Redox Reactions

Case Study Based Questions

Read the following passages and answer the questions that follow:

1. We take copper sulphate solution in a beaker and put a copper strip or rod in it. Then on another breaker put a zinc sulphate solution and put a zinc rod or strip in it. Now reaction takes place in either of the breakers and at the interface of the metal and its salt solution in each beaker, both the reduced and oxidised forms of the same are present. A typical Galvanic cell is designed to make use of the spontaneous redox reaction between zinc and cupric ions to produce an electric current. This cell consists of a copper vessel. In which saturated CuSO4 solution is filled which acts as a depolariser and dil. H2SO4 is filled which acts as an electrolyte. An amalgamated zinc rod is immersed in ZnSO4. In copper vessels, there is a transparent layer all around just below the upper surface in which CuSO4 crystals are kept in contact with CuSO4 solution due to this the solution always remains saturated with ZnSO4

(A) What is a redox couple and how to represent the above experiment as a redox couple?

(B) Explain the observation of the above experiment when the switch is in one position. Which species will act as an oxidant?

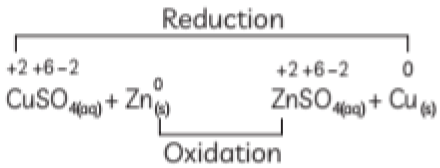
Ans. (A) Redox couple is defined as having together the oxidised and reduced forms of a substance taking part in an oxidation or reduction half-reaction.

Zn^{2+}/Zn and Cu^{2+}/Cu.

(B) When the switch is in the off position, no reaction takes place in either of the beakers and no current flows through the metallic wire. As soon as the switch is in the on position, we make the following observations:

(1) The transfer of electrons does not take place directly from Cu to Zn^{+} but through the metallic wire connecting the two rods.

(2) The electricity from solution in one beaker flows by the migration of ions through the salt bridge. The flow of current is possible only when there is a potential difference between the copper and zinc known as electrodes.



Here $CuSO_4$ acts as an oxidant as it is oxidising Zn and is itself getting reduced.

2. The oxidation number is the oxidation state. This results in a number of oxidation numbers denotes the oxidation state of an element in a compound. The oxidation state/metal in a compound is sometimes present according to the notation given by German chemist Alfred Stock. Which is known as stock notation. The oxidation state of an atom does not represent the "real" formal charge on that atom, or any other actual atomic property. This is particularly true of high oxidation states, where the ionisation energy required to produce a multiply positive ion is far greater than the energies available in chemical reactions. Additionally, the oxidation states of atoms in a given compound may vary depending on the choice of electronegativity scale used in their calculation. Thus, the oxidation state of an atom in a compound is purely a formalism. It is nevertheless important in understanding the nomenclature conventions of inorganic compounds. Also, several observations regarding chemical reactions may be explained at a basic level in terms of oxidation states.

(A) The oxidation state of 'S' in $KAL(SO_4)_2.12H_2O$ is:

(a) -2

(c) 2

(b) -1

(d) +6

(B) Name the rule in which oxidation number will be denoted in roman numbers.

(a) Stock notation

(b) E.M.F

(c) Lewis dot rules

(d) Octet rule

(C) Choose the right option for with respect to stock notation.

(a) NaCl ⟶ 2 Na(II)CL

(b) HgCl⟶2 = 1 Hg(1)Cl_2

(c) AlF_3⟶2 = AL(II)F_3

(d) $SiCl_4$ ⟶ 3 = Si(III)CL_4

(D) A reagent which can increase the oxidation number of an element in the

given substance.

(a) Oxidation

(b) Reducing reagent

(c) Oxidising reagent

(d) Reduction

(E) Which of the following statements regarding $HClO_4$ and $HClO_3$ is true?

(a) The O.N. for chlorine in $HClO_4$ has increased in $HCLO_3$

(b) The O.N. of oxygen in $HClO_4$ has been decreased in $HCLO_3$

(c) The O.N. of chlorine in $HClO_4$ has been decreased in $HCLO_3$

(d) The oxidation numbers for all atoms are the same in both molecules

Ans. (A) (d) +6

Explanation: Let the oxidation number of Sulphur be x in $KAL(SO_4)_2.12H_2O$. Oxidation no. of known elements are:

K = +1, AL = +3,0 = −2, H = +1

+1+3+2x+4(-2)]= 0

+ 4 + 2x-16=0

2x = 12

x = +6

Hence, the oxidation no. of S is +6.

(B) (a) Stock notation

Explanation: Stock notation is the oxidation number expressed by putting a roman numeral representing the oxidation number in parenthesis after the symbol of the metal in the molecular formula.

(C) (b) $HgCl_2 \longrightarrow 1 = Hg(1)Cl_2$

Explanation: The oxidation number of Hg in $HgCl_2$ is 1. Thus according to stock notation, it can be represented as

$HgCl_2 \rightarrow\ 1 = Hg(I)Cl_2$

(D) (c) Oxidising reagent

Explanation: A reagent which can increase the oxidation number of an element in the given substance is known as oxidising reagent

(E) (c) The O.N. of chlorine in $HClO_4$ has been decreased in $HCLO_3$

Explanation:

(1) Atoms in elemental form have an oxidation state of 0.

(2) Halogens are commonly given an oxidation state of -1.
(3) Hydrogen and alkali metals are commonly given an oxidation state of +1.
(4) Oxygen is commonly given an
oxidation number of -2.
We can assume that the hydrogens and oxygens in the two compounds preserve the same oxidation state by keeping these criteria in mind. Yet, in $HClO_3$, chlorine is bound to one less oxygen. Comparing $HCLO_4$ to $HCLO_3$, the oxidation state of Cl has therefore fallen from +7 to +5.

3. Oxidation was used to describe the addition of oxygen to an element or a compound. Because of the presence of dioxygen in the atmosphere (-20%). Many elements combine with it and this is the principal reason why they commonly occur on the earth in the form of their oxides. Oxidation is the loss of electrons during a reaction by a molecule, atom or ion. Oxidation occurs when the oxidation state of a molecule, atom or ion is increased. The opposite process is called reduction, which occurs when there is a gain of electrons or the oxidation state of an atom, molecule, or ion decreases.

(A) The oxidation process involves:
(a) Decrease in oxidation number
(b) Increase in oxidation number
(c) No change in oxidation number
(d) None of the above

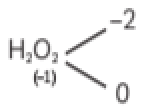
(B) The addition of oxygen or electronegative element to a substance:
(a) Reduction
(b) Oxidising agent
(c) Reducing agent
(d) Oxidation.

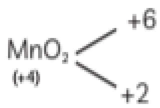
(C) Select the correct option for oxidation example.
(a) $2Mg_{(s)} + O_{2(g)} \rightarrow 2\,MgO_{(s)}$
(b) Zn^{2+} / Zn and Cu^{2+}/ Cu.
(c) $Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$
(d) $Cr_2O_{3(s)} + 2Al_{(s)} \xrightarrow{\Delta} Al_2O_{3(s)} + 2Cr_{(s)}$

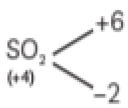
(D) Which of the following may act both as an oxidising and a reducing agent?
(a) H_2O_2
(b) MnO_2

(c) SO_2
(d) All of these

Ans. (A) (b) Increase in oxidation number
Explanation: Oxidation is that process which results in an increase of the oxidation number.
(B) (d) oxidation
Explanation: It is defined as the addition of oxygen or an electronegative element to a substance or the removal of hydrogen/ electropositive element from a substance.
(C) (a) $2Mg_{(s)} + O_{2(g)} \longrightarrow 2\ MgO_{(s)}$
Explanation: In this reaction, the addition of oxygen to magnesium took place which represents oxidation.
(D) (d) All of these
Explanation: All the given species can act as both oxidising and reducing agents.

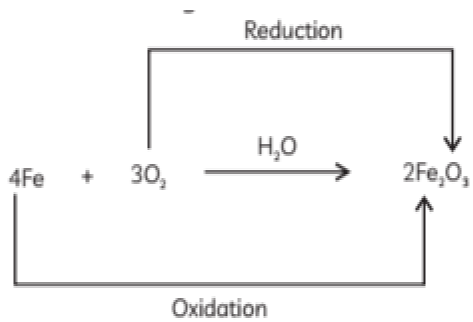






4. Place a strip of metallic zinc in an aqueous solution of copper nitrate for about one hour. We can observe that the strip becomes coated with reddish metallic copper and the blue colour of the solution disappears. Formation of Zn**2+** ions among the product can easily judge when the blue colour solution due to the Cu**2+** has disappeared. Redox reactions are characterised by the actual or formal transfer of electrons between chemical processes, most often with one species undergoing oxidation (losing electrons) while another species undergoes reduction The chemical species from which the electron is removed is said to have been oxidised, while the chemical species to which the electron is added is said to have been reduced.
(A) Explain the redox reaction with the help of an example.
(B) Explain the experiment with the help of an equation.
(C) Why does the metallic zinc strip turn reddish in colour?

Ans. (A) Redox reaction is defined as the reaction in which oxidation and reduction take place simultaneously.



(B)

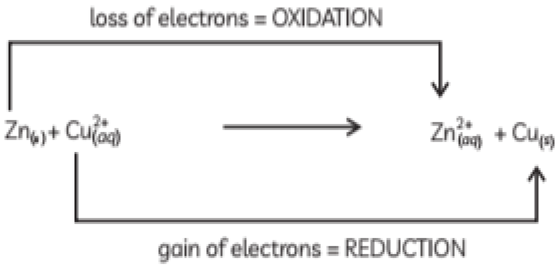
Oxidation half-reaction:

$$Zn_{(s)} \rightarrow Zn^{+2}_{(aq)} + 2e^-$$

Reduction half-reaction:

$$Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$$

$$Cu^{2+}_{(aq)} + Zn_{(s)} \rightarrow Zn^{+2}_{(aq)} + Cu_{(s)}$$



(C) This is because copper ions from copper nitrate solution get reduced by accepting electrons from zinc. This causes deposition of copper on zinc metal strip which is red in colour.