03A: REDOX Reactions: classifications

Solid-Gas Reactions

Oxidation of a metal

Consider oxidation of copper

$$4Cu + O_2 \rightarrow 2Cu_2O \qquad (1)$$

Or lower-level oxide becomes a higher-level oxide,

$$2Cu_2O + O_2 \rightarrow 4CuO \qquad (2)$$

Note that in reaction (1) cuprous oxide has a valence of 1, that is Cu^{+} , while in (2) cupric oxide, copper has a valence of 2, that is Cu^{++}.

Therefore, we can also say that

$$Cu^{+} \rightarrow Cu^{++} + e \qquad (3)$$

Note that the charges a balanced on both sides of the equation (e is negative charge on one electron).

The reaction in Eq.(3), where an electron is released, is by definition, oxidation. In electrochemistry, anode is the oxidizing electrode, that is where an electron is released.

For example consider the anode in lithium ion battery where a lithium atom converts into an ion and enters the electrolyte,

$$Li \rightarrow Li^{+} + e \qquad (4)$$

which is the oxidation of lithium metal into lithium ions.

Reduction of an Oxide into Pure Metal

Reduction is the complementary opposite of oxidation, that is the reaction results in the absorption of an electron. The reduction is shown by reversing the sign of the reactions in (1) to (4).

$$2Cu_2O \rightarrow 4Cu + O_2 \qquad (5)$$

Here cuprous oxide reduces to pure copper, that is

$$Cu^{+} + e \rightarrow Cu \qquad (6)$$

The reaction in Eq.(6), where an electron is captured, is by definition, reduction. In electrochemistry, cathode is always the reducing electrode, that is where an electron is absorbed.

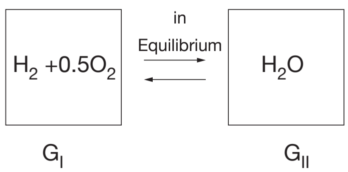
For example in SOFCs the air electrode is the cathode, because of the following reaction:

$$O_2 + 4e \rightarrow 2O^{2-}$$

Keep in mind that both the charge and the mass are balanced in Eqns (1) to (6)

Where the Reaction is among Gases

Consider an equilibrium reaction among H_2, O_2, and $H_2O(g)$ where the sum of their partial pressures is equal to 1 bar.



Here all species are gases.

The reaction is written as

$$2H_2 + O_2 = 2H_2O \qquad (7)$$

The reaction can be broken down into oxidation reactions (where an electron is released), and reduction reactions (where electrons are absorbed) in the following way,

$$2H_2 \rightarrow 4H^+ + 4e \quad \text{(oxidation, electrons are released)} \qquad (8)$$

and

$$O_2 + 4e \rightarrow 2O^{2-} \quad \text{(reduction; electron are captured)} \qquad (9)$$

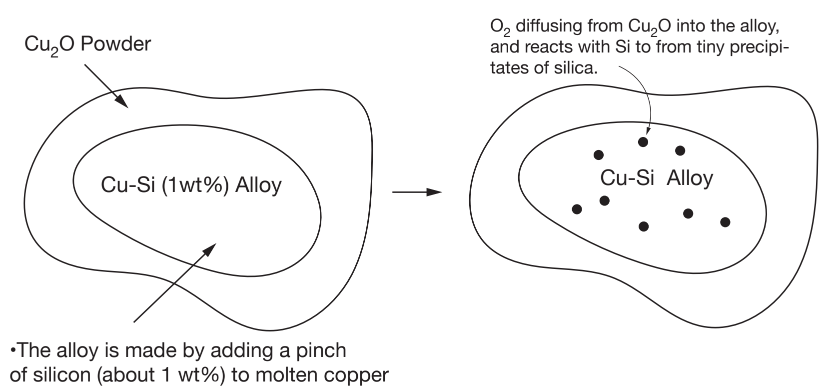
$$4H^+ + 2O^{2-} \rightarrow 2H_2O \qquad (10)$$

Thus you can see that Eq. (7) involved both reduction and oxidation reactions.

We shall see later how the reactio is influenced by partial pressures, that is the activities of the three gases.

Solid-Solid Reactions

A REDOX reaction is used to convert a copper-silicon alloy (with just a very small amount of silicon) into a microstructure where copper is dispersed with small particles of SiO_2. The following scheme is used; the alloy is embedded in powder of Cu_2O. The redox reaction consists of a reduction of cuprous oxide into copper, $Cu_2O \rightarrow 2Cu + O_2$ and, simultaneously oxidation of the silicon within the copper matrix into silicon oxide $Si + O_2 \rightarrow SiO_2$.



The evolution of the length scales of the microstructure, for example the size and spacing of the silica particles depends on the diffusion rates of the different species in the reaction. For example O must diffuse into the copper at a faster rate that the outward diffusion of silicon (if silicon diffuses faster then it would form silica as a coating on the copper matrix)