Chemistry
Atoms and Elements

SCIENTIFIC MODELS

When there is a question you can't answer, or an observation you can't explain, one way of finding an answer is to develop a MODEL.

A Model is mental picture, a diagram or some other means that attempts to explain a concept.

For example: Black Box Activity

The Particle Theory of Matter

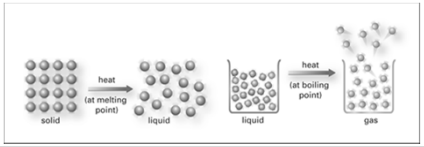
Matter is anything that has **mass** and takes up **space** (has volume). A Greek philosopher, Democritus, suggested that all matter is made up of tiny particles. He called these particles **Atoms**.

This idea is the basis for what we call The Particle theory of Matter.

There are five postulates (statements) of the Particle Theory.

1. All matter is made up of extremely **tiny particles**.
2. Each **pure substance** has its own kind of **particle**, different from the particles of **other** pure substances.
3. Particles **attract** each other. These forces are **stronger** when the particles are **closer** together.
4. Particles are always **moving**. Particles at a **higher** temperature move **faster** on average than particles at a **lower** temperature.
5. There are **spaces** between the particles.

This model can be used to explain simple **changes of state**.



SNC 1DI
The States of Matter and the Particle Theory

			
Particle Motion	SLOWEST -vibrate in a fixed position	FASTER THAN SOLIDS -move around each other in clumps	FASTEST -move constantly and in all directions at high speeds

Particle Spacing	very close together	farther apart than solids	very far apart
Particle Attraction	very strong attraction	weaker attraction than solids	weakest attraction
What happens to particles when heat is added ?	particles vibrate faster in the same spot	particles flow around each other faster	Particles move at extremely higher speeds

SNC 2PI:Classification of Matter

MATTER:
Anything that has mass and takes up space.
For example: water, air, salt

PURE SUBSTANCE:
A substance that contains only **one** type of matter and has **constant** properties.
For example: water, salt, oxygen

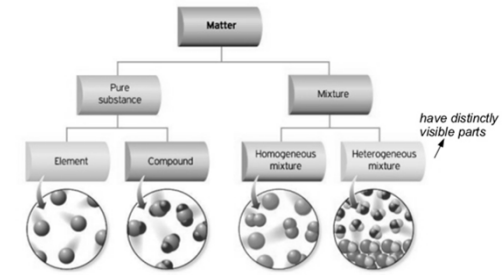
MIXTURES:
Contain **two** or more types of matter where each keep their **own** properties.
For example: sand and salt, salt and water

ELEMENTS:
Made up of only **one** kind of **atom**. (particle).
Cannot be broken down by **chemical** means (rearranged).
For example: gold, oxygen (O_2)

COMPOUND:
Made up of **two** or more **different** atoms.
Can be broken down by chemical means to form **new** substances.
For example: water (H_2O)

SOLUTION:
(Homogeneous Mixture)
Some parts that make up the mixture are **invisible**.
Can only see one part or one **phase**.
For example: salt and water

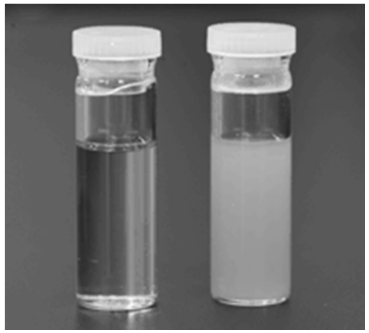
MECHANICAL MIXTURE:
(Heterogeneous Mixture)
Two or more parts are **visible**.
Can see two or more parts or **phases**.
For example: oil and water



Look at a Periodic Table. There are 113 elements in the Periodic Table

Most materials we encounter in the world are mixtures. The air we breathe is a mixture of oxygen, nitrogen, and other gases. The oceans are mixtures of water, salts and other substances

SOLUTION:
(Homogeneous Mixture)
Some parts that make up the mixture are **invisible**.
Can only see one part or one **phase**.
For example:
salt and water

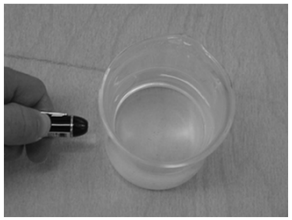


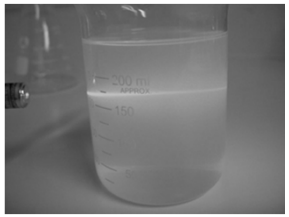
SUSPENSION:
Can only see one part or one **phase** but not all the particles are completely dissolved and they will **settle** over time. Suspensions are a little cloudy.
For example:
fresh orange juice, oil and vinegar salad dressing

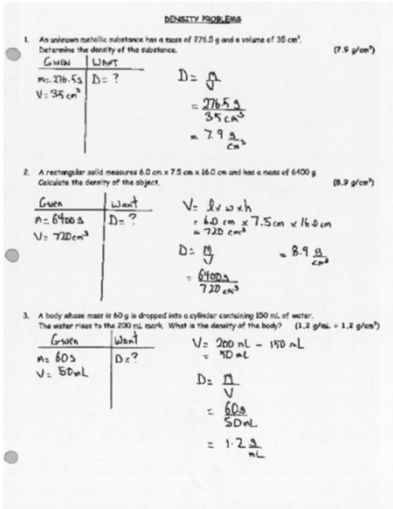
4 hours 48 hours 7 days

SUSPENSION:
Can only see one part or one **phase** but not all the particles are completely dissolved and they will **settle** over time. Suspensions are a little cloudy.
For example:
fresh orange juice, oil and vinegar salad dressing

TYNDALL EFFECT:
The reflection of suspended particles is called the Tyndall Effect.







DENSITY PROBLEMS

1. An unknown metallic substance has a mass of 276.5 g and a volume of 35 cm³. Determine the density of the substance. (7.9 g/cm³)

Given	Want
m = 276.5 g	D = ?
V = 35 cm³	

D = m/V
= 276.5 g / 35 cm³
= 7.9 g/cm³

2. A rectangular solid measures 6.0 cm x 7.5 cm x 16.0 cm and has a mass of 6400 g. Calculate the density of the object. (8.9 g/cm³)

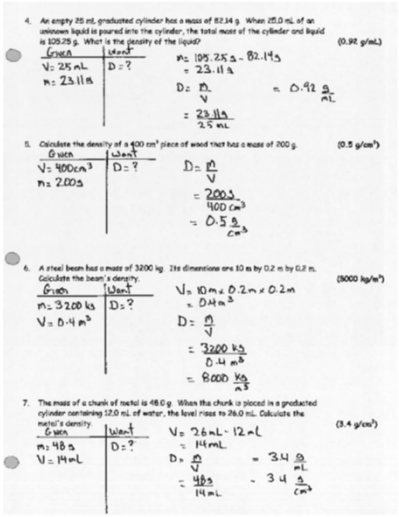
Given	Want
m = 6400 g	D = ?
V = 720 cm³	

V = l x w x h
= 6.0 cm x 7.5 cm x 16.0 cm
= 720 cm³
D = m/V = 8.9 g/cm³
= 6400 g / 720 cm³

3. A body whose mass is 60 g is dropped into a cylinder containing 150 mL of water. The water rises to the 200 mL mark. What is the density of the body? (1.2 g/mL = 1.2 g/cm³)

Given	Want
m = 60 g	D = ?
V = 50 mL	

V = 200 mL − 150 mL
= 50 mL
D = m/V
= 60 g / 50 mL
= 1.2 g/mL



4. An empty 25 mL graduated cylinder has a mass of 82.14 g. When 25.0 mL of an unknown liquid is poured into the cylinder, the total mass of the cylinder and liquid is 105.25 g. What is the density of the liquid? (0.92 g/mL)

Given	Want
V = 25 mL	D = ?
m = 23.11 g	

m = 105.25 g − 82.14 g = 23.11 g

D = m/V = 23.11 g / 25 mL = 0.92 g/mL

5. Calculate the density of a 400 cm³ piece of wood that has a mass of 200 g. (0.5 g/cm³)

Given	Want
V = 400 cm³	D = ?
m = 200 g	

D = m/V = 200 g / 400 cm³ = 0.5 g/cm³

6. A steel beam has a mass of 3200 kg. Its dimensions are 10 m by 0.2 m by 0.2 m. Calculate the beam's density. (8000 kg/m³)

Given	Want
m = 3200 kg	D = ?
V = 0.4 m³	

V = 10 m × 0.2 m × 0.2 m = 0.4 m³

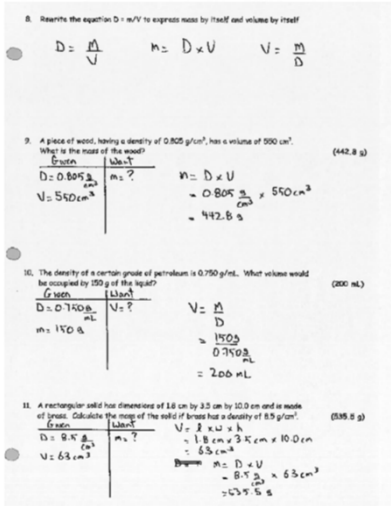
D = m/V = 3200 kg / 0.4 m³ = 8000 kg/m³

7. The mass of a chunk of metal is 48.0 g. When the chunk is placed in a graduated cylinder containing 12.0 mL of water, the level rises to 26.0 mL. Calculate the metal's density. (3.4 g/cm³)

Given	Want
m = 48 g	D = ?
V = 14 mL	

V = 26 mL − 12 mL = 14 mL

D = m/V = 48 g / 14 mL = 3.4 g/mL = 3.4 g/cm³



8. Rewrite the equation D = m/V to express mass by itself and volume by itself

D = m/V m = D × V V = m/D

9. A piece of wood, having a density of 0.805 g/cm³, has a volume of 550 cm³. What is the mass of the wood? (442.8 g)

Given	Want
D = 0.805 g/cm³	m = ?
V = 550 cm³	

m = D × V = 0.805 g/cm³ × 550 cm³ = 442.8 g

10. The density of a certain grade of petroleum is 0.750 g/mL. What volume would be occupied by 150 g of the liquid? (200 mL)

Given	Want
D = 0.750 g/mL	V = ?
m = 150 g	

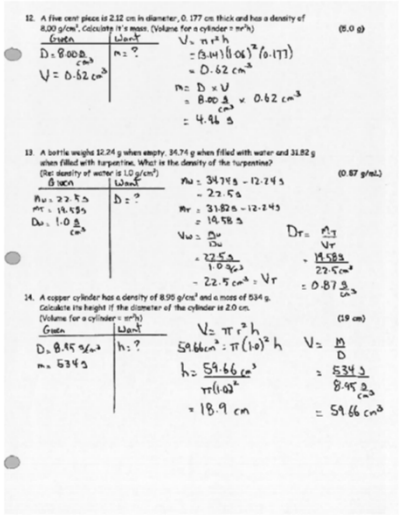
V = m/D = 150 g / 0.750 g/mL = 200 mL

11. A rectangular solid has dimensions of 1.8 cm by 3.5 cm by 10.0 cm and is made of brass. Calculate the mass of the solid if brass has a density of 8.9 g/cm³. (535.8 g)

Given	Want
D = 8.9 g/cm³	m = ?
V = 63 cm³	

V = l × w × h = 1.8 cm × 3.5 cm × 10.0 cm = 63 cm³

m = D × V = 8.9 g/cm³ × 63 cm³ = 535.8 g



12. A five cent piece is 2.12 cm in diameter, 0.177 cm thick and has a density of 8.00 g/cm³. Calculate it's mass. (Volume for a cylinder = πr²h) (5.0 g)

Given	Want
D = 8.00 g/cm³	m = ?
V = 0.62 cm³	

V = πr²h = (3.14)(1.06)²(0.177) = 0.62 cm³

m = D × V = 8.00 g/cm³ × 0.62 cm³ = 4.96 g

13. A bottle weighs 12.24 g when empty, 34.74 g when filled with water and 31.82 g when filled with turpentine. What is the density of the turpentine? (Rel. density of water is 1.0 g/cm³) (0.87 g/mL)

Given	Want
m_w = 22.5 g	D = ?
m_T = 19.58 g	
D_w = 1.0 g/cm³	

m_w = 34.74 g − 12.24 g = 22.5 g

m_T = 31.82 g − 12.24 g = 19.58 g

$V_w = \frac{m_w}{D_w} = \frac{22.5\ g}{1.0\ g/cm^3} = 22.5\ cm^3 = V_T$

$D_T = \frac{m_T}{V_T} = \frac{19.58\ g}{22.5\ cm^3} = 0.87\ g/cm^3$

14. A copper cylinder has a density of 8.95 g/cm³ and a mass of 534 g. Calculate its height if the diameter of the cylinder is 2.0 cm. (Volume for a cylinder = πr²h) (19 cm)

Given	Want
D = 8.95 g/cm³	h = ?
m = 534 g	

V = m/D = 534 g / 8.95 g/cm³ = 59.66 cm³

V = πr²h

59.66 cm³ = π(1.0)²h

h = 59.66 cm³ / π(1.0)² = 18.9 cm

Physical and Chemical Properties

A **property** of a substance is a **characteristic** of that substance or something **specific** about that substance.

Physical Property:
A physical property is something that can be **observed** or **measured** without forming a **new** substance.

For example: colour, odour, melting point, density

Sometimes physical properties are not enough to identify a substance we need more information.

Chemical Property:
A chemical property describes how a substance **reacts** with another substance and forms **something new**.

For example: combustibility, How it reacts with . . .?

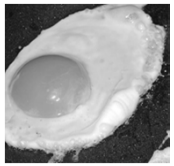
Physical and Chemical Changes

Physical Change
A physical change is a change in **state** or **form**. No **new substance** is created.
For example: **cutting** a piece of paper, **melting** ice

Chemical Change
A chemical change **creates** a new substance with **new** properties.
For example: **burning** a piece of paper, forming of **rust**

Five Clues That a Chemical Change has Occurred

1. A new **colour** appears.
2. **Heat** or **light** is given off.
3. **Bubbles** of a new **gas** are formed.
4. A **solid** material (precipitate) forms in a liquid.
5. The change is **difficult** to **reverse**.



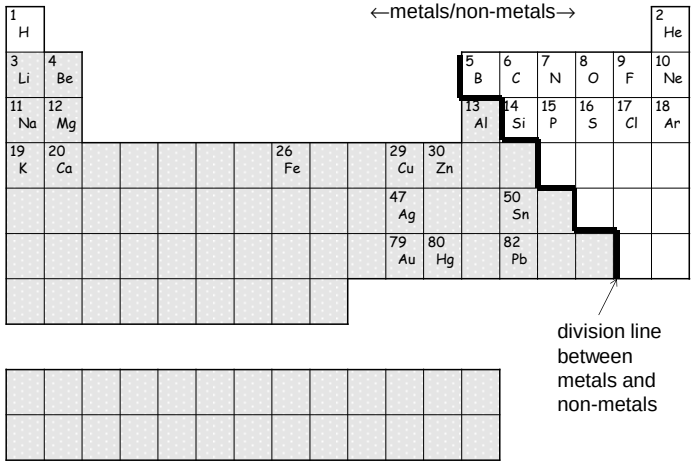
SNC 1DI: GAS TESTS

Gas	How to test for gas.	What is observed if the gas is present.
oxygen (O_2)	**Insert a GLOWING wooden splint into a test tube of the gas.**	**The splint bursts into flames.**
carbon dioxide (CO_2)	**Mix the gas with clear, colourless limewater.**	**The limewater turns cloudy.**
hydrogen (H_2)	**Insert a BURNING wooden splint into a test tube of the gas.**	**A "pop" sound is heard.**

Properties of Hydrogen, Oxygen and Carbon dioxide

Gas	Description	Density Compared to Air?	Does it Burn?	Does it support Combustion?
Oxygen (O_2)	clear, colourless, odourless, gas	similar to air	NO	YES
Carbon dioxide (CO_2)	clear, colourless, odourless, gas	denser than air	NO	NO
Hydrogen (H_2)	clear, colourless, odourless, gas	les dense than air	YES	NO

Periodic Chart of the Elements



Atomic Number	Symbol	Name
1	H	Hydrogen
2	He	Helium
3	Li	Lithium
4	Be	Beryllium
5	B	Boron
6	C	Carbon
7	N	Nitrogen
8	O	Oxygen
9	F	Fluorine
10	Ne	Neon
11	Na	Sodium
12	Mg	Magnesium
13	Al	Aluminum
14	Si	Silicon
15	P	Phosphorous
16	S	Sulfur
17	Cl	Chlorine
18	Ar	Argon
19	K	Potassium
20	Ca	Calcium
26	Fe	Iron
29	Cu	Copper
30	Zn	Zinc
47	Ag	Silver
50	Sn	Tin
79	Au	Gold
80	Hg	Mercury
82	Pb	Lead

The Electrolysis of Water

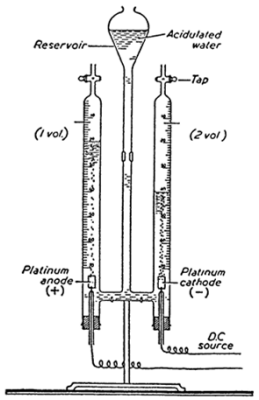
Purpose: To observe what happens when an electric current flows through water. The procedure of passing an electric current through a substance is called **electrolysis.**

Materials: Hoffman apparatus, 2 test tubes, water, wood splints

Procedure: demonstrated by teacher

Observations:

1. Make a labeled diagram of the apparatus used in this experiment.



2. Make a hypothesis: What will happen when an electric current is passed through water?

3. Describe what happens as electricity flows through water.

   - **bubbles form at each electrode**

4. Compare the volumes of the two gases formed.

   - **one gas is produced 2X more in volume than the other gas**

5. Describe the results of each gas test.

   - **glowing splint – relights**
   - **burning splint – "pop" sound**

Discussion:

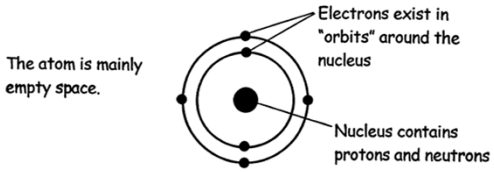
1. Name the gases produced during the electrolysis of water?

   - **Oxygen**
   - **Hydrogen**

2. The formula for water is H_2O. Comment on the relationship between the formula for water and the volumes of the gases produced.

   The formula H_2O means that there is 2:1 (H:O) ratio of atoms. The gases were produced in the same ratio.

History of the Atom



A look back at the development of our current model of the atom.

Dalton's Atomic Theory

Earlier we used the **Particle theory of Matter** to explain observations of matter. However, this theory cannot explain everything we have just learned regarding chemical changes. For example it cannot explain the **electrolysis of water**. John Dalton introduced a new theory to explain chemical changes.

Dalton's Atomic Theory

1. All matter is made up of small particles called atoms.
2. Atoms cannot be created, destroyed or divided into smaller particles.
3. All atoms of the same element are identical in mass and size, but are different in mass and size of other elements.
4. Compounds are created when atoms of different elements link together in definite proportions.

Compounds are described by chemical formulas.

For Example: H_2O_2 **is composed of two atoms of hydrogen and two atoms of oxygen**

John Thomson

Thomson performed experiments and showed that the atom has **negatively** charged particles that can be made to **move.** Scientists agreed to call these tiny, negatively charged bits of matter **electrons.**

Atoms usually have no charge, however. They are electrically **neutral.** Thomson inferred that the atom must possess something with a **positive charge** to balance the **negatively** charged electrons.

In 1886 the German physicist Eugene Goldstein detected the presence of **positive** particles in the atom. Thomson called these particles **protons.**

Here are the five statements that Thomson inferred about protons and electrons:

John Thomson cont'd

Thomson's Model

All atoms contain both **protons** and **electrons**.

All protons are **identical**. All electrons are **identical**. Electrons differ from protons, however.

An electron has a **negative** charge. A proton has a **positive** charge.

An electron has the same amount of charge as a proton, even though the charges are **opposite** in kind.

A proton has much more **mass** than an electron.

The Divisible Atom.

In 1803, Dalton had pictured the atom as a tiny indivisible sphere, like a very tiny **billiard balls.** By Thompson's time, it was clear that atoms could be torn apart by **high-energy** electricity, therefore atoms were divisible.

Protons and electrons came to be called **subatomic particles.** Thompson pictured the atom as a raisin muffin.

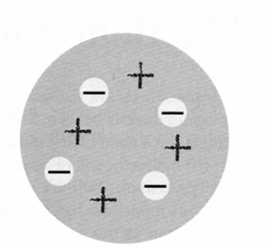


Figure 7.9 In Thomson's model, the negative electrons are like raisins embedded in a doughy framework of positive charge. With a little effort, you can pull the electrons out, just as you can pull the raisins out of a muffin.

The Bohr-Rutherford Model

Ernst Rutherford, who came to England to study with Thompson, performed many experiments with radioactivity. He discovered that radioactivity included three types of radiation. Rutherford named them **alpha, beta and gamma.** Figure 7.13 summarizes the properties of these particles.

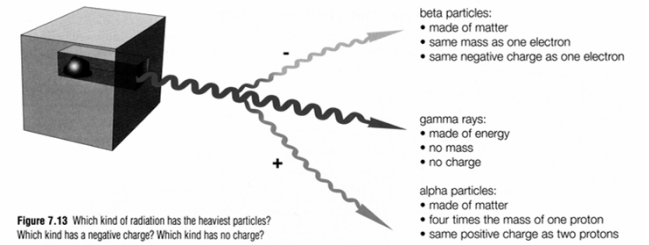


Figure 7.13 Which kind of radiation has the heaviest particles? Which kind has a negative charge? Which kind has no charge?

Bohr-Rutherford cont'd

In 1909 Rutherford designed an experiment to probe the atom using alpha particles as atomic bullets. Figure 7.14 shows his experimental setup and results.

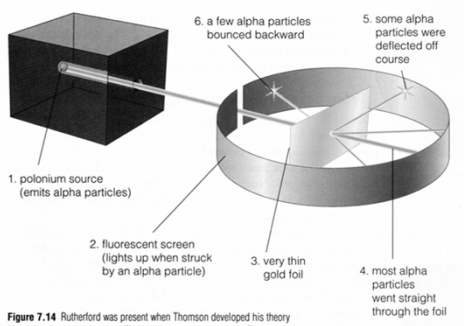


Figure 7.14 Rutherford was present when Thomson developed his theory about the electron and proton. Thus he had no reason to doubt Thomson's muffin model of the atom — until he observed what you see here.

Bohr-Rutherford cont'd

What Rutherford expected:

Rutherford expected all of the alpha particles to **pass right through** the atoms of the gold foil.

What Rutherford saw:

Most of the alpha particles passed straight through as expected because he knew that there is **large spaces** between atoms.

However some alpha particles **deflected** to the side and some **(1 / 20,000)** even bounced straight back!

He then concluded that there must be something in the atom that was **very dense, positively charged and very small**.

Rutherford also reasoned that there is something else in the nucleus of the atom that had the same mass of a proton but no charge. These particles were later known as **neutrons**.

Bohr-Rutherford cont'd

To explain his results he developed the:

Nuclear Model of the Atom

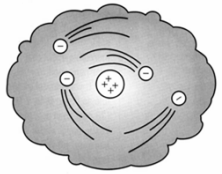


Figure 7.16 Rutherford's nuclear model

Although Rutherford's Model was accepted it did not agree with "The Law of Electric Charges".
Which states, "**opposite charges attract and like charges repel**".
Therefore, the electrons orbiting the nucleus should be **attracted** to the nucleus and eventually crash into the nucleus.

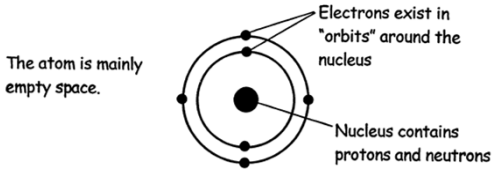
Niels Bohr

Bohr Describes Electron Shells

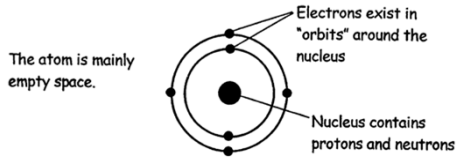
A Danish scientist, Niels Bohr looked at the hydrogen atom and the light it produced in a gas discharge tube.

From his results he inferred that the electrons did not fall into the nucleus because they were **in specific shells.** The location of the electrons was dependent on how much **energy** the electron had.

This model of the atom, known as the Bohr-Rutherford Model is still accepted today.



Bohr-Rutherford Model of the Atom



Subatomic Particles

Protons: Are **positively** charged particles with a relative mass of **1 (one)**. Located **in the nucleus**.

Neutrons: Are neutral particles with a relative mass of **1 (one)**. Located **in the nucleus**.

Electrons: Are **negatively** charged particles with a relative mass of 1/2000 (**almost zero**), located in "orbits" **outside** the nucleus.

Standard Atomic Notation

Atomic Number: The number of **protons** in an atom. *Elements are grouped according to atomic number on the periodic table.*

Mass Number: The sum of the **protons** and **neutrons** in an atom.

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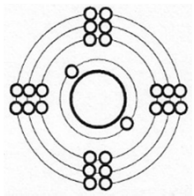
Problem 1: Consider $^{6}_{12}C$ Lewis Diagram

p =



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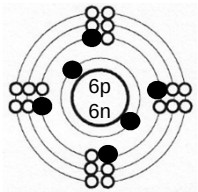
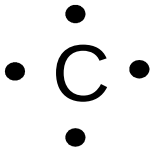
Problem 1: Consider $^{6}_{12}C$

Lewis Diagram

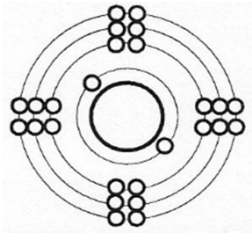
p = 6 (nucleus)
e = 6 (orbits)
n = 12 - 6
= 6 (nucleus)





Problem 2: Consider $^{9}_{19}F$

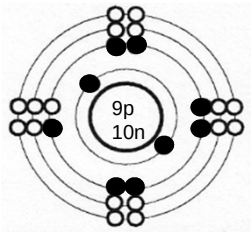
Lewis Diagram

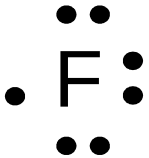


Problem 2: Consider $^{9}_{19}F$

Lewis Diagram

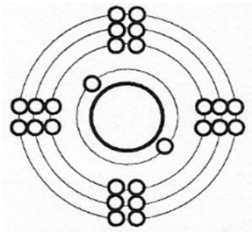
p = 9
e = 9
n = 19-9
= 10





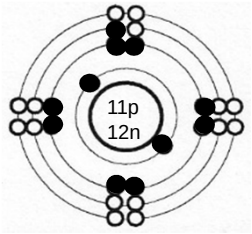
Problem 3: Consider $^{11}_{23}Na$

Lewis Diagram



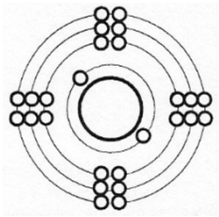
Problem 3: Consider $^{11}_{23}Na$

p = 11
e = 11
n = 23 – 11
= 12

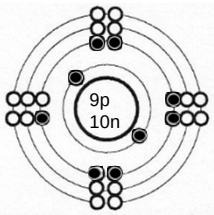
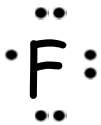


Lewis Diagram

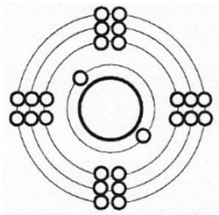
Bohr-Rutherford Diagrams and Lewis Diagrams

Element (AN:MN)	Bohr-Rutherford Diagram	Lewis Diagram
F (9:19)		

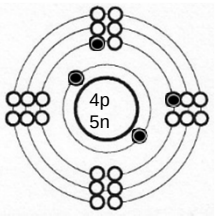
Bohr-Rutherford Diagrams and Lewis Diagrams

Element (AN:MN)	Bohr-Rutherford Diagram	Lewis Diagram
F (9:19) p = 9 e = 9 n = 19-9 = 10		

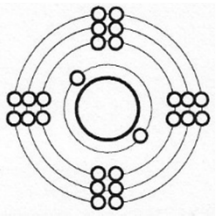
Bohr-Rutherford Diagrams and Lewis Diagrams

Element (AN:MN)	Bohr-Rutherford Diagram	Lewis Diagram
Be (4:9)		

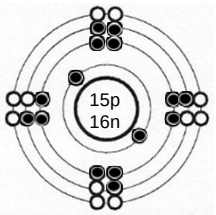
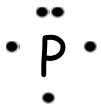
Bohr-Rutherford Diagrams and Lewis Diagrams

Element (AN:MN)	Bohr-Rutherford Diagram	Lewis Diagram
Be (4:9) p = 4 e = 4 n = 9-4 = 5		

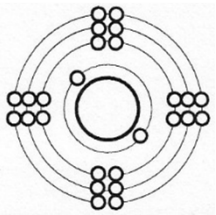
Bohr-Rutherford Diagrams and Lewis Diagrams

Element (AN:MN)	Bohr-Rutherford Diagram	Lewis Diagram
P (15:31)		

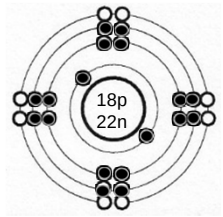
Bohr-Rutherford Diagrams and Lewis Diagrams

Element (AN:MN)	Bohr-Rutherford Diagram	Lewis Diagram
P (15:31) p = 15 e = 15 n = 31-15 = 16		

Bohr-Rutherford Diagrams and Lewis Diagrams

Element (AN:MN)	Bohr-Rutherford Diagram	Lewis Diagram
Ar (18:40)		

Bohr-Rutherford Diagrams and Lewis Diagrams

Element (AN:MN)	Bohr-Rutherford Diagram	Lewis Diagram
Ar (18:40) p = 18 e = 18 n = 40-18 = 22		

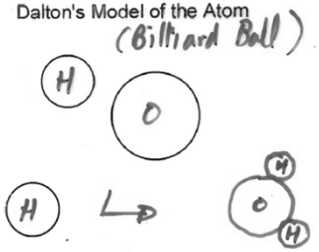
A Look at the Atom Over the Years

The Particle Theory

-good for explaining: **physical changes**

-but can't explain: **chemical changes**

Dalton's Model of the Atom



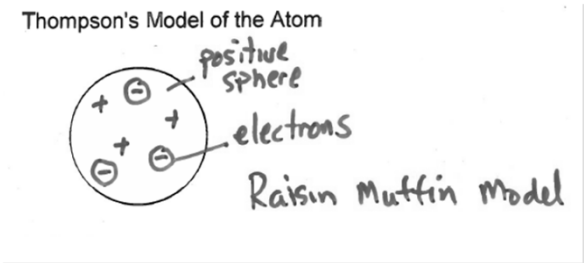
-explains: **chemical changes**

-states that **atoms** make up matter

-elements have **one** kind of atom and **compounds** are a combination of different atoms

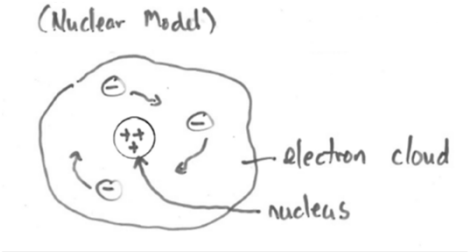
-can't explain: **electricity**

Thompson's Model of the Atom



-explains: **electricity**

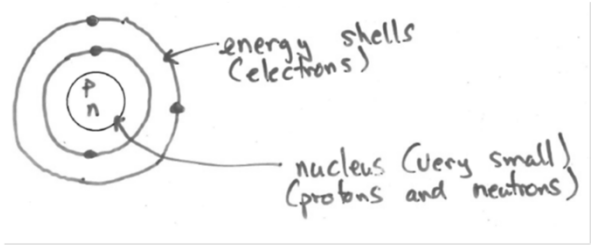
-accounts for the presence of **subatomic particles** (protons and electrons)



-Rutherford using **radioactivity** describes an atom with a **nucleus**

-explains all observations so far **BUT the electrons should crash into the nucleus**

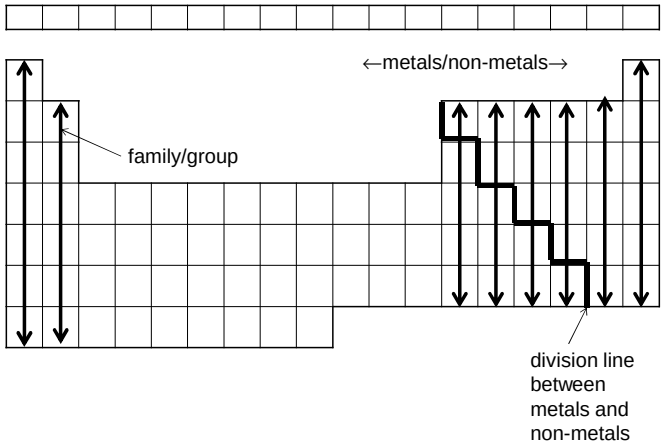
-this model is described as mostly empty space with a small dense positive center called a **nucleus**



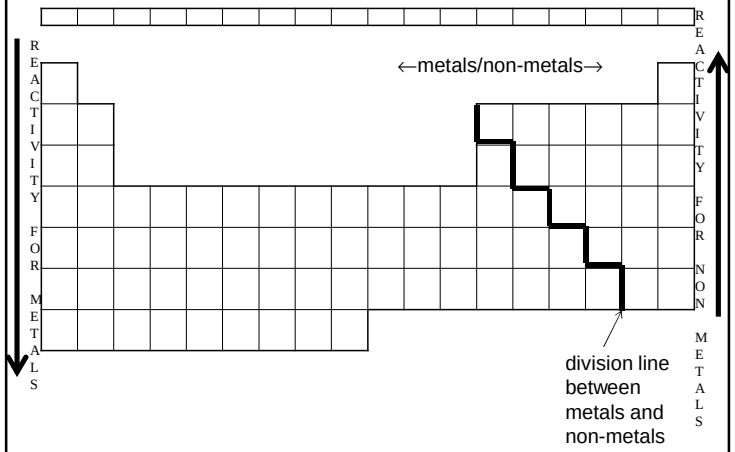
-Niels Bohr describes **energy levels** (orbitals) to explain why the electrons do not attract to the nucleus

-Bohr-Rutherford model is a combination of Rutherford nuclear model and Bohr's energy levels

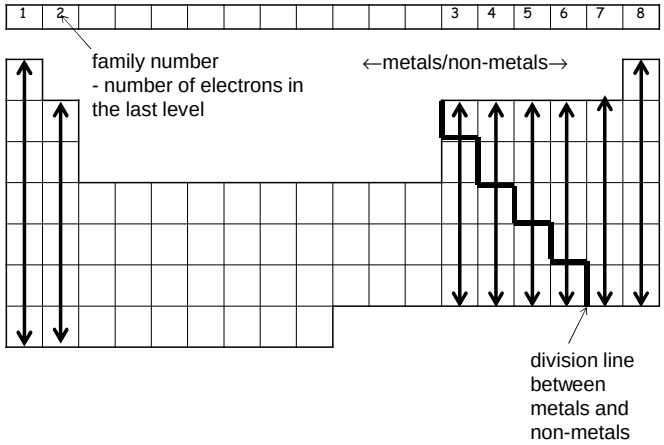
Trends in the Periodic Table



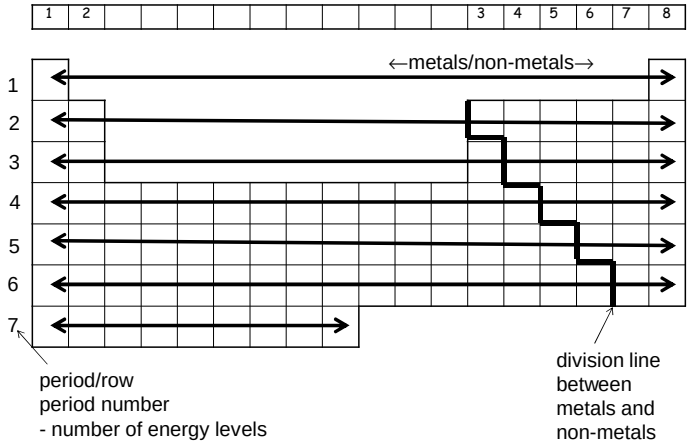
Trends in the Periodic Table



Trends in the Periodic Table



Trends in the Periodic Table



Trends in the Periodic Table