## Atoms, Elements and Isotopes

- To achieve consistent communication between chemists around the globe, the **International Union of Pure and Applied Chemistry** (IUPAC) was formed

- Of the 92 naturally occurring elements in the earth, **25 of these are required for life**
  - **11 of these are vital for biological systems**
    - However, 4 of these, hydrogen, carbon, oxygen and nitrogen make up just under 97% of a human's total body mass. They also constitute 99% of the atoms from which the body is formed

- The quest to discover the composition of matter has spanned for many years. In **440 B.C**, the Greek philosopher **Empedocles** postulated that all matter was a construct from 4 different elements:
  - **Earth, fire, air and water**
    - In 300 B.C this became known as the **Aristotelian view of matter** (from Aristotle)

- In **1643**, a pupil of Galileo, **Evangelista Torricelli** proved that **air had a weight** and that it was capable of pushing down on liquid mercury
  - This lead to the **discovery of the barometer** and further led to the theory that air and other gases consists of loosely packed particles, too small to be seen
    - Furthermore, during the late 18th and early 19th century a scientist, John Dalton developed his **atomic theory**
      - That **all matter is made of atoms** and that they **cannot be broken down** into anything simpler
      - That all atoms in a particular element are **identical to each** other and differ to atoms of other elements
  - In **1987 JJ Thompson discovered the electron**
    - He showed that atoms contain smaller pieces, known as subatomic particles
      - This lead to the discovery by **Earnest Rutherford** in **1911**, that an atom must contain a **central nucleus**
      - **Niels Bohr** used experimental evidence to show that **electrons occupy orbits and** shells around the nucleus

- Atoms can be arranged in different structures known as **allotropes**
  - Both diamonds and graphene are made from carbon atoms
    - The carbon in diamonds is a complex structure consisting of strong covalent bonds
    - The carbon in graphene is arranged in layers being held together with weak bonds

- Atoms with the same number of protons and electrons but a different number of neutrons is known as an **isotope**
  - For example, oxygen has 8 protons, 8 electrons and can either have 8, 9 or 10 neutrons
    - This is written as **$^{16}O$, $^{17}O$ or $^{18}O$**
      - **The number is the atomic mass of the atom**, therefore, 'normal' oxygen is $^{16}O$
  - Plants can discriminate between the 2 isotopes of $CO_2$ in our atmosphere, $^{12}C$ (98.9%) and $^{13}C$ (1.1%)
    - The difference in neutrons is enough to alter the diffusion of $CO_2$ within the plants chloroplast, therefore, $^{12}CO_2$ is preferred
  - Tracers used in metabolic studies also use isotopes such as PTOX tracers which are labelled with $^{13}C$
  - Isotopes can also have severely negative effects
    - $D_2O$ compared with $H_2O$, studies show that a 90% replacement to $D_2O$ proved fatal to fish and other organisms
    - It impaired the organism's haematopoiesis, inhibited mitosis, muscle and nervous function