Early Atomic Theory

Atoms, Molecules, and Ions

Preparation of College Chemistry
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Atoms

Atomic theory

Components of the Atom

Atomic Number

Mass Number

Isotopes

Atomic Theory. Early Thoughts

470 BC

EMPEDOCLES:

- ***Matter is composed of four elements: EARTH, AIR, WATER, FIRE***

440 BC

LEUCIPUS of Miletus and his disciple DEMOCRITUS of Abdera:

- ***Nature consists solely of an infinite number of indivisible particles, having shape, size, impenetrability, and no further properties. These particles move through an otherwise empty space.***
- ***The shape, size, location, and movement of these particles make up literally all of the qualities, relations, and other features of the natural world.***

384 - 270 BC

PLATO and ARISTOTLE reinforces:

- ***Matter is composed of four elements: EARTH, AIR, WATER, FIRE***

1500's

GALILEO GALILEI:

- *Appearance of a new substance through chemical change involves rearrangement of parts too small to be seen.*

1500's

FRANCIS BACON:

- *Heat might be a form of motion of small particles.*

17th Century

ROBERT BOYLE and ISAAC NEWTON:

- *Used atomic concepts to interpret physical phenomena.*

1803 - 1810

Dalton's Model of the Atom

1. ***Elements consist of tiny particles called atoms.***

2. ***Atoms of the same element are alike in mass and size.***

3. ***Atoms combine to form compounds in simple numerical ratios, such as 1:2, 2:3, etc.***

4. ***Atoms of two elements may combine in different ratios to form more than one compound.***

Consequences of Dalton's Law

The Law of conservation of Mass:

"There is no detectable change in mass in an ordinary chemical rxn."

The Law of Constant Composition:

"A compound always contains the same elements in the same proportions by mass."

The Law of Multiple Proportions:

"The masses of one element that combine with a fixed mass of the second element are in a ratio of small whole numbers."

Composition of Compounds

A compound always contains two or more elements combined in a definite proportion by mass.

Atoms of two or more elements may combine in different ratios to produce more than one compound.

	Water	Hydrogen Peroxide
Percent H	11.2	5.9
Percent O	88.8	94.1
Atomic Composition	2H + O	2H + 2 O

1830’s

MICHAEL FARADAY:

Certain substances when dissolved in water can conduct an electric current.

1887

SVANTE ARRHENIUS:

Water is not necessary IONIC SUBSTANCES conduct electricity when melted.

CATIONS: POSITIVE IONS, that “travel” to the CATHODE (negative electrode)

ANIONS: NEGATIVE IONS that “travel" to the ANODE (positive electrode).

1891

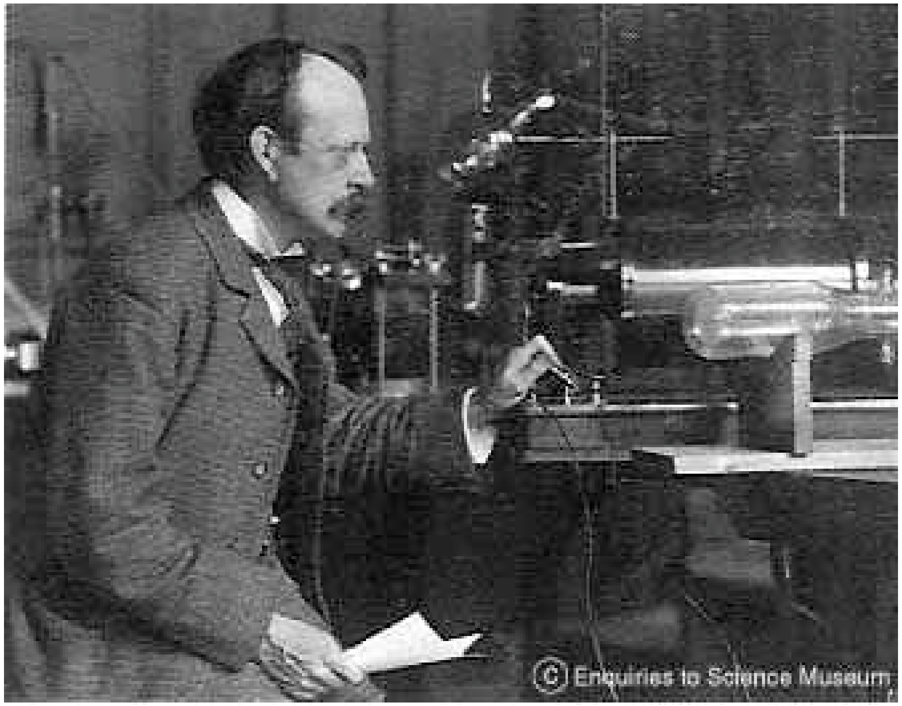
G. J. STONEY:

There must be some FUNDAMENTAL unit of electricity associated with atoms: The ELECTRON.

1897

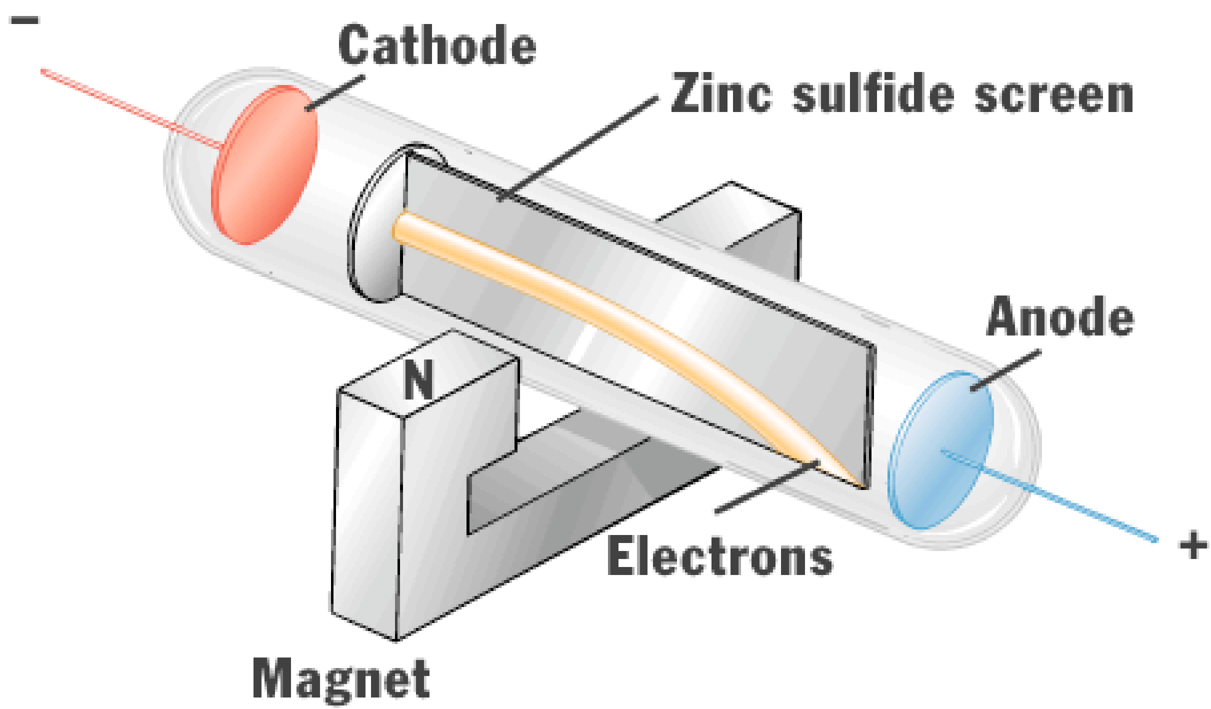
J.J Thomson Discovered the Electron

The first sub-atomic particle



Cathode rays are ELECTRONS (e^-) particles with a negative charge.

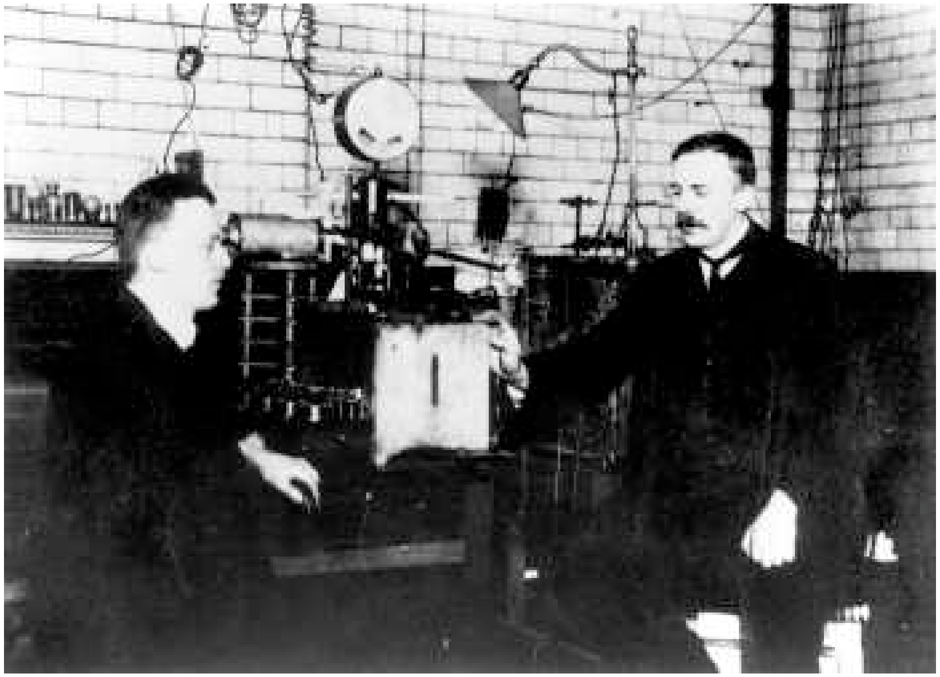
Cathode ray tube



The Nuclear Atom

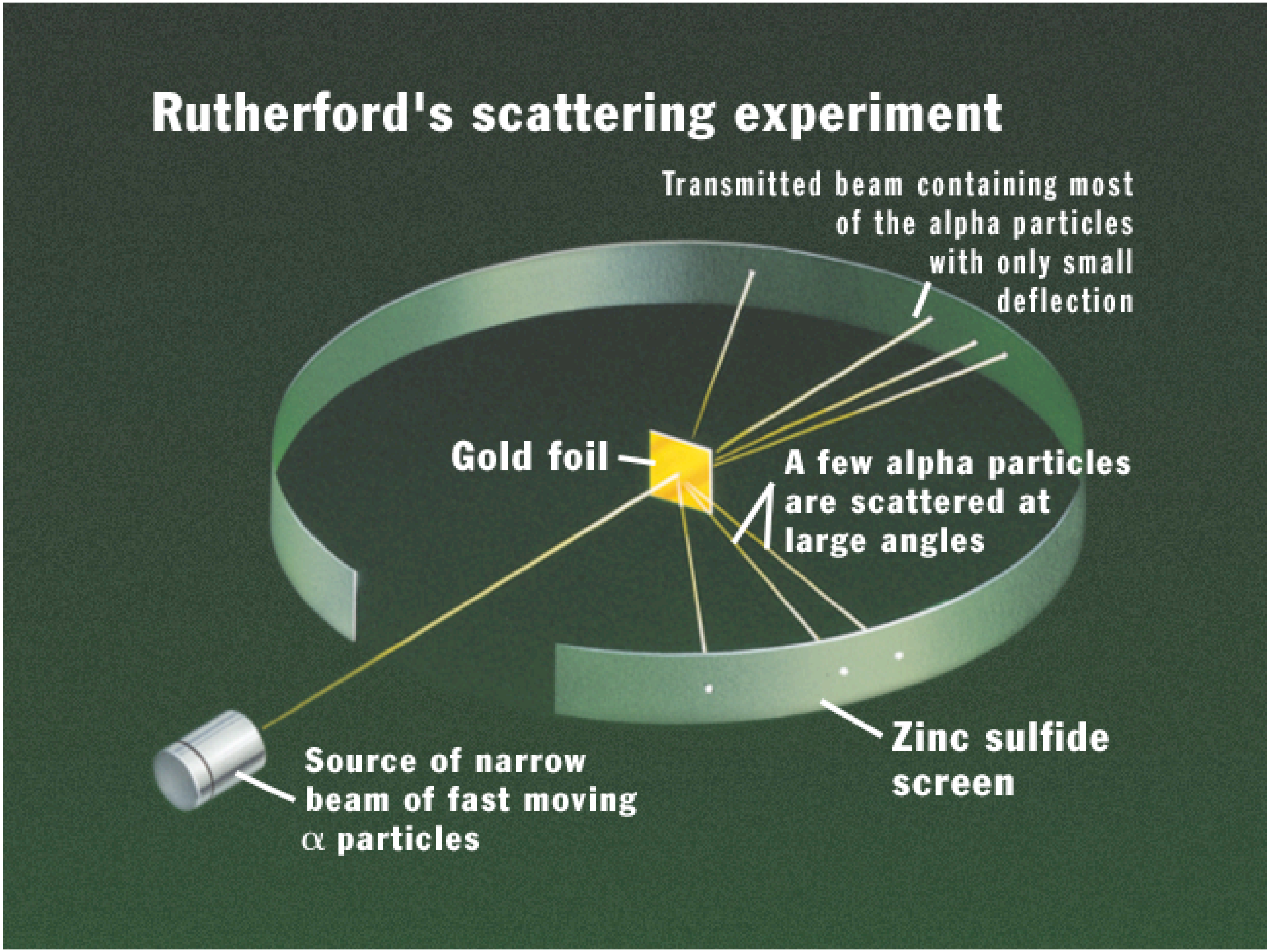
1913

"It was as though you had fired a fifteen-inch shell at a piece of tissue paper and it had bounced back and hit you."

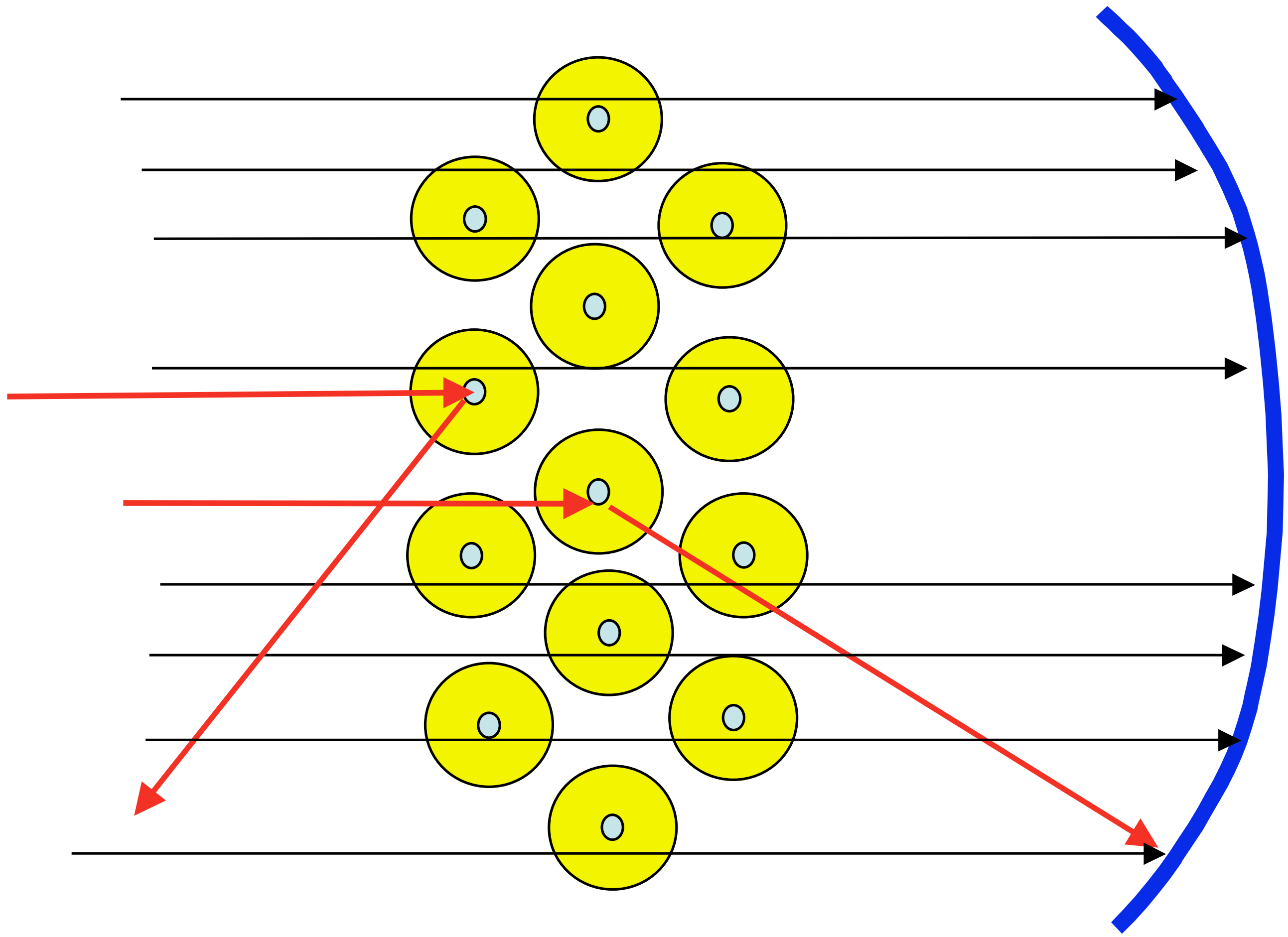


ERNEST RUTHERFORD and HANS GEIGER with the apparatus for counting alpha particles

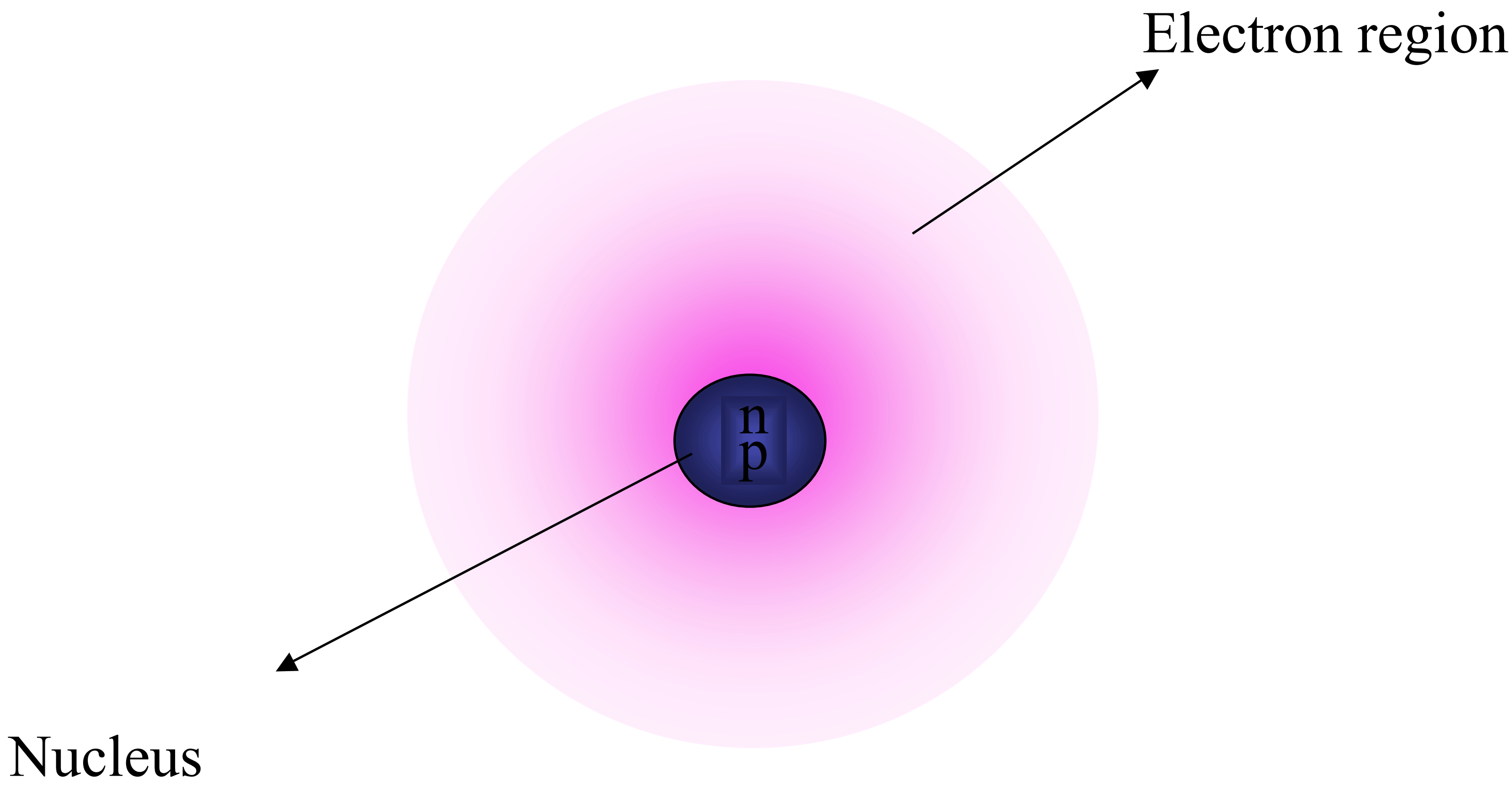
Manchester, 1912


Rutherford's scattering experiment
Transmitted beam containing most of the alpha particles with only small deflection
Gold foil
A few alpha particles are scattered at large angles
Zinc sulfide screen
Source of narrow beam of fast moving α particles

The Nuclear Atom



Arrangement of Subatomic Particles



Atomic Number, Z

Equals number of protons in nucleus

Equals number of electrons in neutral atom

Location of the element in the Periodic Chart

Characteristic of a particular element

Properties of Subatomic Particles

Particle	***Mass(kg)***	***Relative Mass (amu)***	***Charge***
proton	*1.67262×10^{-27}*	*1*	*+ 1*
neutron	*1.67493×10^{-27}*	*1*	*0*
electron	*0.00091×10^{-27}*	*0.0005486*	*- 1*

Mass Number, A

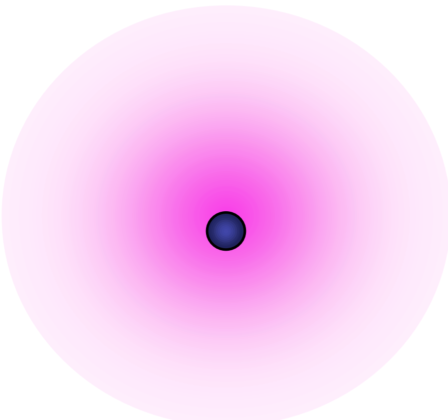
Atoms of the same element can differ in mass number

A = number of protons + number of neutrons

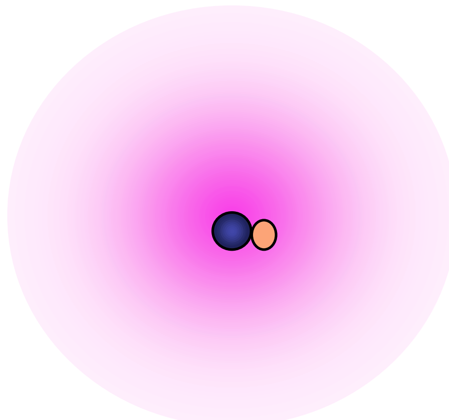
Isotope	# Protons	# Neutrons	Z	A	Symbol
Carbon-12	**6**	**6**	**6**	**12**	${}^{12}_{6}C$
Carbon-14	**6**	**8**	**6**	**14**	${}^{14}_{6}C$

Nuclei Representation

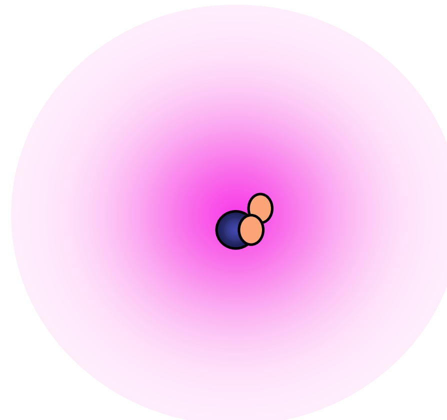
$$^{A}_{Z}E$$



$^{1}_{1}H$



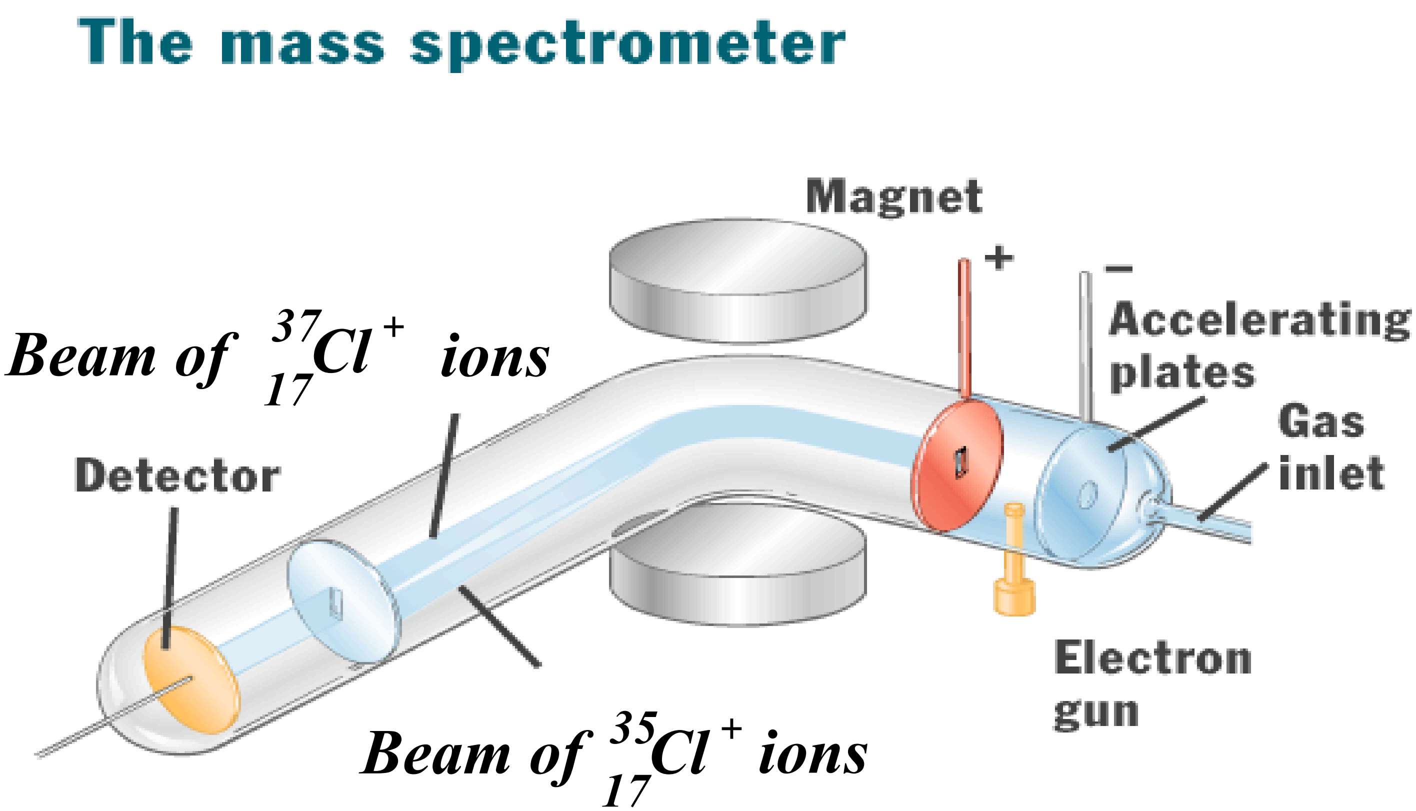
$^{2}_{1}H$



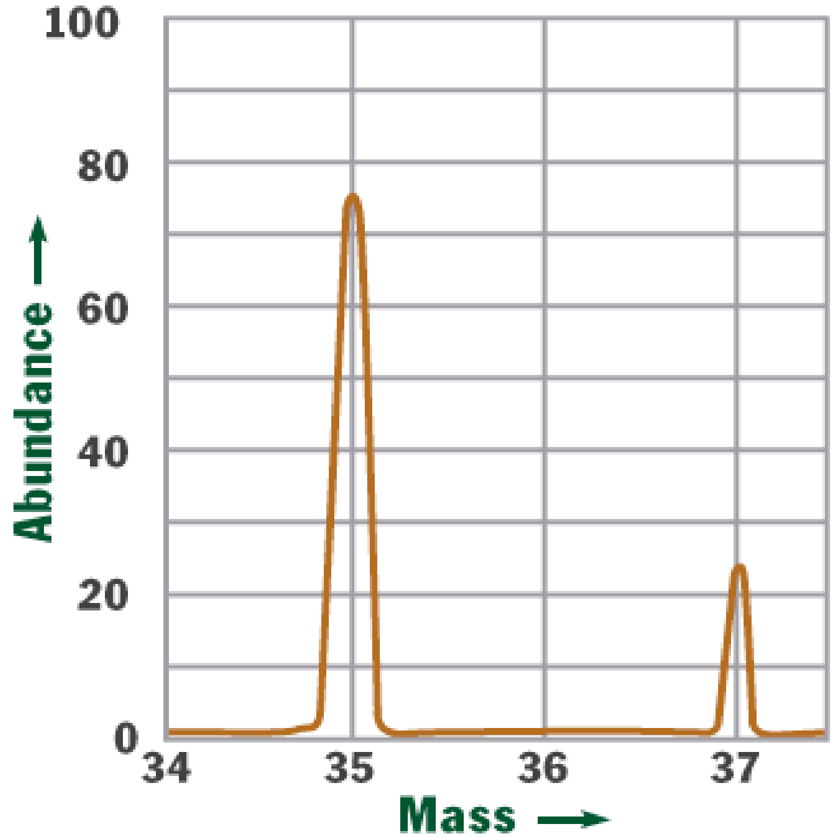
$^{3}_{1}H$

A - Z = number of neutrons

Precise determination of the masses of individual atoms



Mass spectrum of chlorine



Atomic Mass from Isotopic Composition

Isotope	Atomic Mass (amu)	Natural Abundance (%)
Ne-20	20.00	90.48
Ne-21	21.00	0.27
Ne-22	22.00	9.25

$$A.M. = (A.M.isotope_1 \times \frac{\%}{100} + A.M.isotope_2 \times \frac{\%}{100} + \ldots$$

Meaning of Atomic Masses

A nickel atom is 58.69 / 40.08 = 1.464 times as heavy as a calcium ion

It is 58.69 / 10.81 = 5.29 times as heavy as a boron ion

Element	B	Ca	Ni
Atomic Mass (amu)	10.81	40.08	58.69

Atomic Mass from Isotopic Composition

20.00 (0.9048) +
21.00 (0.0027)
22.00 (0.0925)

20.18 amu

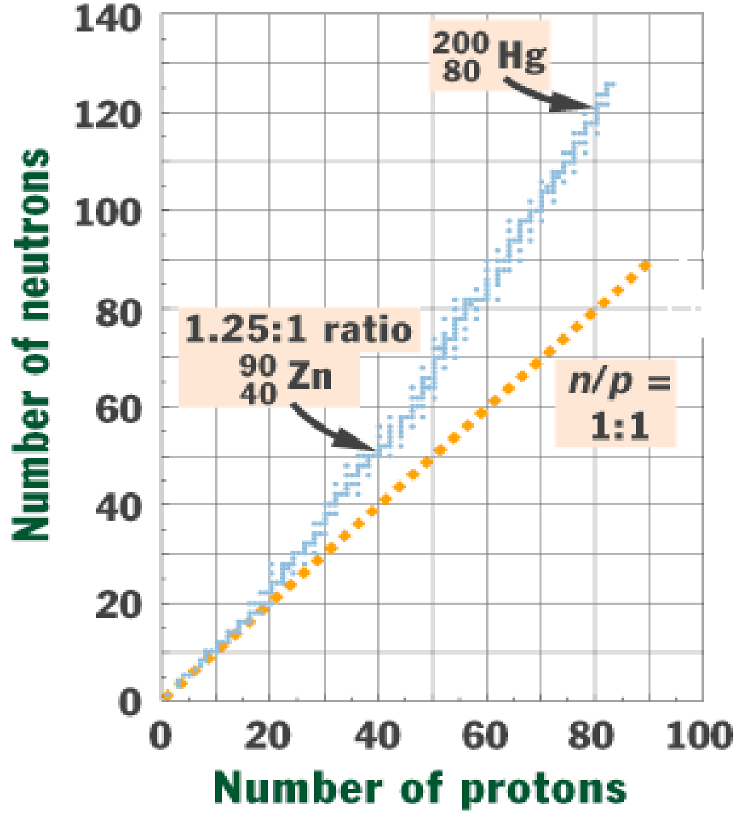
A.M. Ne = 20.18g/mol

Meaning of Atomic Masses

- ***Give relative masses of atoms based on C–12 scale.***
- ***The Most common isotope of carbon is assigned an atomic mass of 12 amu.***
- ***The amu is defined as 1/12 of the mass of one neutral carbon atom***

http://www.c14dating.com/int.html

Belt of stability



For light (Z < 20) isotopes the stable ratio is 1.0; with heavier isotopes it increases to 1.5. There are no stable isotopes for elements of Z > 83 (Bi).

Ions

- ***Formation of Monatomic Ions***
- ***Charges of Monatomic Ions***
- ***Polyatomic Ions***
- ***Formulas***

Formation of Monatomic Ions

Na atom (11p$^+$,11e$^-$) → Na^+ ion (11p$^+$,10e$^-$) + e$^-$

F atom (9p$^+$,9e$^-$) + e$^-$ → F^- ion (9p$^+$,10e$^-$)

Nucleus remains unchanged

Charges of some metallic ions (non-metals, anions)

13	14	15	16	17	18
				H^-	He
		N^{3-}	O^{2-}	F^-	Ne
			S^{2-}	Cl^-	Ar
			Se^{2-}	Br^-	Kr
			Te^{2-}	I^-	Xe
					Rn

Charges of some metallic ions (metals, cations)

1	2	6	7	8	9	10	11	12	13	14	15
Li^+											
Na^+	Mg^{2+}								Al^{3+}		
K^+	Ca^{2+}	Cr^{3+}	Mn^{2+}	Fe^{2+} Fe^{3+}	Co^{2+}	Ni^{2+}	Cu^+ Cu^{2+}	Zn^{2+}			
Rb^+	Sr^{2+}						Ag^+	Cd^{2+}		Sn^{2+}	
Cs^+	Ba^{2+}									Pb^{2+}	Bi^{3+}

Polyatomic Ions

Names and formulas

General structure

Polyatomic Ions

Cations		*Anions*	
Ammonium	NH_4^+	*Permanganate*	MnO_4^-
Mercury(I)	Hg_2^{+2}	*Peroxide*	O_2^{2-}
		Acetate	$C_2H_3O_2^-$

The prefixes and suffixes used to name oxyanions are related to the valence of the element contained in the formula

per– –ate	–ate	–ite	hypo– –ite
XO_4^-	XO_3^-	XO_2^-	XO^-

Ex:

Potassium Permanganate	$KMnO_4$
Potassium Manganate	$KMnO_3$
Ammonium hypochlorite	NH_4ClO
Mercury(I) iodite	$(Hg_2)(IO_2)_2$
Mercury(II) bromate	$Hg(BrO_3)_2$
Iron(III) periodate	$Fe(IO_4)_3$

Writing Ionic Compound Formulas

Apply principle of electrical neutrality

	Anion	peroxide	oxide	dichromate
Cation	HCO_3^-	O_2^{2-}	O^{2-}	$Cr_2O_7^{2-}$
Ammonium NH_4^+	NH_4HCO_3	$(NH_4)_2O_2$	$(NH_4)_2O$	$(NH_4)_2Cr_2O_7$
Mercury(I) Hg_2^{2+}	$Hg_2(HCO_3)_2$	Hg_2O_2	Hg_2O	$Hg_2Cr_2O_7$
Sodium Na^+	$NaHCO_3$	Na_2O_2	Na_2O	$Na_2Cr_2O_7$
Calcium Ca^{2+}	$Ca(HCO_3)_2$	CaO_2	CaO	$Ca\ Cr_2O_7$

Naming Ionic Compounds

Name cation followed by anion

For transition metals cations the charge is indicated by Roman numeral when using the Stock system

NH_4Br	**ammonium bromide**
Na_2SO_4	**sodium sulfate**
$Fe(NO_3)_3$	**iron (III) nitrate**

Oxoanions of nitrogen, sulfur and chlorine

Nitrogen	Sulfur	Chlorine
		ClO_4^- *per*chlor*ate*
NO_3^- nitr*ate*	SO_4^{2-} sulf*ate*	ClO_3^- chlor*ate*
NO_2^- nitr*ite*	SO_3^{2-} sulf*ite*	ClO_2^- chlor*ite*
		ClO^- *hypo*chlor*ite*

Greek prefixes used in nomenclature

Number*	Prefix	Number	Prefix
2	di	6	hexa
3	tri	7	hepta
4	tetra	8	octo
5	penta	9	nona
		10	deca

*The prefix mono (1) is seldom used

Binary Molecular Compounds

Use of Greek prefixes

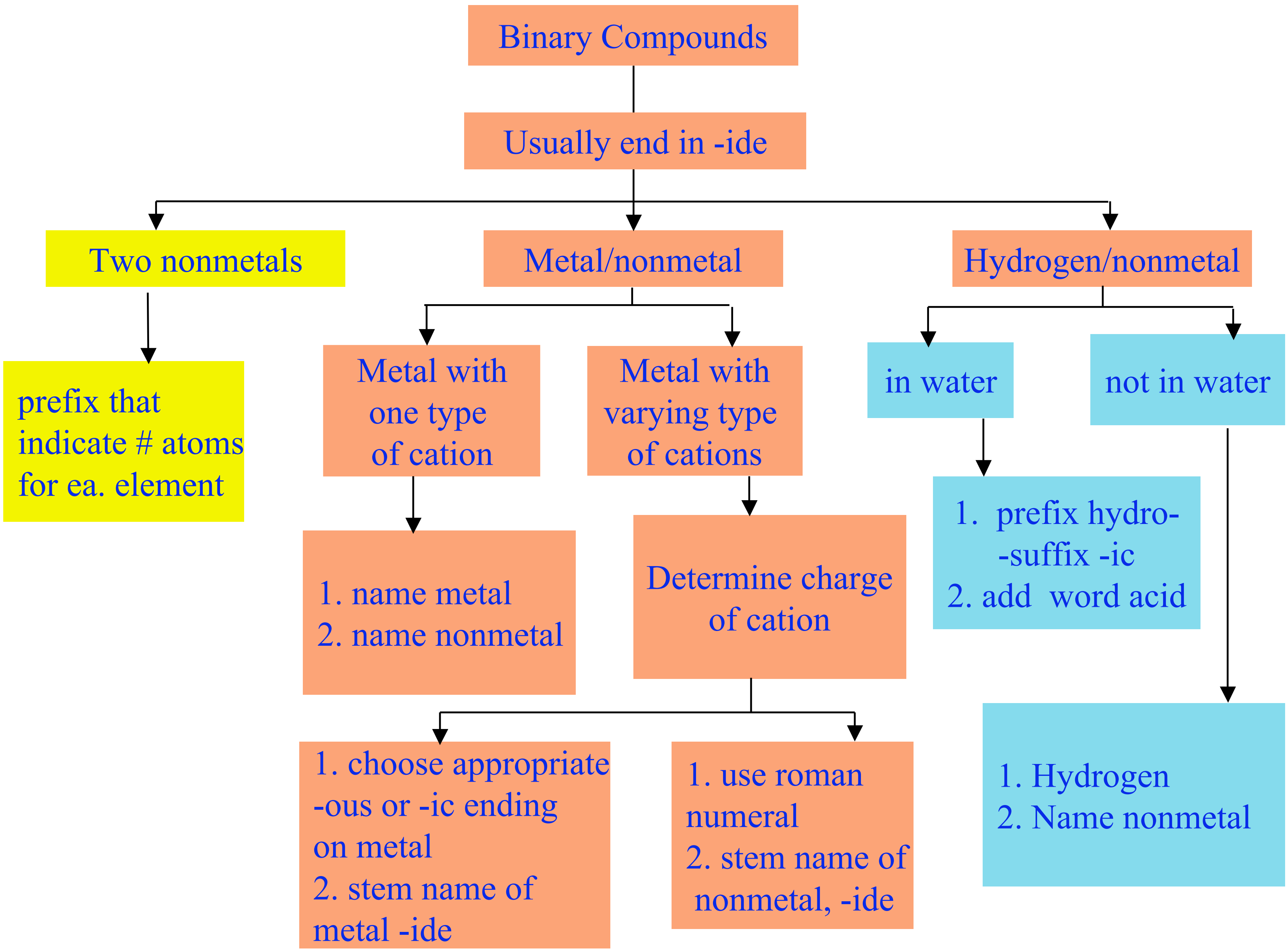
SF_6 sulfur hexafluoride

N_2O_3 dinitrogen trioxide

H_2O dihydrogen monoxide

Types of Acids

- Binary Acids:
  - hydrochloric acid
- Oxoacids:
  - ate salt ic acid
- Examples:
  - $HClO_4$ hyperchloric acid
  - $Ca(ClO_4)_2$ calcium perchlorate



Binary Compounds
Usually end in -ide
Two nonmetals
Metal/nonmetal
Hydrogen/nonmetal
prefix that indicate # atoms for ea. element
Metal with one type of cation
Metal with varying type of cations
in water
not in water
1. name metal
2. name nonmetal
Determine charge of cation
1. prefix hydro- -suffix -ic
2. add word acid
1. choose appropriate -ous or -ic ending on metal
2. stem name of metal -ide
1. use roman numeral
2. stem name of nonmetal, -ide
1. Hydrogen
2. Name nonmetal