

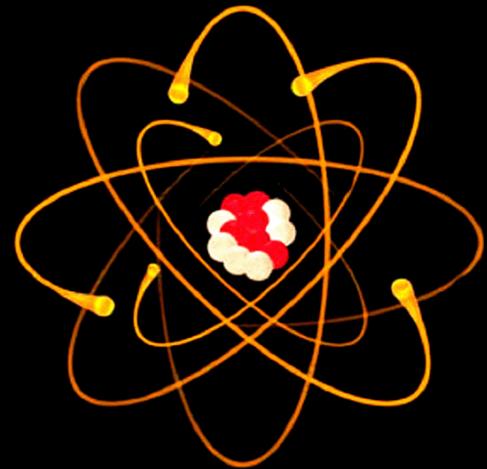
Atoms, Elements, and the Periodic Table
Part 1: The Atomic Model

Atomic Theory Timeline

The atomic model has changed over time.

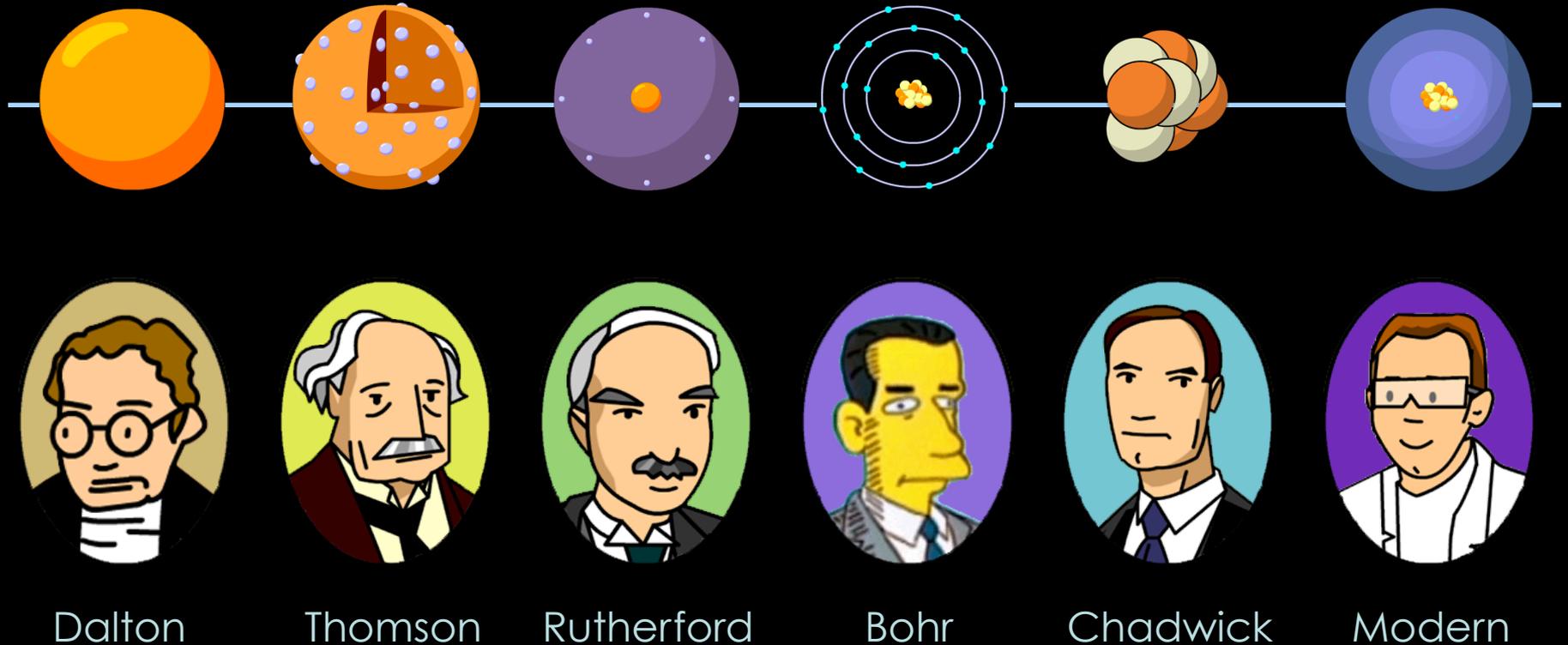
For over two centuries, scientists have created different models of the atom.

As scientists have learned more and more about atoms, the atomic model has changed.



Atomic Theory Timeline

Here is a timeline of some of the major ideas.



But First, Democritus!

Democritus was a Greek philosopher (470-380 B.C.) who is the father of modern atomic thought.

He proposed that matter could NOT be divided into smaller pieces forever.

He claimed that matter was made of small, hard particles that he called "atomos"



John Dalton - 1808

John Dalton created the very first atomic theory.

Dalton was an English school teacher who performed many experiments on atoms.



Dalton viewed atoms as tiny, solid balls.

His atomic theory had 4 statements...

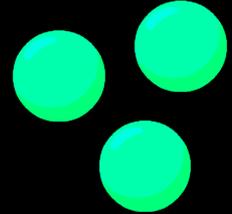


Dalton's Theory

1. Atoms are tiny, invisible particles.



2. Atoms of one element are all the same.



3. Atoms of different elements are different.



4. Compounds form by combining atoms.



J.J. Thomson (1897)

J.J. Thomson discovered electrons.

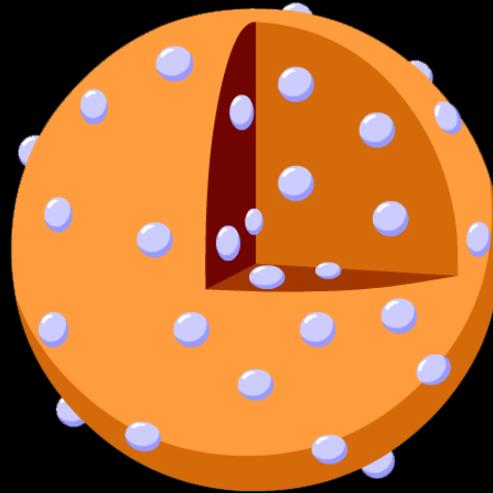
He was the first scientist to show that the atom was made of even smaller things.

He also proposed the existence of a (+) particle...

His atomic model was known as the “raisin bun model”...



Thomson's Model



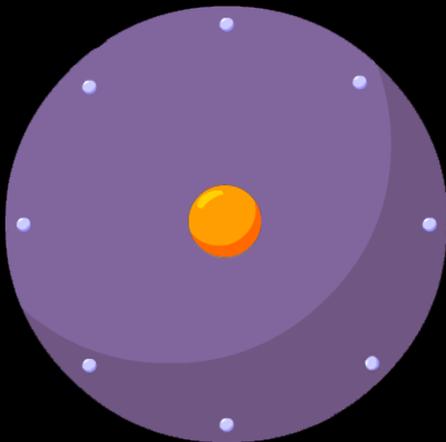
Atoms are made mostly out of (+) charged material, like dough in a bun.

The (-) charged electrons are found inside the (+) dough.

Ernest Rutherford (1911)

Rutherford discovered protons and the nucleus.

He showed that atoms have (+) particles in the center, and are mostly empty space.



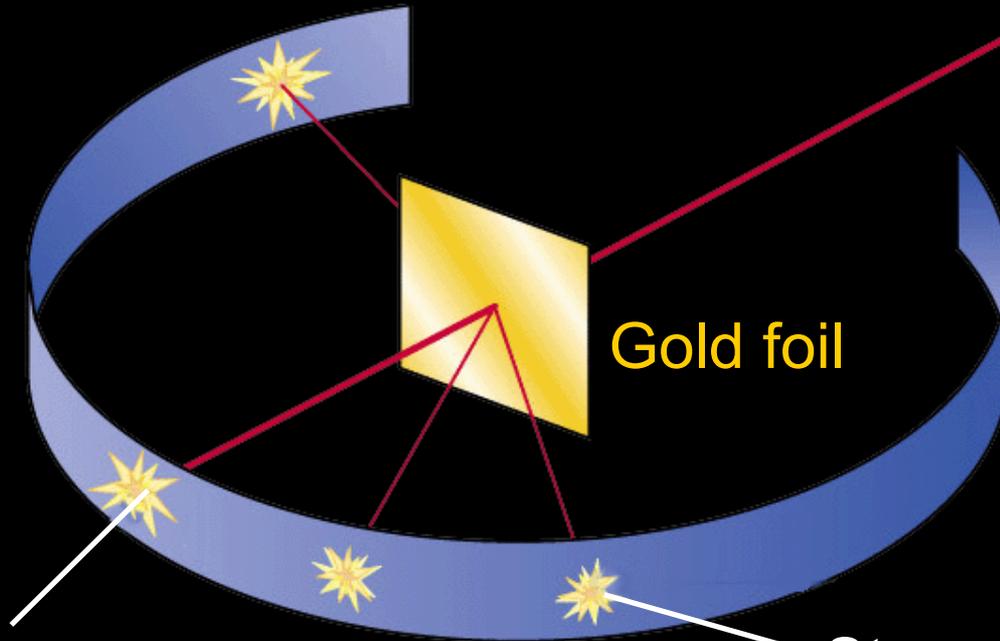
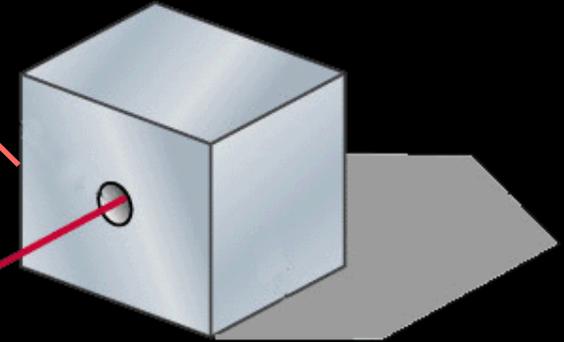
He called these (+) particles protons.

He called the center of atoms the nucleus.



Rutherford's Experiment

Radioactive material emits beam of (+) alpha particles

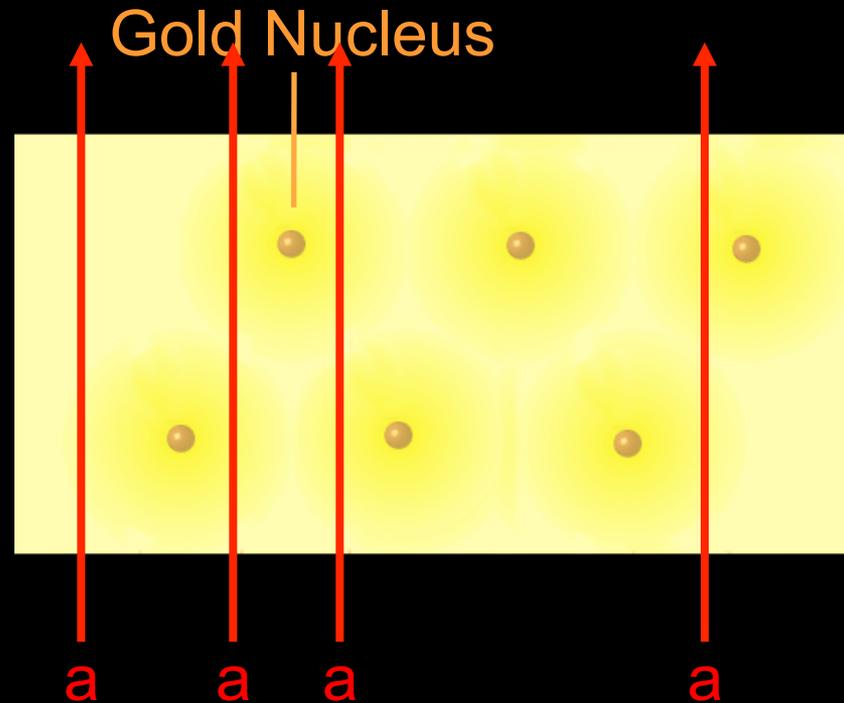


Screen

Most particles went right through!

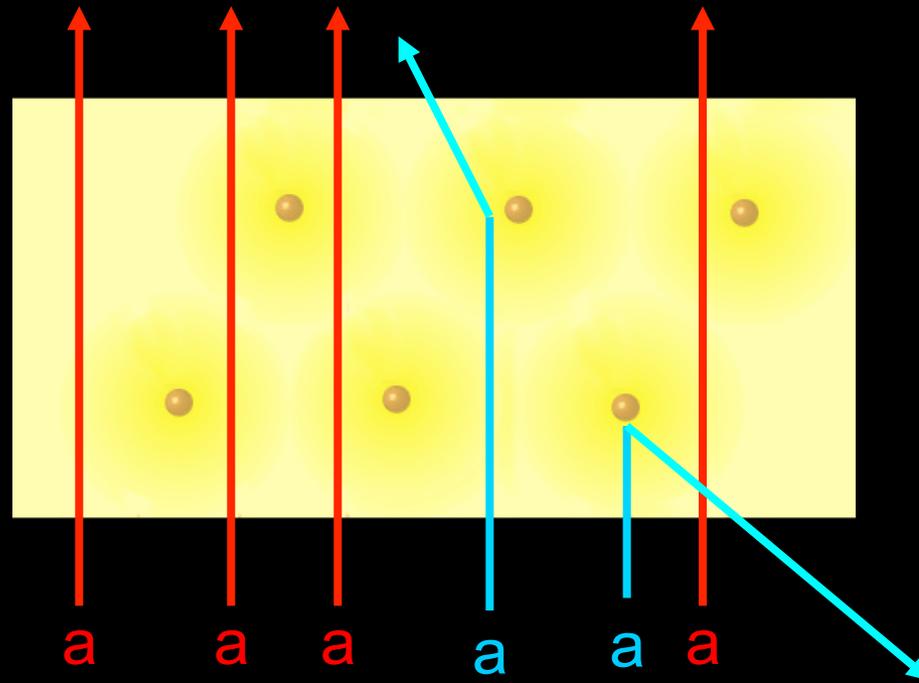
Strangely, some particles are deflected

Rutherford's Experiment



Most α particles went through the gold.
The atom is mostly empty space.

Rutherford's Experiment

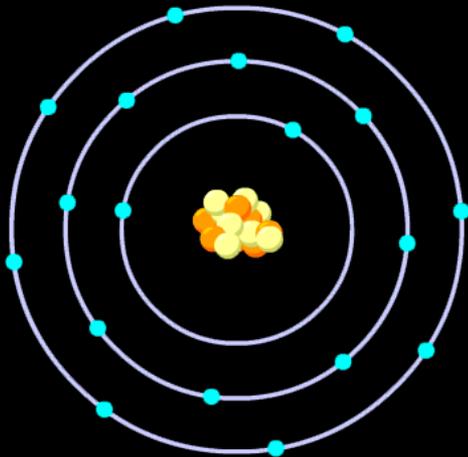


The atom had a very dense (+) center.
Rutherford called it the nucleus.

Niels Bohr (1913)

Niels Bohr improved on Rutherford's model.

He proposed that electrons move around the nucleus in specific layers, or shells.



Every atom has a specific number of electron shells.



James Chadwick (1932)

Chadwick discovered neutrons.

Working with Rutherford, he discovered particles with no charge.



He called these particles neutrons.

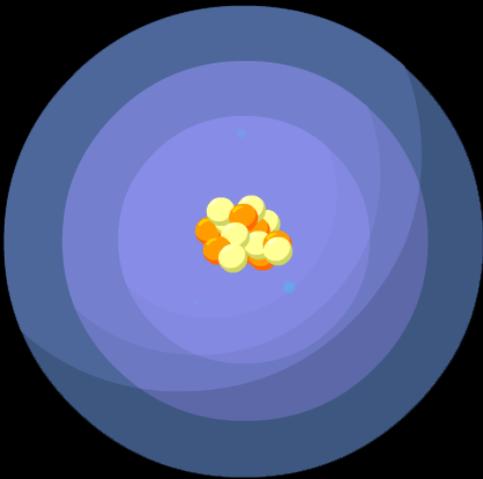
Neutrons are also found in the nucleus.



The Modern Model (1932-)

Work done since 1920 has changed the model.

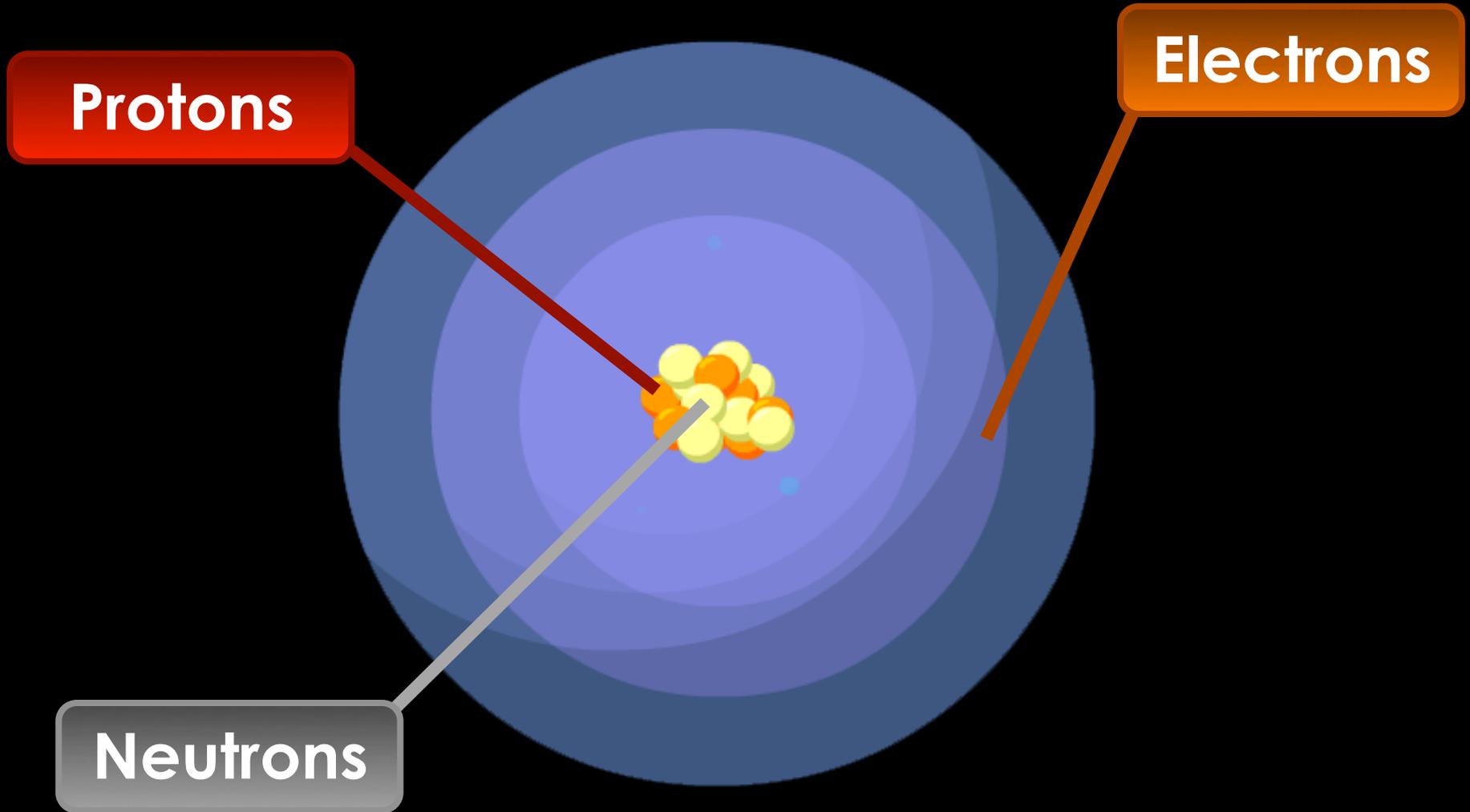
The new atomic model has electrons moving around the nucleus in a cloud.



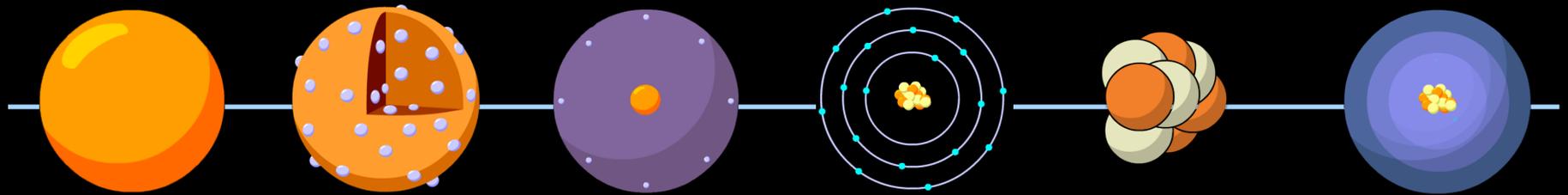
It is impossible to know where an electron is at any given time.



The Current Atomic Model



Atomic Theory Timeline



Dalton



Thomson



Rutherford



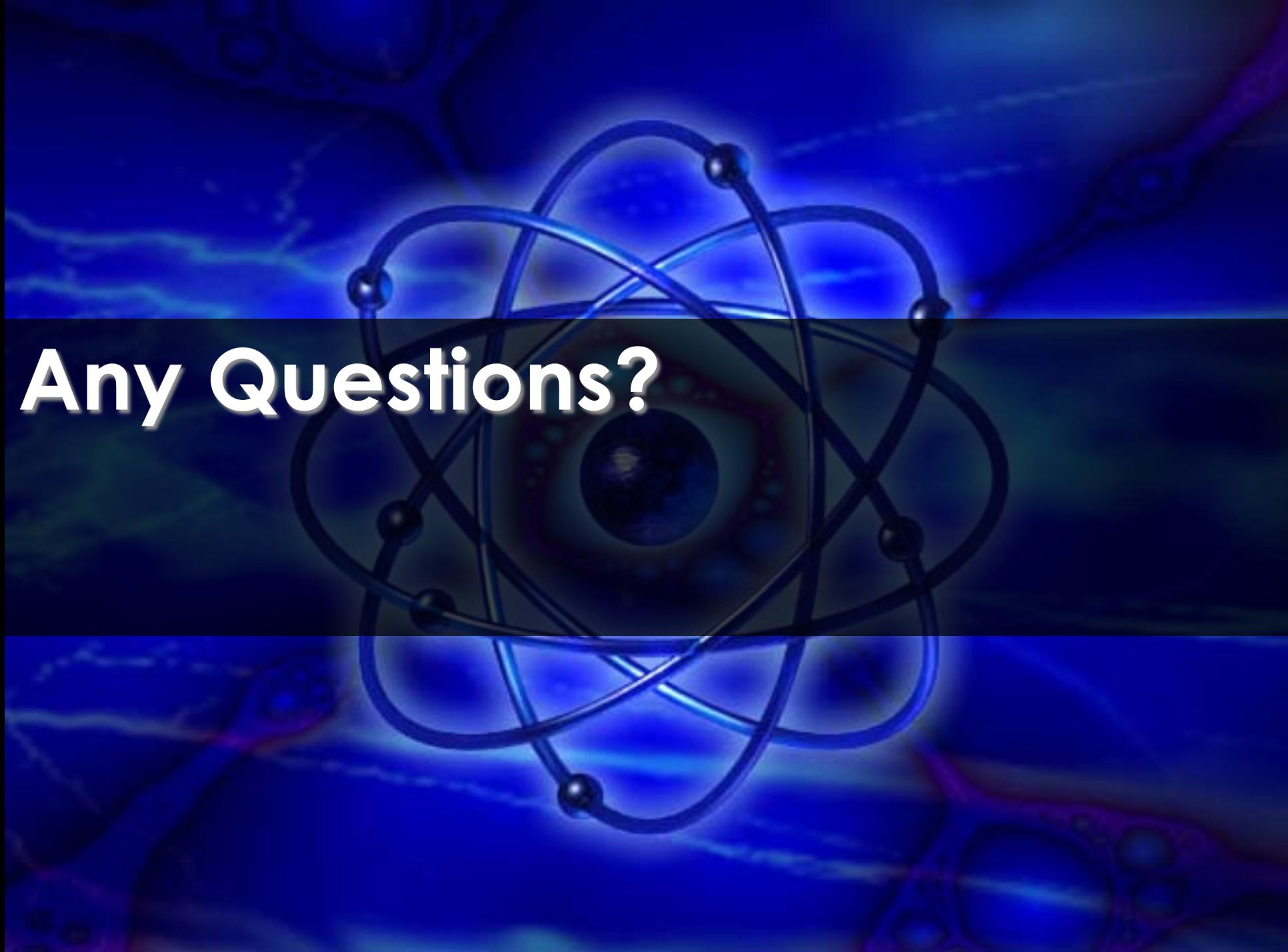
Bohr



Chadwick



Modern



Any Questions?

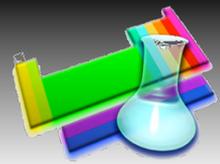
Annotations:

- Red box:** H (Hydrogen), He (Helium)
- Blue box:** Li (Lithium), Be (Beryllium)
- Green box:** Cr (Chromium)
 - Atomic number = 24
 - Atomic weight [amu] = 52.00
 - Radioactivity
 - Name - Chromium
 - Electron configuration = 3d⁵ 4s¹
 - Crystal structure of the metallic elements at room temperature: bcc, fcc, hcp, etc. or physical state: gas, liquid, solid
- Yellow box:** Si (Silicon), P (Phosphorus)
- Pink box:** S (Sulfur), Cl (Chlorine)
- Blue box:** Ar (Argon)
- Blue box:** K (Potassium), Ca (Calcium)
- Green box:** Ga (Gallium), Ge (Germanium)
- Yellow box:** As (Arsenic), Se (Selenium)
- Pink box:** Br (Bromine), Kr (Krypton)
- Blue box:** Rb (Rubidium), Sr (Strontium)
- Green box:** Y (Yttrium), Zr (Zirconium)
- Yellow box:** Nb (Niobium), Mo (Molybdenum)
- Pink box:** Tc (Technetium), Ru (Ruthenium)
- Blue box:** Rh (Rhodium), Pd (Palladium)
- Green box:** Ag (Silver), Cd (Cadmium)
- Yellow box:** In (Indium), Sn (Tin)
- Pink box:** Sb (Antimony), Te (Tellurium)
- Blue box:** I (Iodine), Xe (Xenon)
- Green box:** Ba (Barium), La (Lanthanum)
- Yellow box:** Ce (Cerium), Pr (Praseodymium)
- Pink box:** Nd (Neodymium), Pm (Promethium)
- Blue box:** Sm (Samarium), Eu (Europium)
- Green box:** Gd (Gadolinium), Tb (Terbium)
- Yellow box:** Dy (Dysprosium), Ho (Holmium)
- Pink box:** Er (Erbium), Tm (Thulium)
- Blue box:** Yb (Ytterbium), Lu (Lutetium)
- Green box:** Ac (Actinium), Th (Thorium)
- Yellow box:** Pa (Protactinium), U (Uranium)
- Pink box:** Np (Neptunium), Pu (Plutonium)
- Blue box:** Am (Americium), Cm (Curium)
- Green box:** Bk (Berkelium), Cf (Californium)
- Yellow box:** Es (Einsteinium), Fm (Fermium)
- Pink box:** Md (Mendelevium), No (Nobelium)
- Blue box:** Lr (Lawrencium)

Atoms, Elements, and the Periodic Table

Part 2: The Periodic Table

Periodic Table



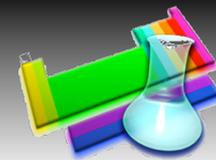
There are \approx 110 different elements in the universe.

The Periodic Table of Elements organizes these 110 elements in a simple way.

Remember!

Elements differ from each other by the # of protons, neutrons and electrons they have.

Before the Table



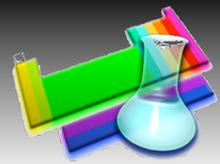
Before the Periodic Table was invented, the field of Chemistry was a gigantic mess!

The known elements were not organized in any way.



It was very difficult to find information on any element AND to predict how each element would react.

Before the Table



A Russian scientist named **Dmitri Mendeleev** discovered patterns in the properties of the elements.

I placed the elements in order of increasing atomic weight. When I did that, I noticed patterns in their properties and their reactivity.



Li 7	Be 9	B 11	C 12	N 14	O 16	F 19	
Na 23	Mg 24	Al 27	Si 28	P 31	S 32	Cl 35.5	
K 39	Ca 40		Ti 48	V 51	Cr 52	Mn 55	Fe ₅₆ Ni ₅₉
Cu 63	Zn 65			As 75	Se 78	Br 80	
Rb 85	Sr 87		Zr 90	Nb 94	Mo 96		Pd ₁₀₆



Then I put the next 7 in a new row, and filled rest of the table like that.

Li 7	Be 9	B 11	C 12	N 14	O 16	F 19	
Na 23	Mg 24	Al 27	Si 28	P 31	S 32	Cl 35.5	
K 39	Ca 40	?	Ti 48	V 51	Cr 52	Mn 55	Fe 56 Ni 59
Cu 63	Zn 65	?	?	As 75	Se 78	Br 80	
Rb 85	Sr 87	?	Zr 90	Nb 94	Mo 96	?	Pd 106



I left gaps for elements that I predicted would be discovered.

Li 7	Be 9	B 11	C 12	N 14	O 16	F 19	
Na 23	Mg 24	Al 27	Si 28	P 31	S 32	Cl 35.5	
K 39	Ca 40	?	Ti 48	V 51	Cr 52	Mn 55	Fe 56 Ni 59
Cu 63	Zn 65	?	?	As 75	Se 78	Br 80	
Rb 85	Sr 87	?	Zr 90	Nb 94	Mo 96	?	Pd 106



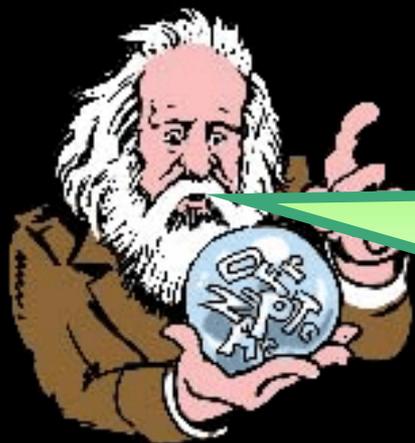
Elements in the same column share similar chemical properties.

Li 7	Be 9	B 11	C 12	N 14	O 16	F 19	
Na 23	Mg 24	Al 27	Si 28	P 31	S 32	Cl 35.5	
K 39	Ca 40	?	Ti 48	V 51	Cr 52	Mn 55	Fe 56 Ni 59
Cu 63	Zn 65	?	?	As 75	Se 78	Br 80	
Rb 85	Sr 87	?	Zr 90	Nb 94	Mo 96	?	Pd 106



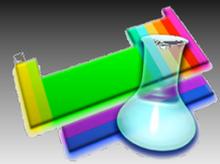
This allowed me to even predict the properties of the unknown elements.

Li 7	Be 9	B 11	C 12	N 14	O 16	F 19	
Na 23	Mg 24	Al 27	Si 28	P 31	S 32	Cl 35.5	
K 39	Ca 40	Sc 44	Ti 48	V 51	Cr 52	Mn 55	Fe 56 Ni 59
Cu 63	Zn 65	Ga 68	Ge 72	As 75	Se 78	Br 80	
Rb 85	Sr 87	Y 88	Zr 90	Nb 94	Mo 96	Tc 100	Pd 106



The elements were soon found,
and they matched my predictions!

Mendeleev's Table



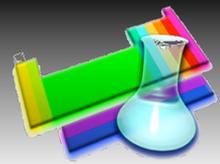
Mendeleev was amazingly accurate with his table.

The Periodic Table has been updated since then with new elements and information.

Once protons were discovered, elements were rearranged by atomic number.

Some elements changed spots, making the pattern of properties even more regular.

The New Table

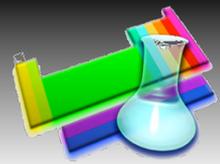


The new periodic table has over 100 squares.

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									
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				

Each square shows the element's name, symbol, atomic number and atomic mass...

Element Information



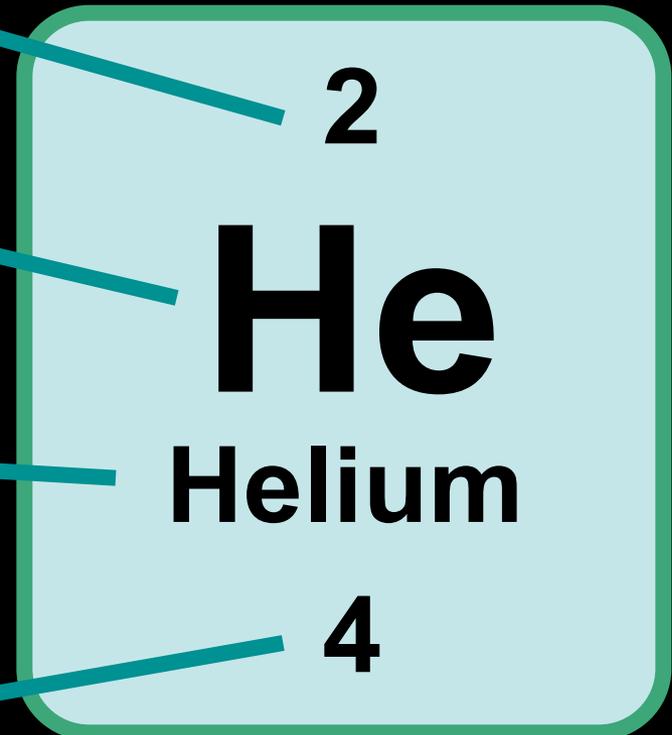
Take the element Helium, for example:

Atomic Number (p)

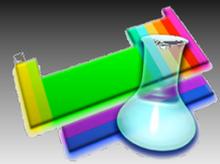
Element Symbol

Element Name

Mass Number (p + n)



Groups



Each group is also called a “family” of elements.

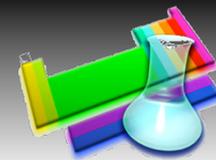


Just like members of the same family, they share similar characteristics.

Each element family has a unique name as well!

Let's look at them now...

Gp 1: Alkali Metals



HIGHLY reactive metals.

They are so reactive that they are never found uncombined in nature.



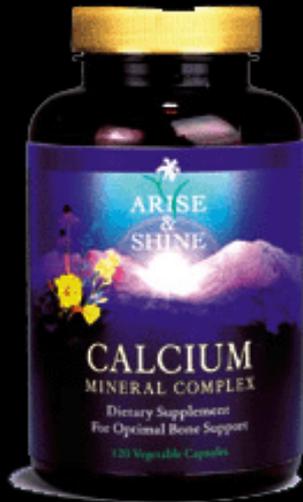
Sodium (Na)

Metals soft enough to be cut with a butter knife!

e.g. Li, Na, K

Gp 2: Alkaline Earth Metals

Fairly reactive metals.



Calcium (Ca)

Not as reactive as the Alkali Metals, but still never found uncombined in nature.

Serve as important minerals for our body.

e.g. Be, Mg, Ca

Gp 3-12: Transition Metals

Less reactive metals.



Nickel (Ni)
Gold (Au)

Hard, dense metals that are useful as building materials, jewellery and coins.

Also used as oxides to make paints and pigments.

e.g. Fe, Cu, Au, Ag

Gp 18: Noble Gases

Unreactive gases.

Do not react naturally -
always found on their
own in nature.

Used in “neon” signs,
balloons and light bulbs.

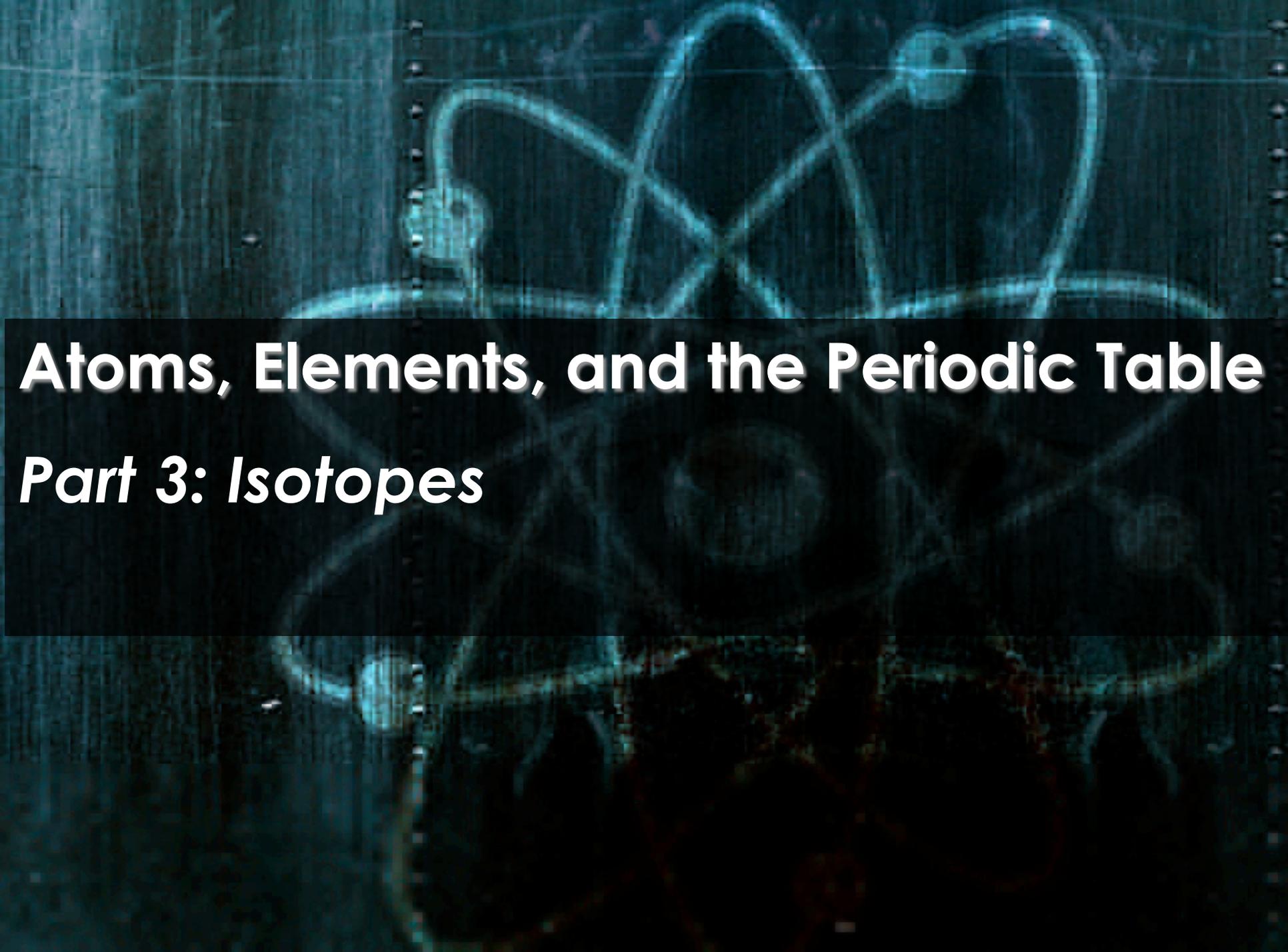
e.g. He, Ne, Ar



Neon (Ne)

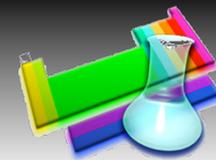
										Noble gases										
										Nonmetals --			Other nonmetals			Halogens				
1 1.0079 H Hydrogen 1s ¹											2 4.003 He Helium 1s ²									
3 6.941 Li Lithium 2s ¹	4 9.012 Be Beryllium 2s ²											5 12.01 B Boron 2s ² 2p ¹	6 12.01 C Carbon 2s ² 2p ²	7 14.01 N Nitrogen 2s ² 2p ³	8 16.00 O Oxygen 2s ² 2p ⁴	9 19.00 F Fluorine 2s ² 2p ⁵	10 20.18 Ne Neon 2s ² 2p ⁶			
11 22.99 Na Sodium 3s ¹	12 24.31 Mg Magnesium 3s ²											13 26.98 Al Aluminum 3s ² 3p ¹	14 28.09 Si Silicon 3s ² 3p ²	15 30.97 P Phosphorus 3s ² 3p ³	16 32.07 S Sulfur 3s ² 3p ⁴	17 35.45 Cl Chlorine 3s ² 3p ⁵	18 39.95 Ar Argon 3s ² 3p ⁶			
<div style="position: absolute; top: 20px; left: 20px; background: white; padding: 5px; border: 1px solid gray;"> <p>Atomic number = 24 52.00 → Atomic weight [amu] number of protons number of neutrons</p> <p>Radioactivity → Cr Crystal structure of the metallic elements at room temperature Native → Chromium ■ bcc ● fcc ◆ hcp ◆ cp Electron → 3d⁴4s¹ configuration or physical state (gas, liquid)</p> </div>																				
19 39.098 K Potassium 4s ¹	20 39.098 Ca Calcium 4s ²	21 39.098 Sc Scandium 3d ¹ 4s ²	22 39.098 Ti Titanium 3d ² 4s ²	23 39.098 V Vanadium 3d ³ 4s ²	24 39.098 Cr Chromium 3d ⁵ 4s ¹	25 39.098 Mn Manganese 3d ⁵ 4s ²	26 39.098 Fe Iron 3d ⁶ 4s ²	27 39.098 Co Cobalt 3d ⁷ 4s ²	28 39.098 Ni Nickel 3d ⁸ 4s ²	29 39.098 Cu Copper 3d ¹⁰ 4s ¹	30 39.098 Zn Zinc 3d ¹⁰ 4s ²	31 39.098 Ga Gallium 4s ² 4p ¹	32 39.098 Ge Germanium 4s ² 4p ²	33 39.098 As Arsenic 4s ² 4p ³	34 39.098 Se Selenium 4s ² 4p ⁴	35 39.098 Br Bromine 4s ² 4p ⁵	36 39.098 Kr Krypton 4s ² 4p ⁶			
37 39.098 Rb Rubidium 5s ¹	38 39.098 Sr Strontium 5s ²	39 39.098 Y Yttrium 4d ¹ 5s ²	40 39.098 Zr Zirconium 4d ² 5s ²	41 39.098 Nb Niobium 4d ⁴ 5s ¹	42 39.098 Mo Molybdenum 4d ⁵ 5s ¹	43 39.098 Tc Technetium 4d ⁵ 5s ²	44 39.098 Ru Ruthenium 4d ⁷ 5s ¹	45 39.098 Rh Rhodium 4d ⁸ 5s ¹	46 39.098 Pd Palladium 4d ¹⁰ 5s ⁰	47 39.098 Ag Silver 4d ¹⁰ 5s ¹	48 39.098 Cd Cadmium 4d ¹⁰ 5s ²	49 39.098 In Indium 5s ² 5p ¹	50 39.098 Sn Tin 5s ² 5p ²	51 39.098 Sb Antimony 5s ² 5p ³	52 39.098 Te Tellurium 5s ² 5p ⁴	53 39.098 I Iodine 5s ² 5p ⁵	54 39.098 Xe Xenon 5s ² 5p ⁶			
55 39.098 Cs Cesium 6s ¹	56 39.098 Ba Barium 6s ²	57 39.098 La Lanthanum 5d ¹ 6s ²	58 39.098 Ce Cerium 5d ¹ 6s ²	59 39.098 Pr Praseodymium 5d ⁰ 6s ²	60 39.098 Nd Neodymium 5d ⁰ 6s ²	61 39.098 Pm Promethium 5d ⁰ 6s ²	62 39.098 Sm Samarium 5d ⁰ 6s ²	63 39.098 Eu Europium 5d ⁰ 6s ²	64 39.098 Gd Gadolinium 5d ¹ 6s ²	65 39.098 Tb Terbium 5d ¹ 6s ²	66 39.098 Dy Dysprosium 5d ¹ 6s ²	67 39.098 Ho Holmium 5d ¹ 6s ²	68 39.098 Er Erbium 5d ¹ 6s ²	69 39.098 Tm Thulium 5d ¹ 6s ²	70 39.098 Yb Ytterbium 5d ¹ 6s ²	71 39.098 Lu Lutetium 5d ¹ 6s ²				
87 39.098 Fr Francium 7s ¹	88 39.098 Ra Radium 7s ²	89 39.098 Rf Rutherfordium 5f ¹⁴ 6d ¹ 7s ²	90 39.098 Db Dubnium 5f ¹⁴ 6d ¹ 7s ²	91 39.098 Sg Seaborgium 5f ¹⁴ 6d ¹ 7s ²	92 39.098 Bh Bohrium 5f ¹⁴ 6d ¹ 7s ²	93 39.098 Hs Hassium 5f ¹⁴ 6d ¹ 7s ²	94 39.098 Mt Meitnerium 5f ¹⁴ 6d ¹ 7s ²	95 39.098 Ds Darmstadtium 5f ¹⁴ 6d ¹ 7s ²	96 39.098 Rg Roentgenium 5f ¹⁴ 6d ¹ 7s ²	97 39.098 Cn Copernicium 5f ¹⁴ 6d ¹ 7s ²	Transition metals									
												Poor metals			Metalloids		Metals			
										13	14	15	17	17	18					
<div style="display: flex; justify-content: space-between;"> <div style="width: 15%;">Alkali metals</div> <div style="width: 15%;">Alkaline earth metals</div> <div style="width: 60%;"></div> </div>																				
72 138.91 La Lanthanum 5d ¹ 6s ²	73 138.91 Ce Cerium 4f ¹ 5d ¹ 6s ²	74 138.91 Pr Praseodymium 4f ³ 6s ²	75 138.91 Nd Neodymium 4f ⁴ 6s ²	76 138.91 Pm Promethium 4f ⁵ 6s ²	77 138.91 Sm Samarium 4f ⁶ 6s ²	78 138.91 Eu Europium 4f ⁷ 6s ²	79 138.91 Gd Gadolinium 4f ⁷ 5d ¹ 6s ²	80 138.91 Tb Terbium 4f ⁹ 6s ²	81 138.91 Dy Dysprosium 4f ¹⁰ 6s ²	82 138.91 Ho Holmium 4f ¹¹ 6s ²	83 138.91 Er Erbium 4f ¹² 6s ²	84 138.91 Tm Thulium 4f ¹³ 6s ²	85 138.91 Yb Ytterbium 4f ¹⁴ 6s ²	86 138.91 Lu Lutetium 4f ¹⁴ 6s ²	Lanthanides					
89 232.04 Ac Actinium 6d ¹ 7s ²	90 232.04 Th Thorium 6d ² 7s ²	91 232.04 Pa Protactinium 5f ² 6d ¹ 7s ²	92 232.04 U Uranium 5f ³ 6d ¹ 7s ²	93 232.04 Np Neptunium 5f ⁴ 6d ¹ 7s ²	94 232.04 Pu Plutonium 5f ⁶ 7s ²	95 232.04 Am Americium 5f ⁷ 7s ²	96 232.04 Cm Curium 5f ⁷ 6d ¹ 7s ²	97 232.04 Bk Berkelium 5f ⁷ 7s ²	98 232.04 Cf Californium 5f ¹⁰ 7s ²	99 232.04 Es Einsteinium 5f ¹¹ 7s ²	100 232.04 Fm Fermium 5f ¹² 7s ²	101 232.04 Md Mendelevium 5f ¹³ 7s ²	102 232.04 No Nobelium 5f ¹⁴ 7s ²	103 232.04 Lr Lawrencium 6d ¹ 7s ²	Actinides					

Any Questions?



Atoms, Elements, and the Periodic Table
Part 3: Isotopes

Review



Each element has a unique # of protons.

Every single atom of that element must have the same number of protons.

So, each element has a unique atomic number.

Atomic Number (p)

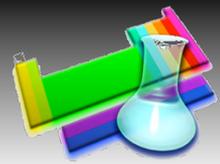
6

C

Carbon

12

Isotopes



Atoms of one element must have the same # of protons, but can have a different # of neutrons.

Isotopes are atoms with the same # of protons and a different # of neutrons.

This gives an isotope a different mass number.

Mass Number (p + n)

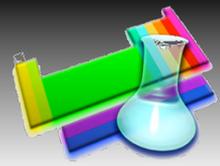
6
C
Carbon

14

6
C
Carbon

12

An Example



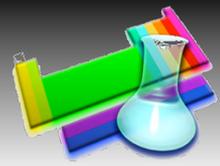
There are 3 isotopes of oxygen:



Each has 8 protons: that's why it's oxygen!

How many neutrons does each isotope have?

An Example



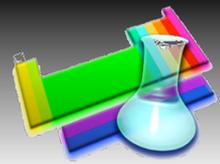
There are 3 isotopes of oxygen:



Each has 8 protons: that's why it's oxygen!

How many neutrons does each isotope have?

A Second Example

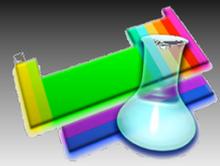


There are 3 isotopes of carbon:



How many neutrons does each isotope have?

A Second Example

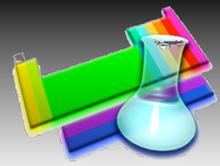


There are 3 isotopes of carbon:



How many neutrons does each isotope have?

Why Decimals?



Mass numbers are normally **decimals**.

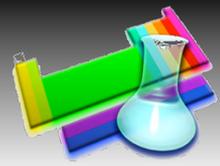


Why is this?

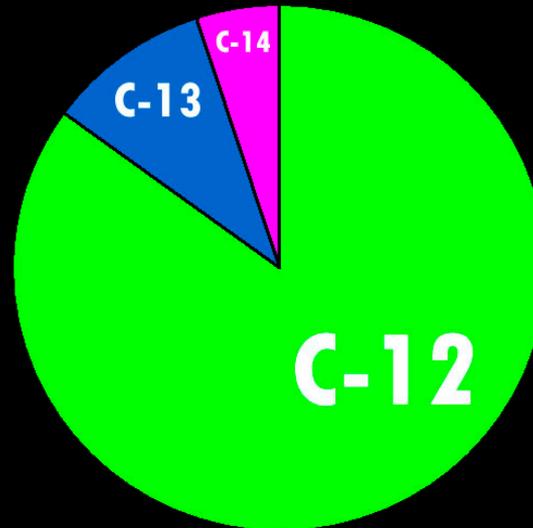
Mass numbers are decimals because some isotopes are **more common** than others.

Lets's look at an example....

Why Decimals?



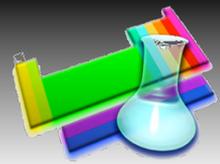
In the universe, there is much more C-12 than C-13 and C-14 isotopes.



The mass # is always closest to the most common isotope.

When you average out all of the masses, you get a number close to 12, but not exactly!

An Example

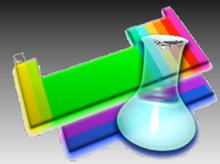


The mass number of oxygen is 15.999



What's the most common oxygen isotope?

An Example



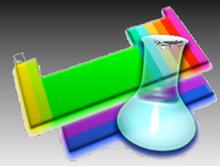
The mass number of oxygen is 15.999



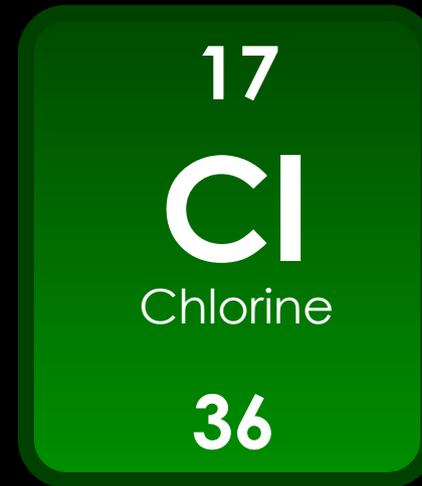
What's the most common oxygen isotope?

This is because 15.999 is closest to O-16.

Another Example

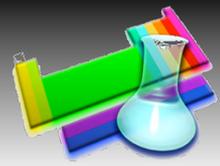


The mass number of chlorine 35.45



What is the most common chlorine isotope?

Another Example

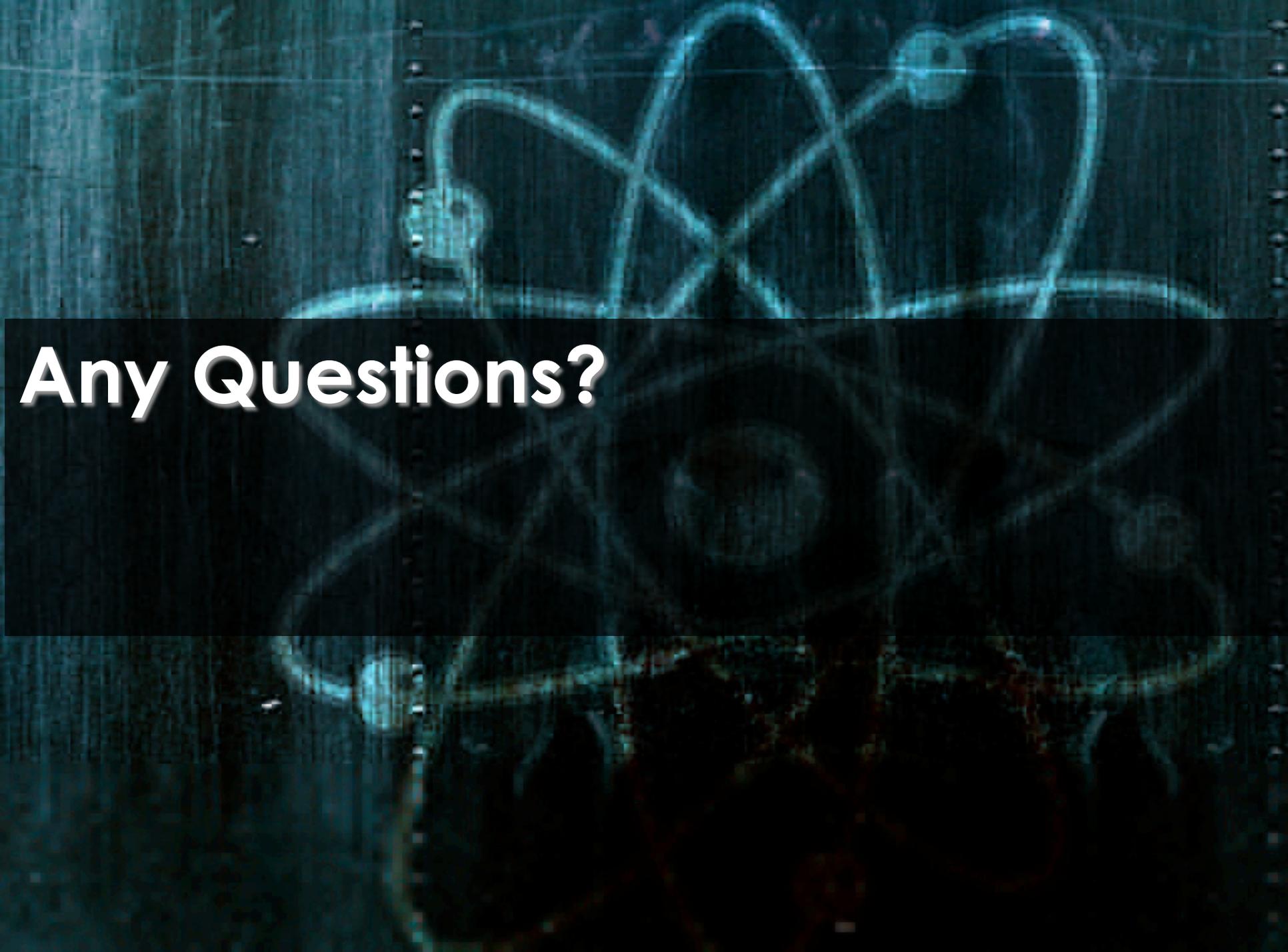


The mass number of chlorine 35.45



What is the most common chlorine isotope?

Chlorine is found in roughly equal amounts.



Any Questions?