BioMedical Admissions Test (BMAT)

Section 2: Chemistry

Topic C5: Oxidation, Reduction and Redox

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One definition of Redox reactions is all about the **electrons**.

- In **oxidation**, electrons are lost
- In **reduction**, electrons are gained

A helpful way to remember this is the mnemonic **OILRIG**:

Oxidation
Is
Loss
Reduction
Is
Gain

In a redox reaction, both oxidation and reduction occur at the same time.

Redox can also be about **oxygen** molecules.

- **Oxidation** is the gain of oxygen.
- **Reduction** is the loss of oxygen.

Oxidising and Reducing Agents

- In a redox reaction, an **oxidising agent** is a species which causes another species to be oxidised.
  - This means that it itself is **reduced**.
  - For example, a metal goes from M^{2+} to M – gaining two electrons.
- Conversely, a **reducing agent** causes another species to be reduced by being oxidised itself.
  - For example, the metal which goes from M to M^{2+} - losing two electrons.

- One example of this is displacement reactions such as between calcium and magnesium ions.

$$\mathbf{Ca + Mg^{2+} \rightarrow Ca^{2+} + Mg}$$

- The calcium moves from an oxidation state of 0 to +2, and so it is **oxidised**.
  - In doing so, it **provides 2 electrons** for magnesium to be **reduced**.
  - This means that it is the **reducing agent**.
- The magnesium ion gains two electrons to go from oxidation state +2 to 0.
  - This means that it itself is **reduced**.
  - But this enables calcium to be **oxidised** and so it is an **oxidising agent**.

Oxidation States

There are some rules to remember when working out the **oxidation states** of atoms/molecules.

- The oxidation state of an atom is always 0.
  - For example, Cl_2 has an oxidation state of 0.
- An ion of one atom will have an oxidation state equal to the ionic charge.
  - For example, O^{2-} has an oxidation state of -2.
- The overall oxidation state for a compound is zero.
  - For example, NaCl has oxidation states which together equal zero.
- An ion of multiple atoms will have an overall oxidation state equal to the ionic charge.
  - For example, SO_4^{2-} will have an overall oxidation state of -2.
- In a compound, group 1 metals always have an oxidation state of +1.
  - E.g. In NaCl, Na has an oxidation state of +1.
- In a compound, group 2 metals always have an oxidation state of +2.
  - E.g. In $MgSO_4$, Mg has an oxidation state of +2
- Apart from with fluorine and in peroxides, oxygen in a compound has an oxidation state of -2.
  - In peroxides (H_2O_2) it has an oxidation state of -1.
  - In compounds with fluorine it has an oxidation state of +2.
- Apart from hydrides, hydrogen always has an oxidation state of +1.
  - In Hydrides (e.g. NaH), it has an oxidation state of -1.

Atom/Molecule	Oxidation state	Exceptions
Atoms	0	
Ions of one atom	Same as ionic charge	
Compounds	Overall 0	
Ions of multiple atoms	Overall same as ionic charge	
Group 1 metals in compounds	+1	
Group 2 metals in compounds	+2	
Oxygen in compounds	-2	Peroxides: -1
		Fluorine compounds: +2
Hydrogen	+1	Hydrides: -1

Spotting Redox Using Oxidation States

We can use known **oxidation values** to spot **redox reactions**.

For example: we can see this in the reaction of sodium and hydrochloric acid.

$$2Na_{(s)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + H_{2(g)}$$

- On the left-hand side:
  - Sodium is an atom with an oxidation state of 0.
  - Hydrogen has an oxidation state of 1+.
  - Chlorine has an oxidation state 1-.

- On the right-hand side:
  - Sodium is in a compound and so has the oxidation state of 1+
  - Hydrogen is in a compound with oxidation state of 0.
  - Chlorine still has an oxidation state of 1-.

- This means that the oxidation state of sodium has increased by 1.
  - This is the loss of electrons (oxidation).

- Conversely the oxidation state of hydrogen has decreased by 1
  - This is the gain of electrons (reduction).

Disproportionation

This is a reaction in which a **single** species of atom is **both** oxidised and reduced.

For example: this occurs when chlorine gas is reacted with a solution of cold, dilute sodium hydroxide.

$$Cl_2 + NaOH \rightarrow NaClO + NaCl + H_2O$$

- On the left-hand side:
  - Cl_2 is a gas so has oxidation state 0.
  - Na is a group one metal in a compound so has the state 1+.
  - OH as a -1 ion has an overall state of 1-.

- On the right-hand side:
  - Na has the state 1+.
  - Oxygen in this case always has the state 2-.
  - This means the Cl in NaClO must have the state 1+ to have an overall compound charge of zero.
  - In NaCl, the Cl must have the state 1- for the same reason.

- As a compound, H_2O will have an overall oxidation state of zero.

- This means that Cl atoms have simultaneously gained one electron to form a 1- state and lost one electron to form a 1+ state.
  - This is **disproportionation** – it has been oxidised and reduced at the same time.