Name:

Atomic Structure	**Objectives**
5. Oxidation and Reduction	-define oxidation and reduction in terms of electron transfer -use simple examples , e.g. Na with Cl_2, Mg with O_2, Zn with Cu^{2+} to describe oxidation and reduction in terms of electron transfer -apply knowledge of oxidation and reduction to explain the rusting of iron -define oxidising agent and reducing agent -carry out an experiment to show that halogens act as oxidising agents(reactions with bromides, iodides, Fe^{2+} and sulfites; half equations only required) -carry out an experiment to demonstrate the displacement reactions of metals (Zn with Cu^{2+}, Mg with Cu^{2+})
Chemical Bonding	
6. Oxidation Numbers	**-define oxidation number, oxidation state** **-define oxidation and reduction in terms of change of oxidation numbers** **-state the rules for oxidation numbers (exclude peroxides, except for hydrogen peroxide)** **-calculate oxidation numbers of transition metals in their compounds and of other elements** **-use oxidation numbers in nomenclature of transition metal compounds** **-give an example of an oxidising and a reducing bleach**

Oxidation and reduction can be described in four ways:

In terms of:

1. Addition/removal of oxygen.
2. Addition/removal of hydrogen.
3. Electron transfer.
4. Change in oxidation number.

1. Addition/Removal of Oxygen:

Def^n: Oxidation is the addition of oxygen.

E.g. $C + O_2 \rightarrow CO_2$ The carbon gains oxygen, therefore the carbon is oxidised.

Def^n: Reduction is the removal of oxygen.

E.g. $CuO + H_2 \rightarrow Cu + H_2O$ The copper loses oxygen, therefore the copper is reduced.

2. Addition/Removal of Hydrogen:

Def^n: Oxidation is the removal of hydrogen.

E.g. $H_2S + Cl_2 \rightarrow S + 2HCl$ The sulphur loses hydrogen, therefore the S is oxidised.

Def^n: Reduction is the addition of hydrogen.

E.g. $CO + 2H_2 \rightarrow CH_3OH$ The carbon monoxide gains hydrogen, therefore the CO is reduced.

3. <u>Electron Transfer:</u>

Def^n^: Oxidation is the loss of electrons.

E.g. $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$ The zinc loses $2e^-$, therefore the zinc is oxidised.

Def^n^: Reduction is the gain of electrons.

E.g. $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$ The copper gains $2e^-$, therefore the copper is reduced.

Remember, for electron transfer: **O**xidation **I**s **L**oss **R**eduction **I**s **G**ain.

4. <u>Change in Oxidation Number:</u> (Finding oxidation numbers mentioned later in these notes)

Def^n^: Oxidation is an increase in oxidation number.

E.g. $\underset{2(0)}{H_2} + \underset{2(0)}{½O_2} \rightarrow \underset{2(+1)\ (-2)}{H_2O}$ The O.N. of H increased from 0 to +1, therefore H is oxidised.

Def^n^: Reduction is a decrease in oxidation number.

E.g. $\underset{2(0)}{H_2} + \underset{2(0)}{½O_2} \rightarrow \underset{2(+1)\ (-2)}{H_2O}$ The O.N. of O decreased from 0 to -2, therefore O is reduced.

<u>Oxidising/Reducing Agents:</u>

Def^n^: An **Oxidising Agent** is a substance that brings about oxidation in other substances by being reduced.

Def^n^: A **Reducing Agent** is a substance that brings about reduction in other substances by being oxidised.

$+2e^- \rightarrow$ reduced $\rightarrow$ oxidising agent

E.g. $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$

<u>Assigning Oxidation Numbers:</u>

Def^n^: **Oxidation Number** is the apparent charge an atom has when electrons are distributed according to certain rules.

Rules:

1. The oxidation number of any element that is not bonded to another different element is 0.
   E.g. O.N. of H in H_2 is 0. O.N. of Na is 0. O.N. of Cl in Cl_2 is 0.

2. The oxidation number of an ion of an element is the same as its charge.
   E.g. O.N. of H in H^+ is +1. O.N. of Ca in Ca^{2+} is +2. O.N. of Cl in Na^+Cl^- is -1.

3. The total of the oxidation numbers in a neutral compound must add to give 0.
   E.g. For H_2O, each H is +1 and O is -2. This gives $2(+1)+(-2)=0$.

4. Oxygen has an oxidation number of -2.
   Exceptions:
   (a) Peroxides like H_2O_2, as O.N of H = +1, each O must have an O.N. of -1 to give a total sum of 0.
   (b) In OF_2, as O.N. of F = -1, O must have an O.N. of +2.

5. Hydrogen has an oxidation number of +1.
   Exception:
   (a) In metal hydrides like NaH, CaH_2 (H after a metal). Here H has an O.N. of -1.

6. Halogens (Group VII elements) have an oxidation number of -1.
   Exception:
   (a) When bonded to a more electronegative element (O or F), halogens can have other oxidation numbers which are calculated using rule 3.

7. The total of the oxidation numbers in a complex ion must add to give the charge on the ion.
   E.g. For NO_3^-, each O has an O.N. of -2, giving 3(-2)=-6. The total must give -1 as this is the charge on the ion. Therefore N must have an O.N. of +5.

Balancing Redox Equations:

Using oxidation numbers, balance the following equation:

$$MnO_4^- + Fe^{2+} + H^+ \rightarrow Mn^{2+} + Fe^{3+} + H_2O$$

1. Assign oxidation numbers:

$$\begin{array}{ccccccccccc} MnO_4^- & + & Fe^{2+} & + & H^+ & \rightarrow & Mn^{2+} & + & Fe^{3+} & + & H_2O \\ (+7)\ 4(-2) & & (+2) & & (+1) & & (+2) & & (+3) & & 2(+1)\ (-2) \end{array}$$

2. Show the number of electrons gained/lost:

$$\begin{array}{ccccccccccc} MnO_4^- & + & Fe^{2+} & + & H^+ & \rightarrow & Mn^{2+} & + & Fe^{3+} & + & H_2O \\ (+7)\ 4(-2) & & (+2) & & (+1) & & (+2) & & (+3) & & 2(+1)\ (-2) \end{array}$$

$Fe^{2+} \xrightarrow{-1e^-} Fe^{3+}$

$MnO_4^- \xrightarrow{+5e^-} Mn^{2+}$

3. Write the half-equations for the oxidation/reduction of the two substances above:

$$MnO_4 + 5e^- \rightarrow Mn^{2+}$$
$$Fe^{2+} - 1e^- \rightarrow Fe^{3+}$$

   Balance so that:
   (a) No. of Mn atoms is equal on both sides
   (b) No. of Fe atoms is equal on both sides
   (c) electrons gained = electrons lost:

$$MnO_4 + 5e^- \rightarrow Mn^{2+}$$
$$\mathbf{5}Fe^{2+} - \mathbf{5}e^- \rightarrow \mathbf{5}Fe^{3+}$$

4. Write the coefficients from step 3 into the original equation:

$$MnO_4^- + \mathbf{5}Fe^{2+} + H^+ \rightarrow Mn^{2+} + \mathbf{5}Fe^{3+} + H_2O$$

5. Balance the rest of the equation by inspection (leave H until last):

$$MnO_4^- + \mathbf{5}Fe^{2+} + \mathbf{8}H^+ \rightarrow Mn^{2+} + \mathbf{5}Fe^{3+} + \mathbf{4}H_2O$$