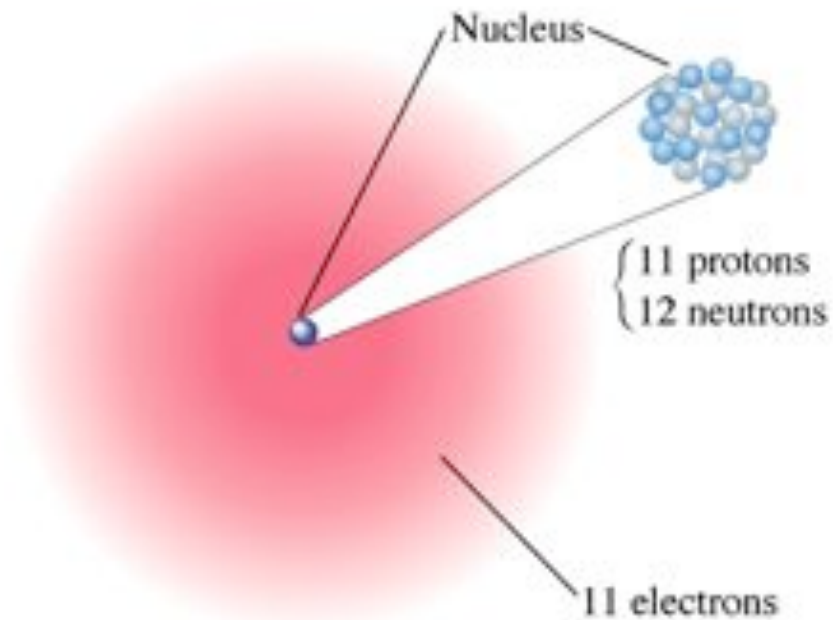
The Modern View of Atomic Structure

The atom contains:

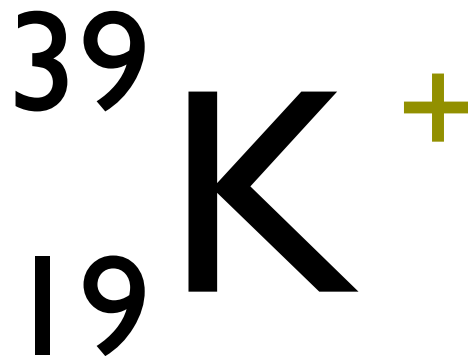


Particle	Abbrev.	Mass(kg)	Charge
Electron	e^-	About 9.1×10^{-31} kg 1800x lighter	-1
Proton	p^+	1.67×10^{-27}	+1
Neutron	n^0	1.67×10^{-27}	0

The Chemists' Shorthand: Atomic Symbols - Isotopes of Sodium



Chemists' Shorthand for Chemical Symbols



Atomic Number = 19

Mass Number = 39

p⁺ = 19

n⁰ = 20

e⁻ = 18

Periodic Table of the Elements

Chemical Symbols

abbreviations for the names of the elements

the first letter is always capitalized

O, Al, C, Cl, H, He.....

TABLE 2.2 The Symbols for the Elements That Are Based on the Original Names

Current Name	Original Name	Symbol
Antimony	Stibium	Sb
Copper	Cuprum	Cu
Iron	Ferrum	Fe
Lead	Plumbum	Pb
Mercury	Hydrargyrum	Hg
Potassium	Kalium	K
Silver	Argentum	Ag
Sodium	Natrium	Na
Tin	Stannum	Sn
Tungsten	Wolfram	W

An element's position on the periodic gives indications of its various physical and chemical properties

Main groups

group numbers identified by suffix A

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	1A	2A											3A	4A	5A	6A	7A	8A
Period																		
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca											31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr											49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba											81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra											113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo

Main group metals

Alkali metals



Alkaline earth metals



Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	1A	2A	3B	4B	5B	6B	7B	8B			1B	2B	3A	4A	5A	6A	7A	8A
Period																		
1																		
2	3 Li	4 Be																
3	11 Na	12 Mg																
4	19 K	20 Ca																
5	37 Rb	38 Sr																
6	55 Cs	56 Ba																
7	87 Fr	88 Ra																

13 Al			
31 Ga	32 Ge		
49 In	50 Sn	51 Sb	
81 Tl	82 Pb	83 Bi	84 Po

Lanthanides

transition metals

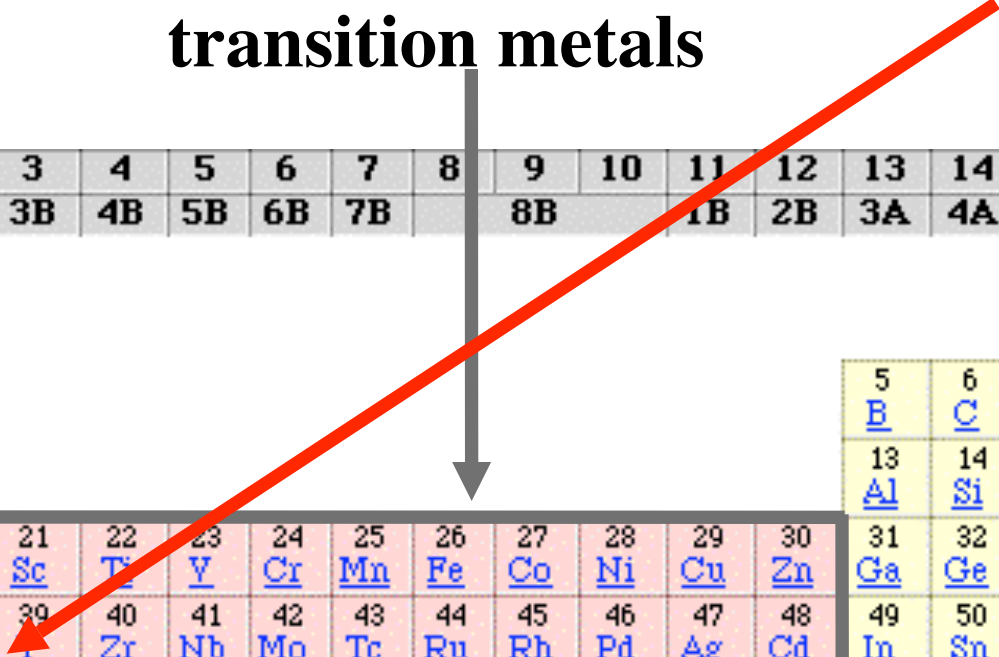
Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	1A	2A	3B	4B	5B	6B	7B		8B		1B	2B	3A	4A	5A	6A	7A	8A
Period																		
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	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
6	55 Cs	56 Ba	* 71 Lu	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
7	87 Fr	88 Ra	** 103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Uun	111 Uuu	112 Uub	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo
lanthanides			* 57 La	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		
actinides			** 89 Ac	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		

Actinides

Lanthanides

transition metals

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
	1A	2A	3B	4B	5B	6B	7B		8B		1B	2B	3A	4A	5A	6A	7A	8A	
Period																			
1	1 H																		2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne	
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
4	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	
5	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	
6	55 Cs	56 Ba	* La	71 Hf	72 Ta	73 W	74 Re	75 Os	76 Ir	77 Pt	78 Au	79 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn	
7	87 Fr	88 Ra	** Lr	103 Rf	104 Db	105 Sg	106 Bh	107 Hs	108 Mt	109 Uun	110 Uuu	111 Uub	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo	
lanthanides			* La	57 Ce	58 Pr	59 Nd	60 Pm	61 Sm	62 Eu	63 Gd	64 Tb	65 Dy	66 Ho	67 Er	68 Tm	69 Yb			
actinides			** Ac	89 Th	90 Pa	91 U	92 Np	93 Pu	94 Am	95 Cm	96 Bk	97 Cf	98 Es	99 Fm	100 Md	101 No			



The Periodic Table

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

*Lanthanides

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu

†Actinides

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

Ions

Cation: A positive ion



Anion: A negative ion



Ions and the Periodic Table

1A	2A											3A	4A	5A	6A	7A	8A
Li ⁺														N ³⁻	O ²⁻	F ⁻	
Na ⁺	Mg ²⁺											Al ³⁺			S ²⁻	Cl ⁻	
K ⁺	Ca ²⁺				Cr ²⁺ Cr ³⁺	Mn ²⁺ Mn ³⁺	Fe ²⁺ Fe ³⁺	Co ²⁺ Co ³⁺			Cu ⁺ Cu ²⁺	Zn ²⁺					Br ⁻
Rb ⁺	Sr ²⁺									Ag ⁺	Cd ²⁺		Sn ²⁺ Sn ⁴⁺				I ⁻
Cs ⁺	Ba ²⁺										Hg ₂ ²⁺ Hg ²⁺		Pb ²⁺ Pb ⁴⁺				



Common Type I cations



Common Type II cations



Common monatomic anions

Naming Common Monatomic Cations, Anions

TABLE 2.3 Common Monatomic Cations and Anions

Cation	Name	Anion	Name
H^+	Hydrogen	H^-	Hydride
Li^+	Lithium	F^-	Fluoride
Na^+	Sodium	Cl^-	Chloride
K^+	Potassium	Br^-	Bromide
Cs^+	Cesium	I^-	Iodide
Be^{2+}	Beryllium	O^{2-}	Oxide
Mg^{2+}	Magnesium	S^{2-}	Sulfide
Ca^{2+}	Calcium	N^{3-}	Nitride
Ba^{2+}	Barium	P^{3-}	Phosphide
Al^{3+}	Aluminum		
Ag^+	Silver		

(**monatomic** anion names
end in -ide)

(cation names same as element)

Polyatomic Ions

TABLE 2.5 Common Polyatomic Ions

Ion	Name	Ion	Name
Hg_2^{2+}	Mercury(I)	NCS^-	Thiocyanate
NH_4^+	Ammonium	CO_3^{2-}	Carbonate
NO_2^-	Nitrite	HCO_3^-	Hydrogen carbonate (bicarbonate is a widely used common name)
NO_3^-	Nitrate	ClO^-	Hypochlorite
SO_3^{2-}	Sulfite	ClO_2^-	Chlorite
SO_4^{2-}	Sulfate	ClO_3^-	Chlorate
HSO_4^-	Hydrogen sulfate (bisulfate is a widely used common name)	ClO_4^-	Perchlorate
OH^-	Hydroxide	$\text{C}_2\text{H}_3\text{O}_2^-$	Acetate
CN^-	Cyanide	MnO_4^-	Permanganate
PO_4^{3-}	Phosphate	$\text{Cr}_2\text{O}_7^{2-}$	Dichromate
HPO_4^{2-}	Hydrogen phosphate	CrO_4^{2-}	Chromate
H_2PO_4^-	Dihydrogen phosphate	O_2^{2-}	Peroxide
		$\text{C}_2\text{O}_4^{2-}$	Oxalate

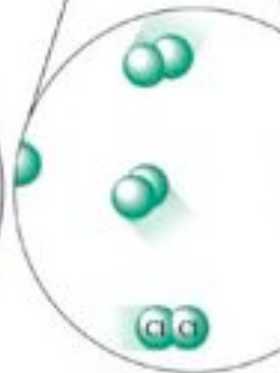
Ionic Bonding

Ionic Bonding: Force of attraction between oppositely charged ions.

Sodium, Na(s)



Chlorine, Cl₂(g)



Demo: MgO, CaS

Naming Compounds

Type I Binary Ionic Compounds:

Type I: when cations have only **one** possible charge.

Cation first, then anion, eg. CaCl_2

Monatomic cation = name of the element

Ca^{2+} = calcium ion

Monatomic anion = root + -ide

Cl^- = chloride

CaCl_2 = calcium chloride

Naming Compounds

(continued)

Binary Ionic Compounds (Type II):

Type II: metal forms more than one cation

- ✓ use Roman numeral for metal to specify its charge

Example: PbCl_2

The charge on Cl is always: -1

The lead ion can be +2 or +4. To make the compound neutral, the charge on Pb must be: +2

So the cation is Pb^{2+}

PbCl_2 = lead(II) chloride

TABLE 2.4 Common Type II Cations

<u>Ion</u>	<u>Systematic Name</u>
Fe^{3+}	Iron(III)
Fe^{2+}	Iron(II)
Cu^{2+}	Copper(II)
Cu^{+}	Copper(I)
Co^{3+}	Cobalt(III)
Co^{2+}	Cobalt(II)
Sn^{4+}	Tin(IV)
Sn^{2+}	Tin(II)
Pb^{4+}	Lead(IV)
Pb^{2+}	Lead(II)
Hg^{2+}	Mercury(II)
Hg_2^{2+*}	Mercury(I)
Ag^{+}	Silver†
Zn^{2+}	Zinc†
Cd^{2+}	Cadmium†

*Note that mercury(I) ions always occur bound together to form Hg_2^{2+} ions.

†Although these are transition metals, they form only one type of ion, and a Roman numeral is not used.

Naming Ionic Compounds

Al_2O_3	aluminum oxide
BaSO_4	barium sulfate
CoCl_3	cobalt(III) chloride
CoCl_2	cobalt(II) chloride

Naming Compounds (continued)

Binary compounds (Type III):

Compounds between two nonmetals

First element in the formula is named first.

Second element is named as if it were an anion.

Use prefixes mono, di, tri, etc.

✓ Never use mono prefix for first element

Examples: P_2O_5 = diphosphorus pentoxide

CO = carbon monoxide

TABLE 2.6 Prefixes Used to Indicate Number in Chemical Names

Prefix	Number Indicated
<i>mono-</i>	1
<i>di-</i>	2
<i>tri-</i>	3
<i>tetra-</i>	4
<i>penta-</i>	5
<i>hexa-</i>	6
<i>hepta-</i>	7
<i>octa-</i>	8
<i>nona-</i>	9
<i>deca-</i>	10

Naming Type III Compounds

N_2O	dinitrogen monoxide
NO_2	nitrogen dioxide
N_2O_4	dinitrogen tetroxide
H_2O	dihydrogen monoxide

TABLE 2.8 Names of Some Oxygen-Containing Acids

Acid	Anion Suffix	Name
HNO_3	nitrate	Nitric acid
HNO_2	nitrite	Nitrous acid
H_2SO_4	sulfate	Sulfuric acid
H_2SO_3	sulfite	Sulfurous acid
H_3PO_4	phosphate	Phosphoric acid
$\text{HC}_2\text{H}_3\text{O}_2$	acetate	Acetic acid

TABLE 2.7 Names of Acids*
That Do Not Contain Oxygen

Acid	Anion Suffix	Name
HF	ide	hydrofluoric acid
HCl	ide	hydrochloric acid
HBr	ide	hydrobromic acid
HI	ide	hydroiodic acid
HCN	ide	hydrocyanic acid
H ₂ S	ide	hydrosulfuric acid

*Note that these acids are aqueous solutions containing these substances.