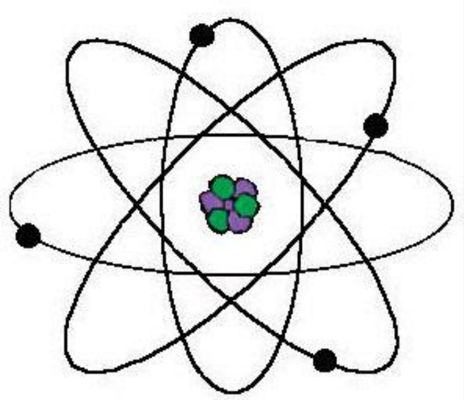
Chapter 4



Atomic Structure

Focus Questions

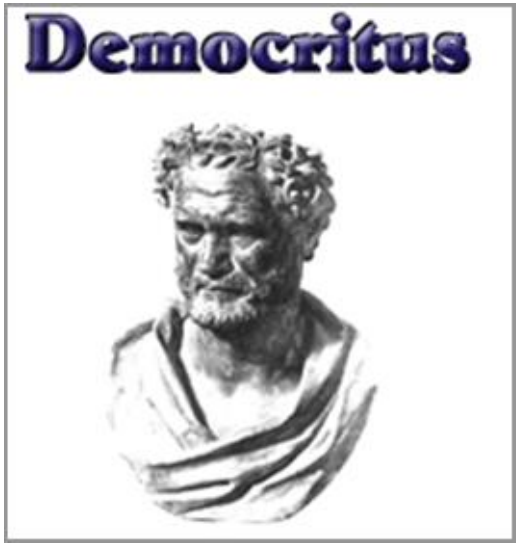
LESSON QUESTION

1. Explain Atomic History from specific scientists perspectives (Democritus, Dalton, Thomson, Chadwick, Bohr, Rutherford).
2. Understand atomic structure (atomic number, atomic mass, and subatomic particles) and be able to define and draw all components. Draw a nuclear symbol for an element.
3. Explain what makes elements unique in properties (e.g. atomic number, mass, valence) and distinguish isotopes.

Democritus

Greek philosopher (460 – 370 BC)

Coined the term "Atom"



"Matter consists of discrete, indivisible particles"

Democritus held a very general theory with no experimental evidence

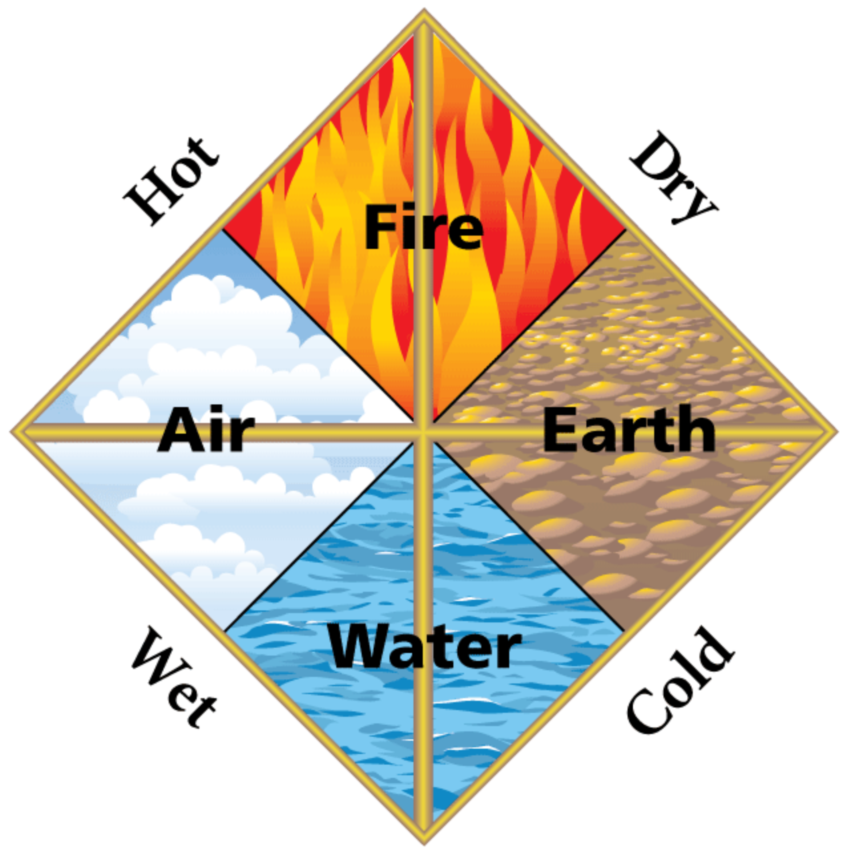
Democritus' ideas were rejected by Plato & Aristotle (*fathers of philosophy and ancient "scientific thinking"*) … & therefore, set aside

Ancient Greek Models of Atoms

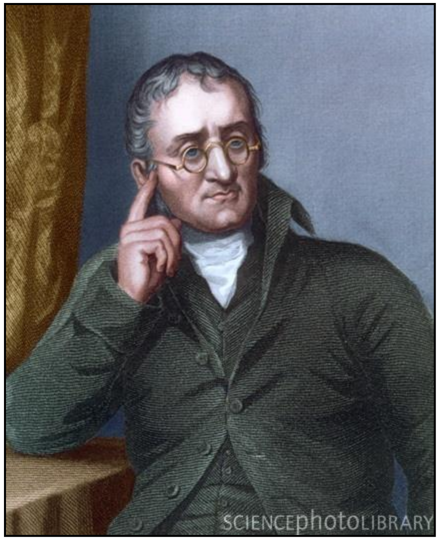
Aristotle, a philosopher, thought that all substances were made of only four elements—earth, air, fire, and water.

For many centuries, most people accepted Aristotle's views on the structure of matter.

By the 1800s, scientists had enough experimental data to support an atomic model.



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. **Compounds contain atoms of more than one element.**

4. In a particular compound, atoms of different elements always combine in the same way.

Dalton's Atomic Theory

When magnesium burns, it combines with oxygen.

In magnesium oxide, the ratio of the mass of magnesium to the mass of oxygen is always about 3:2.

Magnesium dioxide has a fixed composition.

A theory must explain the data from many experiments. Over time, scientists found that not all of Dalton's ideas about atoms were completely correct.

Acrylic Tape

Watch the "Electrostatic Force" video on Study Place (complete the worksheet).

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

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.

Continue watching the video "Electrostatic Force" on Study Place (complete the worksheet).

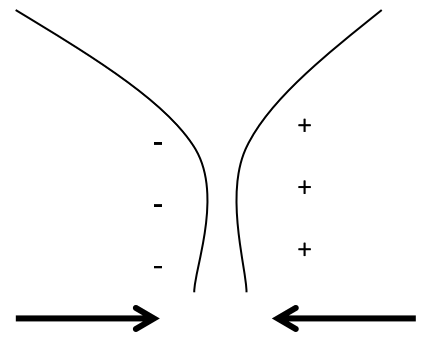
NOW, take TWO other separate pieces of acrylic tape ~ 7.5 cm long (3 inches).

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*****.**

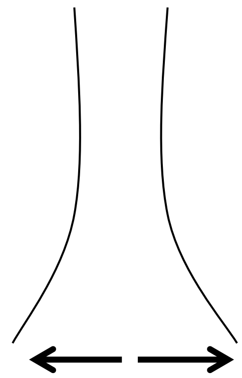
Pull the pieces off the table. Pull them apart and then bring them together slowly "back" to "back" & observe.

Acrylic Tape

In the first case you should have noticed "attraction"



In the second case, "Repulsion"



WHY?

Continue with the last activities on the "Electrostatic Force" worksheet.

Watch the Van der Graaf machine video and consider what causes what you observe.

http://somup.com/cFQ22DVSKM

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

Electrostatic Forces Worksheet Conclusions

Benjamin Franklin

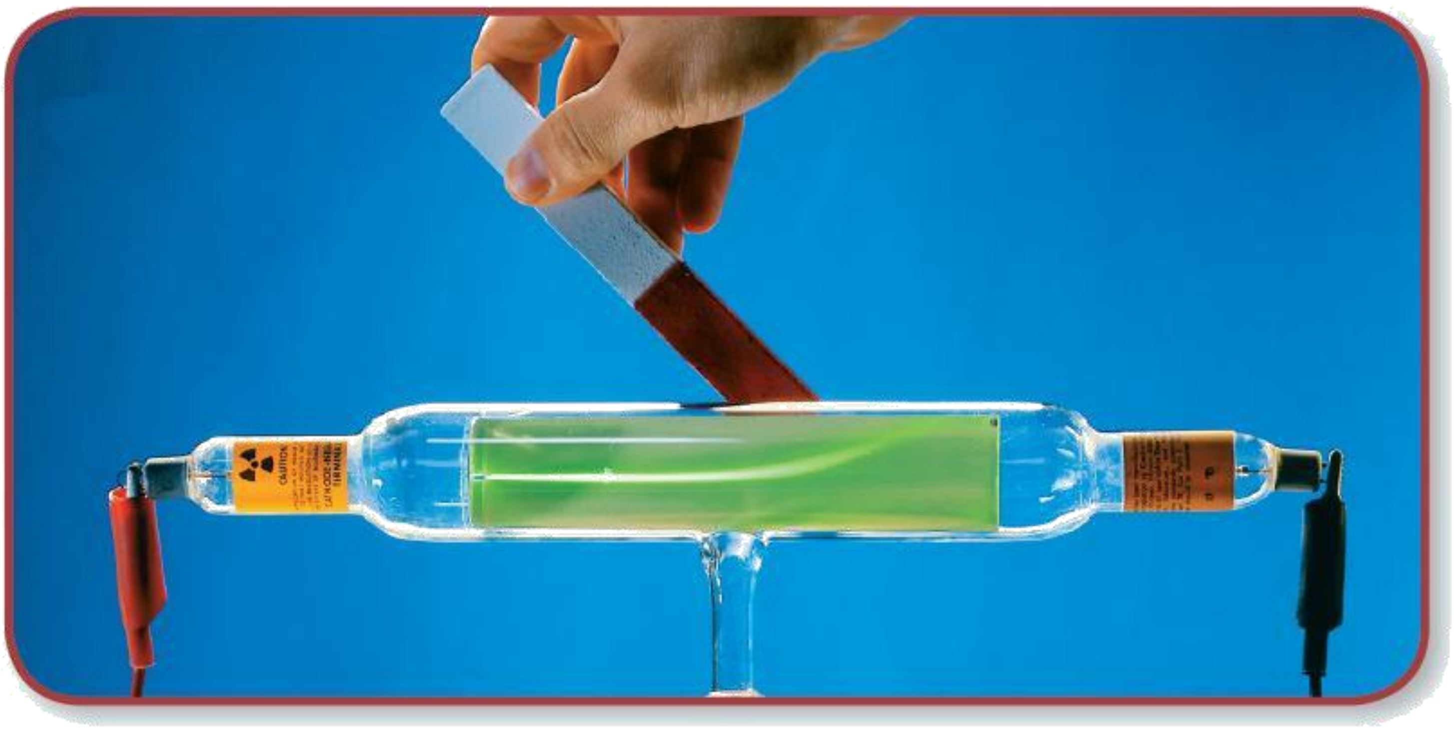
Learned from experiments with thunderstorms, that lightning is a flow of electrical energy through the atmosphere.

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)

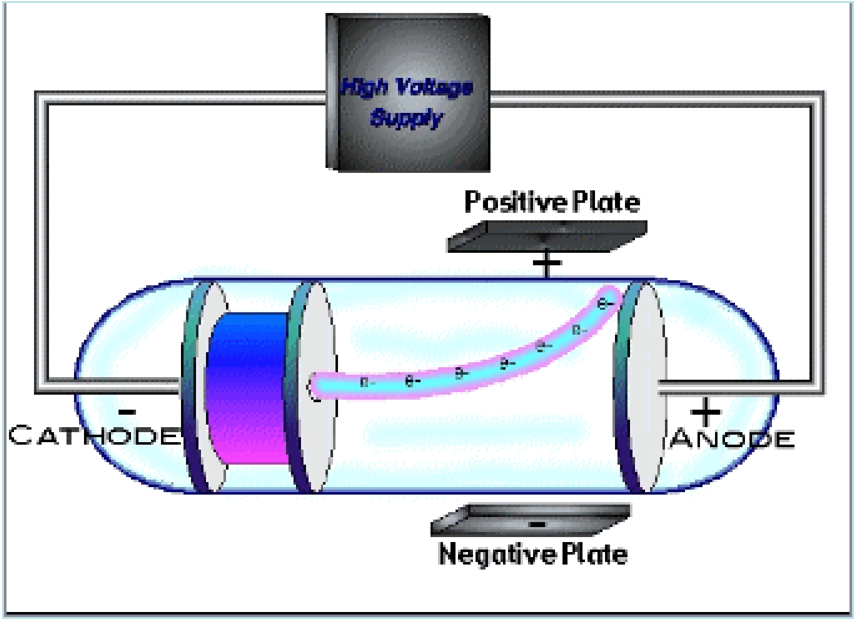


2 Structure of the Atom

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.

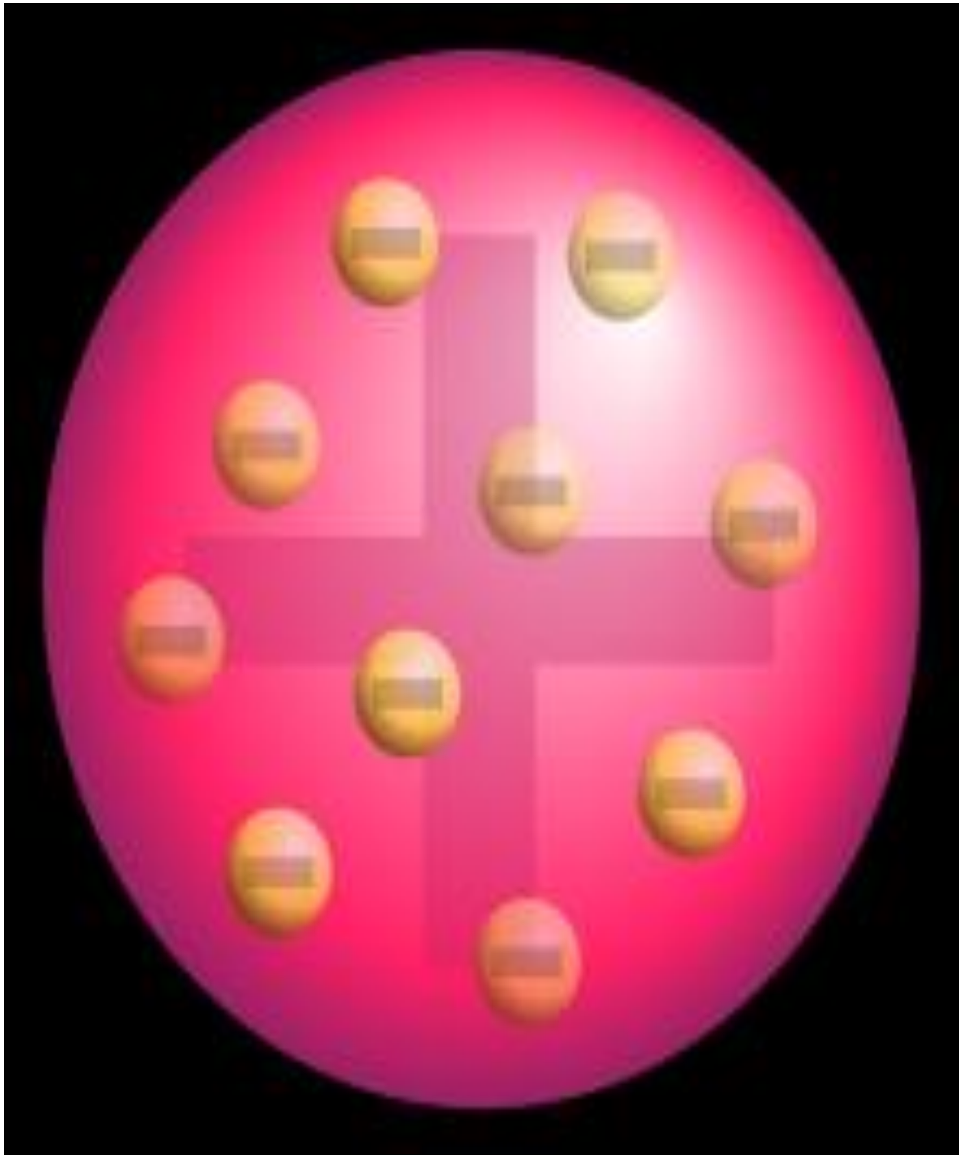
He theorized the existence of a particle common to all atoms → using the charged plates on either side of the tube, he showed the particle was negatively charged.



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 … atoms are subDIVIDED.**
- **Recognition of the existence of electrons and the neutrality of the whole atom.**



Testing the Plum Pudding Model

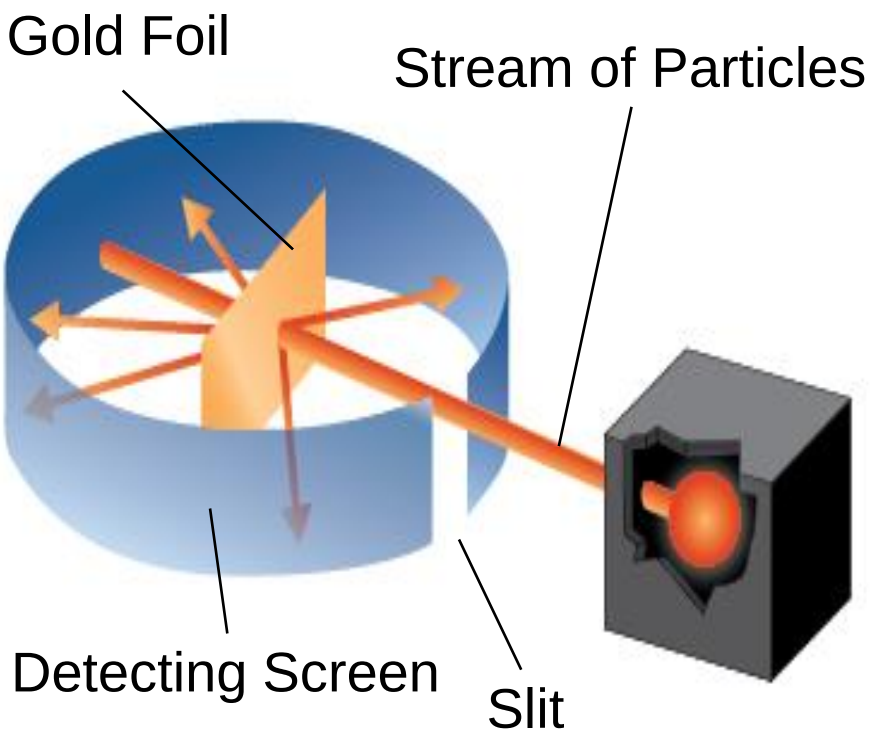
Ernest Rutherford (*right*) developed an experiment to test the plum pudding model of JJ Thomson (*left*).

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:

- ?

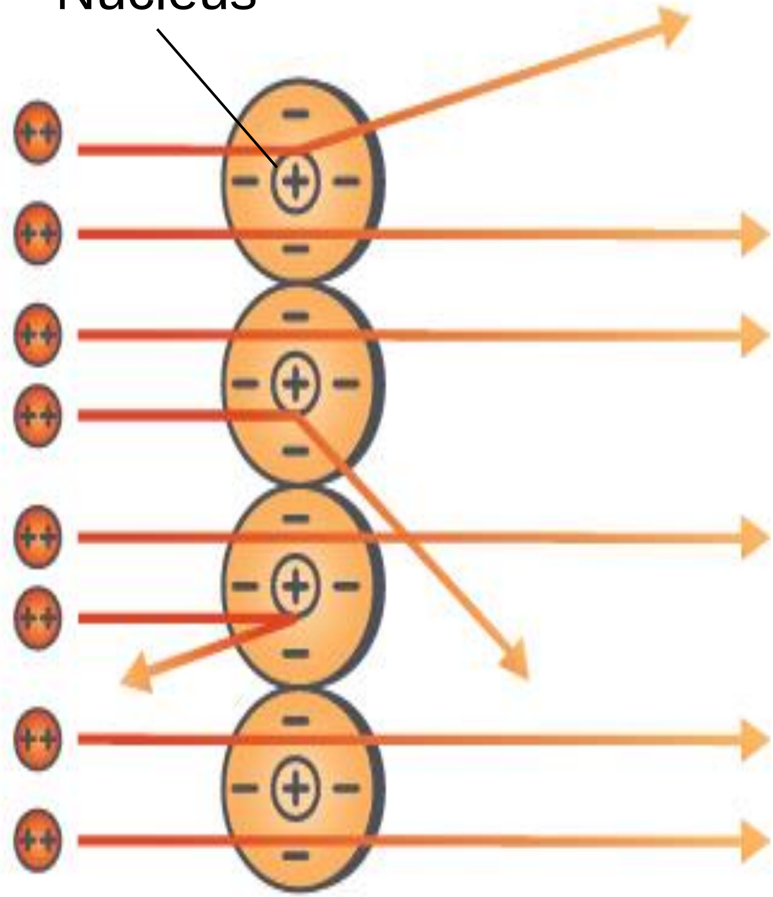


Diagram is not drawn to scale

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

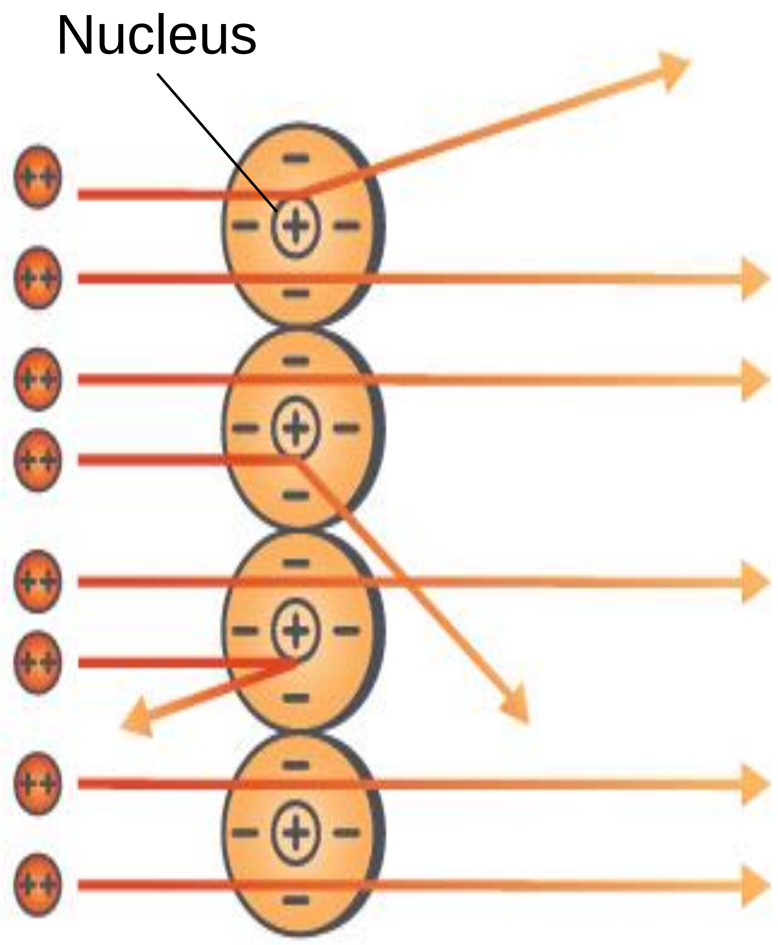
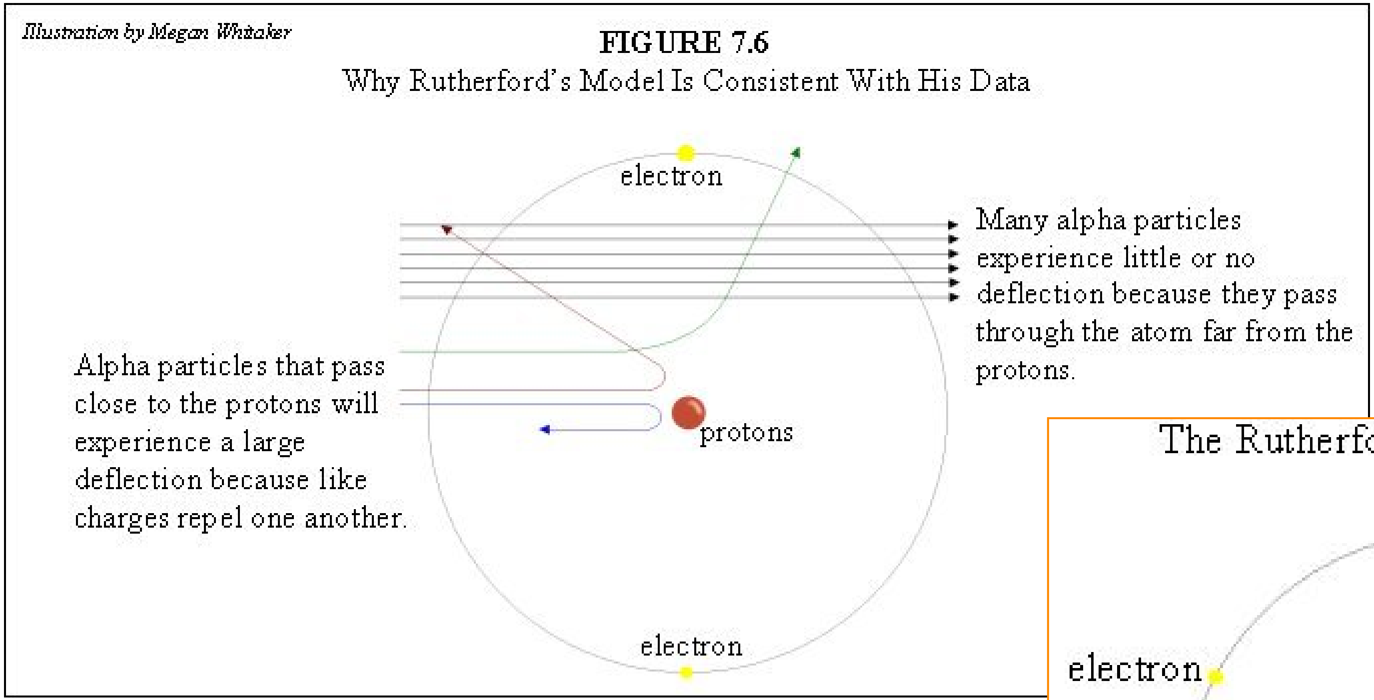
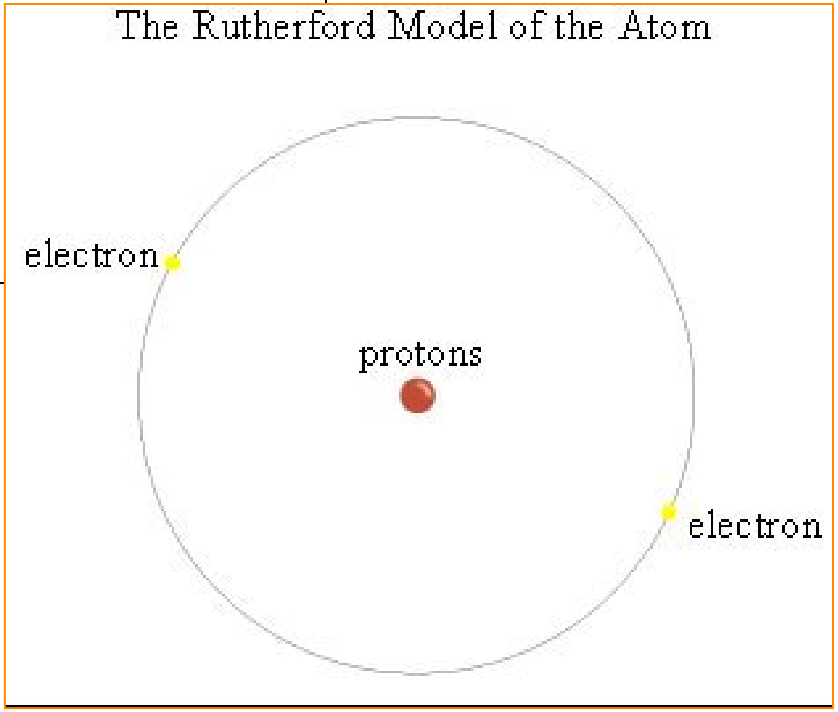


Diagram is not drawn to scale

Led to the Initial *Planetary* Model of the Atom





Dense, positive nucleus of atom orbited by electrons

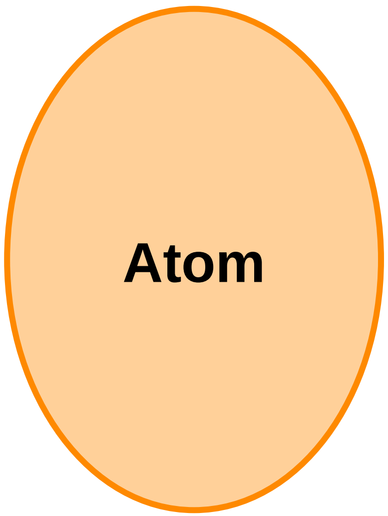
Relative Size of the Hydrogen Atom ENRICHMENT

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

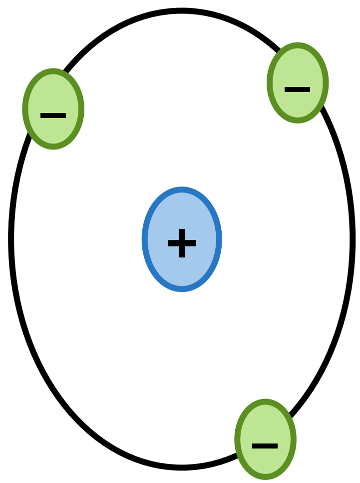
QUICK CHECK

Modifying the Atomic Model

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



A



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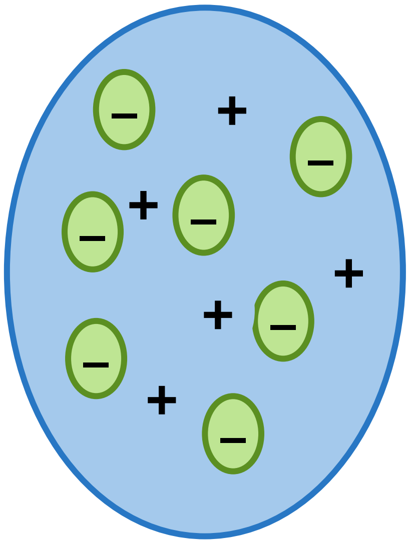

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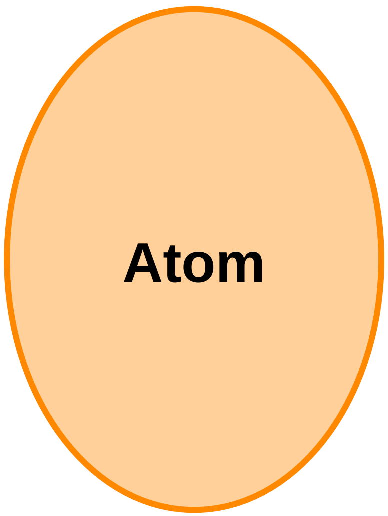
QUICK CHECK

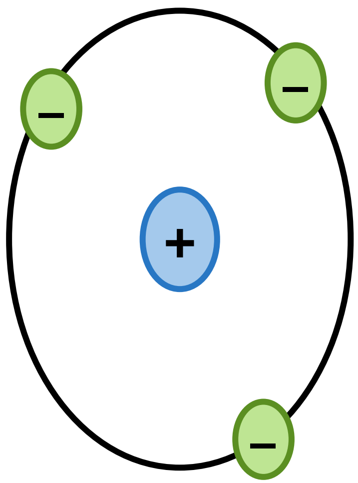
Modifying the Atomic Model

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



Dalton

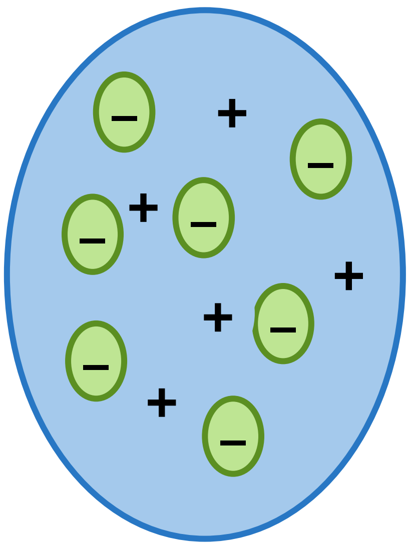
Indivisible particle



Rutherford

“nucleus”

(positive center) with orbiting electrons



Thomson

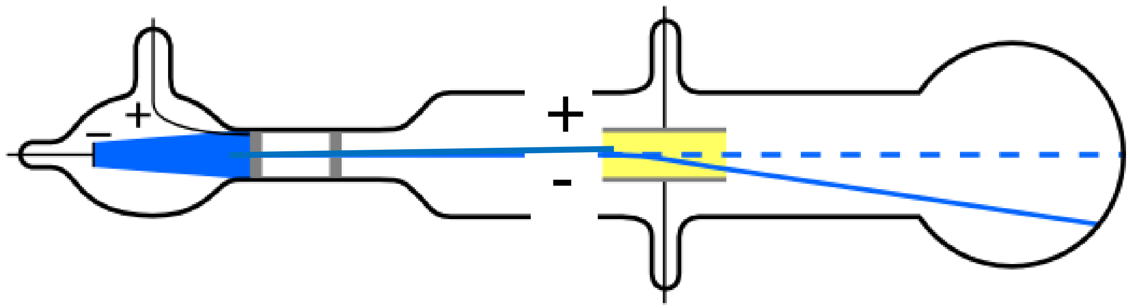
Plum pudding

Protons

In 1886, Eugen Goldstein (1850–1930) observed a cathode-ray tube to discover a new particle. Rutherford also gets some credit for the "proton".

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.

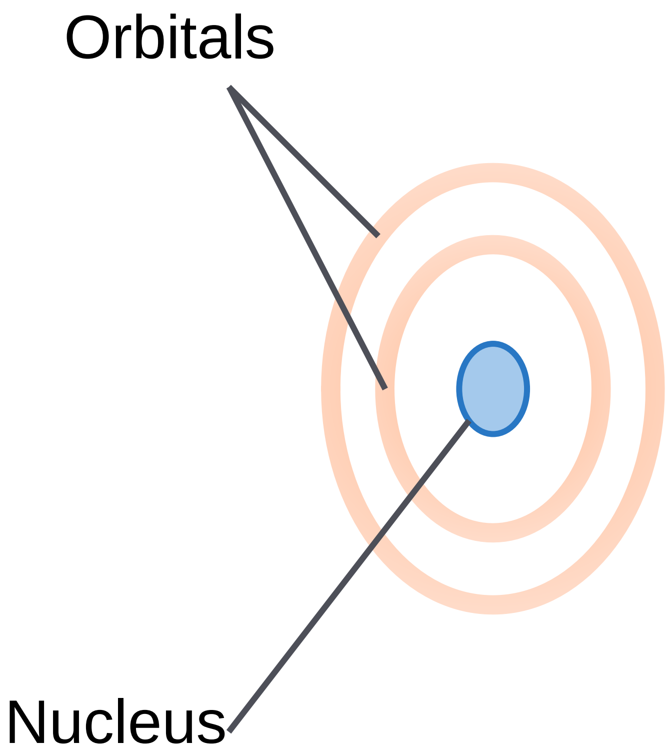
- Chadwick bombarded Beryllium with alpha particles and found a new particle was released
- **No charge** (*did not deflect under electric or magnetic field influence*)
- Essentially the same mass as the proton
- Highly penetrable particle (*could penetrate 10-20 cm into lead*)

The Atom

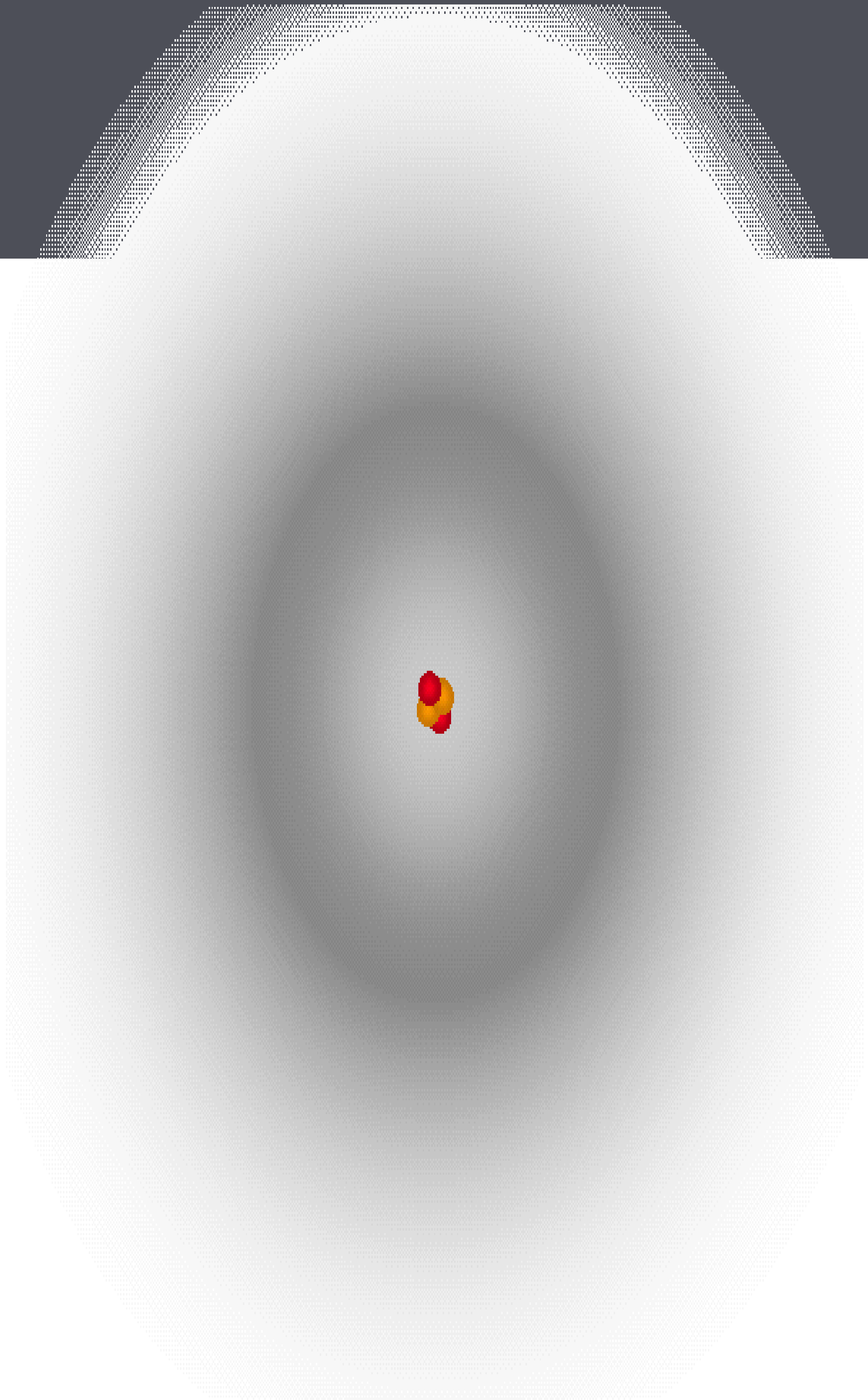
An **Atom** is the smallest particle of an element that has the same properties as the element.

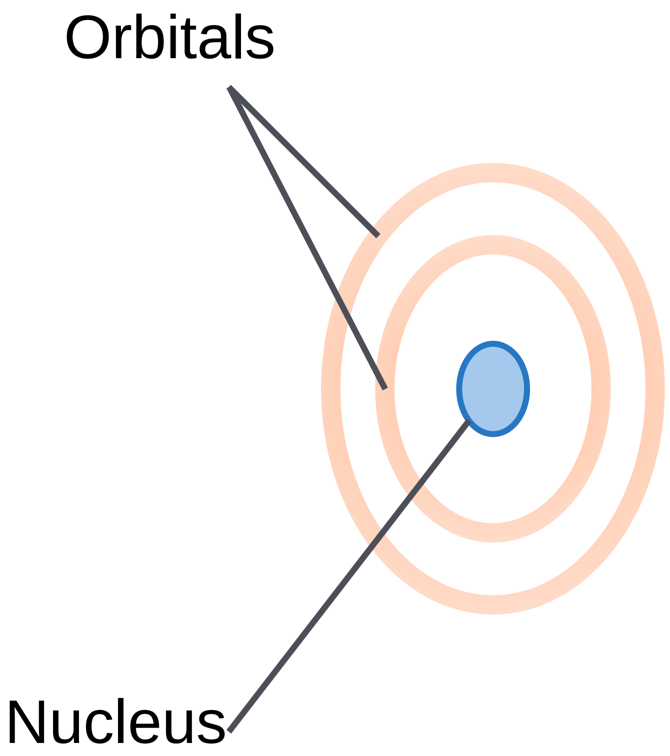
The atom can be divided into two parts:

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



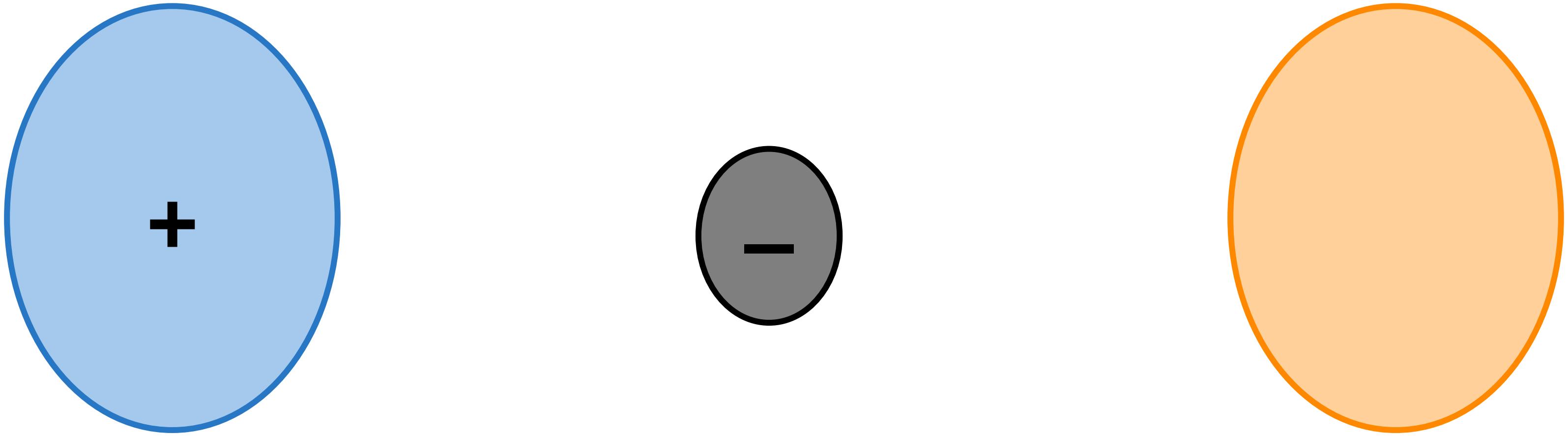
Electron Cloud Model





Charged Particles in the Atom

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

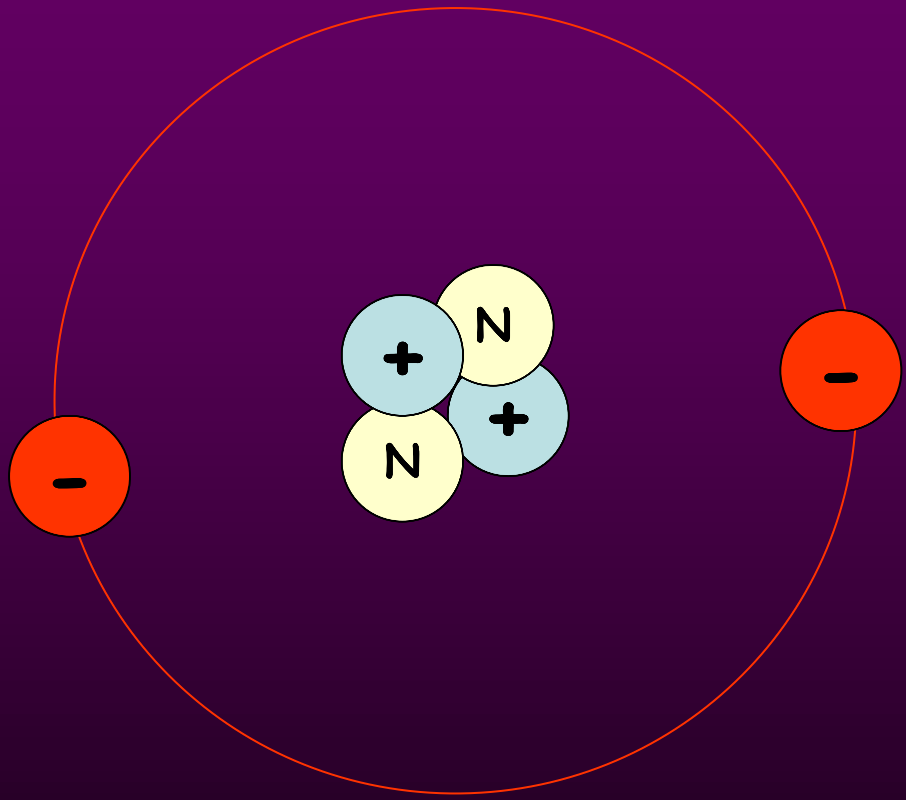


Protons are positively charged.

Electrons are negatively charged.

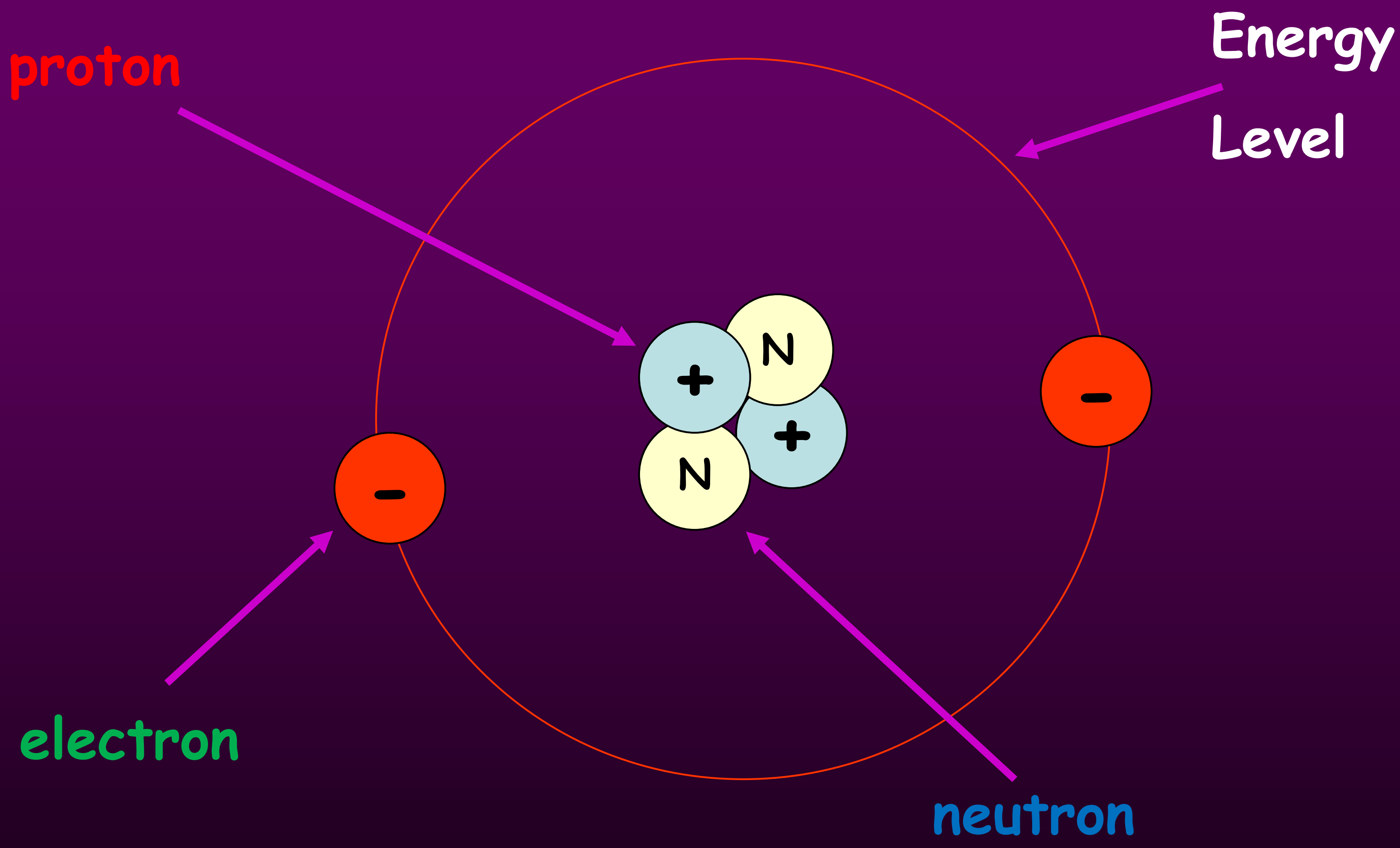
Neutrons have a net zero charge.

Label the major parts of the atom (proton, electron, neutron, energy level):



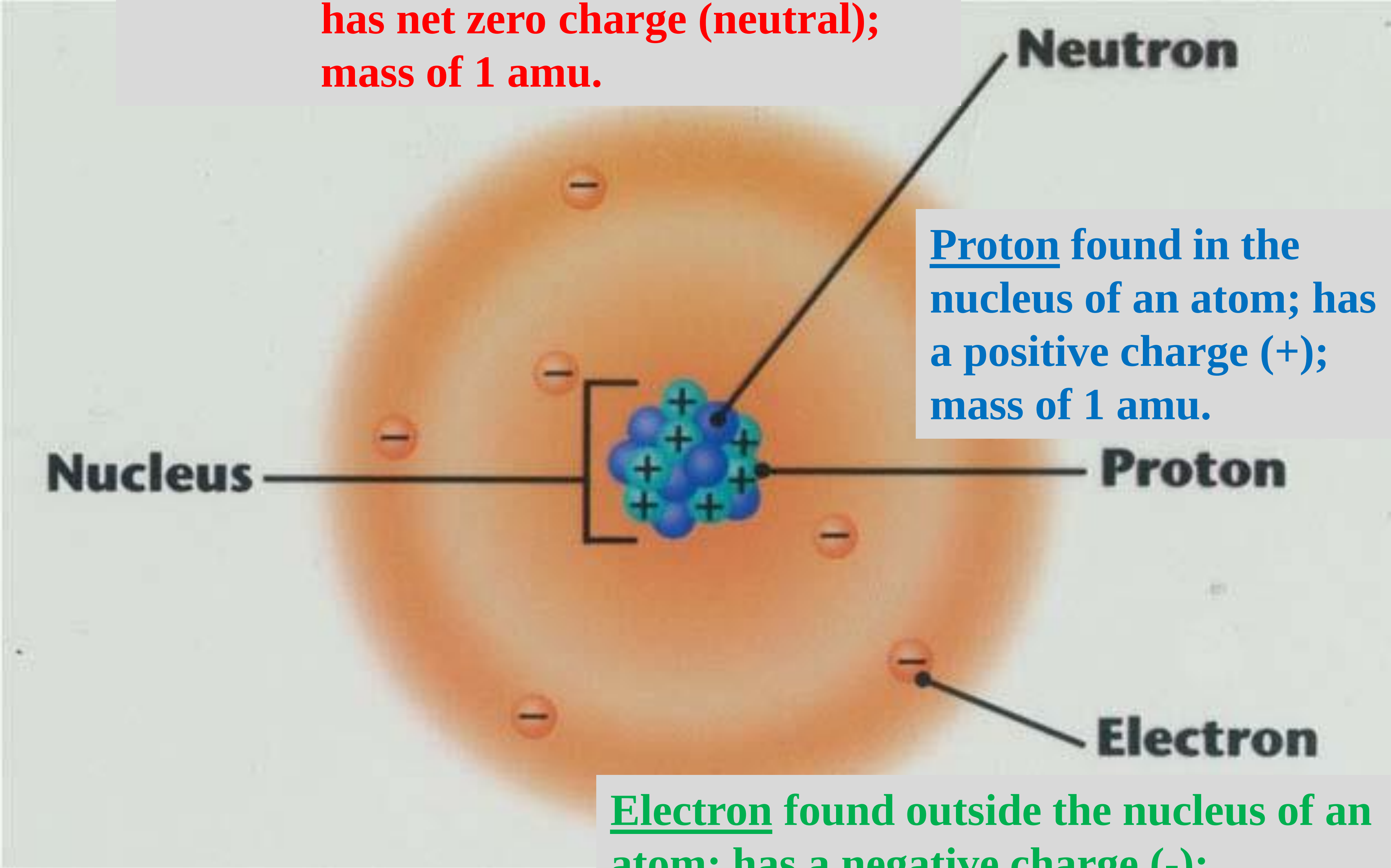
TRY IT

HELIUM ATOM



Different elements have different particle counts and arrangements.

Neutron found in the nucleus of an atom; has net zero charge (neutral); mass of 1 amu.



Proton found in the nucleus of an atom; has a positive charge (+); mass of 1 amu.

Electron found outside the nucleus of an atom; has a negative charge (-); ~1/1836th the mass of a p+ or n

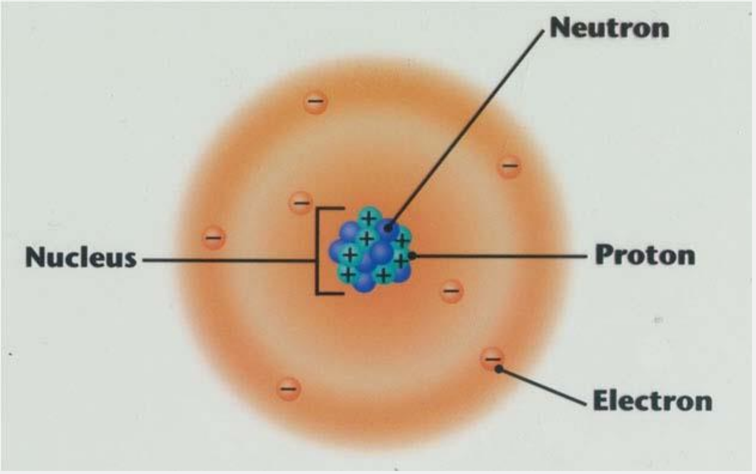
Parts of an Atom

A **neutron** is made of a *proton* and an *electron* and an *antineutrino*.

Thus, the net charge of a **neutron** is **zero** (a "**+**" and a "**–**" equals zero).

Protons and **neutrons** have almost exactly the same mass (**1 amu**).

Electrons have a mass that is about 1/1836 the mass of a proton. Therefore, we ignore it. (**0 amu**)



Subatomic Particles

Atomic Number represents the number of **protons** for a particular element.

In neutral atoms, the number of **electrons** equals the number of **protons.**

Atomic Mass represents the sum of **protons** and **neutrons** in a particular element .

NOTE: *Do NOT confuse atomic # with atomic mass;*
Atomic mass is always the ***larger*** *number*.

QUICK CHECK

This table summarizes the properties of the subatomic particles. (*You do NOT need to know the actual masses of the subatomic particles*.)

Properties of Subatomic Particles				
Particle	**Symbol**	**Relative charge**	**Relative mass (mass of proton = 1)**	**Actual mass (g)**
	e^-			9.11×10^{-28}
	p^+			1.67×10^{-24}
	n^0			1.67×10^{-24}

Structure of the Atom

QUICK CHECK

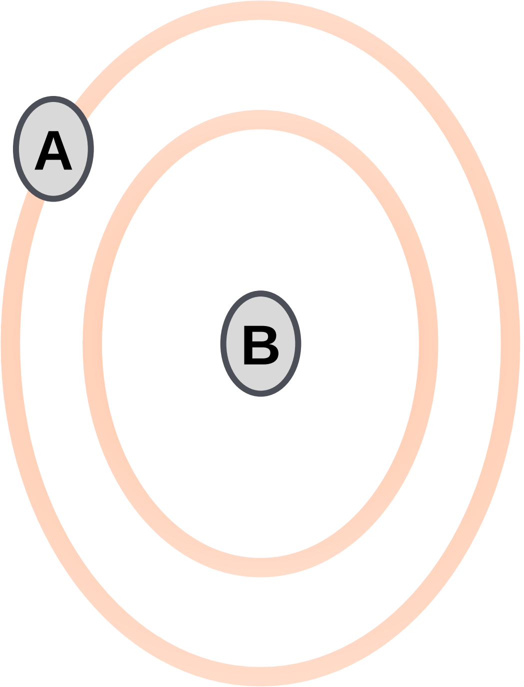
This table summarizes the properties of the subatomic particles. (*You do NOT need to know the actual masses of the subatomic particles*.)

Properties of Subatomic Particles				
Particle	**Symbol**	**Relative charge**	**Relative mass (mass of proton = 1)**	**Actual mass (g)**
Electron	e^-	1–	1/1836 = 0 amu	9.11×10^{-28}
Proton	p^+	1+	1 amu	1.67×10^{-24}
Neutron	n^0	0	1 amu	1.67×10^{-24}

Determine the Locations of Subatomic Particles

Type the name of the location of each particle.

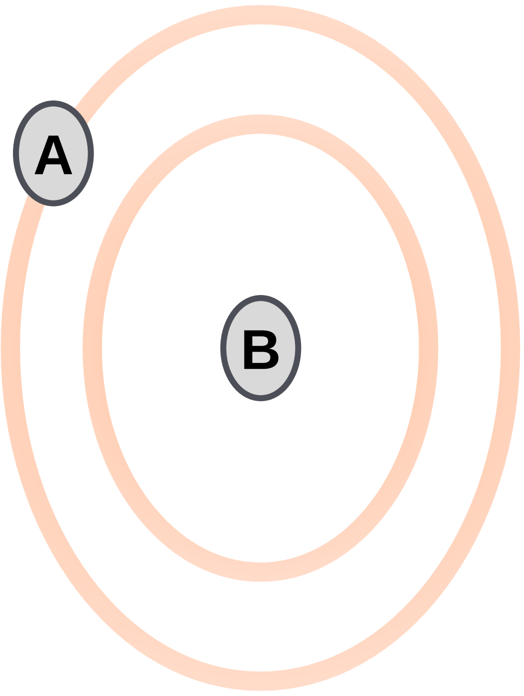
Particle	Charge	Location	~Mass
?	+1	?	?
?	0	?	?
?	-1	?	?



Determine the Locations of Subatomic Particles

Type the name of the location of each particle.

Particle	Charge	Location	~Mass
p+	+1	nucleus	1 amu
n^0	0	nucleus	1 amu
e-	-1	orbit	0 amu
		energy level	



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?

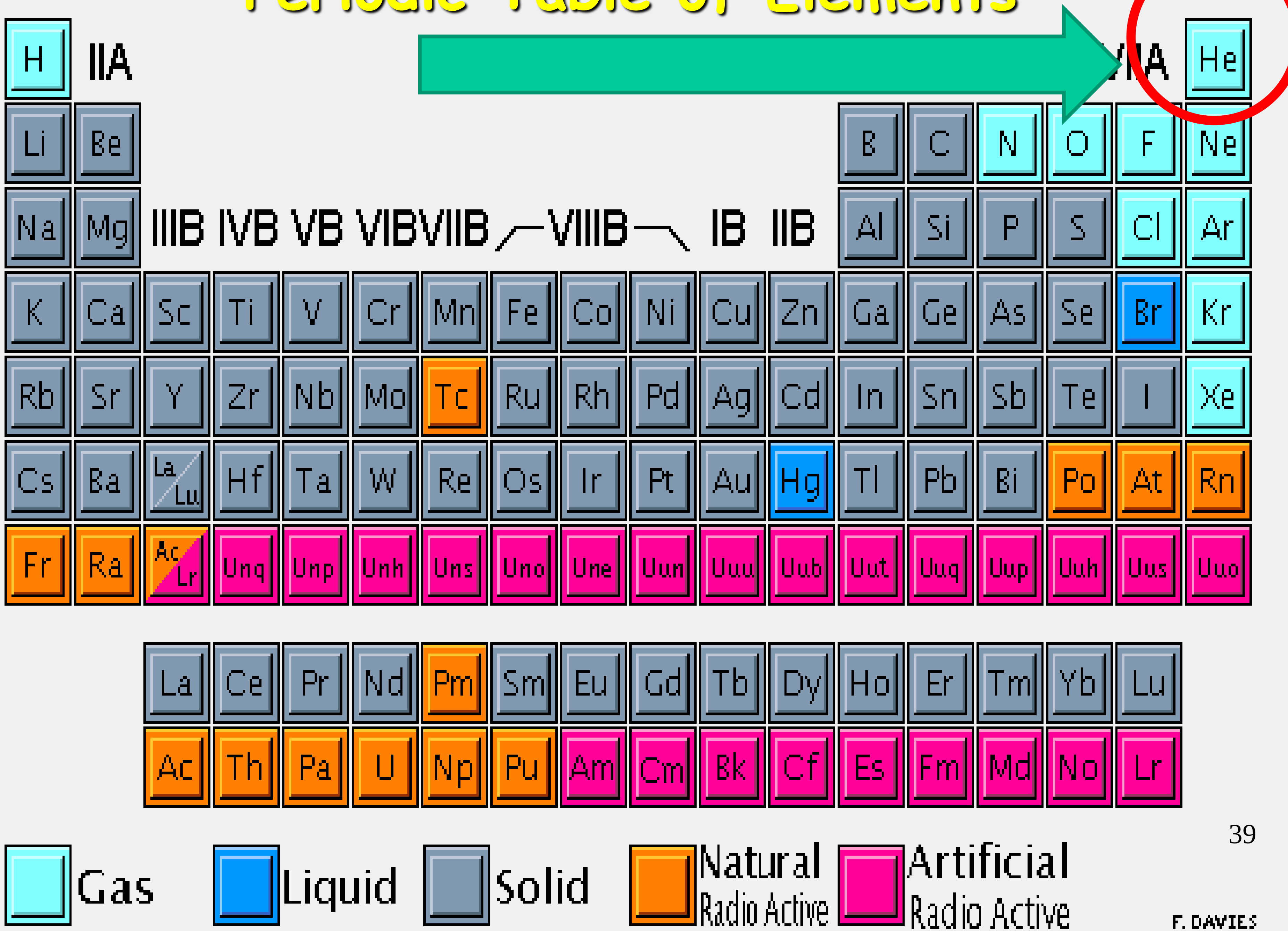
Periodic Table with Atomic Numbers & Masses

The top number in each cell is the atomic number (protons).

The bottom number in each cell is the average atomic weight.

1 H Hydrogen 1.01																	2 He Helium 4.00
3 Li Lithium 6.94	4 Be Beryllium 9.01											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.61	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
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 95.94	43 Tc Technetium 98.00	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.60	53 I Iodine 126.90	54 Xe Xenon 131.29
55 Cs Cesium 132.91	56 Ba Barium 137.33	57 - 71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.20	83 Bi Bismuth 208.98	84 Po Polonium 208.98	85 At Astatine 209.99	86 Rn Radon 222.02
87 Fr Francium 223.00	88 Ra Radium 226.00	89 - 103	104 Rf Rutherfordium 261.00	105 Db Dubnium 262.00	106 Sg Seaborgium 266.00	107 Bh Bohrium 264.00	108 Hs Hassium 277.00	109 Mt Meitnerium 268.00	110 Ds Darmstadtium 281.00	111 Rg Roentgenium 272.00	112 Cn Copernicium 285.00	113 Uut Ununtrium 284.00	114 Fl Flerovium 289.00	115 Uup Ununpentium 288.00	116 Lv Livermorium 291.00	117 Uus Ununseptium Unknown	118 Uuo Ununoctium 294.00
			57 La Lanthanum 138.91	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium 145.00	62 Sm Samarium 150.36	63 Eu Europium 151.97	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
			89 Ac Actinium 227.00	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium 237.00	94 Pu Plutonium 244.00	95 Am Americium 243.00	96 Cm Curium 247.00	97 Bk Berkelium 247.00	98 Cf Californium 251.00	99 Es Einsteinium 252.00	100 Fm Fermium 257.00	101 Md Mendelevium 258.00	102 No Nobelium 259.00	103 Lr Lawrencium 262.00

Periodic Table of Elements



"Nuclear Symbols"

LESSON QUESTION

Atomic Mass

He

Atomic number

Elements are represented by Nuclear symbols

"Nuclear Symbols"

Atomic Mass

He

Atomic number 2

2 protons

Elements are represented by Nuclear symbols

"Nuclear Symbols"

Atomic Mass **4**

2 protons &
2 neutrons

He

Atomic number **2**

2 protons

Elements are represented by Nuclear symbols

Due to Word Processing

Atomic Mass

2 protons &
2 neutrons

^{4}He

The superscript ("4" in this case) can be written on either side.

Atomic number 2

2 protons

Elements are represented by Nuclear symbols

"Nuclear Symbols"

Atomic Mass 4

2 protons &
2 neutrons

He

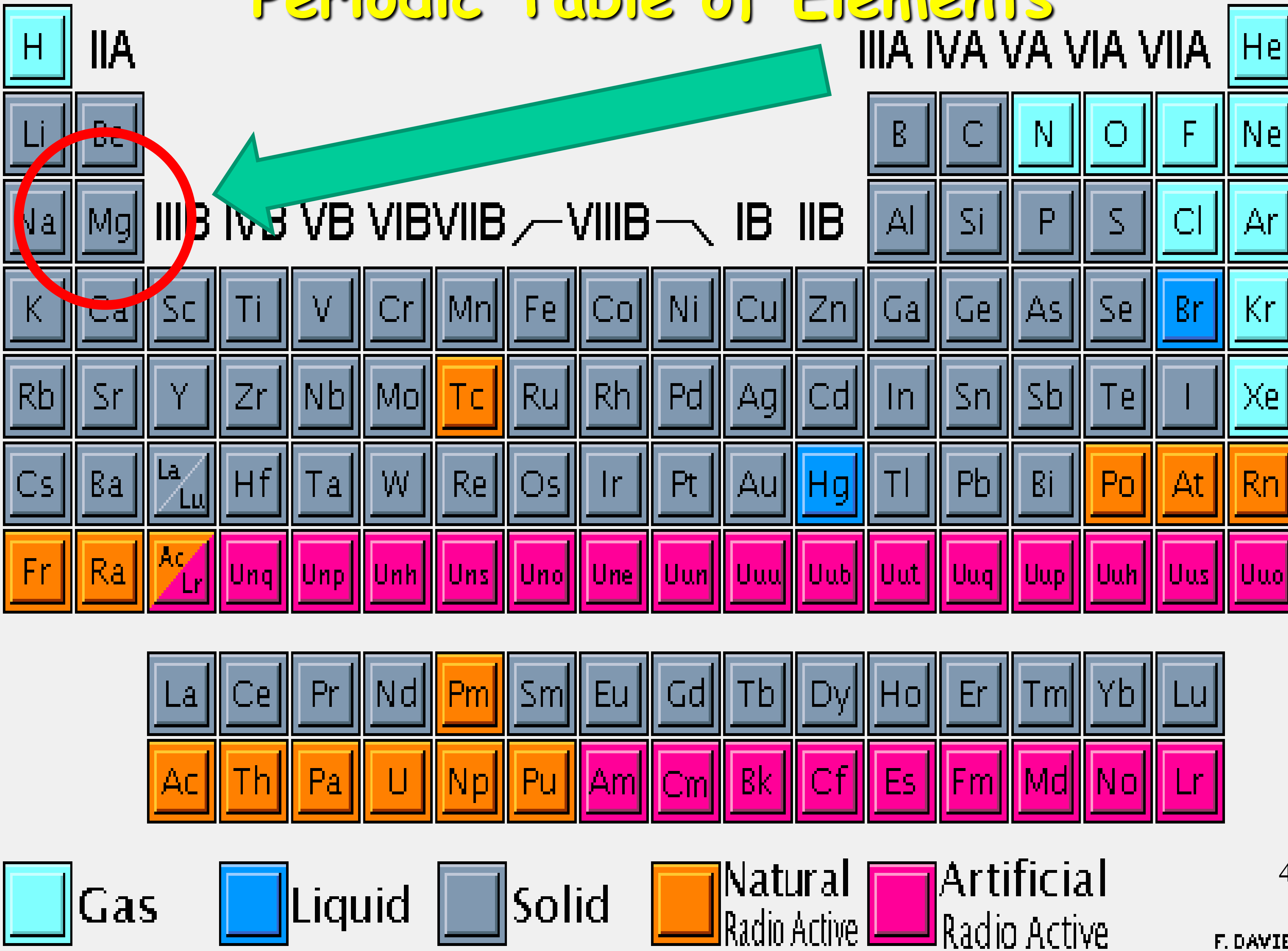
Atomic number 2

2 protons

In a neutral atom

number of electrons = number of protons

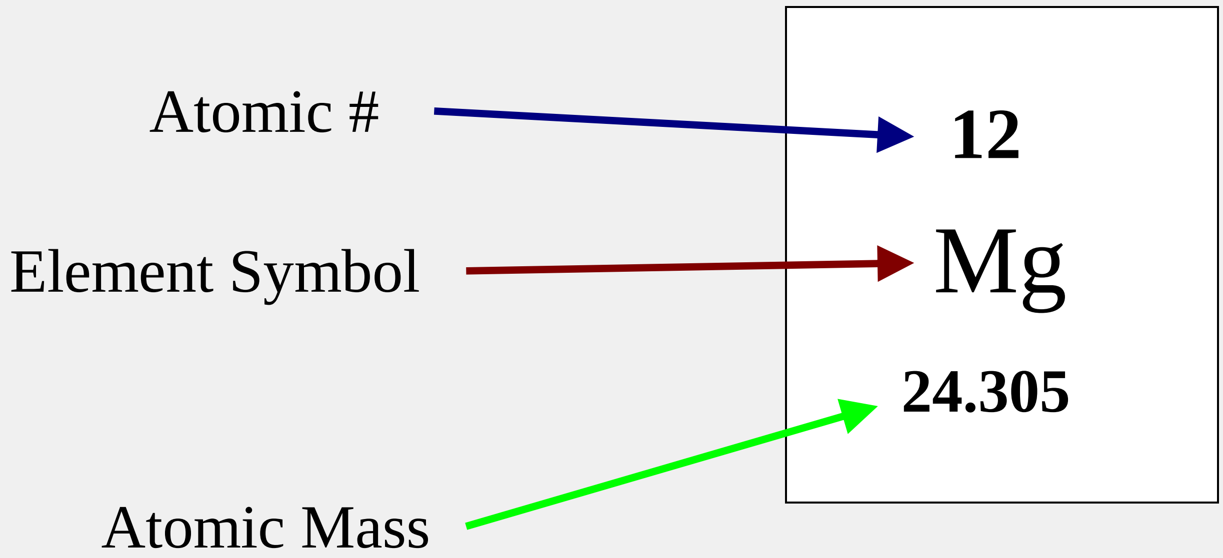
Periodic Table of Elements



F. DAVIES

Example: Magnesium

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



(this is an average mass)

TRY IT

"Nuclear Symbols"

$^{?}_{?}$ Mg $^{?}_{?}$

? protons and ? neutrons

In a neutral atom

number of ? = number of ?

TRY IT

"Nuclear Symbols"

12 protons and 12 neutrons

Atomic mass

24

Mg

12

Atomic #
12 protons

In a neutral atom

number of electrons = number of protons

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

$${}_{1}\mathrm{H}^{1}$$

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

atomic mass

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

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?]***

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

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

atomic mass

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

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?]***

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

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

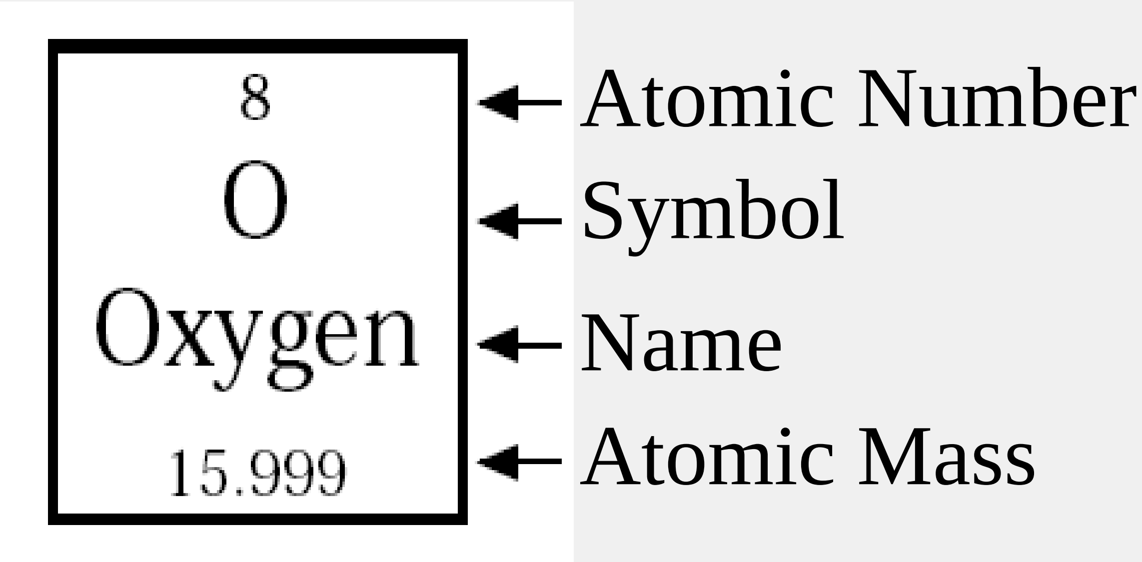
atomic mass

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

atomic #

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

Practice Making Nuclear Symbols



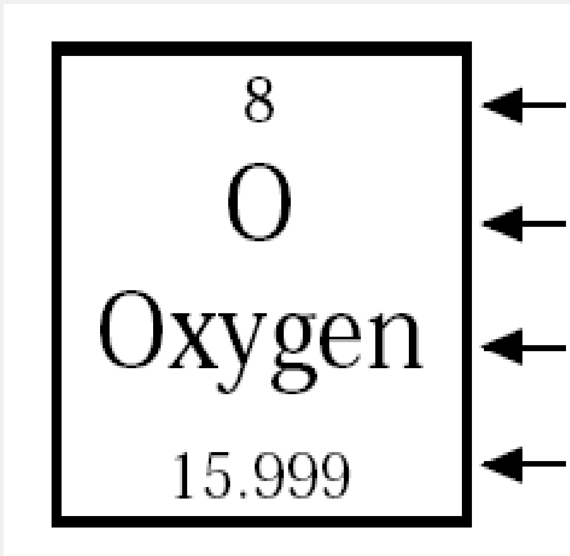
REMEMBER:

In a neutral atom, the

number of electrons = number of protons

TRY IT

Practice Making Nuclear Symbols



← Atomic Number

← Symbol

← Name

← Atomic Mass

(*atomic mass*)

$^{16}_{8}\text{O}$

(*atomic number*)

REMEMBER:

In a neutral atom, the number of electrons = number of protons

TRY IT

Nuclear Symbol

3

Li

____

6.941

Atomic # = ______

Atomic Mass = ________

# of Protons = _______

# of Neutrons = _______

# of Electrons = _______

TRY IT

Nuclear Symbol

3
Li
______
6.941

(p) Atomic # = __3__

(p + n) Atomic Mass = __7__

\# of Protons = __3__

\# of Neutrons = __4__

\# of Electrons = __3__

(*atomic mass*)

$$_{3}Li^{7}$$

(*atomic number*)

(*atomic mass - protons*)

TRY IT

Nuclear Symbol

30

____

Zinc

65.39

Atomic # = _____

Atomic Mass = _______

# of Protons = ______

# of Neutrons = ______

# of Electrons = ______

TRY IT

Nuclear Symbol

30

____

Zinc

65.39

(p) Atomic # = __30__

(p + n) Atomic Mass = ___65_____

# of Protons = ___30____

# of Neutrons = ___35____

# of Electrons = ___30____

(*atomic mass*)

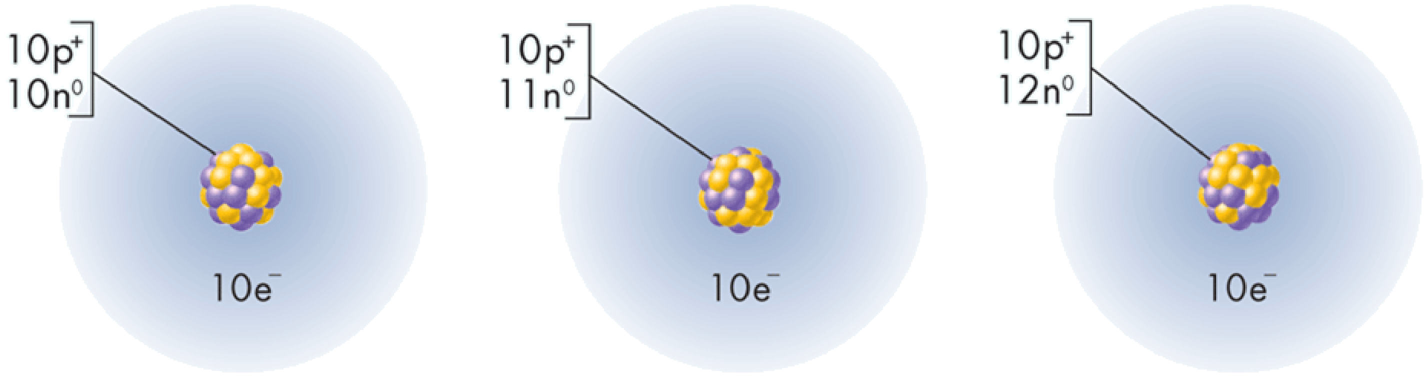
$$^{65}_{30}\mathrm{Zn}$$

(*atomic number*)

(*atomic mass - protons*)

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
10 protons
10 neutrons
10 electrons

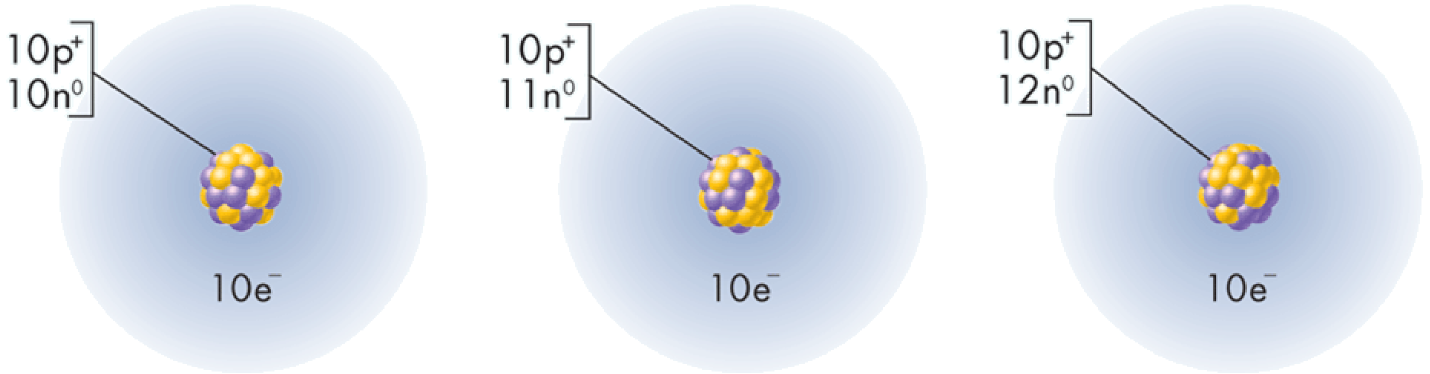
Neon-21
10 protons
11 neutrons
10 electrons

Neon-22
10 protons
12 neutrons
10 electrons

LESSON QUESTION

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

PEARSON

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	*Atomic #*	***n***	*Mass*
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

Distinguishing Among Atoms

Isotopes

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