Atomic Structure

Created	@February 28, 2023 12:31 PM
Class	Chemistry
Type	
Materials	
Reviewed	☐

John Dalton

1807: Proposed “Atomic Theory of Matter“

1. Matter (elements) is composed of small, **indivisible**, particles called “atoms”
2. All atoms for a given element are identical (same shape, size, mass, chemical properties)
3. Atoms are not created, destroyed or changed into different types in a chemical reaction: a chemical reaction involves the rearrangement, combination or separation of atoms
4. Atoms combine in fixed proportions to form compounds
5. Atom is a sphere

Disadvantages

1. Atoms **are divisible**: they are made of smaller particles known as **subatomic particles**
2. Not all atoms for a given element are identical: some elements have atoms that **differ** in **mass** and **density (different number of neutrons)**. These are known as **isotopes**.
3. Dalton claimed that atoms for different elements are different in all respects: Proved wrong in certain cases: Argon and Calcium both have an AMU of 40: known as **isobars**
4. Dalton also claimed that different elements combined in whole-number ratios to form compounds. Not observed in complex compounds, e.g. sugar (CHO)

12

22

11

5. This theory fails to explain the existence of allotropes: it does not account for differences in properties of charcoal, graphite, diamond

J.J. Thompson

1897: Discovered Electron, and proposed Plum Pudding Model

Cathode Ray Experiment

1. A **high voltage** causes electrons to be discharged from the cathode to the anode. J.J. Thompson discovered the same cathode ray for all metals, i.e. same cathode ray was emitted regardless of material. He also discovered that metals exposed to cathode rays would become charged
2. Cathode rays were passed through an **electric** and **magnetic field**
3. First, it was passed through an **electric field only**. The cathode rays were noted to be deflected towards the **positive** side of the electric field
4. Then, it was passed through **both** an **electric field** and a **magnetic field** applied **alongside** the electric field. The cathode rays passed **straight through**
5. Thus, the cathode rays were affected by both an electric and magnetic field
6. Since he knew the magnitude of the fields, using physics, Thompson determined the mass of the particle to be 1/1000 AMU
7. Since light is not affected by charge/electrical fields, and the cathode rays deviated towards the positive plate, and all metals produced the same cathode ray:
8. Thompson stated that a cathode ray was a **beam of negatively charged particles with mass**, that was present in all matter(i.e. atom)

Plum Pudding Model: Proposed due to findings of Cathode Ray Experiment

1. Thompson knew that atoms were electrically neutral **and** contained particles of negative charge: therefore, they must contain equal amounts of positive charge
2. Therefore, Thompson suggested that an atom comprised of electrons spread within a region of uniform mass and charge
3. **Negative** particles **inside** a **positively-charged** sphere

Disadvantages

1. It is known that this is incorrect; electrons occupy fixed orbitals, and the positive charge is concentrated in the nucleus as protons
2. **Could not explain** the **findings** made by Ernest Rutherford's **Gold Foil Experiment**

Ernest Rutherford

1908-1913: Discovered nucleus, protons, and that most of an atom is empty space

Gold Foil Experiment

1. A lead block containing radioactive alpha emitters was used: this produced **alpha particles** that were targeted at a **zinc sulphide** screen
2. These alpha particles were directed to a very thin sheet of **gold** (only a few atoms wide)
3. When the alpha particles collided with the **zinc sulphide** screen, **flashes of light** were produced and the **impact positions** could be viewed through a **microscope**

Observations

1. Most of the alpha particles passed straight the gold foil
    a. **Contradicts** the **Plum Pudding Model**, if it was true, a wall of spheres of positive charge would be formed, and **alpha particles** would have been **repelled**
    b. Therefore, since **most** alpha particles passed through the **gold foil**, an atom must comprise of **mostly empty space**
2. Some alpha particles were deflected in a minor way

    a. **Contradicts** the **Plum Pudding Model**, as it states that the entire atom is neutral due to the equal distribution of positive and negative charge; there is **no neutral region**
    b. Therefore, the repulsion is due to an electrical repulsion and in the context of the atom: There must be a positively charged region. **Rutherford** called this the **proton**
    c. Finally, since only a small amount of alpha particles were deflected, the positive charge must be concentrated to a **small volume** at the centre of the atom: i.e., the **nucleus**
3. Some alpha particles were deflected quite significantly (1 in 20 000)
    a. A significant deflection like this occurs only when there is a direct collision of 2 heavy charged particles; therefore, this deflection must be due to a direct collision with the positive region; this **reconfirmed** that the protons must be concentrated at the centre of the atom, i.e., the nucleus
    b. Therefore, deflection only occurs if the nuclear region has a **positive charge** and so the electrons must exist **separate** to the **protons** - Rutherford stated that the electrons must be orbiting **around** the nucleus

Rutherford Model

1. The atom comprises of mostly empty space occupied by very low mass negatively charged particles called electrons
2. The electrons orbit a very small (0.05% by volume) central region called the nucleus which is comprised of subatomic particles called protons
3. Protons are subatomic particles concentrated at the nucleus that comprise of the **majority** of an atom’s mass and a **positive charge**

Problems with the Rutherford Model

1. It could not explain the stability of an atom because it doesn’t obey Maxwell’s law of electrodynamics
    a. An electron (an accelerating charge) should continuously emit radiation and gradually lose energy, so its distance from the nucleus should become shorter and finally fall into the nucleus. However, this never happens
2. The arrangement of electrons is not described at all
3. It cannot explain the atomic line-emission spectra

4. It does not have neutrons in its model

Niels Bohr

Explained the orbitals of electrons, and the line emission spectra: 1913

Context

1. Scientists found that when an electric discharge is passed through a discharge tube containing hydrogen gas at low pressure, it emits some light
2. When this light is passed through a prism, it splits up into a set of 5 lines. This spectrum is called the line spectrum of hydrogen. This is known as the **line emission spectrum**. Scientists were unable to explain this

Bohr's Model: The Three Postulates

1. **Fixed orbitals**: Electrons move in a circular orbit around the nucleus under the influence of the electrostatic attraction of the nucleus
2. **Angular momentum is quantised**
    a. Electrons occupy fixed energy levels and for these fixed energy levels electrons do not emit radiation as these orbits are stable (hence Maxwell's Law)
    b. Energy levels are a specific distance from the centre of the nucleus, proportional to their energies
3. **Energy transitions**: Electrons can transition to higher or lower energy levels by emitting or absorbing fixed quantities of energy (photons)
    a. An electron can transition to a higher state by absorbing a photon with energy equal to the exact difference in energies between 2 electron orbits (final and initial)
    b. An electron can transition to a lower state by emitting a photon with energy equal to the exact difference in energies between 2 electron orbits (initial and final)

What Bohr's Model tells us

1. **Emission spectra**

a. When an **electric discharge** is passed through a discharge tube, electrons that are found in that discharge transfer some kinetic energy during collision to the atoms' electrons

b. The electron issued the atom is then **excited to a higher energy state**(as it has experienced an increase in energy exactly equal to E2 - E1) and the incident electron will decelerate and be deflected in another direction

c. As electrons are **unstable** in the **higher transition state**, they will **transition down** to the **ground state**, thus releasing energy in the form of **radiation** that has an energy exactly equal to E2-E1

d. As the "frequency" of the radiation (and therefore its "colour") is **proportional to the energy** it has, **one specific** wavelength/frequency of light will be produced per transition

e. Since **multiple transitions can occur within an atom**, a unique set of photons with a specific wavelength each is produced; thus when these emissions are captured an analysed in a line spectrometer; we only see specific light present

2. **Unique Spectra**: As the discrete energy levels for atoms are fixed and unique to each atom, the discrete energy level differences are also fixed and unique to each element. Therefore, each element has different and unique emission and absorption spectra as the range of frequencies of light emitted are based on this unique set of discrete energy level differences

Problems with Bohr's Model

1. **Multi-electron Atoms**

    a. Does not work for atoms with more than 1 electron in the valence shell, and it is not possible to calculate all the spectral lines of all other atoms, as this model still has classical components, e.g., electrostatic attraction, whereas Schrodinger's model is explains this, and is Q.E.D.

2. **Relative Intensities of Spectral Lines**

    a. The spectral lines are not of equal intensity, but Bohr's model cannot explain why some electron transition would be favoured, and thus some wavelength of light appeared more intense in the spectra

3. **Hyperfine Lines**

   a. Careful observations showed that there were other known lines (hyperfine lines) i.e., 2 bands contained in a single band, thus the energy levels of Bohr’s model must be split but the model cannot account for this

4. **Zeeman effect**
   a. When a gas is excited in a magnetic field, the emission spectrum shows a splitting of the spectral lines (Zeeman effect) . The Bohr model cannot account for this

Sir James Chadwick

Discovered the Neutron: 1932

1. Sir Chadwick determined that protons made only 1/2 the mass of the atom when he analysed Rutherford’s experimental data; specifically the extent and frequency of alpha particle deflIection
2. Thus, he believed that there was a hidden component to the atom that constituted its remaining mass (50%)

Experiment and Results

1. In 1932 it was discovered that Beryllium, when bombarded by alpha particles, emitted a very energetic stream of radiation, originally thought to be gamma
2. However, further investigation into its properties revealed contradictory results. Like gamma rays, they were extremely penetrating, and since they were not deflected upon passing through a magnetic field, neutral
3. Sir Chadwick fired alpha particles at beryllium which emitted an unknown radiation. This radiation was then allowed to incident at paraffin (proton rich) causing paraffin to release protons
4. Using the equation of linear momentum, Chadwick determined that the radiation was a particle of mass 1 AMU (similar to protons) but with 0 electrical charge. He called this the **neutron**