Chapter 2
ATOMS, MOLECULES, & IONS

Atomic Theory & Atomic Structure

Periodic Table of the Elements

Naming Simple Compounds

Chemistry & The Elements

- **Chemistry Is The Study Of _____ And The _____ It Undergoes**
- **What Is MATTER Composed Of?**
  - **Matter Is Formed From One Or More Of The _____**

What Are The Elements Composed Of?

- Elements Are _____ Substances That Can Not Be Broken Down Chemically
- How do we know that ?
- Experiment !

How Do We Study Chemistry ?

THE SCIENTIFIC METHOD

1. Experiment
2. "Explain" Experiment
3. Do More Experiments to Test "Explanation"

Experiments and Observations

- Mass is neither _____ nor _____in ordinary chemical reactions.
- Different samples of a pure chemical substance always contain the same proportion of elements by _____.
- If two elements combine to form different substances, the mass ratios are small, whole number _____of each other.

Atomic Theory & Atomic Structure

The key concept in chemistry is that _____ is composed of tiny particles called _____.

First Atomic Theory

- John Dalton (1766 – 1844) _____ the Theory of Matter in 1808.
- What does postulated mean ?
  - 1. To assume to be true
  - 2. To take for granted

Postulates of Dalton's Atomic Theory

1. All matter (elements) is composed of tiny particles called _____.

2. All atoms of a given element have _____ properties and atoms of different elements have different properties.

- **Dalton**
  - 3. Atoms of different elements combine in ratios of small _____ numbers when forming compounds.
  - 4. Chemical reactions only rearrange the way atoms are combined; the atoms themselves are _____ changed.

Why is Dalton's theory significant?

Dalton's theory explains The Laws of

- Conservation of _____
- Definite _____
- Multiple _____

Experiments and Observations

Madam and Pierre Curie
discovered some materials

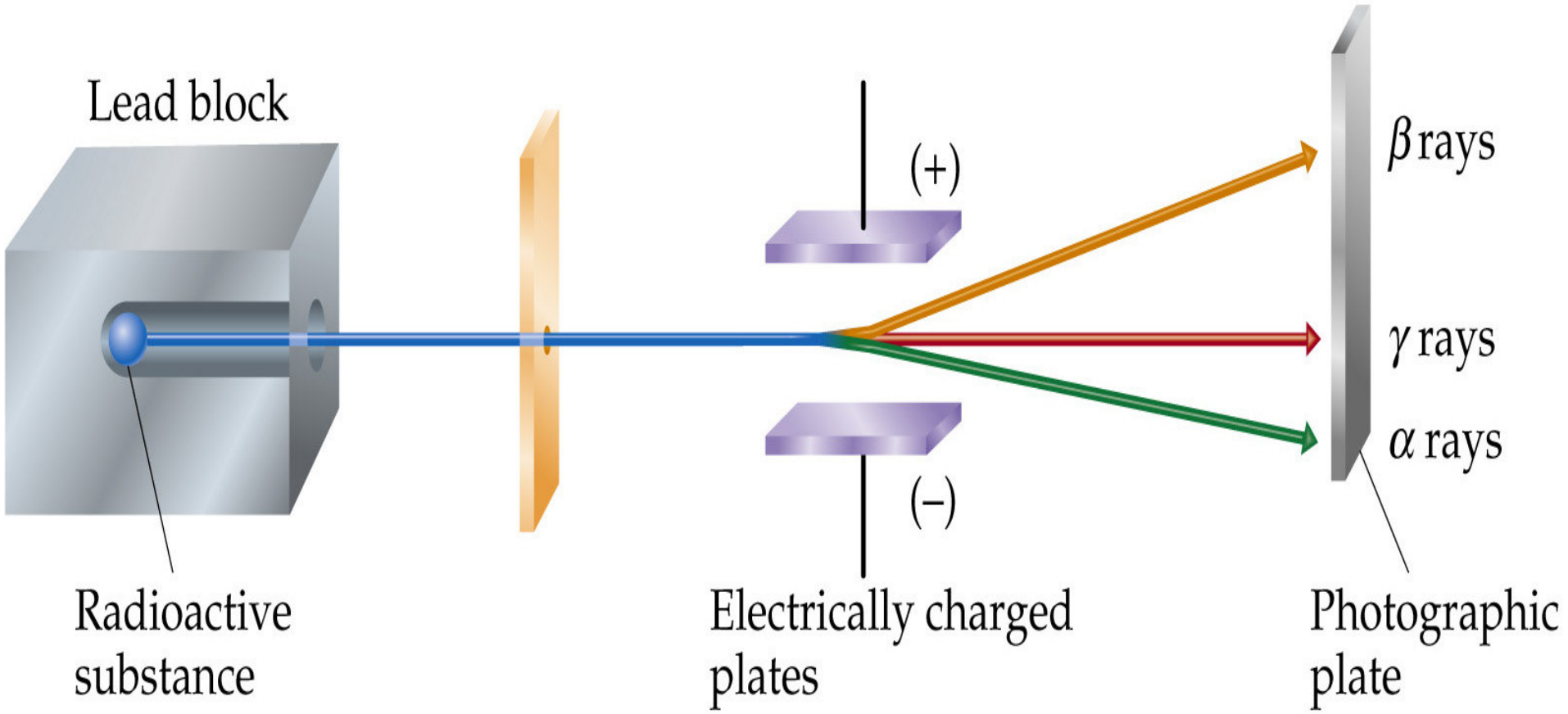
---

emitted high energy radiation

RADIATION

1. Which elements are radioactive ?
2. What does radioactive mean ?
3. What are the types of radiation ?
4. How do the types of radiation differ ?

Types of Radiation
alpha(α) beta(β) gamma(γ)



Types of Radiation
alpha(α) beta(β) gamma(γ)

_____ and _____ **radiation** are **both**

affected by an electric field

while _____ **radiation** is **unaffected**

The Discovery of Atomic Structure

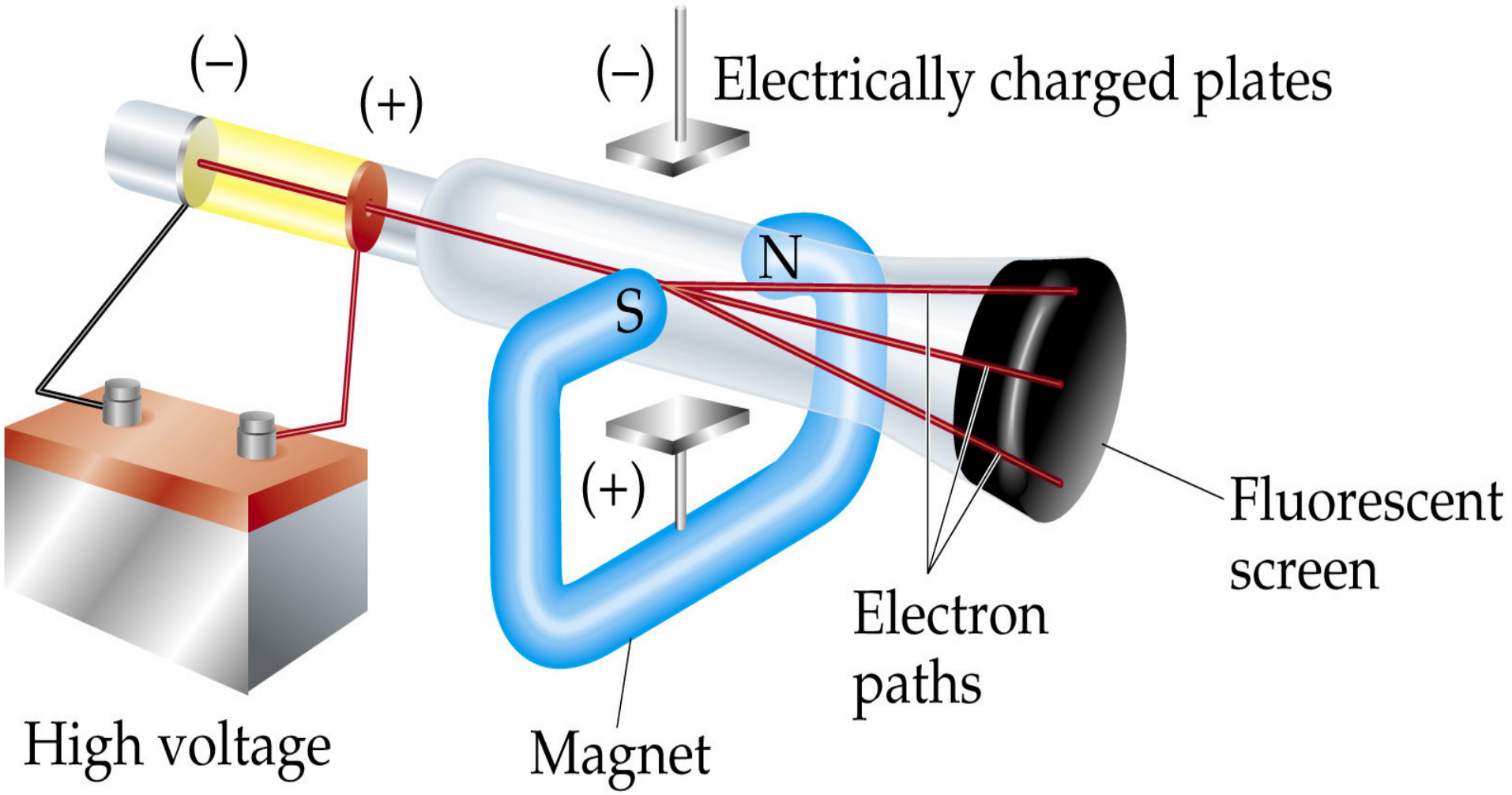
1. Thomson
2. Millikan
3. Rutherford

THOMSON'S EXPERIMENTS

Discovered _____

Electrons are also called Cathode Rays

Cathode Rays and Electrons



Millikan's Oil Drop Experiment

Determined the

- The _____ on an electron

and

- The _____ of the electron

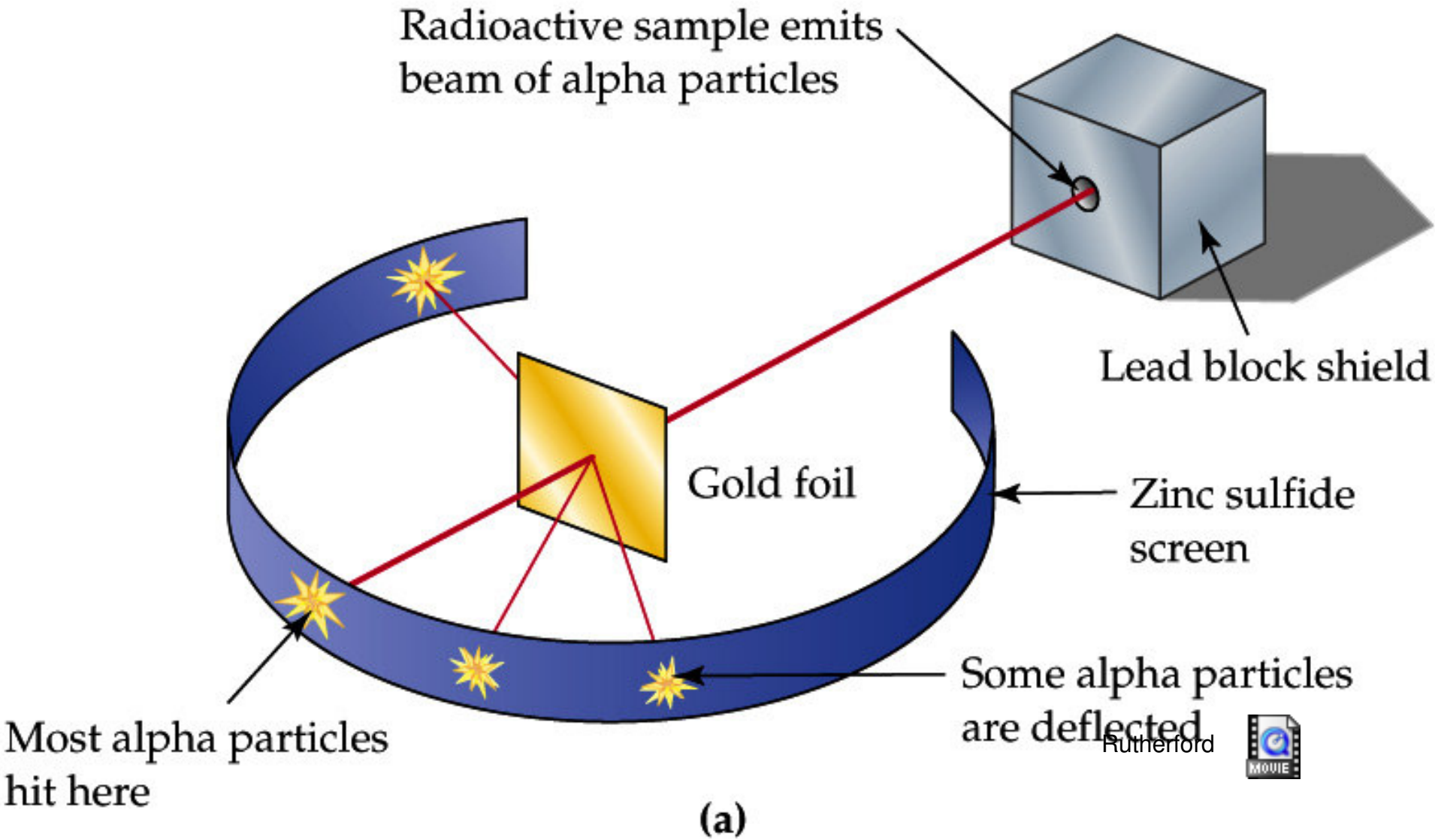
RUTHERFORD'S EXPERIMENTS

Determined the

_____ of ATOMS

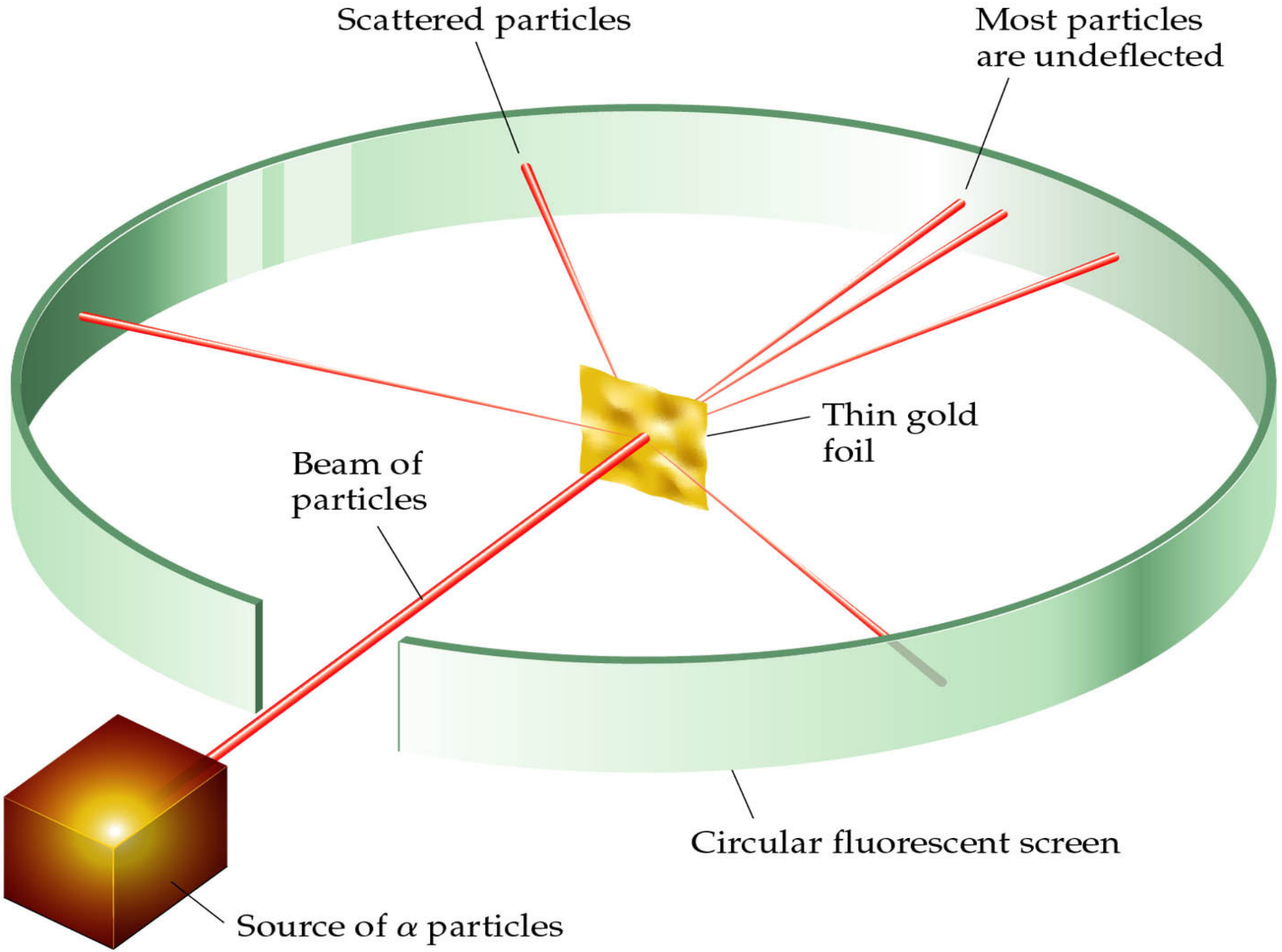
PROTONS and NEUTRONS

Discovery of Nucleus *(Rutherford, 1871 – 1937)*

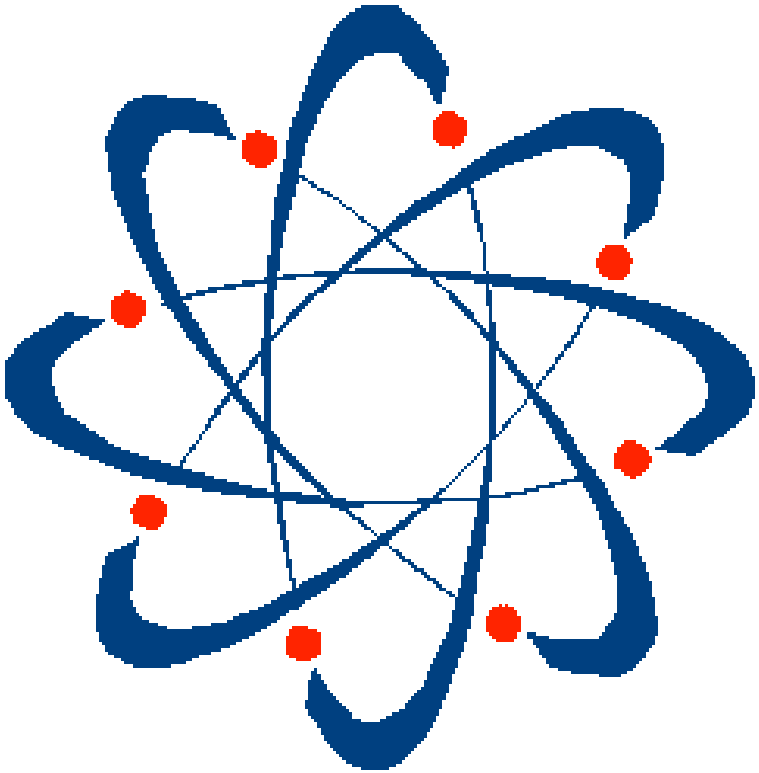


CONCLUSION OF RUTHERFORD'S EXPERIMENTS

Gold Foil is Mostly


Scattered particles
Most particles are undeflected
Thin gold foil
Beam of particles
Circular fluorescent screen
Source of α particles

The Modern View of Atomic Structure



The Nucleus,

containing

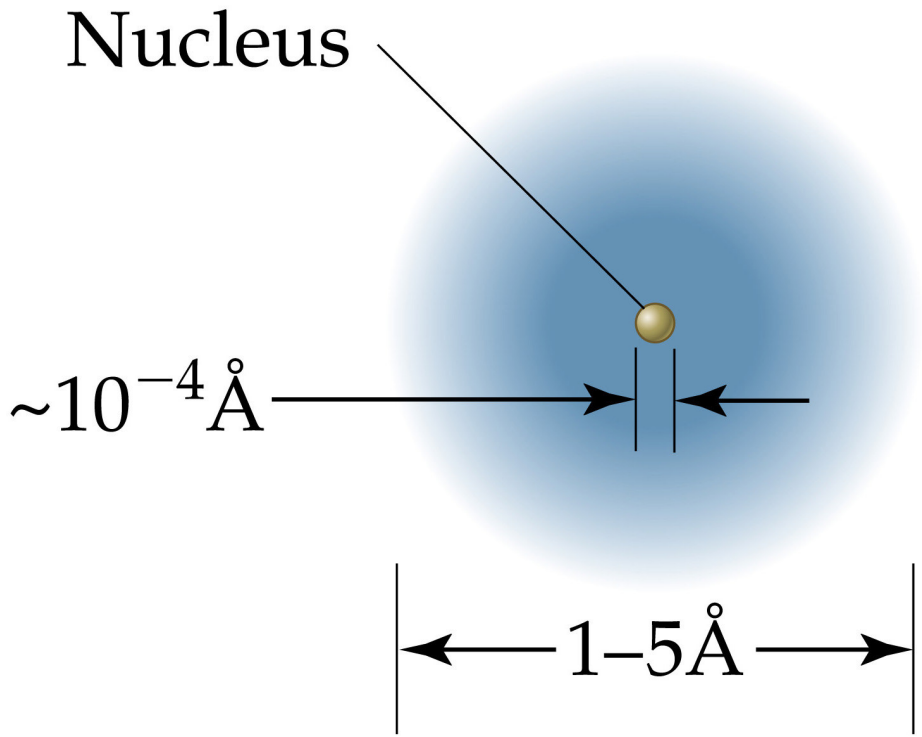
_____

(*protons* an *neutrons)*

is surrounded

by _____

Atomic Number (Z): Number of protons
Mass Number (A): Number of protons + neutrons



What is Å

1 Å = 1×10^{-10} meters

Weight of ATOMIC PARTICLES

Name	Charge	Mass (grams)
• **Proton**	**+1**	**1.66×10^{-24}**
• **Neutron**	**0**	**1.67×10^{-24}**
• **Electron**	**-1**	**9.11×10^{-28}**

The Atomic Mass Unit **(amu)**

- defined as one–twelfth the mass of an atom of $^{12}_{6}C$ and is equal to 1.66054×10^{-24}g.

- Also known as the **Dalton (Da)**

Relative Weight of Atomic Particles

Name	Charge	Mass (amu)
Proton	**+1**	**1**
Neutron	**0**	**1**
Electron	**-1**	**0**

Atomic Weights

Using atomic mass units:

$$1 \text{ amu} = 1.66054 \times 10^{-24} \text{ g}$$

$$1 \text{ g} = 6.02214 \times 10^{23} \text{ amu}$$

Atomic Mass & Molar Mass

- **Atomic Mass**: A weighted _____ of the isotopic masses of an element's naturally occurring isotopes.

- **Molar Mass:** The _____ mass of one _____ of any substance.

THE ATOMIC MASS SCALE

By definition mass of ^{12}C = exactly 12 amu

<u>Using atomic mass units:</u>

1 amu = 1.66054×10^{-24} g

1 g = 6.02214×10^{23} amu

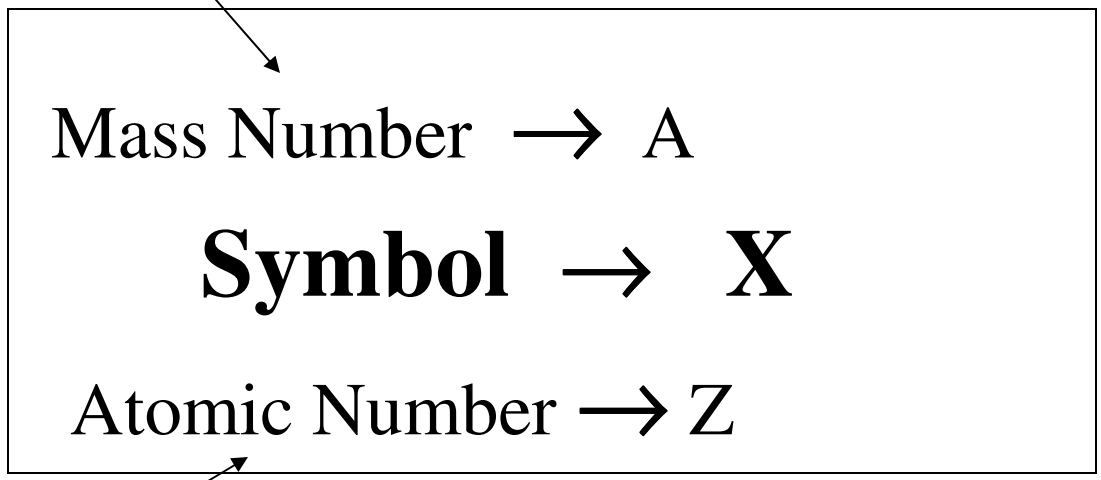
<u>Then</u>

^{1}H weighs 1.6735×10^{-24} g

^{16}O weighs 2.6560×10^{-23} g

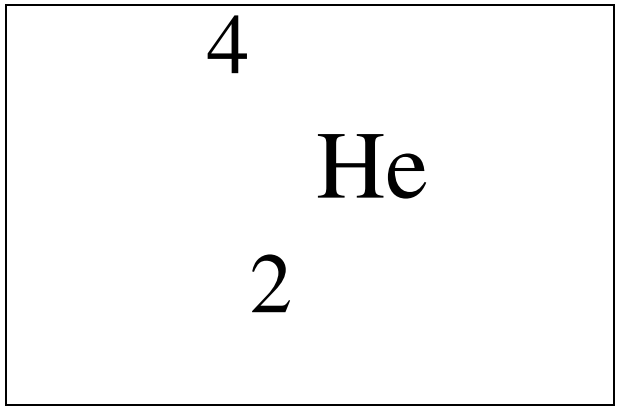
Notation For Atoms

Mass Number = Protons + Neutrons



Atomic Number = Number of Protons

Notation For Helium



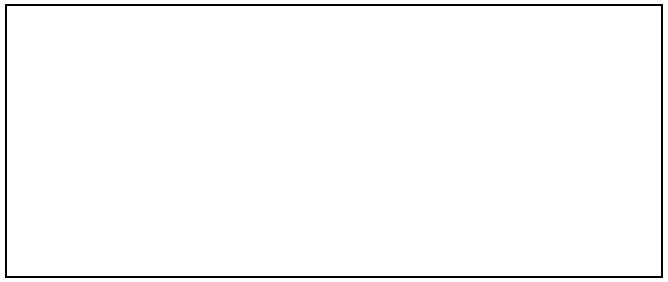
Number of Protons ? 2

Number of Neutrons ? 2

Number of Electrons ? 2

What is an ALPHA particle?

An α Particle is the Helium nucleus

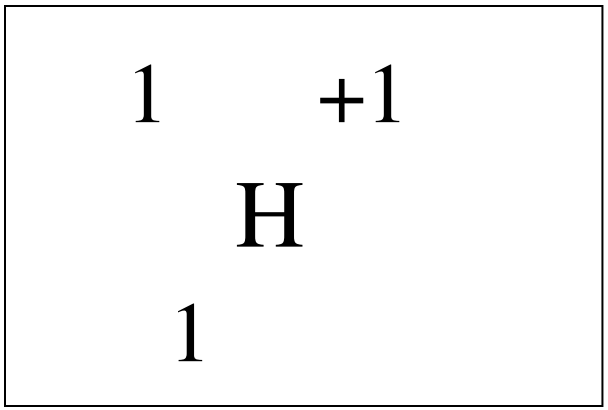


Number of Protons ? ……_____

Number of Neutrons ? ……_____

Number of Electrons ? ……_____

Notation For proton



Number of Protons ? _____

Number of Neutrons ? _____

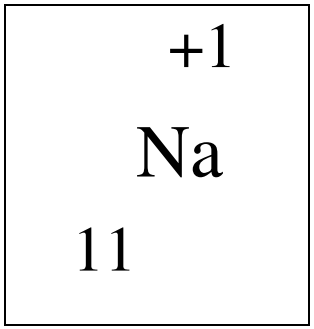
Number of Electrons ? _____

The Structure of Atoms

- The isotope $^{75}_{34}Se$ is used medically for diagnosis of pancreatic disorders. How many protons, neutrons, and electrons does an atom of Selenium 75 have?
- Protons = ?....._____
- Neutrons = ? ……._____
- Electrons = ? ……._____

Notation For Sodium Ion

Symbol for sodium	Na
Atomic Number	11
Number of Protons	11
Number of Neutrons	Unknown
Number of Electrons	10



Notation For Chloride Ion

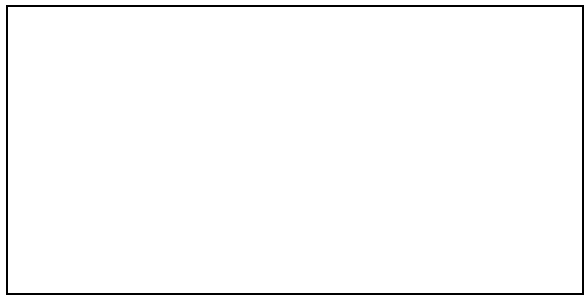
Symbol for Chlorine	Cl
Atomic Number	17
Number of Protons	17
Number of Neutrons	Unknown
Number of Electrons	18

$$^{17}_{\ }\mathrm{Cl}^{-1}$$

Identify the element that contains 47 protons and 61 neutrons.

47 protons = Atomic number

47 + 61 = 108 which is the Atomic Mass



What is the mass number of an isotope of mercury that has 122 neutrons?

(a) 120

(b) 80

(c) 200

(d) 202

ISOTOPES

Atoms with identical atomic numbers, but different mass numbers.

Isotopes of Hydrogen: $_{1}{}^{1}H$ $_{1}{}^{2}H$ $_{1}{}^{3}H$

Number of Protons ? ___. ___ ___

Number of Neutrons ? ___ ___ ___

Number of Electrons ? _ ___ ___ ____

Same Number of Protons, Different number of Neutrons

Isotopes of Carbon : $_{6}^{12}C$ $_{6}^{13}C$ $_{6}^{14}C$

Number of Protons ? ___ ____ ___

Number of Neutrons ? ___ ____ ___

Number of Electrons ? ___ ____ ____

Average Atomic Mass

Atomic weights are listed on the periodic table

A weighted average of the isotopic masses of an element's _____ occurring isotopes

Atomic weight is also known as average atomic mass (atomic weight).

AVERAGE ATOMIC MASSES

Naturally occurring Isotopes of Carbon are ^{12}C and ^{13}C

98.892 % ^{12}C and 1.108 % ^{13}C.

AVERAGE mass of C is therefore

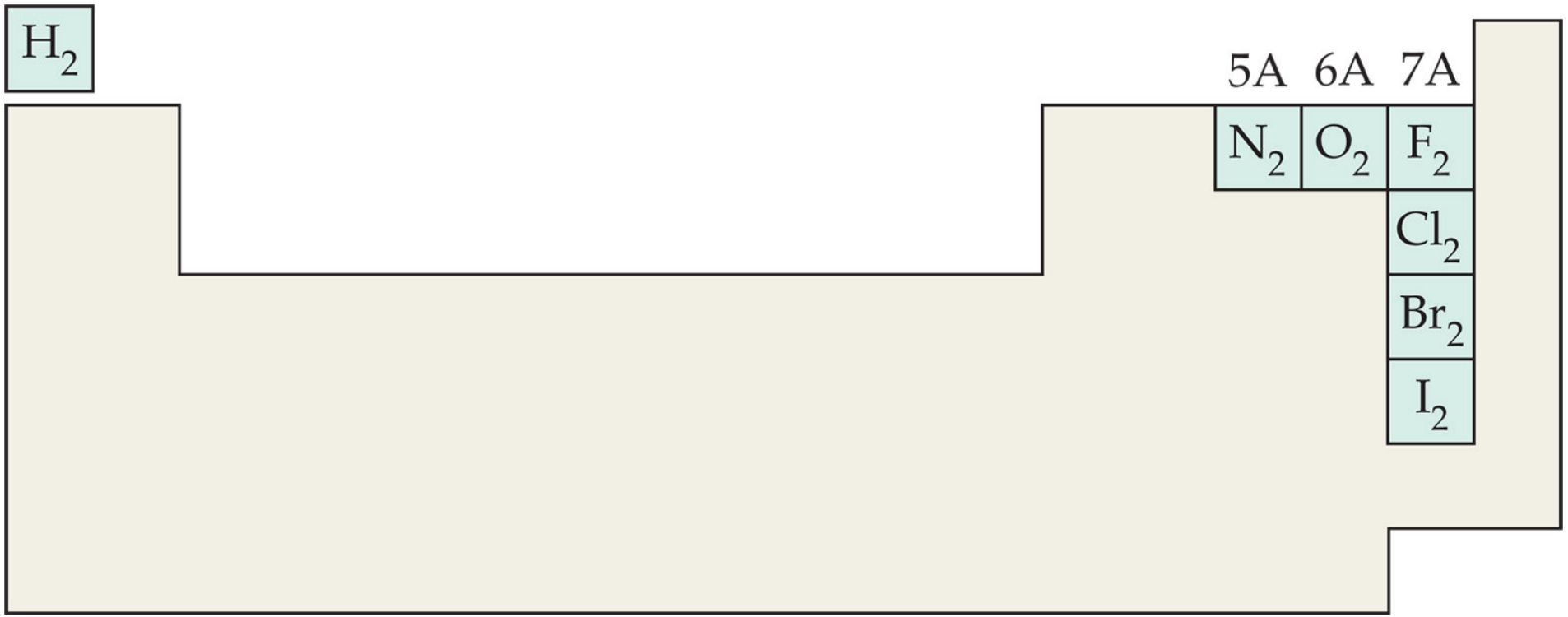
(0.98892)(12.000) + (0.0108)(13.00335) =

??????

Atoms , Elements & Compounds

- _____ The smallest representative particle of an Element
- _____ Are Fundamental Substances That Can Not Be Broken Down Chemically
- A _____ Is A PURE Substance Formed When TWO or More ELEMENTS Combine

Seven elements that occur naturally as Diatomic Molecules (two atoms)



Chemicals in Everyday Life

"Table" Salt	$NaCl$
"Peroxide"	H_2O_2
Household Ammonia	$NH_3(aq)$
Household bleach	$NaClO$
Baking Soda	$NaHCO_3$
Epsom Salt	$MgSO_4\ 7H_2O$
Milk of Magnesia	$Mg(OH)_2$
Vinegar	$HC_2H_3O_2(aq)$

CORRECT NAMES

Sodium Chloride	$NaCl$
Hydrogen Peroxide	H_2O_2
Ammonium Hydroxide	$NH_3(aq)$
Sodium HypoChlorite	$NaClO$
Sodium bi Carbonate	$NaHCO_3$
Magnesium Sulfate	$MgSO_4\ 7H_2O$
Magnesium Hydroxide	$Mg(OH)_2$
Acetic Acid	$HC_2H_3O_2(aq)$

PERIODIC TABLE

Divided Into

ROWS …….. _____

& COLUMNS……_____

of

METALS

METALLOIDS

& **NONMETALS**

Periodic Table of the ELEMENTS

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											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	111	112						

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

Metals

Semimetals

Nonmetals

All of the following *except* _____ are metalloids.

(a) B

(b) As

(c) Al

(d) Ge

(e) Si

METALS & NON METALS

I. METALS

1. REPRESENTATIVE Metals

GROUP IA …… _____ Metals

GROUP IIA……_____ Metals

2. TRANSITION Metals

II. NONMETALS

GROUP VIIA ……. HALOGENS

GROUP VIIIA ……NOBLE GASES

Which of the following is a metal?

(a) S

(b) Si

(c) Sr

(d) Se

(e) P

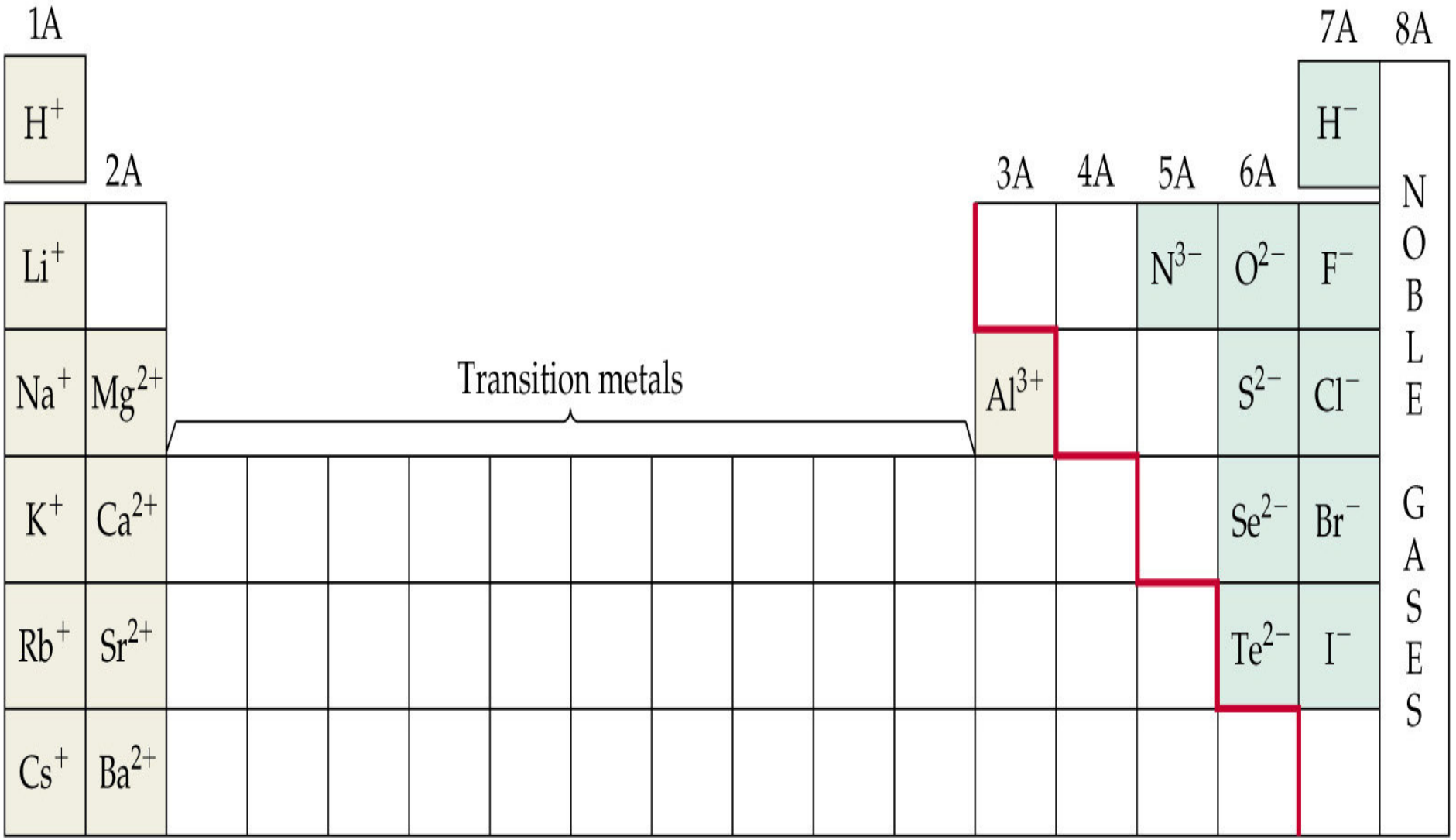
PREDICTING IONIC CHARGE

- The number of electrons an atom loses is related to its _____ on the periodic table

metal atoms *tend to* ____ _____ *to form cations (positive ions)*

nonmetal atoms *tend to* ____ _____ *to form anions* (negative ions)

Predicting Ionic Charge



Can you count to three (3) ?

+1 +2 +3

Now can you count to three BACKWARDS

-1 -2 -3

Ions With a +1 Charge

H^{+1} ……Hydrogen Ion

Li^{+1} …… Lithium Ion

Na^{+1} ……Sodium Ion

K^{+1} ……Potassium Ion

Rb^{+1} ……Rubidium Ion

Cs^{+1} ……Cesium Ion

Ag^{+1} …… Silver Ion

NH_4^{+1} ……Ammonium Ion

Ions With a +2 Charge

Be^{+2} ..... Beryllium Ion

Mg^{+2} ..... Magnesium Ion

Ca^{+2} ..... Calcium Ion

Sr^{+2} ..... Strontium Ion

Ba^{+2} .....Barium Ion

Zn^{+2} ..... Zinc Ion

TABLE 2.4 Common Cations

Charge	Formula	Name	Formula	Name
1+	H^+	Hydrogen ion	NH_4^+	Ammonium ion
	Li^+	Lithium ion	Cu^+	Copper(I) or cuprous ion
	Na^+	Sodium ion		
	K^+	Potassium ion		
	Cs^+	Cesium ion		
	Ag^+	Silver ion		
2+	Mg^{2+}	Magnesium ion	Co^{2+}	Cobalt(II) or cobaltous ion
	Ca^{2+}	Calcium ion	Cu^{2+}	Copper(II) or cupric ion
	Sr^{2+}	Strontium ion	Fe^{2+}	Iron(II) or ferrous ion
	Ba^{2+}	Barium ion	Mn^{2+}	Manganese(II) or manganous ion
	Zn^{2+}	Zinc ion	Hg_2^{2+}	Mercury(I) or mercurous ion
	Cd^{2+}	Cadmium ion	Hg^{2+}	Mercury(II) or mercuric ion
			Ni^{2+}	Nickel(II) or nickelous ion
			Pb^{2+}	Lead(II) or plumbous ion
			Sn^{2+}	Tin(II) or stannous ion
3+	Al^{3+}	Aluminum ion	Cr^{3+}	Chromium(III) or chromic ion
			Fe^{3+}	Iron(III) or ferric ion

Ions With a - 1 Charge

F^{-1}	Fluoride Ion
Cl^{-1}	Chloride Ion
Br^{-1}	Bromide Ion
I^{-1}	Iodide Ion
CN^{-1}	Cyanide Ion
OH^{-1}	Hydroxide Ion
NO_3^{-1}	Nitrate Ion
$C_2H_3O_2^{-1}$	Acetate Ion

TABLE 2.5 Common Anions

Charge	Formula	Name	Formula	Name
1−	H^-	Hydride ion	$C_2H_3O_2^-$	Acetate ion
	F^-	Fluoride ion	ClO_3^-	Chlorate ion
	Cl^-	Chloride ion	ClO_4^-	Perchlorate ion
	Br^-	Bromide ion	NO_3^-	Nitrate ion
	I^-	Iodide ion	MnO_4^-	Permanganate ion
	CN^-	Cyanide ion		
	OH^-	Hydroxide ion		
2−	O^{2-}	Oxide ion	CO_3^{2-}	Carbonate ion
	O_2^{2-}	Peroxide ion	CrO_4^{2-}	Chromate ion
	S^{2-}	Sulfide ion	$Cr_2O_7^{2-}$	Dichromate ion
			SO_4^{2-}	Sulfate ion
3−	N^{3-}	Nitride ion	PO_4^{3-}	Phosphate ion

Ions combine to form *NEUTRAL* compounds

- **Metals + Nonmetals**

For Example **NaCl Sodium Chloride**

and **$FeCl_3$ Iron (III) Chloride**

- **Nonmetals + Nonmetals**

For Example **CO Carbon Monoxide**

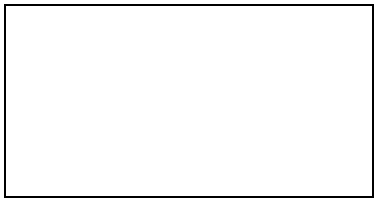
and **CO_2 Carbon Dioxide**

formula for Sodium Chloride

Sodium ion Na^{1+}

Chloride ion Cl^-

One Na^+ and one Cl^- combine to form

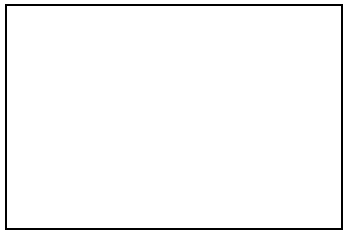


formula for Calcium Chloride

Calcium ion : Ca^{2+}

Chloride ion : Cl^-

One Ca^{2+} and two Cl^- combine to form

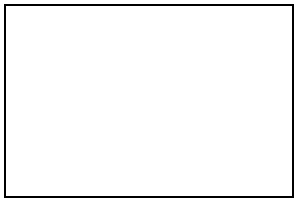


formula for Aluminum Chloride

Aluminum ion : $\mathbf{Al^{3+}}$

Chloride ion : Cl^-

One Al^{3+} and three Cl^- combine to form



Nonmetals + Nonmetals

Greek prefixes such as *mono–*, *di–*, or *tri–* Are used:

CO Carbon _____oxide

CO_2 Carbon _____oxide

SO_3 Sulfur _____oxide

CCl_4 Carbon _____chloride

TABLE 2.6 Prefixes Used in Naming Binary Compounds Formed Between Nonmetals

Prefix	Meaning
Mono-	1
Di-	2
Tri-	3
Tetra-	4
Penta-	5
Hexa-	6
Hepta-	7
Octa-	8
Nona-	9
Deca-	10

Naming Binary Ionic Compounds:

Identify the positive ion and then the negative ion.

- The positive ion uses its elemental name.
- The negative ion substitutes the second half of its elemental name with *–ide*.
- Do not use Greek prefixes such as *mono–*, *di–*, or *tri–*.

Names and Formulas of Binary Molecular Compounds

- **Binary compounds have _____ elements**
- **The most metallic element is _____ written first (i.e., the one to the farthest left on the periodic table). Exception: NH_3.**
- **If both elements are in the same group, the lower one is written first.**
- **Greek prefixes are used to indicate the number of atoms.**

ACIDS You Should Know

1. HCl (g) Hydrogen Chloride
2. HCl (aq) Hydro Chloric Acid
3. HNO_3 (aq) Nitric Acid
4. $HC_2H_3O_2$ (aq) Acetic Acid
5. H_2CO_3 (aq) Carbonic Acid
6. H_2SO_4 (aq) Sulfuric Acid
7. H_3PO_4 (aq) Phosphoric Acid
8. H_3BO_3 (aq) Boric Acid

Naming Inorganic Compounds

Polyatomic anions containing oxygen with additional hydrogens are named by adding hydrogen or **bi**- (one H), **di**hydrogen (two H), to the name as follows:

CO_3^{2-} is the carbonate anion

HCO_3^- hydrogen carbonate (or bicarbonate)

$H_2PO_4^-$ is the dihydrogen phosphate anion.

TABLE 2.4 Some Common Oxoacids and Their Anions

Oxoacid		Oxoanion	
HNO_2	Nitr*ous* acid	NO_2^-	Nitrite ion
HNO_3	Nitr*ic* acid	NO_3^-	Nitrate ion
H_3PO_4	Phosphor*ic* acid	PO_4^{3-}	Phosphate ion
H_2SO_3	Sulfur*ous* acid	SO_3^{2-}	Sulfite ion
H_2SO_4	Sulfur*ic* acid	SO_4^{2-}	Sulfate ion
HClO	*Hypo*chlor*ous* acid	ClO^-	Hypochlorite ion
$HClO_2$	Chlor*ous* acid	ClO_2^-	Chlorite ion
$HClO_3$	Chlor*ic* acid	ClO_3^-	Chlorate ion
$HClO_4$	*Per*chlor*ic* acid	ClO_4^-	Perchlorate ion

ORGANIC COMPOUNDS

Organic chemistry

the study of the chemistry of carbon compounds

Alkanes

contain only C and H and are called _____