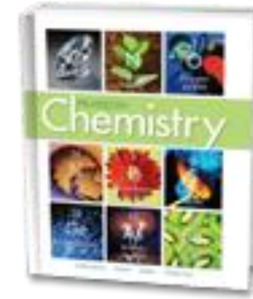
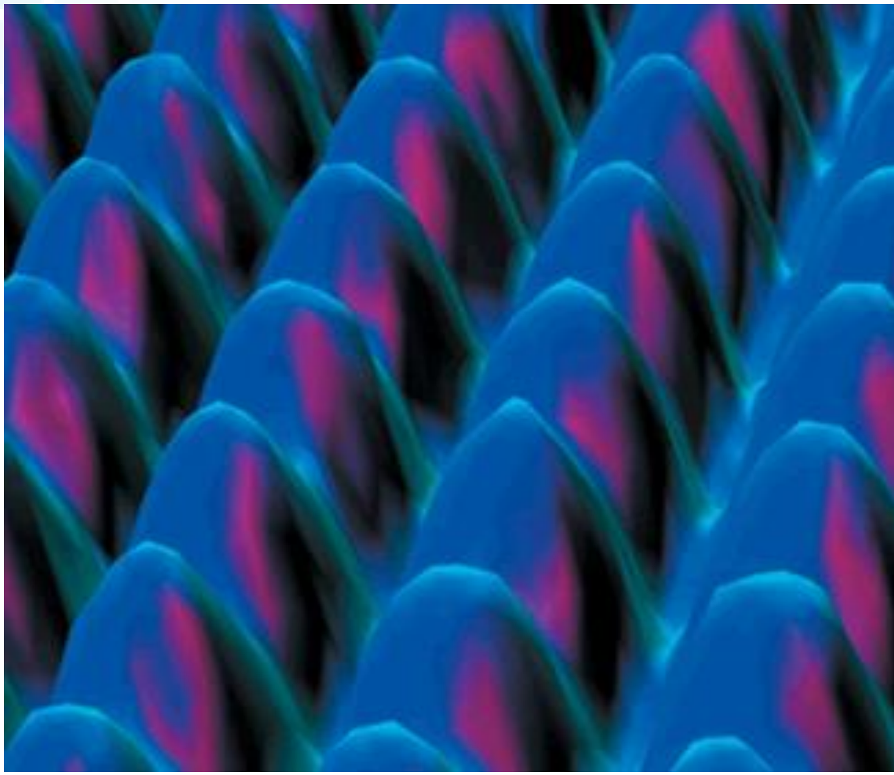




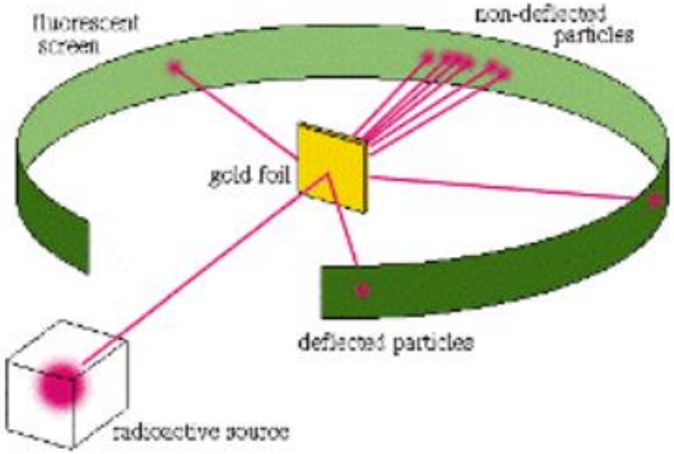
Chapter 4
Atomic Structure

Defining the Atom

Structure of the Nuclear Atom

Distinguishing Among Atoms

Atomic Structure Chapter 4



Topics:

1. Atomic Structure

Objectives:

1. Explain Atomic History from specific scientists perspectives (Democritus, Dalton, Thomson, Millikan, Goldstein, Chadwick, Rutherford).
2. Understand subatomic particles in a typical atom (charge, mass, location).
3. Explain what makes elements (atomic number, mass), use nuclear symbols, and understand isotopes.
4. Determine the weighted average of an element on the Periodic Table using relative abundance.

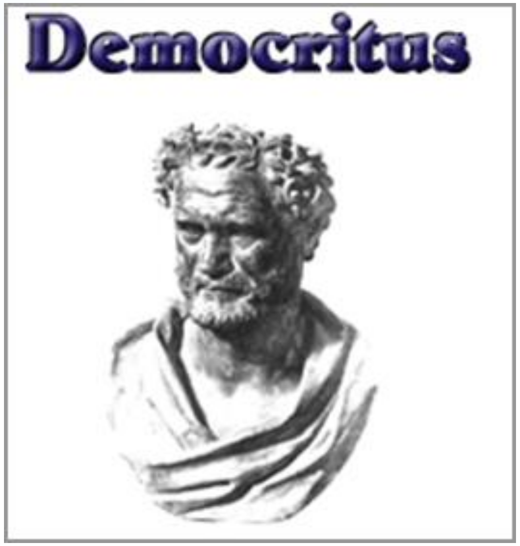
WARM-UP

Watch the video and consider what causes what you observe.

http://somup.com/cFQ22DVSKM

Light, sparks, pie tin, Styrofoam, toy (1:15)

Democritus



Greek philosopher (460 – 370 BC)

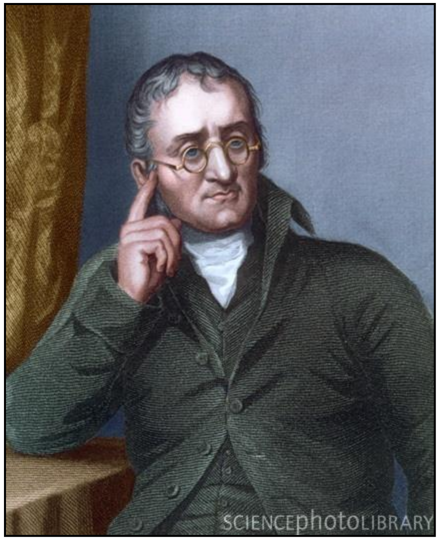
Coined the term "Atom"

"Matter consists of discrete, indivisible particles"

Democritus held a very general theory with <u>no experimental evidence</u>

Democritus' ideas were rejected by Plato & Aristotle (*fathers of <u>philosophy</u> and <u>ancient "scientific thinking</u>"*) … & therefore, set aside

John Dalton 1766-1844



Dalton's Atomic Theory (1808)

1. All elements are composed of extremely small, indivisible particles called "atoms."

2. All atoms of the same element have the same chemical properties. Atoms of different elements have different properties.

3. **In the course of an ordinary chemical reaction, no atom of one element disappears or is changed into an atom of another element.**

4. Compounds are formed when atoms are joined together in simple, whole-number ratios (*Law of "Multiple Proportions")*.

Dalton's Work

Forming Tin oxides

- Discovered that tin reacts with a fixed ratio of oxygen
  - 100 g tin reacts with 27 g (SnO) or 13.5 g oxygen (SnO_2) … [definite proportions]
- Oxygen is always consumed in a 1:2 ratio BETWEEN the compounds (multiple proportions).

SnO

SnO_2

Dalton's Work

Forming Tin oxides

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SnO

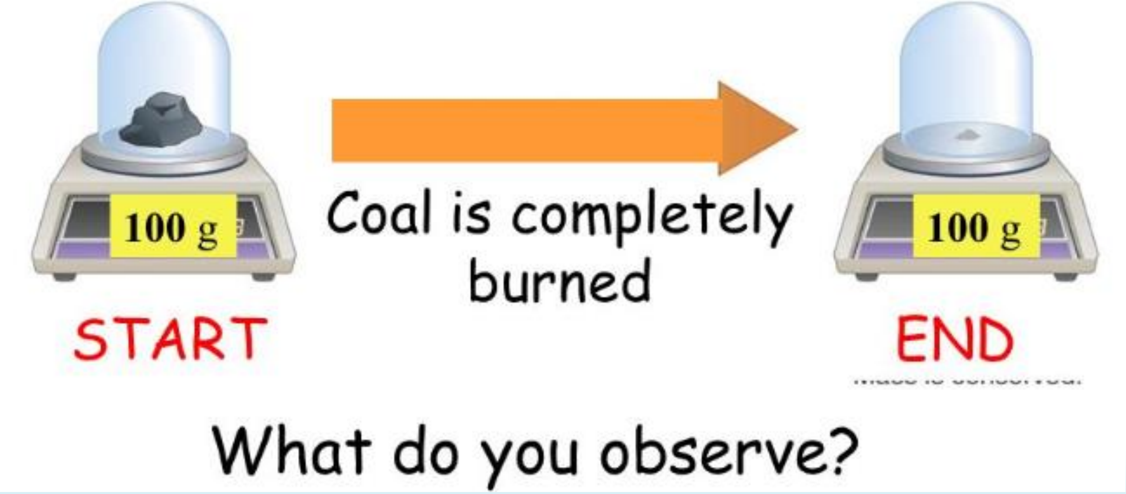
SnO_2

Each tin atom can combine with one or two oxygen atoms. The atoms cannot combine in any other ratios.

 Lavoisier, ~1770

The Law of Conservation Of Mass

- Matter cannot be created nor destroyed.
- There is no detectable change in mass in an ordinary chemical reaction.
    - All compounds/elements that react are just rearranging their atoms.



Take TWO separate pieces of acrylic tape ~ 7.5 cm long (3 inches).

Hold them "back" to "back" so the NON sticky sides are facing each other.

Bring them together slowly and observe.

Watch the video "Electrostatic Force"

http://somup.com/cF6elPnVza (2:59)

THINK ABOUT IT

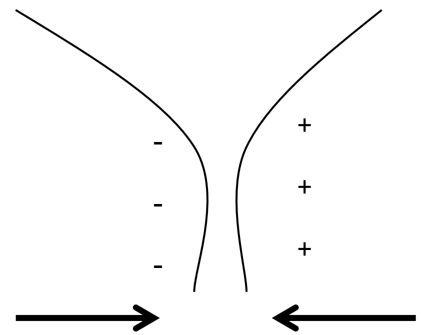
NOW, take TWO other separate pieces of acrylic tape ~ 7.5 cm long (3 inches).

Hold them by the ends and place one on top of the other on your table ***so that one sticks to the table & the other sticks to the NON sticky side of the one on the table*****.**

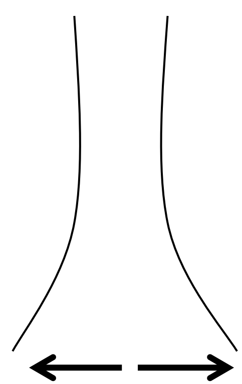
Pull the pieces off the table. Pull them apart and then bring them together slowly "back" to "back" & observe.

THINK ABOUT IT

In the first case you should have noticed "attraction"



In the second case, "Repulsion"



WHY?

Benjamin Franklin

Learned from experiments with thunderstorms, that lightning is a flow of electrical energy through the atmosphere.

He arbitrarily decided that there must be "charges" … and called them charge "A" and charge "B".

Electrons

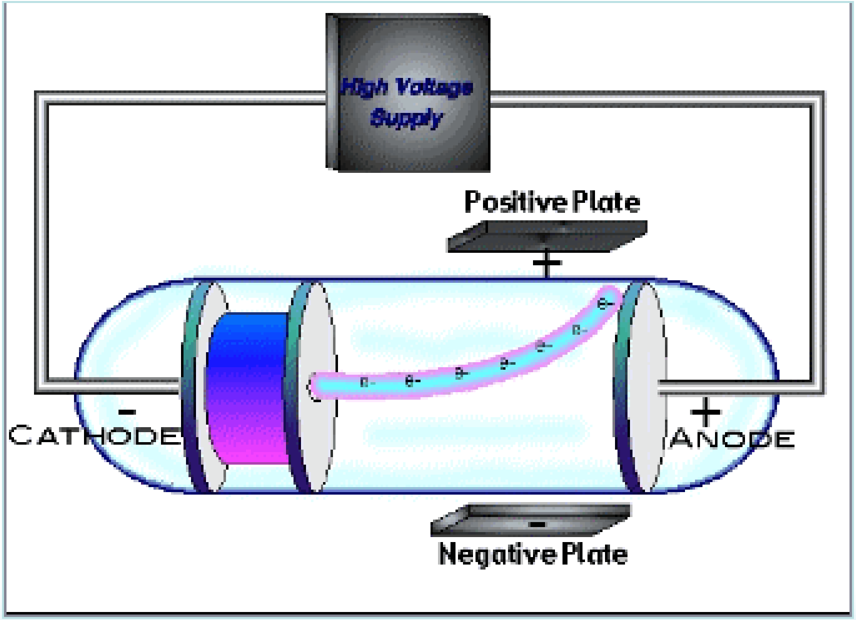
A "cathode ray" can also be deflected by a magnet.

http://somup.com/cF6eVJnVy6 (1:07)

Electron: J.J. Thomson

In 1897, JJ Thomson got the same result as Crookes with any gas he used, which contradicted Dalton's assumption that all atoms are indivisible.

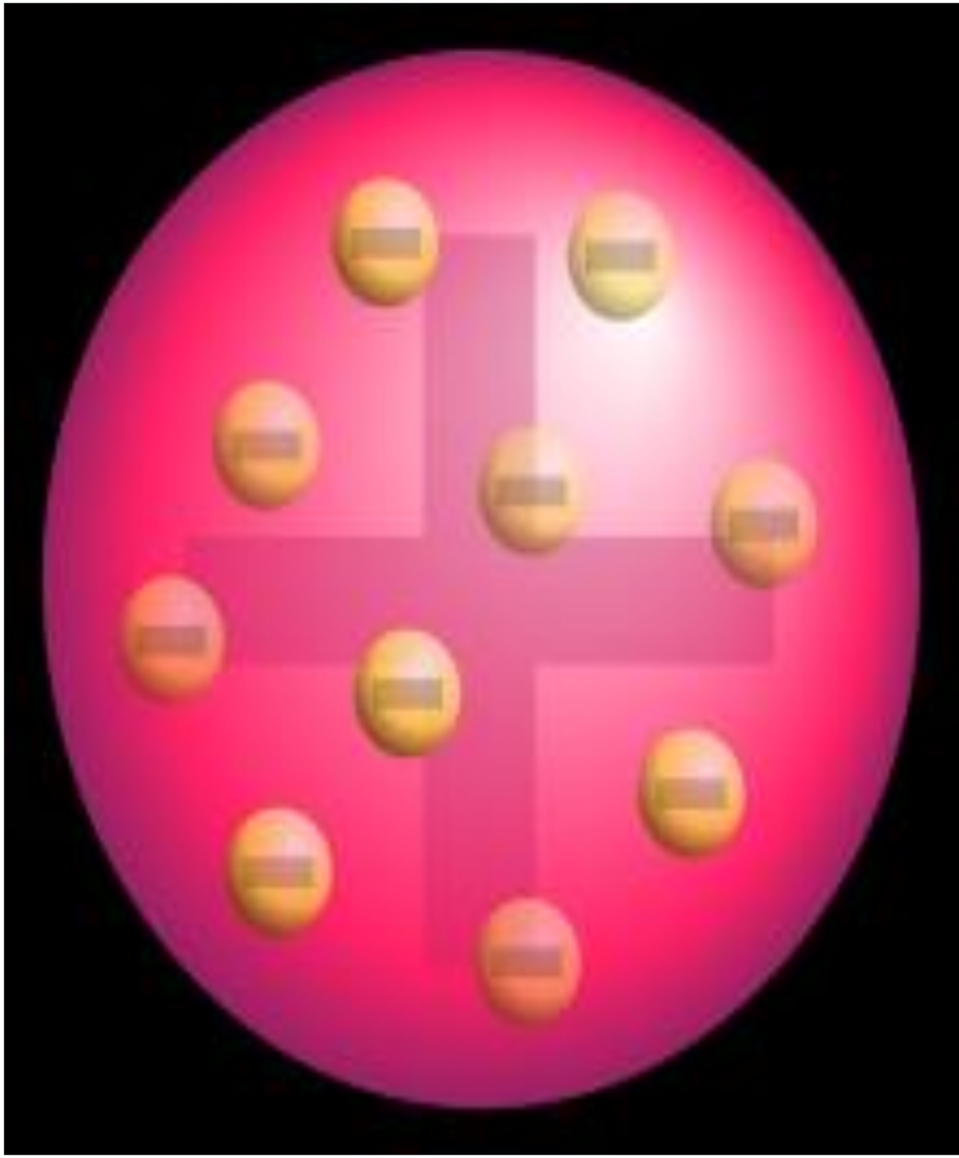
He theorized the existence of a particle common to all atoms → using the charged plates on either side of the tube, he showed the particle was negatively charged.



The Plum Pudding Model

Thomson's results led to the proposal of a new atomic model, the plum pudding model.

- **Electrons floating in a sea of positive charges**
- **Modification of Dalton's model of a solid, indivisible sphere**
- **Recognition of the existence of electrons and the neutrality of the whole atom**

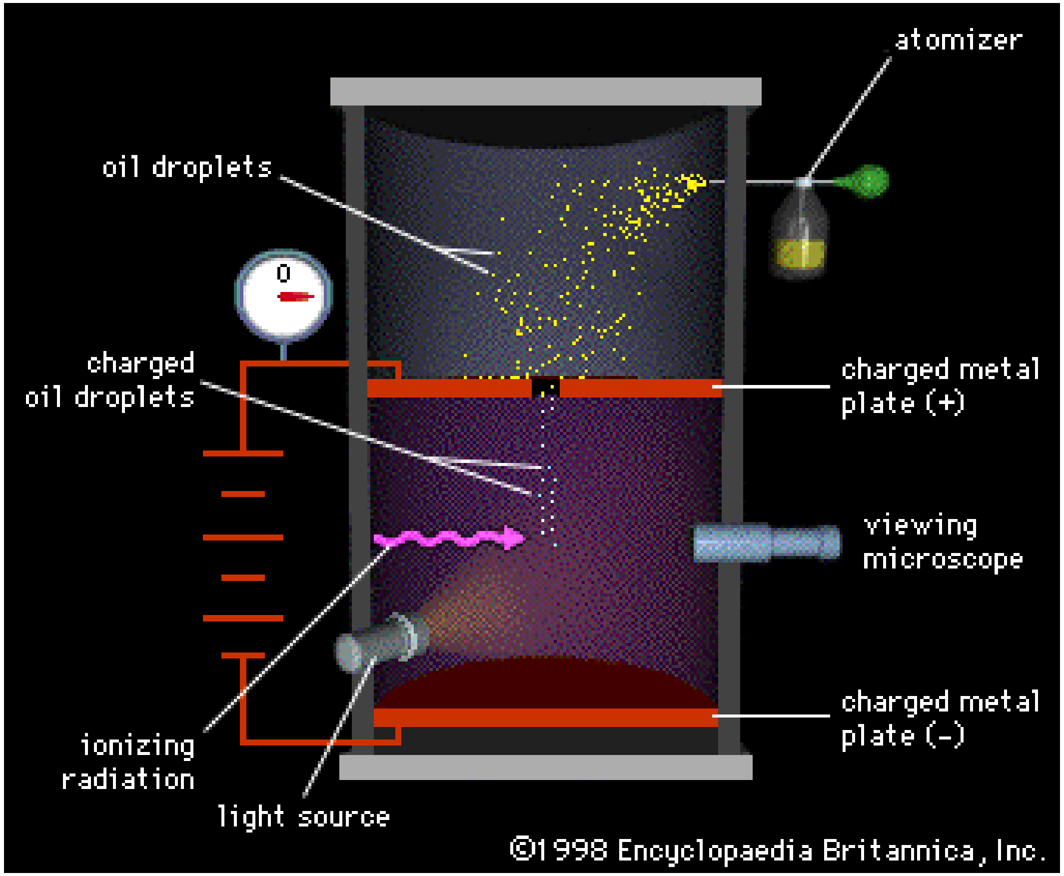


Millikan's Oil Drop Experiment

http://somup.com/cF6eVdnVyl (1:14)

Millikan repeatedly measured charges between the positive and negatively charged plates and found that they were always a multiple of 1.60×10^{-19} coulomb.

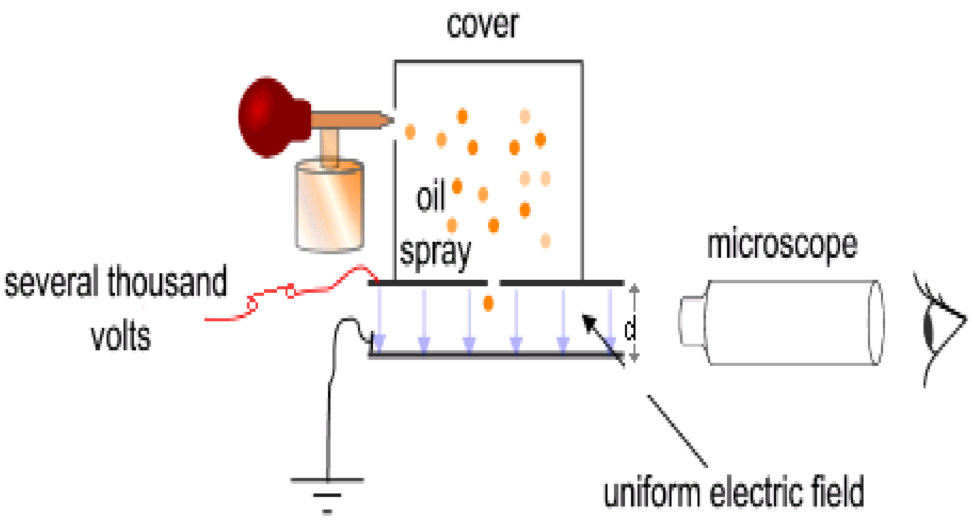
Millikan called this the **charge** on the **electron**.



Millikan's Oil Drop Experiment

Oil drop experiment

- Measured rate of fall of charged oil droplets.
- Determined the **charge** on an electron.
- Thomson's experiment: mass-to-charge ratio for an electron.



Millikan’s Oil Drop Experiment

Oil drop experiment

- Measured rate of fall of charged oil droplets
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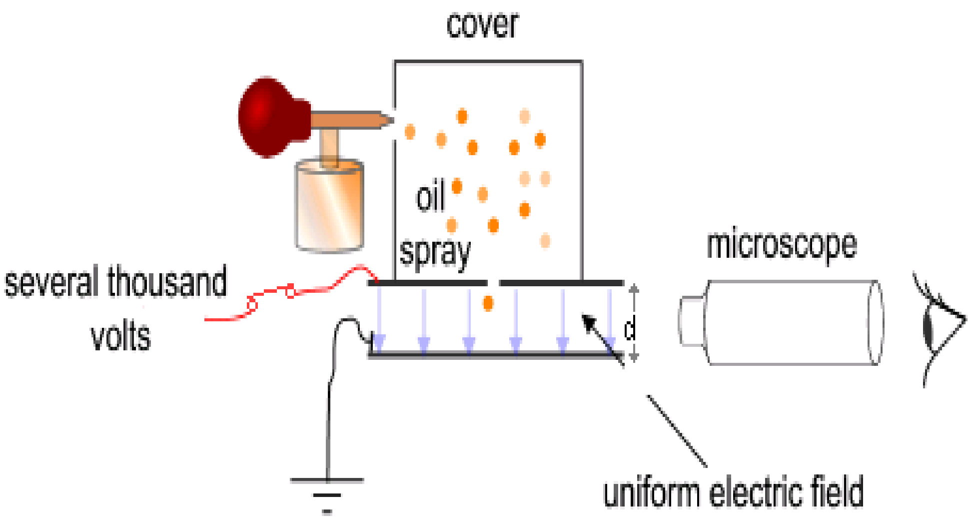


Together, Millikan’s and Thomson’s results allowed for the determination of the mass and charge of the electron.

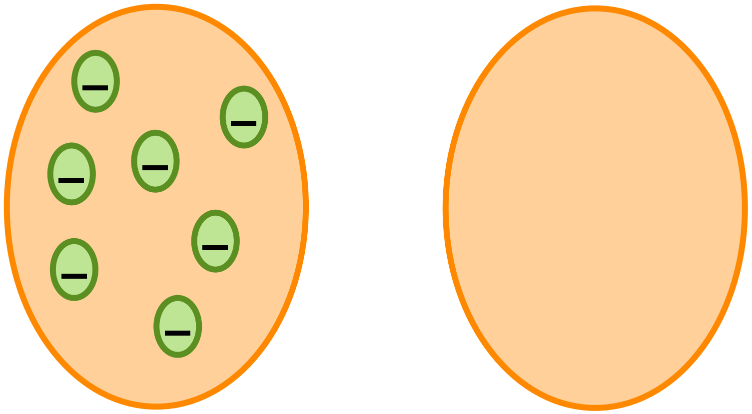
Modify the Theory

QUICK CHECK

The pictures show two different models of the atom.

Which model best represents Dalton’s atomic theory?

Which model best represents the modifications to the theory that Thomson’s results made necessary?



Model A

Model B

Modify the Theory

QUICK CHECK

The pictures show two different models of the atom.

Which model best represents Dalton's atomic theory?

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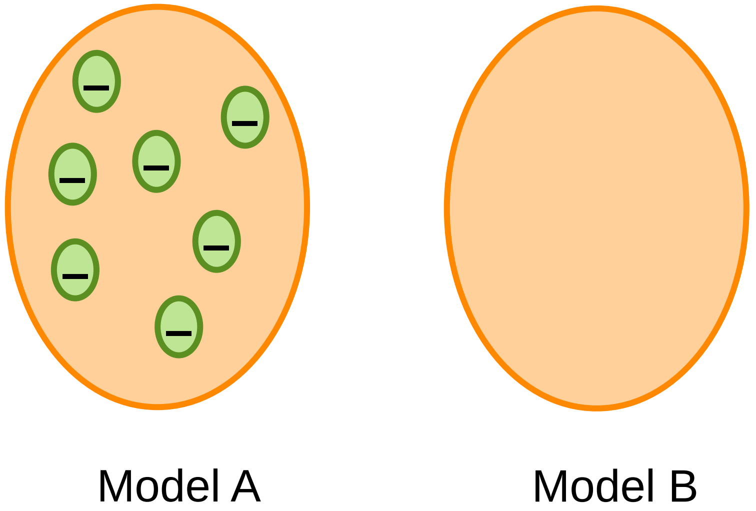


Thomson

"plum pudding"

Dalton

Indivisible particle

Testing the Plum Pudding Model

Ernest Rutherford (*right*) developed an experiment to test the plum pudding model of JJ Thomson (*left*).

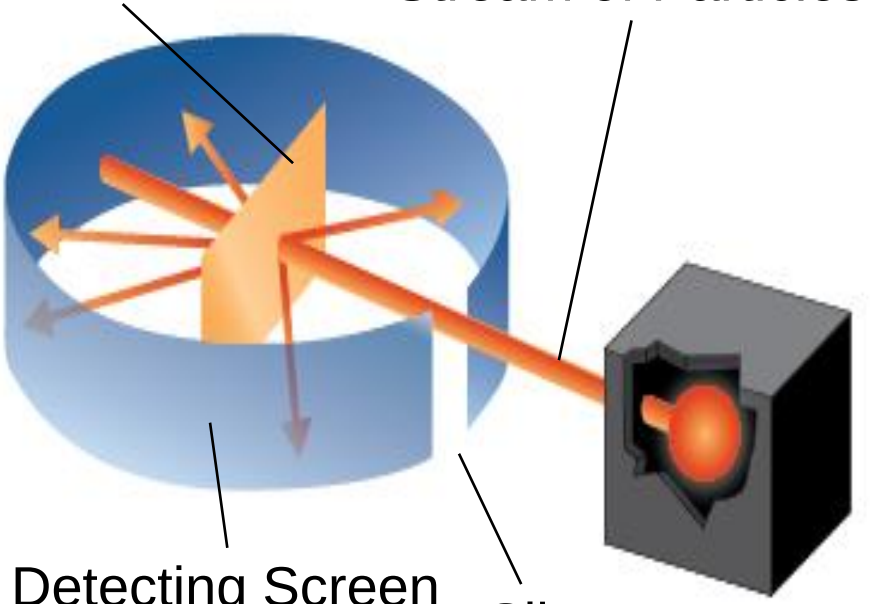
http://somup.com/cF6eVsnVyD
Empty space (0:48)

http://somup.com/cF6eVMnVyb
Rutherford (0:47)

Rutherford’s Experiment (1871–1937)

- He shot alpha particles (+) at a thin sheet of gold foil.

- Reflected particles are detected at various angles.



Rutherford's Results: Discovery of the Nucleus

- Most particles pass straight through gold foil (99%)
- **A few particles deflected at <u>very large angles</u> ???**

Conclusions:

- ?

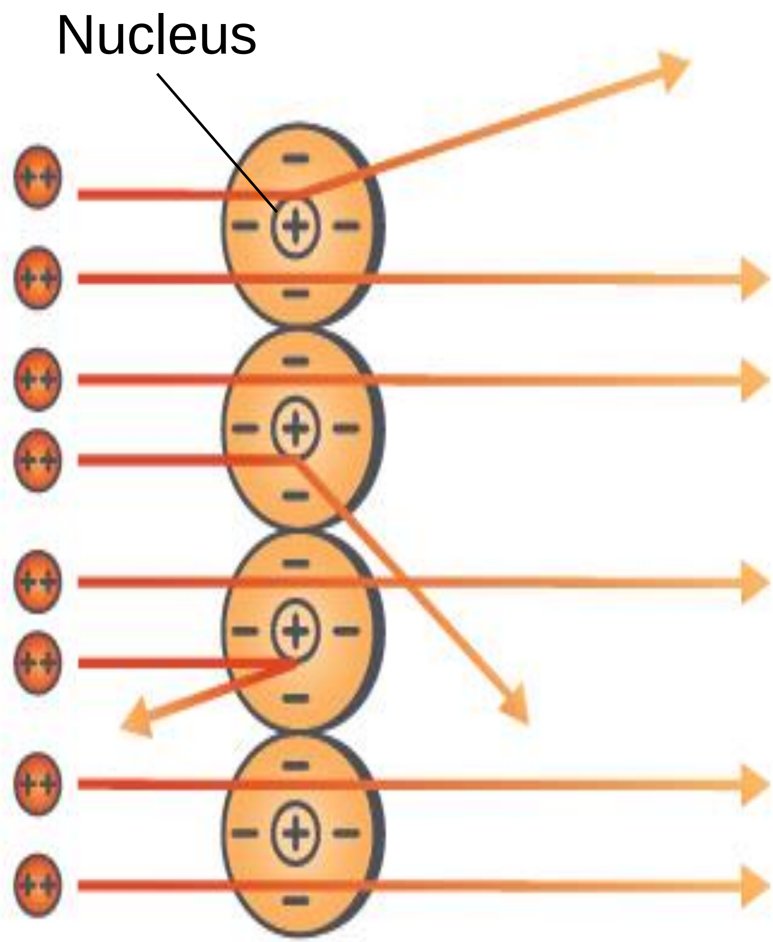


Diagram is not drawn to scale

Rutherford’s Results: Discovery of the Nucleus

- Most particles pass straight through gold foil (99%)
- **A few particles deflected at <u>very large angles</u> ???**

Conclusions:

- Atom: mostly empty space.
- Positive charge is concentrated in small, central region (nucleus).
- Volume of nucleus: small; mass: large.

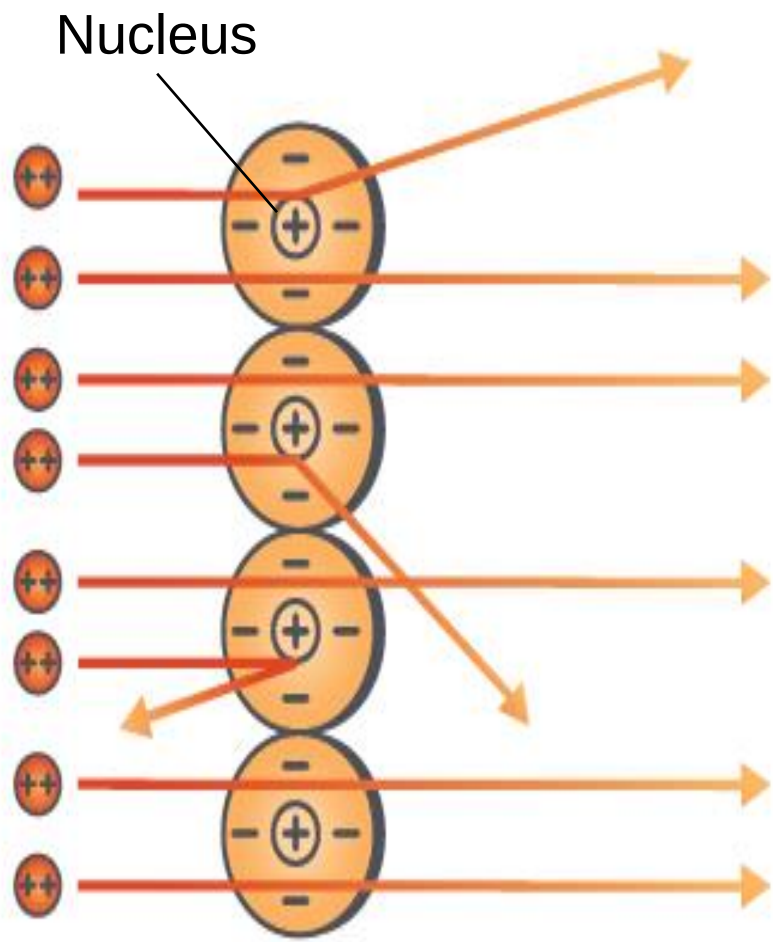
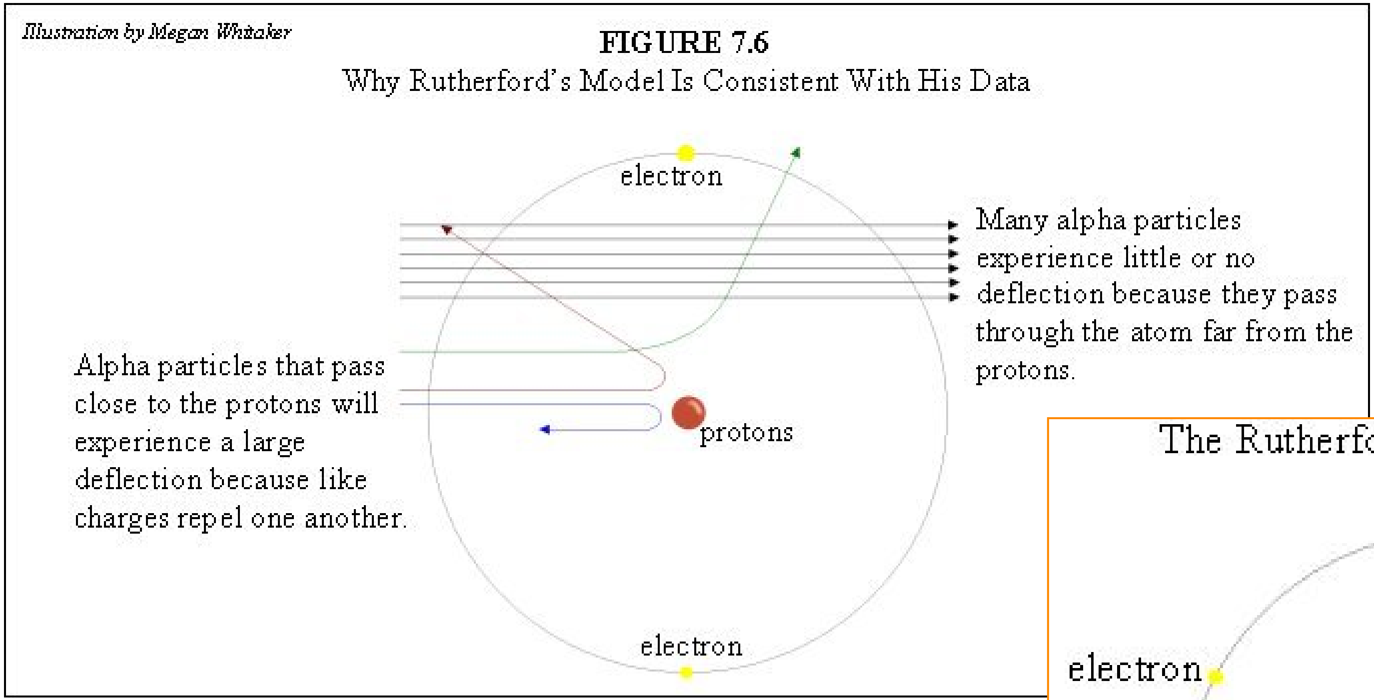
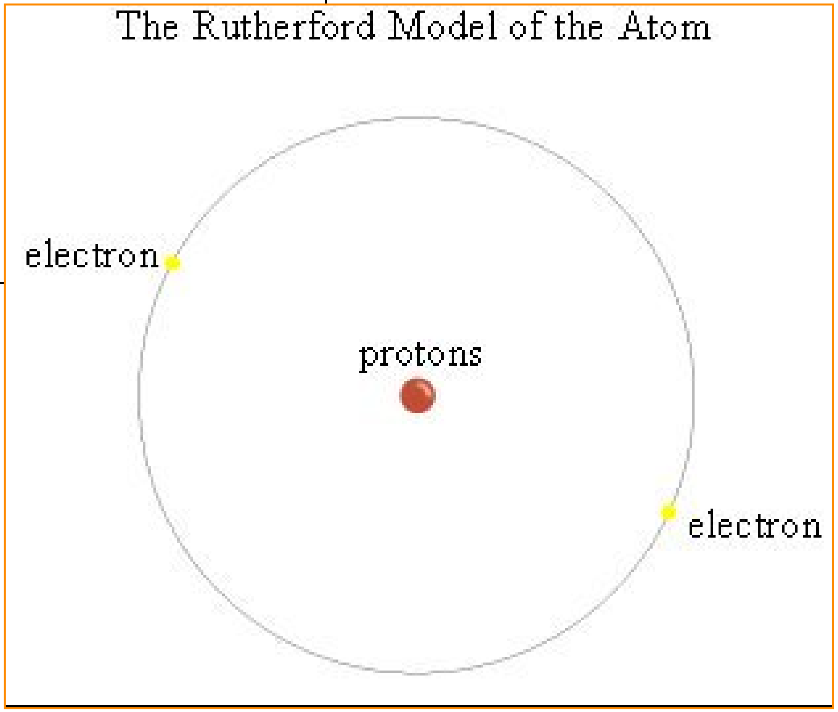


Diagram is not drawn to scale

Led to the Initial *Planetary* Model of the Atom





Dense, positive nucleus of atom orbited by electrons.

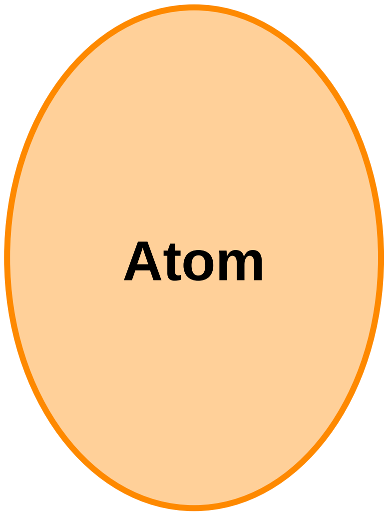
Relative Size of the Hydrogen Atom ENRICHMENT

Diameter of the ATOM ~ the size of Houston astrodome with a NUCLEUS the size of a marble

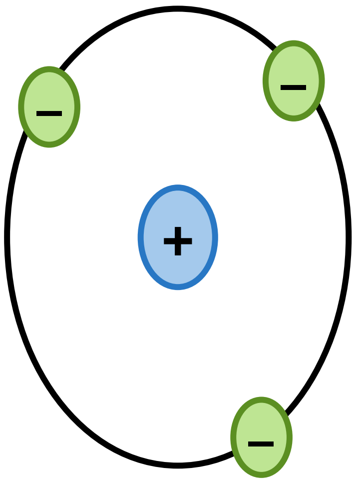
Modifying the Atomic Model

QUICK CHECK

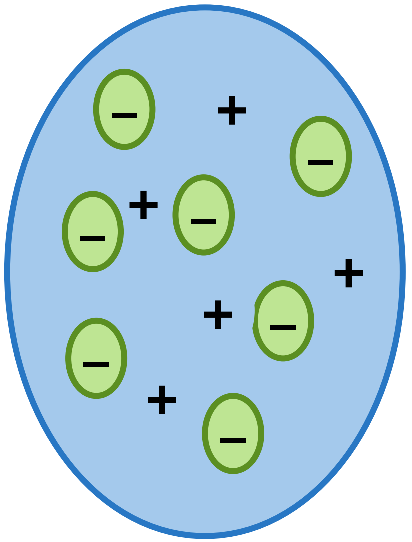
Place the models in chronological order and state who is responsible for each model (Dalton, Rutherford, Thomson)?



A



B

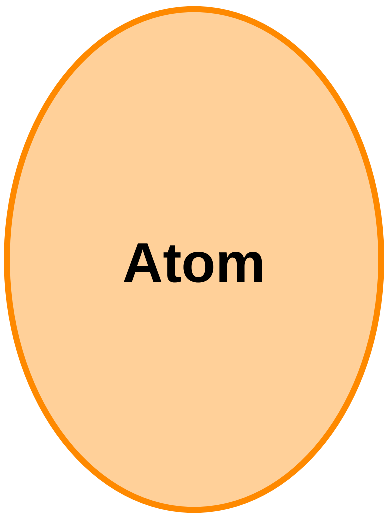


C

QUICK CHECK

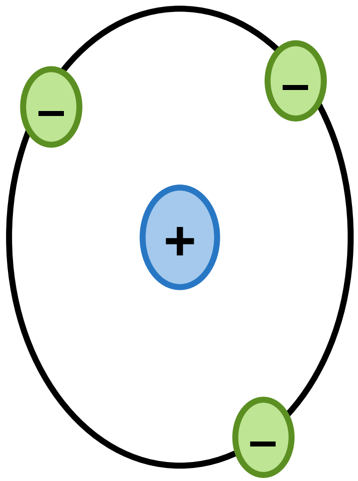
Modifying the Atomic Model

Place the models in chronological order and state who is responsible for each model (Dalton, Rutherford, Thomson)?



Dalton

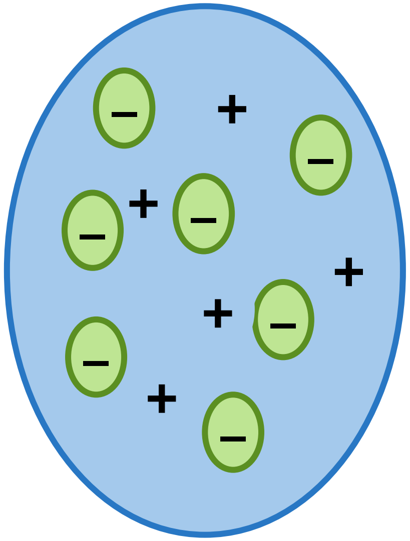
Indivisible particle



Rutherford

“nucleus”

(positive center) with orbiting electrons



Thomson

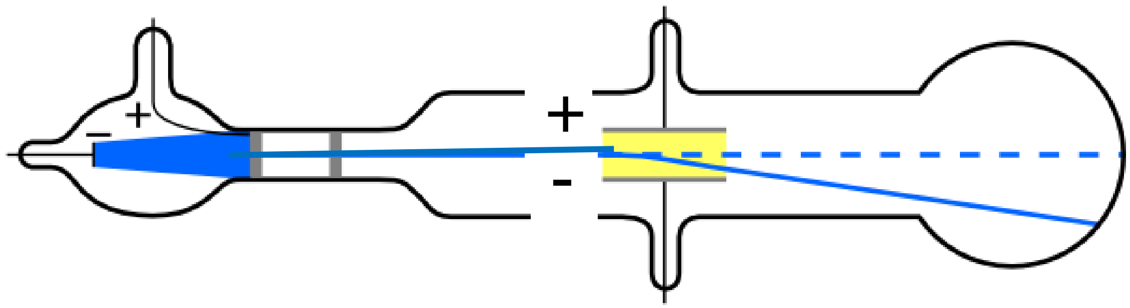
Plum pudding

Protons

In 1886, Eugen Goldstein (1850–1930) observed a cathode-ray tube to discover a new particle.

Protons were originally called “canal rays” in the CRT, electrons were called “cathode rays”.

“Canal Rays” responded opposite to the “cathode rays” (electrons) indicating an opposite charge.



Neutrons

Physicist James Chadwick (1891–1974) confirmed the existence of yet another subatomic particle: the neutron.

- Chadwick bombarded Beryllium with alpha particles and found a new particle was released.
- **No charge** (*did not deflect under electric or magnetic field influence*).
- Essentially the same mass as the proton.
- Highly penetrable particle (*could penetrate 10-20 cm into lead*).

Atomic Mass Unit

LESSON QUESTION

The **atomic mass unit** is the unit used to express the mass of an atom.

- One-twelfth the mass of a C-12 atom
- Corresponds to **$1.660538921 \times 10^{-24}$ g**

This table summarizes the properties of the subatomic particles.

Properties of Subatomic Particles				
Particle	**Symbol**	**Relative charge**	**Relative mass (mass of proton = 1)**	**Actual mass (g)**
Electron	e^-	1–	1/1840 amu	9.11×10^{-28}
Proton	p^+	1+	1 amu	1.66×10^{-24}
Neutron	n^0	0	1 amu	1.66×10^{-24}

Atom History Song

http://somup.com/cFQ22rVSKR

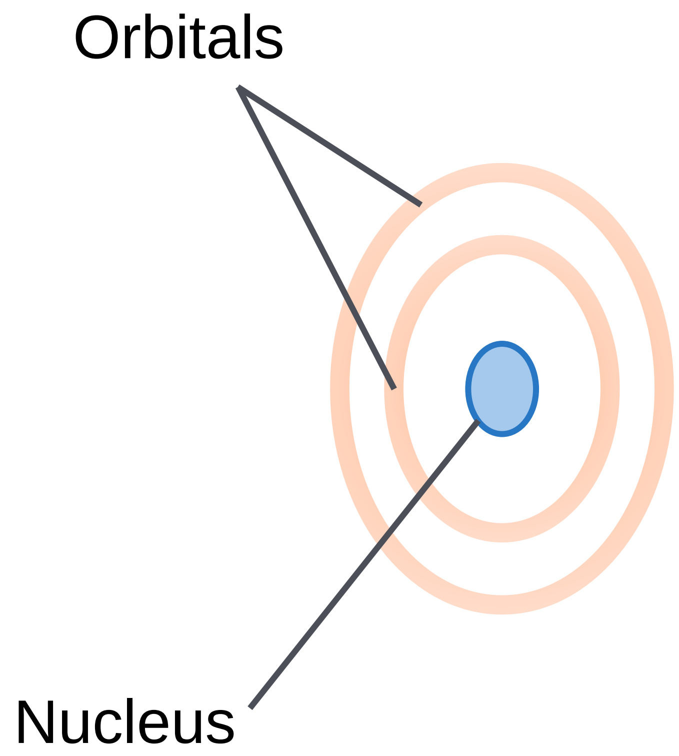
Mark Rosengarten Atom History (4:14)

The Atom

Atom is the smallest particle of an element that has the same properties as the element.

The atom can be divided into two parts:

- **Nucleus**: Central portion of the atom
- **Orbitals**: Regions surrounding the nucleus



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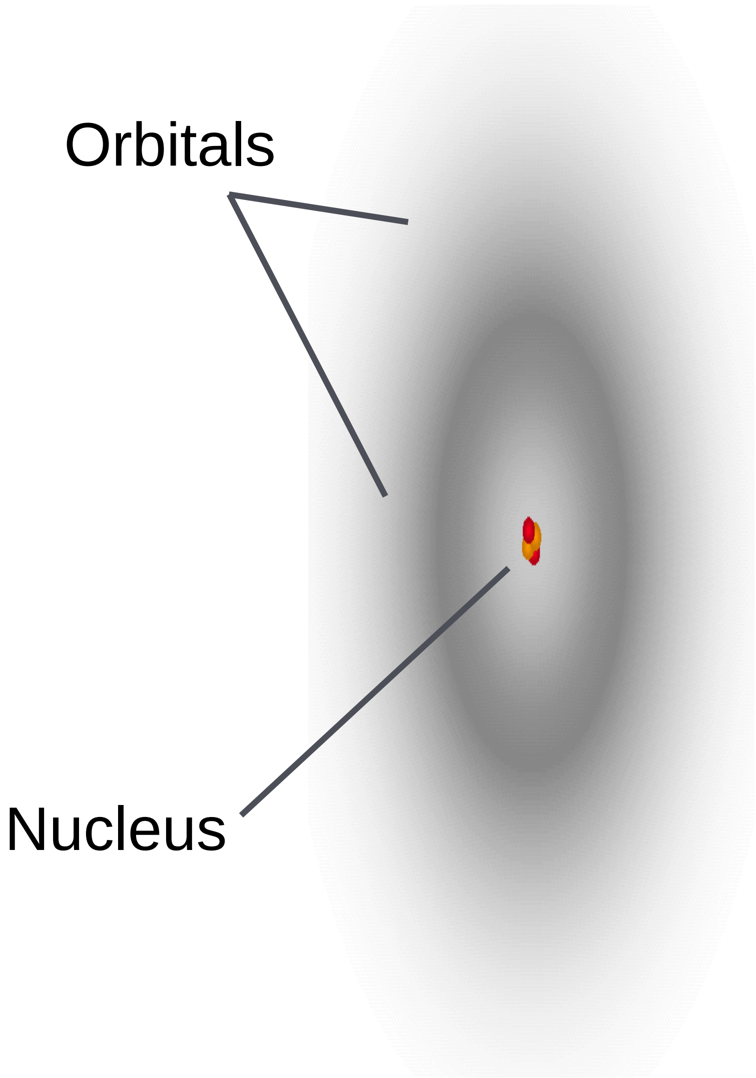
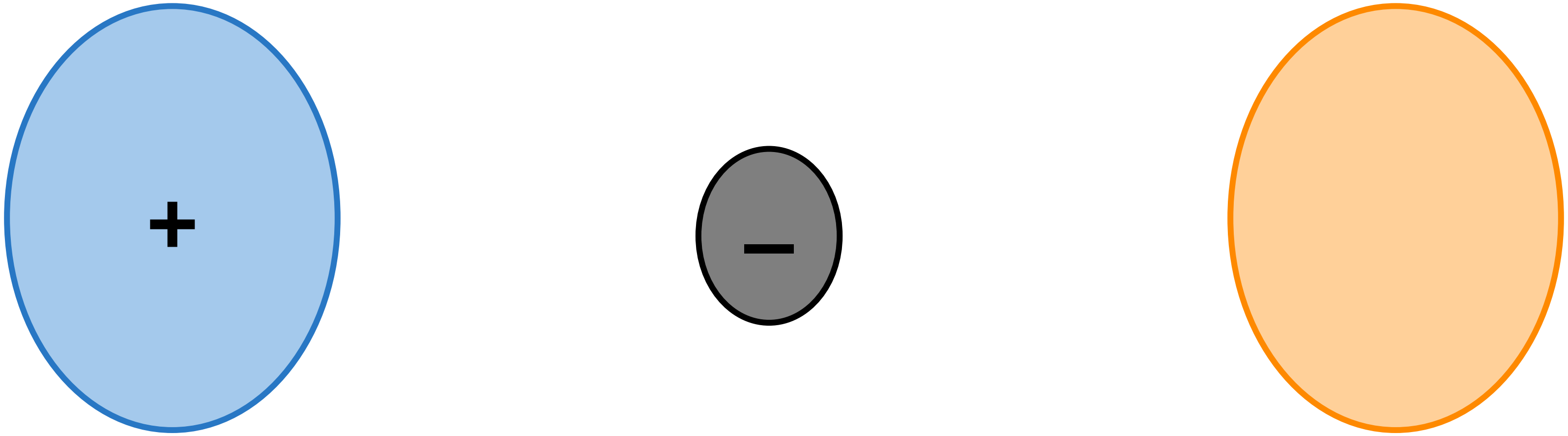


Charged Particles in the Atom

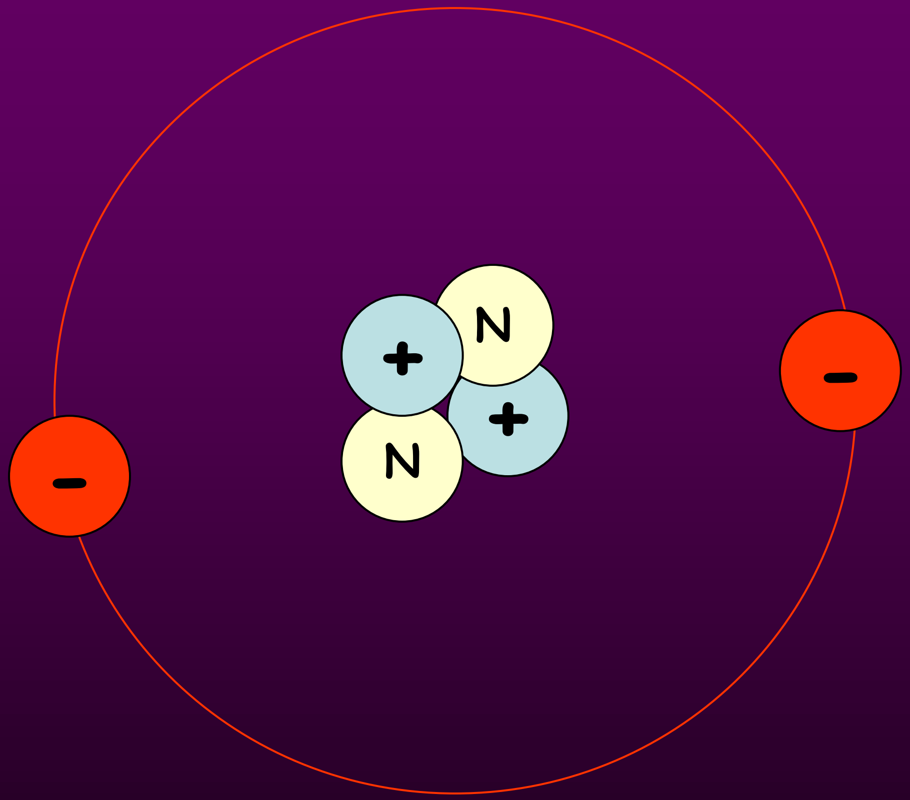
The atom is made of three particles: protons, electrons, and neutrons.



Protons are positively charged.

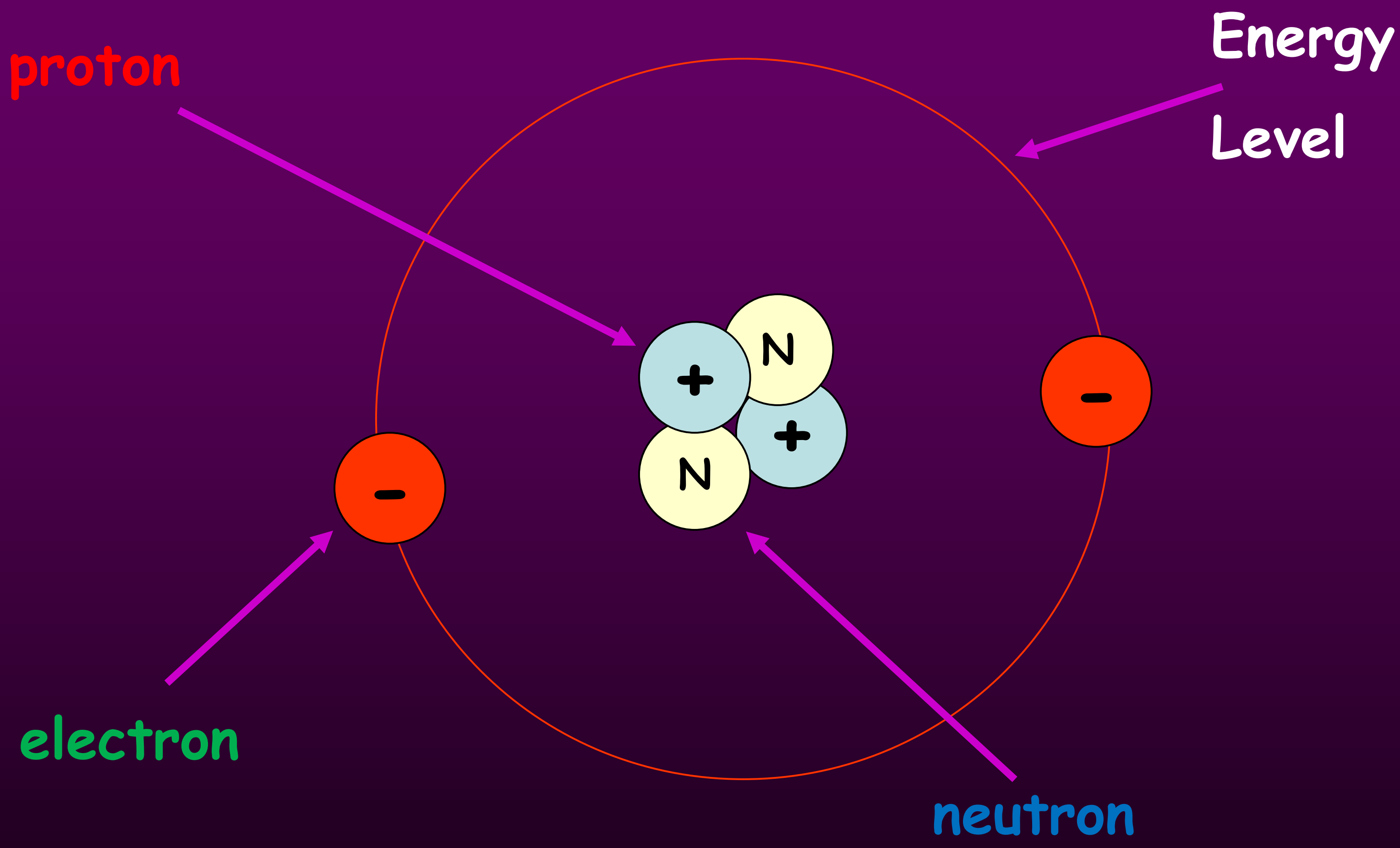
Electrons are negatively charged.

Neutrons are not charged.



Different elements have different particle counts and arrangements

HELIUM ATOM

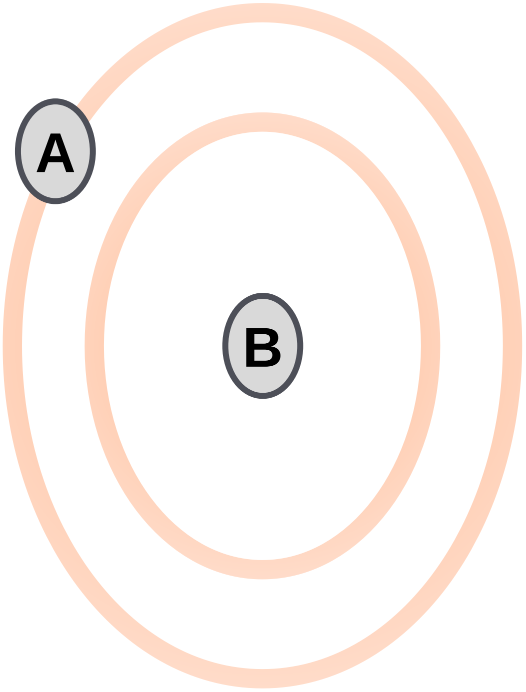


Different elements have different particle counts and arrangements

Determine the Locations of Subatomic Particles

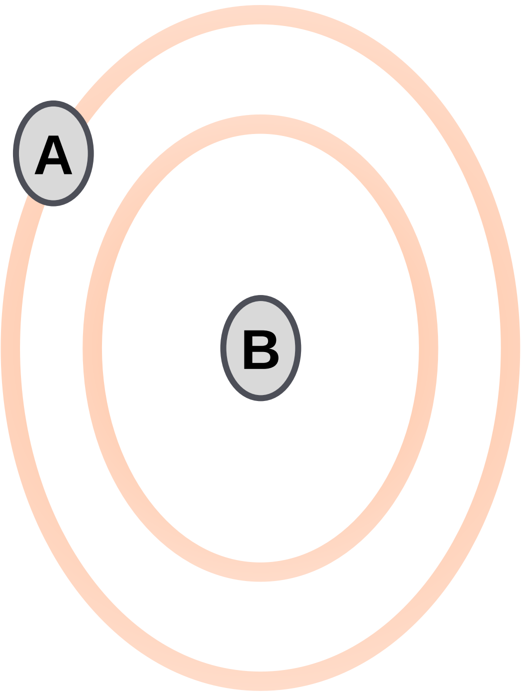
Type the name of the location of each particle.

Particle	Charge	Location	~Mass
?	+1	?	?
?	0	?	?
?	-1	?	?



Determine the Locations of Subatomic Particles

Particle	Charge	Location	Approximate mass (amu)
Proton	+1	Nucleus	1
Neutron	0	Nucleus	1
Electron	–1	Orbitals	0



What is the structure of the atom?

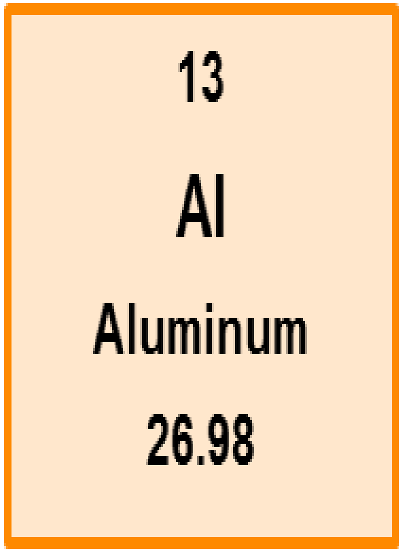
13	14	15
Al	Si	P
Aluminum	Silicon	Phosphorus
26.98	28.09	30.974

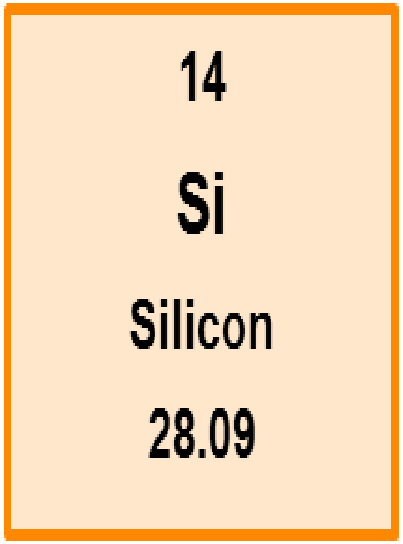
How do we distinguish atoms of different elements?

Atomic number

Atomic number (*Z*)

- Number of protons in an atom
- Differs for each element





Atomic number

Atomic number (*Z*)

- Number of protons in an atom
- Differs for each element

13	14
Al	**Si**
Aluminum	Silicon
26.98	28.09

Every atom of a given element has the same atomic number, and atomic number can be used to identify an element.

Mass number (A)

LESSON QUESTION

- Total number of protons + neutrons
- Usually varies from atom to atom

?

$^{27}_{13}Al$

?

neutrons = ?

Aluminum-27

- Al-27
- ^{27}Al

Mass number (A)

LESSON QUESTION

- Total number of protons + neutrons
- Usually varies from atom to atom

Mass number

$$^{27}_{13}\mathrm{Al}$$

Atomic number

Aluminum-27

- Al-27
- ^{27}Al

 # neutrons = A – Z

27 – 13 = **14 neutrons**

All atoms of an element have the same atomic number, but atoms of the same element can have different mass numbers.

"Nuclear Symbols"

LESSON QUESTION

Mass number

He

Atomic number

"Nuclear Symbols"

LESSON QUESTION

Mass number

$$_{2}\mathrm{He}$$

Atomic number 2

2 protons

"Nuclear Symbols"

LESSON QUESTION

Mass number 4

2 protons &
2 neutrons

$^{4}_{2}He$

Atomic number 2

2 protons

Due to Word Processing

LESSON QUESTION

Mass number

2 protons &
2 neutrons

He^{4}

Atomic number 2

2 protons

"Nuclear Symbols"

LESSON QUESTION

Mass number 4

2 protons &
2 neutrons

He

Atomic number 2

2 protons

In a neutral atom

number of electrons = number of protons

QUICK CHECK

Determining the Composition of an Atom

What is the atomic number (Z) and atomic mass (A) for each element? How many protons, electrons, and neutrons are in each atom?

$^{9}_{4}Be$ $^{20}_{10}Ne$ $^{23}_{11}Na$

QUICK CHECK

Determining the Composition of an Atom

How many protons, electrons, and neutrons are in each atom?

$^{9}_{4}Be$ $^{20}_{10}Ne$ $^{23}_{11}Na$

Use the definitions of atomic number and mass number to calculate the numbers of protons, electrons, and neutrons.

Beryllium (Be)
atomic number = 4
mass number = 9

Neon (Ne)
atomic number = 10
mass number = 20

Sodium (Na)
atomic number = 11
mass number = 23

Be has 4 **protons**, 5 **neutrons**, and 4 **electrons**

Ne has 10 **protons**, 10 **neutrons**, and 10 **electrons**

Na has 11 **protons**, 12 **neutrons**, and 11 **electrons**

Nuclear symbols are used by scientist as a standard way to represent elements, showing both the **atomic** and **mass numbers** ***[Which is which?]***

TRY IT

$$ {}_{1}H^{1} $$

Hydrogen has ? **proton**, ? **neutrons**, and ? **electron**

Nuclear symbols are used by scientist as a standard way to represent elements, showing both the atomic and mass numbers

mass number

$$_{1}H^{1}$$

atomic #

Hydrogen has 1 **proton**, 0 **neutrons**, and 1 **electron**

Nuclear symbols are used by scientist as a standard way to represent elements, showing both the **atomic** and **mass numbers** ***[Which is which?]***

$$^{14}_{7}\mathrm{N}$$

Nitrogen has ? **protons**, ? **neutrons**, and ? **electrons**

Nuclear symbols are used by scientist as a standard way to represent elements, showing both the atomic and mass numbers

mass number

$$^{14}_{7}N$$

atomic #

Nitrogen has 7 **protons**, 7 **neutrons**, and 7 **electrons**

Nuclear symbols are used by scientist as a standard way to represent elements, showing both the **atomic** and **mass numbers** ***[Which is which?]***

TRY IT

$_{26}Fe^{56}$

Iron has ? **protons**, ? **neutrons**, and ? **electrons**

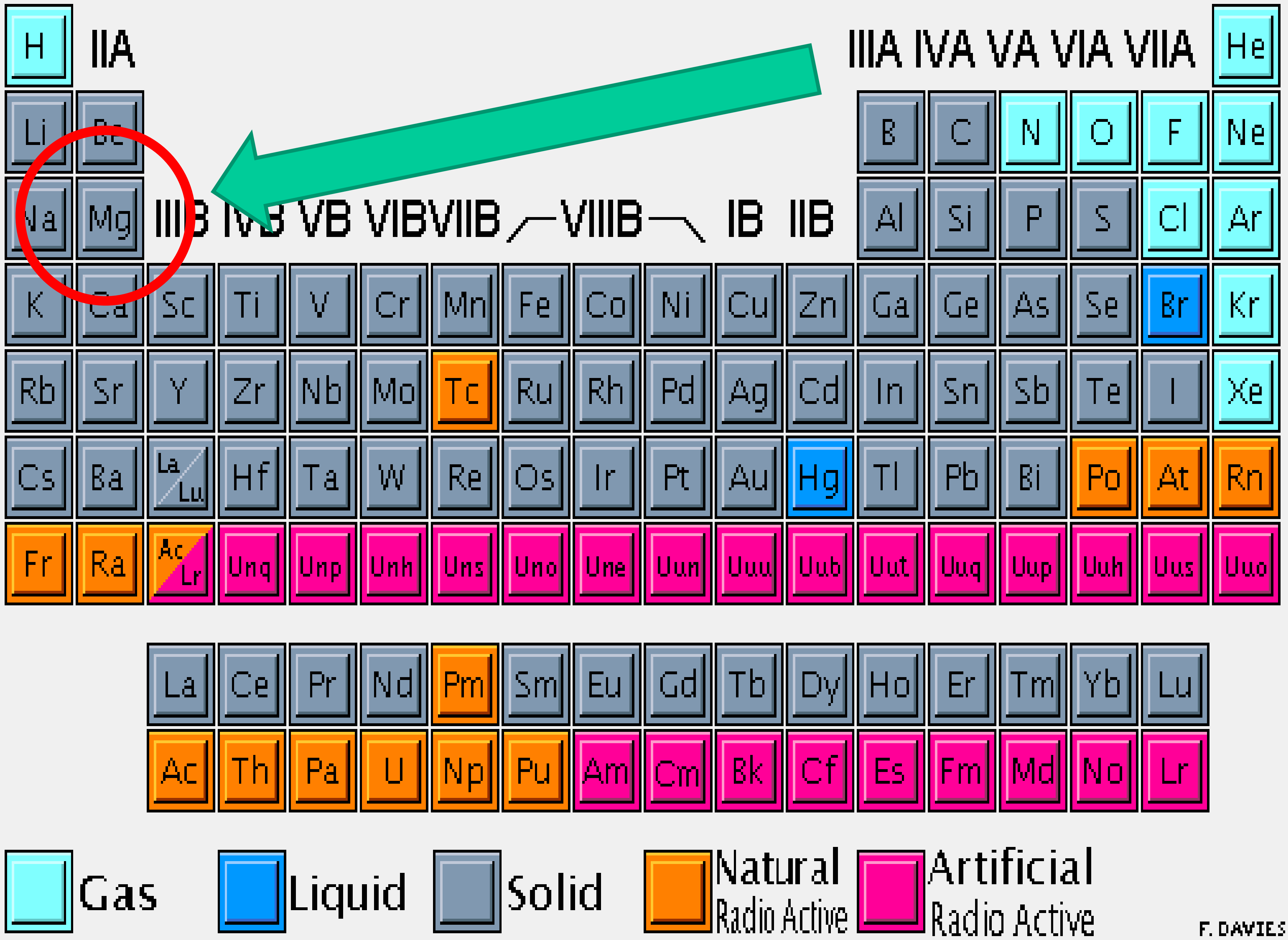
Nuclear symbols are used by scientist as a standard way to represent elements, showing both the atomic and mass numbers

mass number

$$^{56}_{26}Fe$$

atomic #

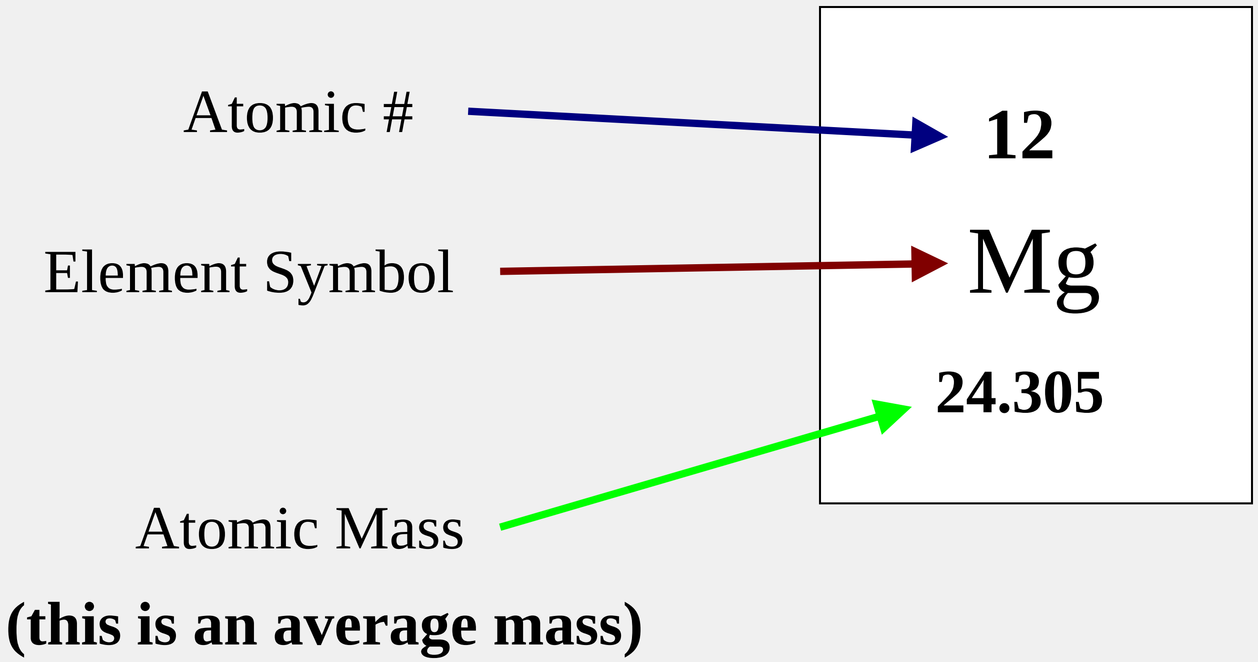
Iron has 26 **protons**, 30 **neutrons**, and 26 **electrons**



H
IIA
IIIA IVA VA VIA VIIA
He
Li Be
B C N O F Ne
Na Mg
IIIB IVB VB VIBVIIB VIIIB IB IIB
Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba La Lu Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra Ac Lr Unq Unp Unh Uns Uno Une Uun Uuu Uub Uut Uuq Uup Uuh Uus Uuo
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr
Gas
Liquid
Solid
Natural Radio Active
Artificial Radio Active
F. DAVIES

Example: Magnesium

Elements are often represented in the following format in tables or charts



TRY IT

30
___
Zinc
65.39

Atomic # = _____

Atomic Mass = ________

# of Protons = _______

# of Neutrons = _______

# of Electrons = _______

Nuclear symbol?

TRY IT

30
___
Zinc
65.39

Atomic # = ___30___

Atomic Mass = ___65___

# of Protons = ___30___

# of Neutrons = ___35___

# of Electrons = ___30___

$$_{30}Zn^{65}$$

35

___

Bromine

79.904

Atomic # = _____

Atomic Mass = _______

# of Protons = _______

# of Neutrons = _______

# of Electrons = _______

TRY IT

Nuclear symbol?

TRY IT

35

____

Bromine

79.904

Atomic # = 35

Atomic Mass = 80

# of Protons = 35

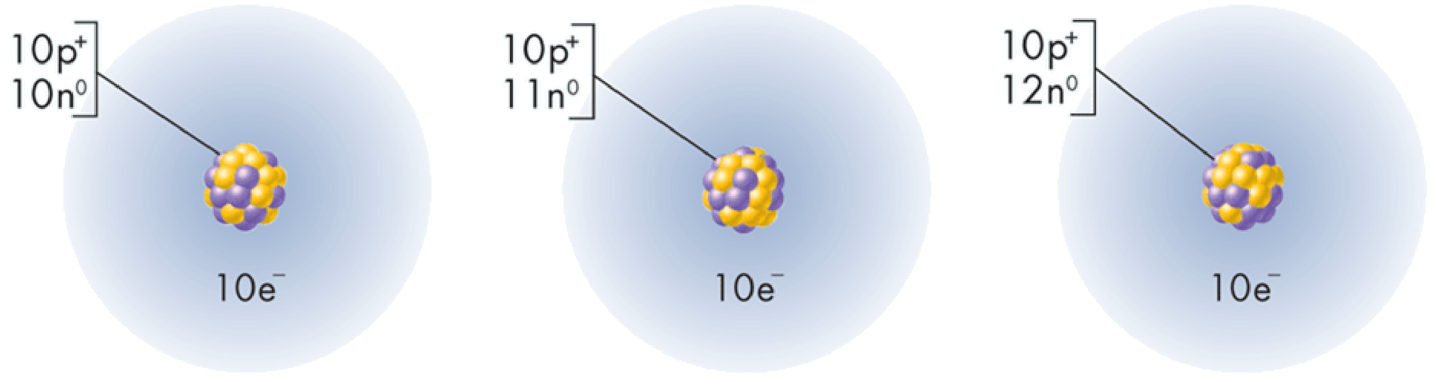
# of Neutrons = 45

# of Electrons = 35

$_{35}Br^{80}$

Isotopes are atoms that have the same number of protons but different numbers of neutrons. *Therefore, they have the same chemical properties.*

Neon-20, neon-21, and neon 22 are isotopes of neon.

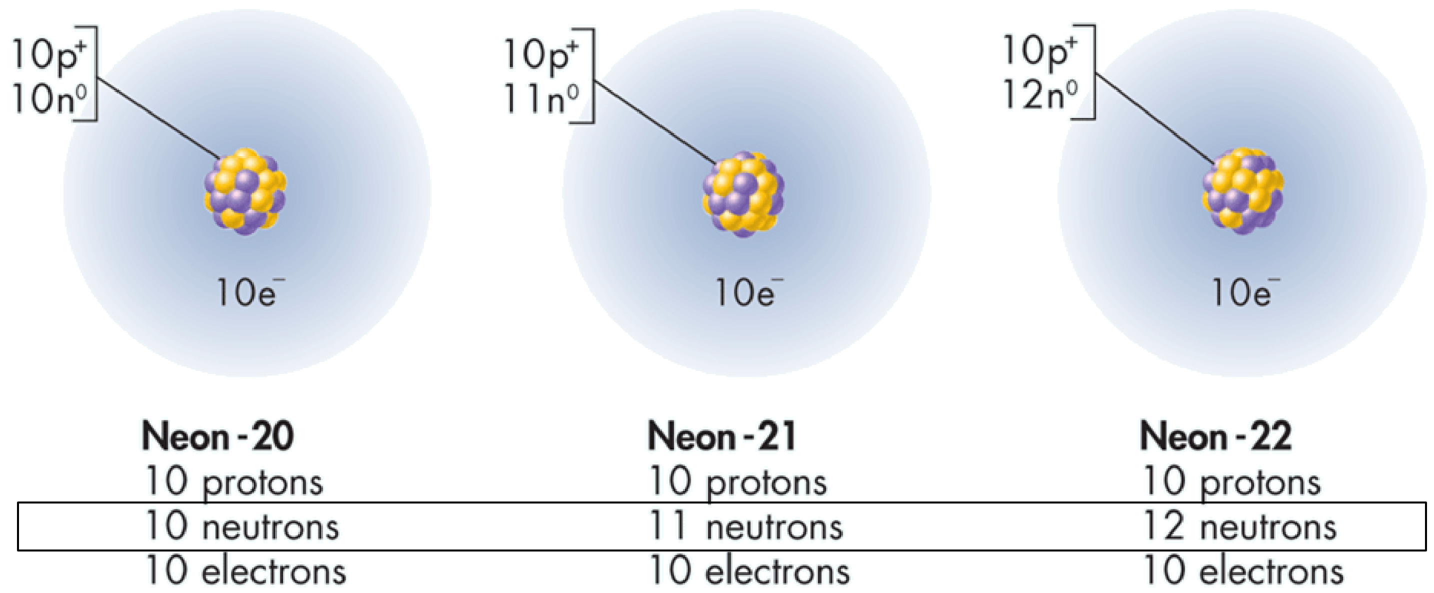


Neon-20	Neon-21	Neon-22
10 protons	10 protons	10 protons
10 neutrons	11 neutrons	12 neutrons
10 electrons	10 electrons	10 electrons

Isotopes

Isotopes are atoms that have the same number of protons but different numbers of neutrons. *Therefore, they have the same chemical properties.*

Neon-20, neon-21, and neon 22 are isotopes of neon.



Isotopes of Neutral Atoms

- Atoms of the same element with different mass numbers.
  - Number of protons are the same
  - Number of electrons are the same
  - Number of neutrons are different

Isotope	*Z*	*n*	*A*
Sn-112	50	62	112
Sn-114	50	64	114
Sn-115	50	65	115
Sn-116	50	66	116
Sn-117	50	67	117
Sn-118	50	68	118
Sn-119	50	69	119

An **atomic mass unit (amu)** is defined as one-twelfth of the mass of a carbon-12 atom.

This isotope of carbon has been assigned a mass of exactly 12 atomic mass units.

In nature, most elements occur as a mixture of two or more isotopes.

Each isotope of an element has a fixed mass and a **natural percent abundance**.

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$$^{12}_{6}C$$

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Each isotope of an element has a fixed mass and a **natural percent abundance**.

Atomic Mass

Natural Percent Abundance of Stable Isotopes of Some Elements				
Name	Symbol	Natural percent abundance	Mass (amu)	Atomic mass
Hydrogen	$^{1}_{1}H$ $^{2}_{1}H$ $^{3}_{1}H$	99.985 0.015 negligible	1.0078 2.0141 3.0160	1.0079
Helium	$^{3}_{2}He$ $^{4}_{2}He$	0.0001 99.9999	3.0160 4.0026	4.0026
Carbon	$^{12}_{6}C$ $^{13}_{6}C$	98.89 1.11	12.000 13.003	12.011
Oxygen	$^{16}_{8}O$ $^{17}_{8}O$ $^{18}_{8}O$	99.759 0.037 0.204	15.995 16.995 17.999	15.999
Chlorine	$^{35}_{17}Cl$ $^{37}_{17}Cl$	75.77 24.23	34.969 36.966	35.453

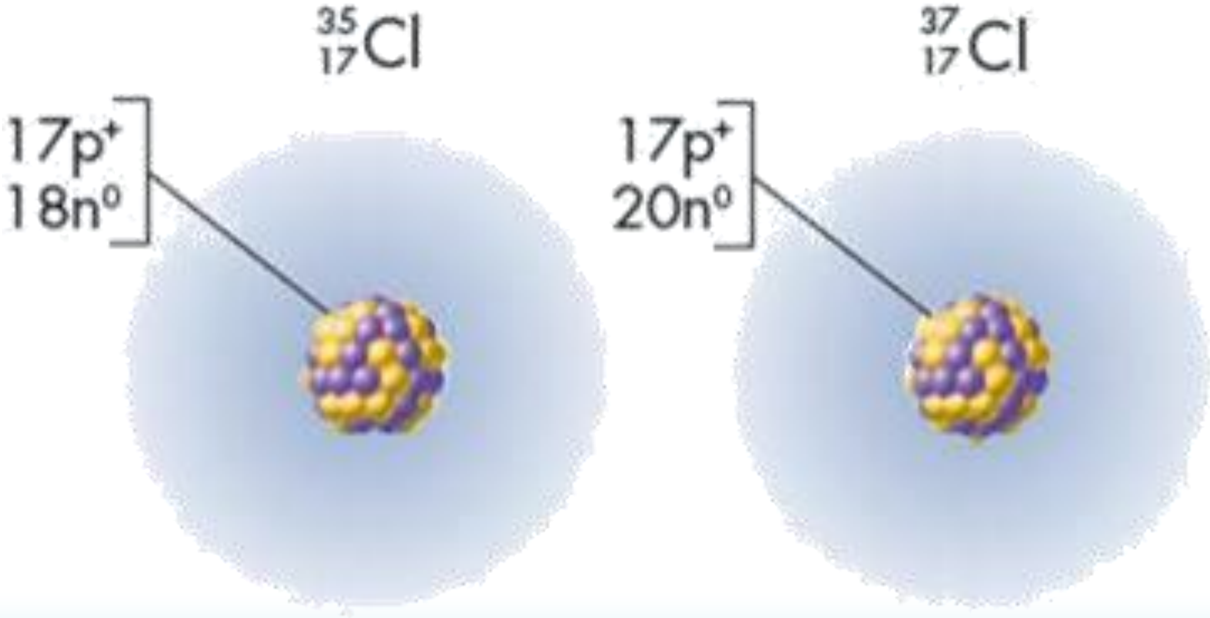
Atomic Mass

THINK ABOUT IT

Chlorine exists as chlorine-35 and chlorine-37.

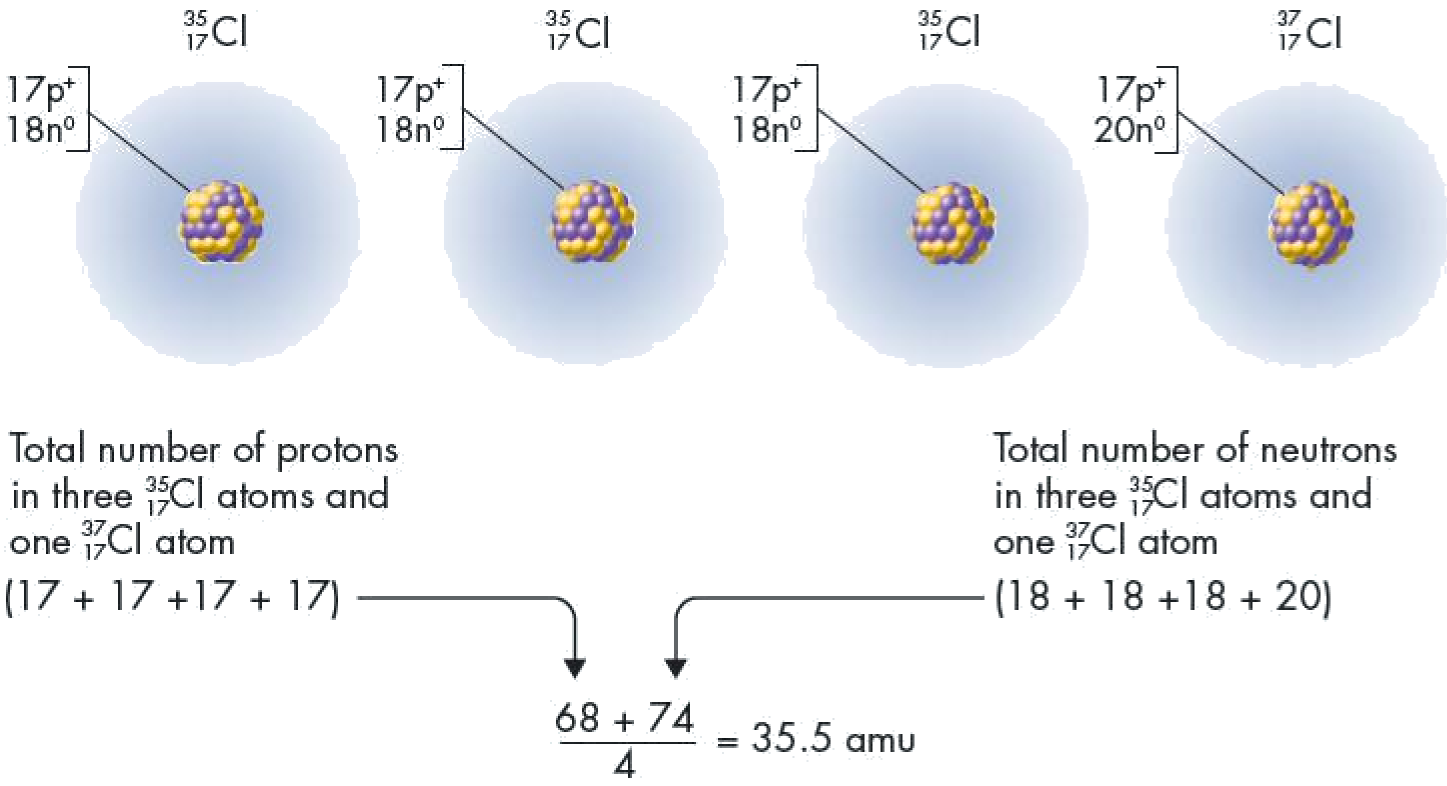
Chlorine's atomic mass on the Periodic Table is 35.453 amu. (*Notice it is not exactly in-between.*)

Which isotope is more abundant?



Atomic Mass

In nature there is 76% Cl-35 than 24% Cl-37, therefore, the atomic mass of chlorine, 35.453 amu, is closer to 35 than to 37.



Weighted Average Mass of a Chlorine Atom

Calculating Average Atomic Mass

The **average atomic mass** is the weighted average mass of all isotopes of an element.

Abundance of aluminum isotopes:

- 100% is from Al-27
- Therefore, no isotopes
- Al-26 is radioactive (not natural)

13
Al
Aluminum
26.98

Average Atomic Mass

Abundance of silicon isotopes:

- 92.2297% is from Si-28
- 4.6832% is from Si-29
- 3.0872% is from Si-30

14

Si

Silicon

28.09

How do you arrive at a mass of 28.09?

The weighted average mass reflects both the **mass** and the **relative abundance (%)** of the isotopes as they occur in nature.

- Multiply the mass of each isotope by its natural abundance and add the products.

92.2297% (28) + 4.6832% (29) + 3.0872% (30) =

OR

0.9223(28) + 0.0468(29) + 0.03087(30) = **28.09**

25.82 + 1.36 + 0.93

14
Si
Silicon
28.09

TRY IT

Carbon has two stable isotopes: carbon-12, natural abundance 98.89%, and carbon-13, natural abundance 1.11%.

What is the Average Atomic Mass of C-12?

TRY IT

Carbon has two stable isotopes: carbon-12, natural abundance 98.89%, and carbon-13, natural abundance 1.11%.

The mass of carbon-12 is 12.000 amu;

The mass of carbon-13 is 13.003 amu.

The atomic mass of carbon is calculated as follows:

= (12.000 amu x 0.9889) + 13.003 amu x 0.0111)

= (11.867 amu) + (0.144 amu)

= 12.011 amu