CHEM10003 – Chemistry 1 Notes

Contents

Introduction to Chemistry and Chemical Bonding

Why do we study chemistry?

- To understand the properties of matter
- To understand the interactions of materials
- To understand biological processes (biochemistry)
- To develop new drugs (pharmacology)
- To develop new materials (chemical engineering)

Scientists have been synthesising new chemicals since 1828

- Wohler first prepared urea
- Perkin made 'maueveine' from tar in 1857

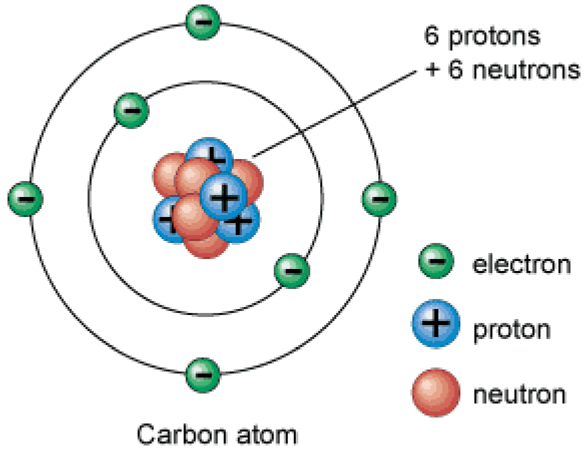
Before we get into Chemistry, we need to understand what chemistry is about.

Atoms are the unit of matter from which everything else is built. Atoms themselves are made up of other particles. There are over 100 identified *species* of atoms, and are arranged on the periodic tables. Atoms can be bound together to form molecules.

Atoms are made up from three subatomic particles. These particles are used to identify atomic species, and are crucial for the chemical properties of an atomic species.

These particles are;

- Protons
  - positive charge
  - denoted p^+
- Neutrons
  - No charge (neutral)
  - denoted n^0
- Electrons
  - negatively charges
  - denoted e^-



Carbon atom

Electrons are very light, and effectively have no, or rather, negligible weight.
Protons and neutrons are heavier, and each has a mass of 1 atomic mass unit (amu, or u).
1 amu = 1.66×10^{-24} grams

Elements are two or more atoms of the same species bound together. They may be molecular or metallic. Everyday examples include hydrogen (H_2), oxygen (O_2), and ozone (O_3). Metals may also be elements, provided only one species of metal is present in the substance.

Molecules may also be compounds, by which there are two or more different atomic species bound together. Molecules vary enormously in size and complexity. Common compounds include water (H_2O), carbon dioxide (CO_2), and glucose ($C_6H_{12}O_6$).

Electrons orbit the atom in 'shells'. The shell structure is very similar across the elements. These shells contain a set number of electrons. Atoms are only 'happy' when they have the ideal number of electrons in their shells. These shells are built from the inside out. The first shell is closest to the nucleus. This shell contains room for 2 electrons. Therefore, hydrogen (element 1) has 1 electron in this shell, and wants 1 more in order to be happy. Helium (element 2) already has 2 electrons in this shell, and is therefore unreactive as it is happy.

The next shell out has room for 8 electrons. Lithium (element 3) has 2 electrons in the inner shell, but only 1 in the outer shell. Therefore, it would be happy to lose that electron and be left with the inner shell. At the other end, fluorine (element 9) has 7 electrons in the outer shell, and wants 1 more electron so that it has an outer shell of 8 electrons. The octet rule works for the first 20 elements (up to calcium).

These shells contain *subshells* or *orbitals*.

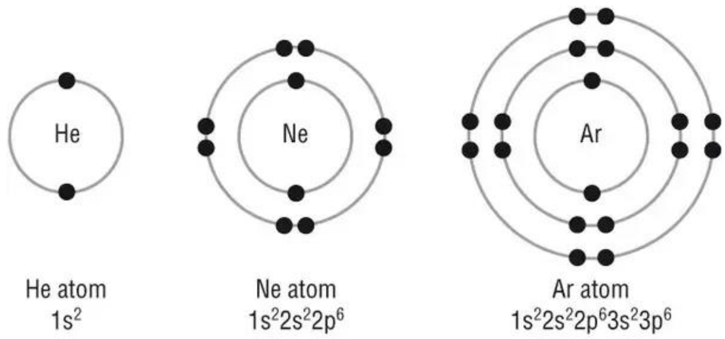
- Each shell contains a different number of orbitals
- Orbitals are named s, p, d, f.
- Shell 1 contains only one orbital, 1s
- Shell 2 contains 2 orbitals, 2s and 2p
- There are four possible orbitals, and they are defined by their shape and the number of electrons they can hold
  - when we say 'shape', it means a diagram of most likely location of the electrons, it is not a physical structure

- the s orbital is spherical, and can hold 2 electrons
- the p orbital is bipolar shaped, and is oriented in three planes (p_x, p_y, p_z). Each plane can hold two electrons, therefore, the p shell can hold 6 electrons in total
- the d orbital is tetrapolar shaped in four planes, with a ring shape between the four planes, making five planes in total. Each plane can hold 2 electrons, to 10 electrons can be held in total
- the f orbital is octopolar shaped

We can write out the orbital patterns for each atom as well. For example, boron (N = 5) would be $1s^2 2s^2 2p^1$, where the superscript numbers relate to the number of electrons. These can also be condensed down, and can use the filling pattern of the nearest noble gas to describe. For boron, this would look like $[He]2s^2 2p^1$. For potassium, K, this would look like $[Ar]4s^1$. This notation also allows for easy identification of the number of valence electrons present.
Note: This does become very easy, very quickly.

The Noble Gases

- The Noble Gases form Group 8 on the periodic table
- They have a complete outer shell, and are therefore unreactive
- Include Helium, Neon and Argon
- Often used in examples of gas laws (later) due to their unreactive and spherical nature



Allotropic species

- Elements can come in different forms
- These different forms are called allotropes
    - Same elements, just arranged in different structures
- Carbon is a classic example, and elemental carbon can be found in graphite, diamond, buckminsterfullerene, and other structures
    - More on these later

Ionic Bonding

- occurs between metals and non-metals
    - involves the <u>transfer</u> of electrons from one atom to another
- Ionic substances are composed of a large number of electrically charged particles called *ions*
- We call the positively charged ions *cations* and the negatively charged ions *anions*
    - cations are positively charged because they have lost an electron
    - anions are negatively charged because they have gained an electron
- The number of electrons lost by the metal is equal to the number of electrons gained by the non-metal
    - overall compound formed is neutral – no net charge
- anions and cations are held together by electrostatic forces
    - positive forces attract negative forces
- Bind together to form a 3D lattice of alternating anions and cations
    - each cation is surrounded by 6 anions, and each anion is surrounded by 6 cations
- The last electron to be added to the valence shell is the first to go from the cation

Properties of ionic compounds

- high melting point