Structure and Properties of Matter

Models of the Atom

Unit 1 - Lesson 3 - 4

Models of the Atom

Learning Objectives:

- Describe each model of the atom, linking it to the scientist which made the discovery.
- Identify the shortcomings of each atomic model and how the subsequent model further developed our understanding.

Core Vocabulary:

isotope, neutron, proton, electron, plum pudding model, alpha particle, planetary quantum model, electron cloud model, energy level, photon, quarks, nuclear model

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Origins of the Atom

- The structure of the atom as we know it has been developed over hundreds of years with a number of scientists building on the current knowledge of the time. The concept of the atom was first hypothesised by two Greek philosophers, Democritus and his mentor Leucippus in the fifth century BC.
- They imagined that atoms were the smallest indivisible structure known to man, unable to be broken into smaller pieces. However, at the time their theory had little support.

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Origins of the Atom

- These scholars suggested that atoms varied in shape depending on the type of atom. For example,
  - Iron atoms had hooks which locked them together, which helped to explain iron's solid state at room temperature.
  - Water atoms, by contrast, were liquid a room temperature because they were smooth and slippery and could be poured.

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Dalton's Solid Sphere Model of the Atom

- Atoms were thought of this way for centuries until the English chemist John Dalton challenged the theory in 1803. Dalton was responsible for developing one of the earliest scientific models of the atom.
- He hypothesized that atoms were small, hard spheres that were indivisible and that atoms of a particular element were identical. The latter part of the theory is still considered to be correct, with the exception of isotopes which vary in the number of neutrons they possess.
- Neutrons would be discovered over a century later.

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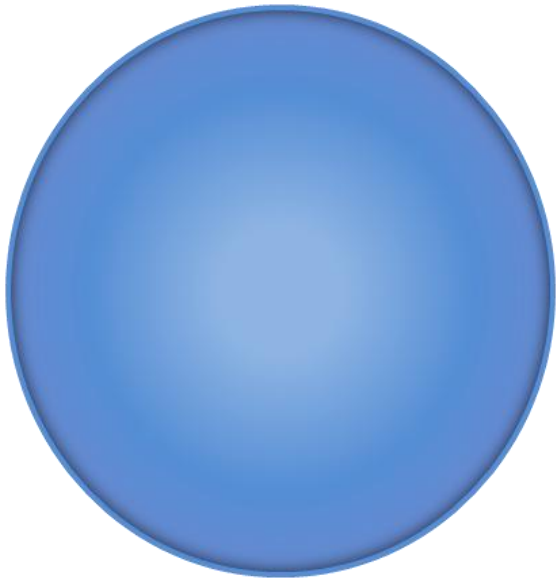
Dalton's Solid Sphere Model of the Atom

- Dalton also theorized about how atoms combine to make compounds and was the first scientist to attribute symbols to each of the known elements.
- Dalton's theories were somewhat limited in that they still didn't explain much about the nature of atoms themselves, or their appearance



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Thomson's Plum Pudding Model of the Atom

- The next major breakthrough in atomic structure came in 1897 when J.J Thomson discovered the electron, which he referred to as ‘corpuscles’. This discovery proved that atoms were not as indivisible as was previously thought, introducing us to the idea of subatomic particles.
- Thomson carried out experiments using cathode rays produced in a discharge tube. He observed that the rays were attracted by positively charged metal plates but were repelled by negatively charged ones. This led Thomson to the conclusion that the rays were negatively charged, based on the fact that opposite charges attract and like charges repel.

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Thomson's Plum Pudding Model of the Atom

- By measuring the charges of the particles in the rays, Thomson also deduced that these particles were two thousand times lighter than a hydrogen atom and that by changing the type of metal used on the cathode, these particles were present in many different types of atoms.

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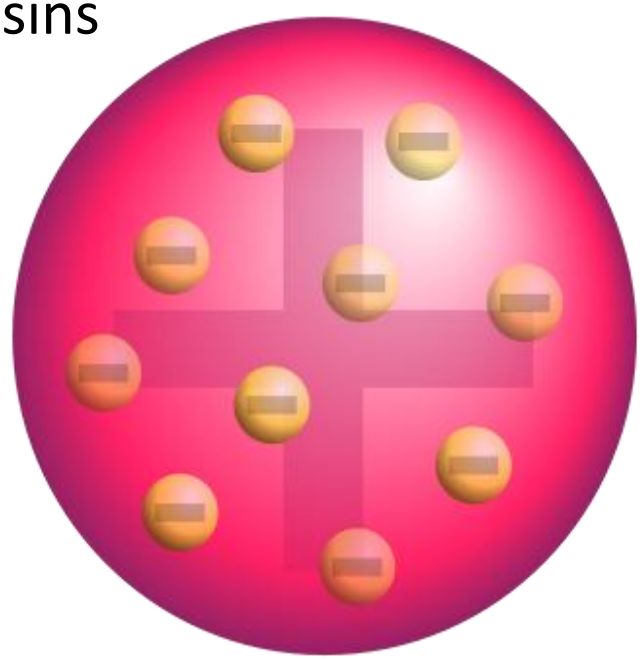
Thomson's Plum Pudding Model of the Atom

- The findings led to Thomson's "plum pudding model" in 1904. In this model, the atom consists of negative electrons that float in a sphere of positive charge, in a similar way that plums are scattered in a pudding or raisins are dotted throughout a fruit cake.
- Although this model saw Thomson awarded the Nobel Prize for his work in this field in 1906, it still provided no understanding of the arrangement of the electrons in the atom.



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Rutherford's Nuclear Model of the Atom

- In 1911, Thomson's student Ernest Rutherford carried out an experiment which would directly challenge the current structure of the atom.
- Using his previous work on the chemistry of radioactive substances, Rutherford devised an experiment to further investigate atomic structure, in the hopes of confirming Thomson's atomic theory.

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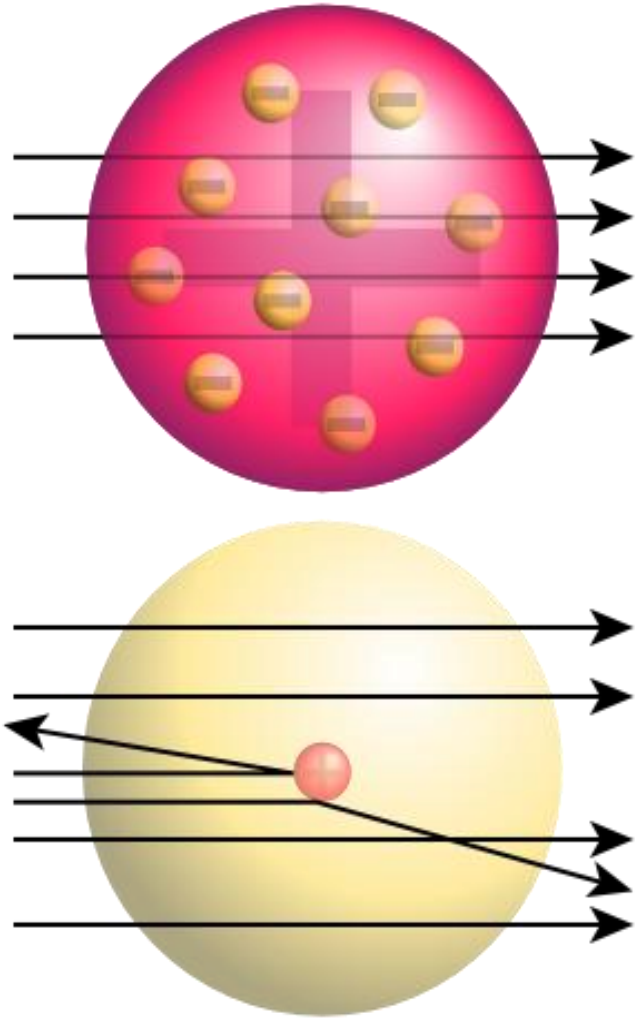
Rutherford's Nuclear Model of the Atom

- Rutherford fired positively charged alpha particles at a thin sheet of gold foil which, according to Thomson's model, should have been able to pass through the gold foil without being deflected. However, Rutherford instead observed something unexpected.



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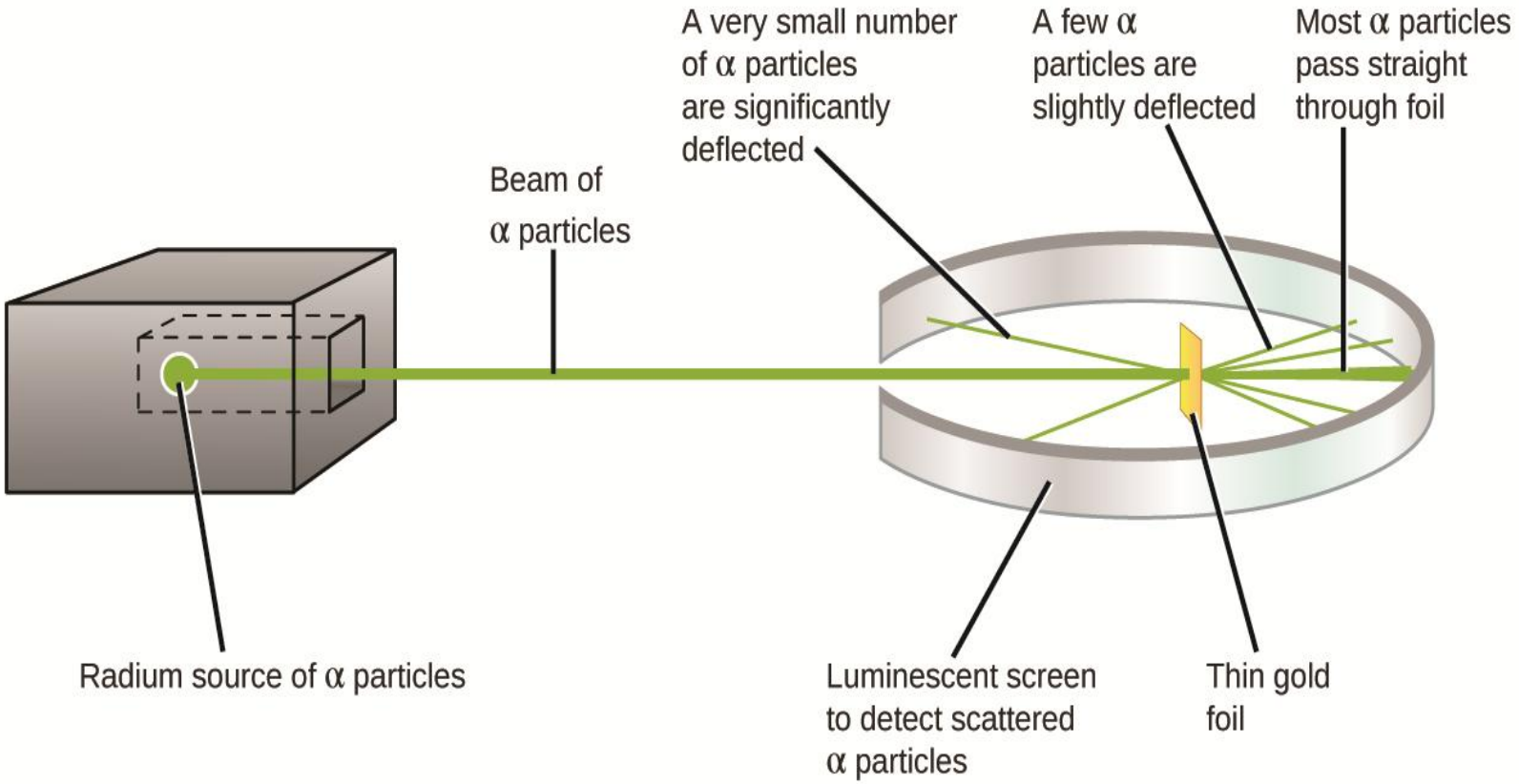
Rutherford's Nuclear Model of the Atom



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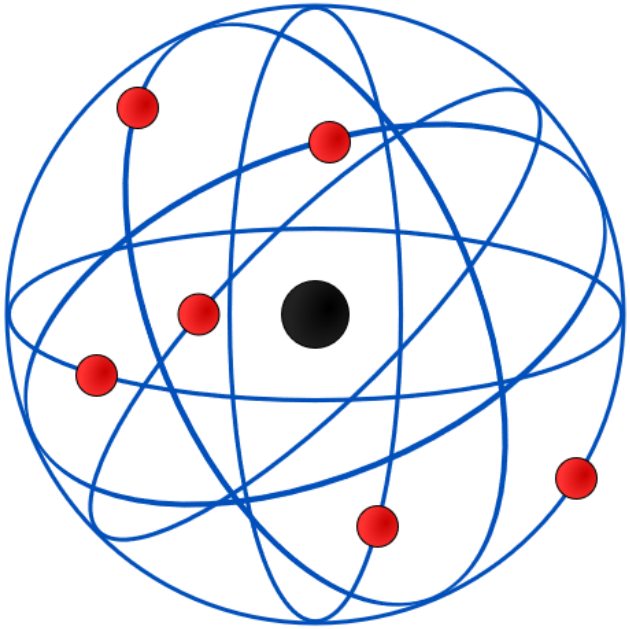
- This observation led Rutherford to suggest that the atom was similar to a tiny solar system, consisting of a dense, positively charged core called a nucleus which was orbited by lighter, negatively charged electrons in a circular motion.
- Rutherford's model is sometimes referred to as the nuclear model of the atom and was one of the first to suggest that the atom consisted mostly of empty space.



The nuclear model of the atom. Image of Rutherford atom from Wikimedia Commons, CC-BY-SA-3.0.

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Bohr's Planetary Model of the Atom

- Following on from Rutherford's work, the Danish physicist Niels Bohr used quantum theory in an attempt to explain the arrangement of the electrons. He proposed that electrons could only orbit the nucleus in certain orbitals and were found at different energy levels around the nucleus.
- This model is sometimes referred to as the electron cloud model, retaining the concept of a nucleus from Rutherford's model, but changing the motion of the electrons.

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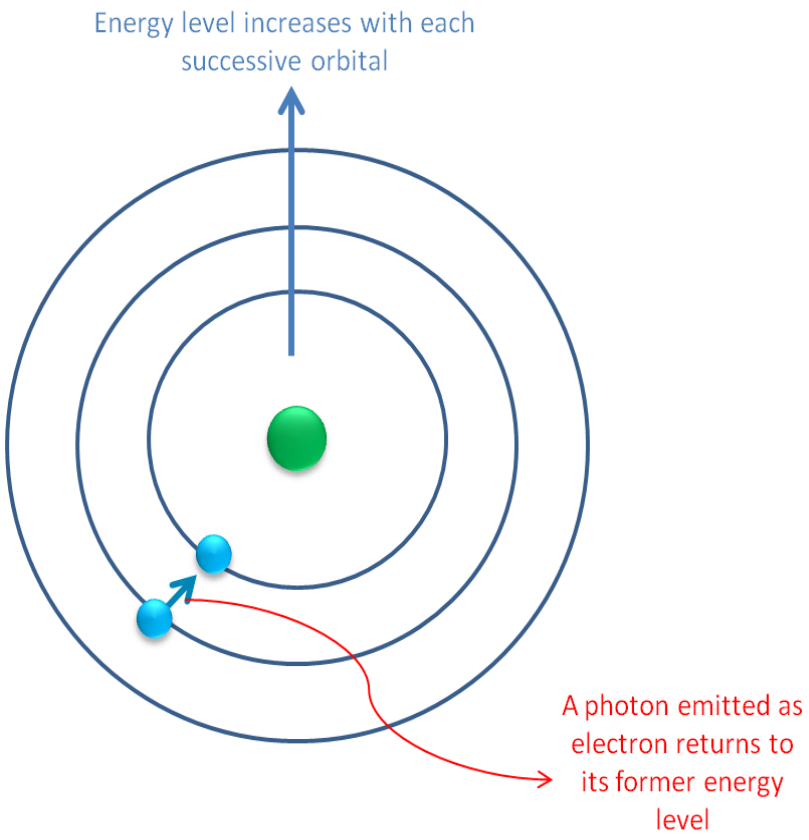
Bohr's Planetary Model of the Atom

- Bohr's model introduced the idea that there were regions of the atom of which there was a greater probability of finding electrons.
- The regions with a higher probability were associated with the specific energy levels possessed by the electron and displayed a variety of unusual shapes (known as shells).



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Bohr's Planetary Model of the Atom

- Bohr also suggested that the electrons were able to move between energy levels by either absorbing or emitting energy in the form of photons.

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Erwin Schrödinger's Quantum Model

- In 1926 Erwin Schrödinger proposed that, rather than the electrons moving in fixed orbits or shells, the electrons behaved more like waves in the same way that light can. Using mathematical equations, Schrödinger developed a model for the distribution of electrons in an atom. This model consisted of the nucleus surrounded by dense clouds or regions of electrons, which are referred to as orbitals. This is the accepted model of today.

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James Chadwick

- James Chadwick's work followed on from the prediction made by Rutherford in 1920 that another kind of particle must be present in the nucleus along with the proton. This prediction was based on the idea that if there were only positively charged protons in the nucleus, then it should break apart due to the repulsive forces between the like-charged protons.
- Therefore, in order to ensure that that the atom remained electrically neutral (i.e. had the same number of negative and positive charges); a neutral particle would also have to be present. This led to the discovery and measurement of the mass of the neutron by Chadwick in 1932, completing the picture of the subatomic particles which makes up the atom.

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- Since then scientists have discovered that the protons and neutrons that make up the nucleus are themselves divisible into particles called quarks.

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