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Experiments & Conclusion that Developed Atomic Theory 6A

Atom The smallest particle of an element that retains all of the chemical properties of the element.

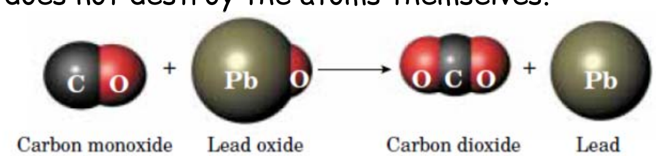
The Theory & Evidence for John Dalton's Atomic Theory:

Around 1805 an English chemist, John Dalton (1766–1844), put forth a **scientific atomic theory**. The major difference between Dalton's theory and that of others before him is that Dalton based his theory on evidence rather than a belief. First, let us state his theory. We will then see what kind of evidence supported it.

Theory:

1. All matter consists of tiny particles called atoms.
2. Atoms are indestructible and unchangeable. Atoms of an element cannot be created, destroyed, broken into smaller parts or transformed into atoms of another element. Dalton based this hypothesis on the law of conservation of mass and on centuries of experimental evidence.
3. All atoms of the same element are identical. Elements are characterized by the mass of their atoms. All atoms of the same element have identical weights,
4. Atoms combine in new ways during a chemical change. When elements react, their atoms combine in simple, whole-number ratios.

Evidence: Evidence for theories is often that they provided logical explanations for observed observations. Two criteria are usually applied to any theory. First, does it agree with facts which are already known? Second, does it predict new relationships and stimulate additional observation and experimentation?

Observation (results of experiments done by other scientist.)	**Explanation**
The Law of Conservation of Mass which states that matter can be neither created nor destroyed. (Antoine Lavoisier's)	Dalton's theory explained this fact in the following way: If all matter consists of indestructible atoms, then any chemical reaction simply changes the attachments between atoms but does not destroy the atoms themselves.  All of the original atoms are still present at the end; they have merely changed partners. Thus the total mass after this chemical change remains the same as it was before the change took place.

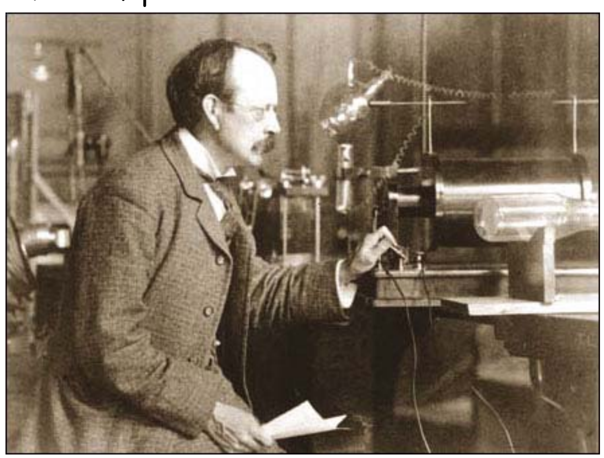
Law of Constant Composition, often called **Law of Definite Proportions** (Joseph Proust's) which states that any compound is always made up of elements in the same proportion by mass. For example, if you decompose water, you will always get 8.0 g of oxygen for each 1.0 g of hydrogen. The mass ratio of oxygen to hydrogen in pure water is always 8.0 to 1.0, whether the water comes from the Atlantic Ocean or the Seine River.	This fact was also evidence for Dalton's theory. If a water molecule consists of one atom of oxygen and two atoms of hydrogen, and if an oxygen atom has a mass 16 times that of a hydrogen atom, then the mass ratio of these two elements in water must always be 8.0 to 1.0. The two elements can never be found in water in any other mass ratio.
Predicted new relationship Law of Multiple Proportions	**Law of Multiple Proportions**: When two elements form several compounds, the mass ratio in one compound will be a small whole-number multiple of the mass ratio in another. Until the atomic theory was proposed, no one had expected any relationship to exist between mass ratios in two or more compounds containing the same elements. Because the theory predicted such relationships, Dalton and other chemists began to look for them.

The Theory has been modified to account for new observations.

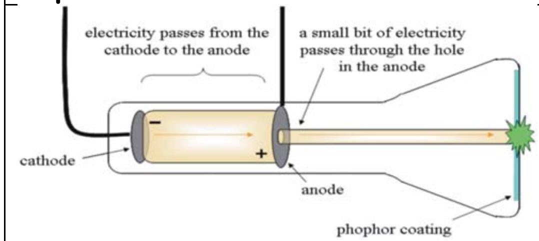
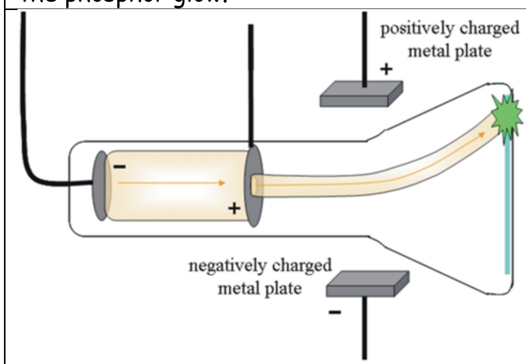
1. Atoms are indestructible and unchangeable. Atoms of an element cannot be created, destroyed, broken into smaller parts or transformed into atoms of another element. We now know elements have subatomic particles and can be transformed by nuclear change but not by physical or chemical change.

2. All atoms of the same element are identical. Elements are characterized by the mass of their atoms. All atoms of the same element have identical weights. Atoms of the same element may have different numbers of neutrons but all atoms of the same elements have the same number of protons.

J. J. Thomson and Discovery of the Electron: Experiment & Conclusions



The below figure shows a basic diagram of a cathode ray tube like the one J. J. Thomson would have used. A cathode ray tube is a small glass tube with a cathode (a negatively charged metal plate) and an anode (a positively charged metal plate) at opposite ends. By separating the cathode and anode by a short distance, the cathode ray tube can generate what are known as "cathode rays" – rays of electricity that flowed from the cathode to the anode, J. J. Thomson wanted to know what cathode rays were, where cathode rays came from and whether cathode rays had any mass or charge.

Experiment	**Observation**	**Conclusion**
 J. J. Thomson painted a substance known as "phosphor" so he could see exactly where the cathode rays hit because the cathode rays made the phosphor glow.	The Cathode ray traveled away from the negative cathode and towards the positive anode.	Cathode Ray may be negatively charged.
 He placed a positively charged metal plate on one side of the cathode ray tube and a negatively charged metal plate on the other side of the cathode ray tube, as shown in the above figure.	The flow of the cathode rays passing through the hole in the anode was bent upwards towards the positive metal plate and away from the negative metal plate.	Using the "opposites attract, likes repel" rule, J. J. Thomson argued that if the cathode rays were attracted to the positively charged metal plate and repelled from the negatively charged metal plate, they themselves must have a negative charge!
 He put an object in the path of the cathode ray in order to observe the shadow that would result. Energy that travels as waves will bend around the object resulting in a shadow with fuzzy edges. If the ray is a stream of particles the ray will not bend around the object and the shadow will have sharp edges.	The edges of the shadow were sharp (not fuzzy). No particles can be seen.	The cathode ray consists of very small particles.

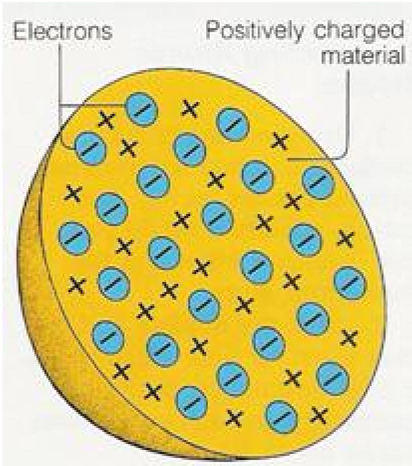
Thomson's experiment also revealed the electron has a very large charge-to-mass ratio. In 1909, experiments conducted by the American physicist Robert A. Millikan measured the charge of the electron. Scientists used this information and the charge-to mass ratio of the electron to determine that the mass of the electron is about one two-thousandth the mass of the simplest type of hydrogen atom, which is the smallest atom known. More-accurate experiments conducted since then indicate that the electron has a mass of 9.109×10^{-31} kg, or 1/1837 the mass of the simplest type of hydrogen atom.

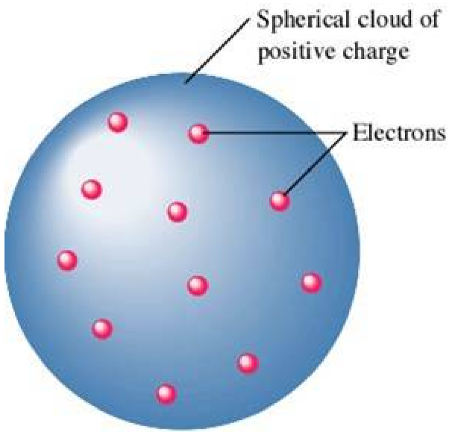
Based on what was learned about electrons, two other inferences were made about atomic structure.

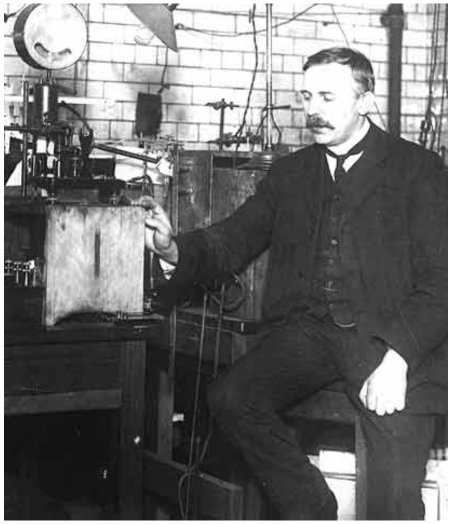
1. Because atoms are electrically neutral, they must contain a positive charge to balance the negative electrons.

2. Because electrons have so much less mass than atoms, atoms must contain other particles that account for most of their mass

Final Conclusion **Plum Pudding model of the atom**.

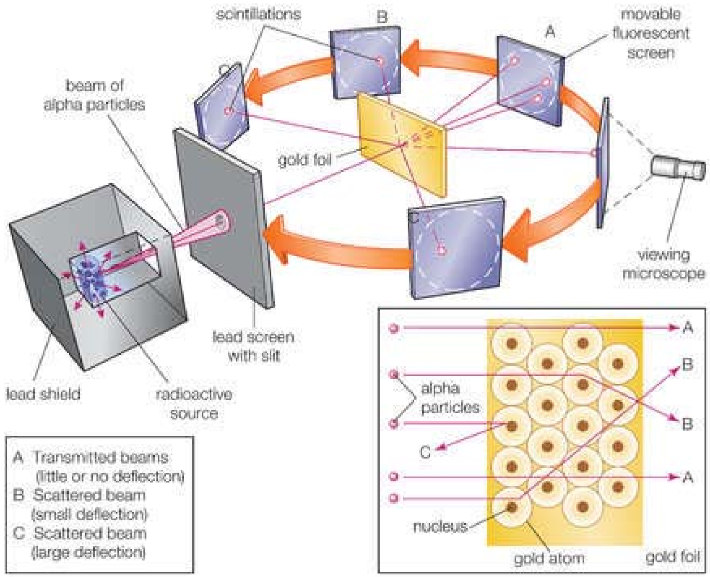




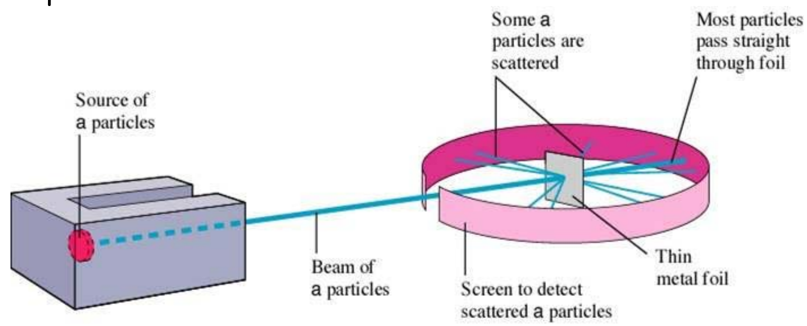


Ernest Rutherford's Experiment and Conclusions

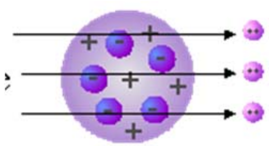
More detail of the atom's structure was provided in 1911 by New Zealander Ernest Rutherford and his associates Hans Geiger and Ernest Marsden. The scientists bombarded a thin piece of gold foil with fast-moving alpha particles, which are positively charged particles with about four times the mass of a hydrogen atom.



Experiment:

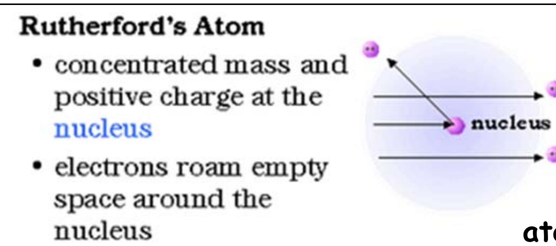


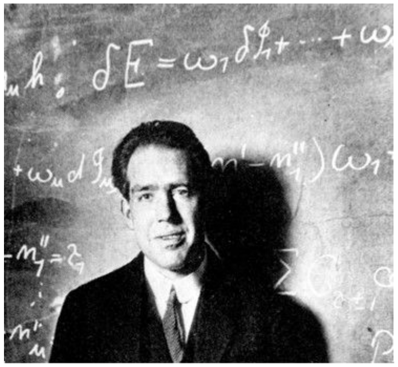
Alpha particles are very dense positively charged radiation. The alpha particles are emitted from a radioactive ore housed in a lead box with one opening for the fast traveling particles to leave the box. The alpha particles are shoot at a piece of gold foil that Rutherford thought was not very dense because the model of the atom at the time was the Plum pudding model. In the plum pudding model the mass is spread out over



the entire volume of the atom. Rutherford thought shooting the alpha particles at the very this sheet of gold foil was like shooting a 16 inch shell at a piece of tissue paper. He thought the high speed very dense alpha particle would go through the gold leaf.

Hypothesis: If the plum pudding model of the atom is correct, atoms have no concentration of mass or charge (atoms are 'soft' targets)

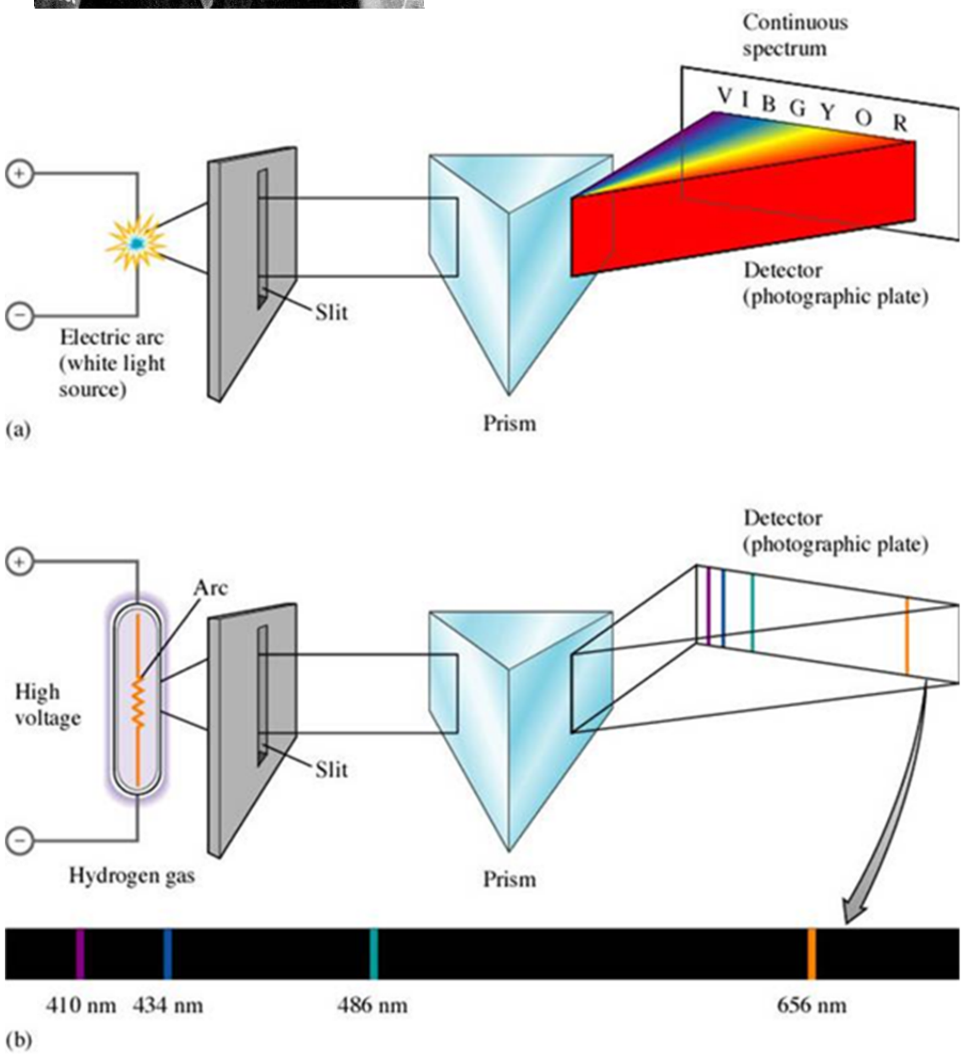
Experiment	**Observations**	**Conclusion**
Gold Leaf Scattering Experiment 1. fire massive alpha particles at the atoms in thin metal foil 2. alpha particles should pass like bullets straight through soft plum pudding atoms	Most of the alpha particle went straight through the gold leaf. But to his great surprise a few alpha particles ricocheted!	 Most of the alpha particles went straight through the gold leaf because **most of the atom was empty space.** All the mass and positive charged occupies about 1/10,000 the volume. (this is our nucleus). **The electrons are in the empty space outside the center of very dense positive charge called the nucleus** The nucleus has to be extremely dense for the alpha particles to be deflected. For the nucleus to be dense enough to reflect the alpha particles it had to have very little volume and almost all the mass.



Niels Bohr Observations, Conclusions and Model of the Hydrogen Atom

Observation: that light emitted from samples of atom exposed to energy (energizing the atoms) when passed through a prism emit distinct wavelengths of light line spectrum instead of emitting all the colors of light. Each element emits the same line spectrum and are just as characteristic to that element as finger prints are to people.

Hypothesis: if energized atoms emit only discrete wavelengths, maybe electrons can have only discrete energies



Conclusion:

Bohr's Theory

- Electrons occupy orbits at discrete distances from the nucleus called **energy levels**.
- Electrons in an non-energized atom occupy the lowest energy orbit (closest to nucleus this is called **ground state**.)
- Electrons in energized atoms absorb just enough energy to move from a lower energy orbital to a higher energy orbit (further from nucleus) this is called **excited state**.
- Electrons do not remain in excited state and return to ground state **releasing energy** that corresponds to all the possible difference in energy of the allowed orbits in the atom.

To simplify these assumptions, remember these key words and concepts:

1. **CIRCULAR ORBIT** in which the electron travels around the nucleus.

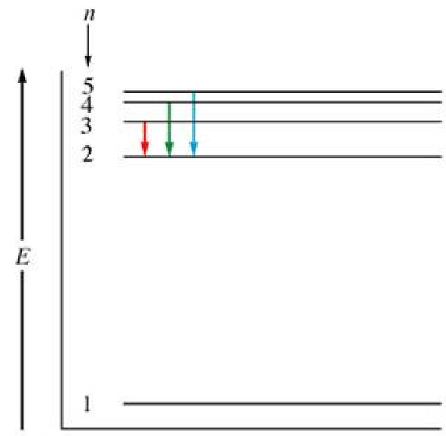
2. **ENERGY $\propto$DISTANCE** energy of an orbital is directly proportional to the distance from the nucleus.

3. **QUANTIZED** limited number of countable allowed energy levels.

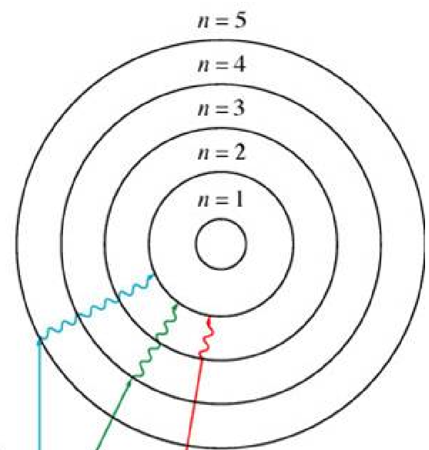
4. **ABSORPTION IS LOW E TO HIGH E**

5. **EMISSION IS HIGH E TO LOW E**

6. **ENERGY OF ABSORPTION/EMISSION** = E DIFFERENCE OF ENERGY LEVELS.



(a)



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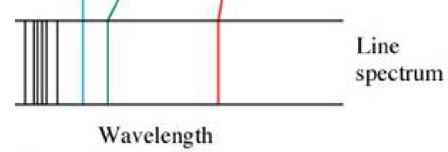
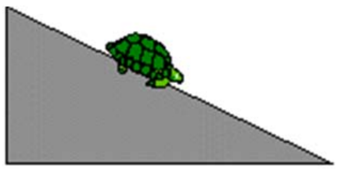
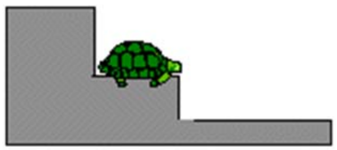


(c)

Bohr Model Analogy

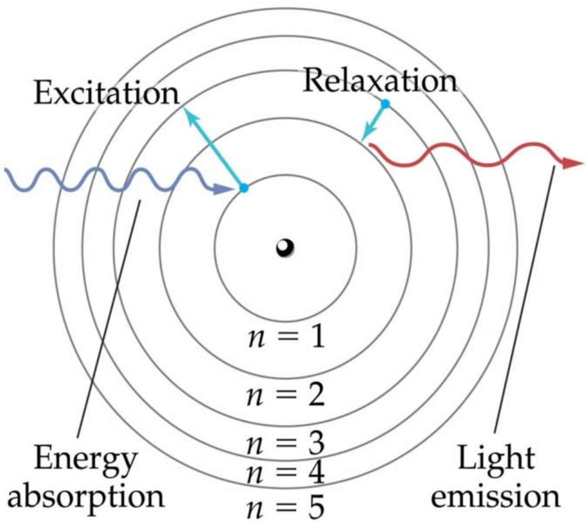


A turtle sitting on a ramp can have any height above the ground- and so, any potential energy



A turtle sitting on a staircase can take on only certain discrete energies

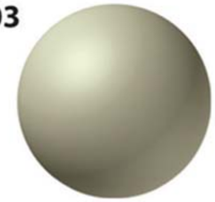
- energy is required to move the turtle up the steps (absorption)
- energy is released when the turtle moves down the steps (emission)
- only discrete amounts of energy are absorbed or released (energy is said to be **quantized**)



- Electrons can move from a lower to a higher (farther from nucleus) energy level by absorbing energy
- When the electron moves from a higher to a lower (closer to nucleus) energy level, energy is emitted from the atom as a ***photon of light***

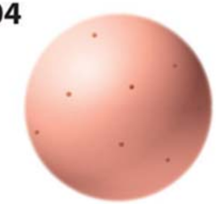
Comparisons of models on the next page

1803



Dalton proposes the indivisible unit of an element is the atom.

1904

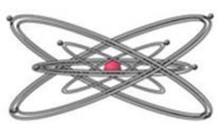


Thomson discovers electrons, believed to reside within a sphere of uniform positive charge (the plum pudding model).

1911

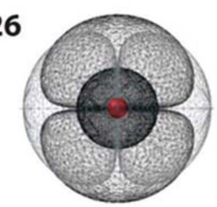
Rutherford demonstrates the existence of a positively charged nucleus that contains nearly all the mass of an atom.

1913



Bohr proposes fixed circular orbits around the nucleus for electrons.

1926



In the current model of the atom, electrons occupy regions of space (orbitals) around the nucleus determined by their energies.