

# Electrochemistry

## Long Answer Questions

**Q1. Define oxidation state. What are the rules for assigning oxidation state?**

**Ans.** "Oxidation state or oxidation number (O.N) is the apparent charge assigned to an atom of an element in a molecule or in an ion".

**Rules for assigning oxidation number (O.N)**

- i. The oxidation number of all elements in the free state is zero.
- ii. The oxidation number of an ion consisting of a single element is the same as the charge on the ion.
- iii. The oxidation number of different elements in the periodic table is: in Group-1 it is +1 in Group-2 it is +2 and in Group-3 it is +3.
- iv. The oxidation number of hydrogen in all its compounds is +1. But in metal hydrides it is -1.
- v. The oxidation number of oxygen in all its compounds is -2. But it is -1 in peroxides,  $\frac{1}{2}$  in superoxide and +2 in  $\text{OF}_2$ .
- vi. In any substance the more electronegative atom has the negative oxidation number.
- vii. In neutral molecules, the algebraic sum of the oxidation numbers of all the elements is zero.
- viii. In ions, the algebraic sum of oxidation numbers equal to the charge on the ion.

**Q2. Explain oxidation-reduction reaction with suitable examples.**

**Ans.** "Chemical reactions in which the oxidation state of one or more substances changes are called oxidation-reduction or redox reactions".

**Example: 1**

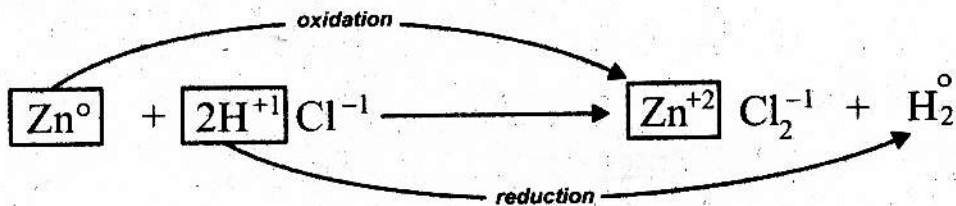
Let us discuss a reaction of zinc metal with hydrochloric acid.



The oxidation states or oxidation numbers of all the atoms or ions in this reaction are indicated below:



Let us find, the atoms that are oxidized or reduced or whether there is a change in their oxidation state, it is indicated as follows:



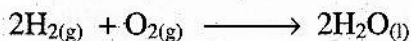
In this reaction:

Zinc is oxidized and acts as a reducing agent.

Hydrogen is reduced and acts an oxidizing agent.

**Example: 2**

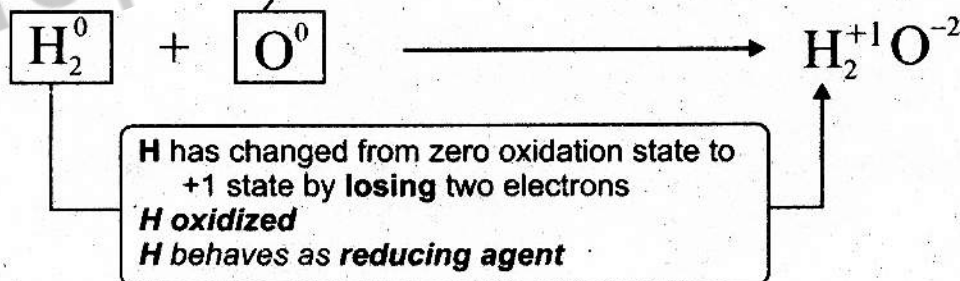
In the case of formation of water from hydrogen and oxygen gases, Redox reaction takes places as follows:



The oxidation states or oxidation number of all the atoms or ions in this reaction are:



**O** has changed from zero oxidation state to  $-2$  state by **gaining** electrons  
**O reduced**  
**O behaves as oxidizing agent**



**In this reaction:**

Hydrogen is oxidized and acts as a reducing agent.

Oxygen is reduced and acts an oxidizing agent.

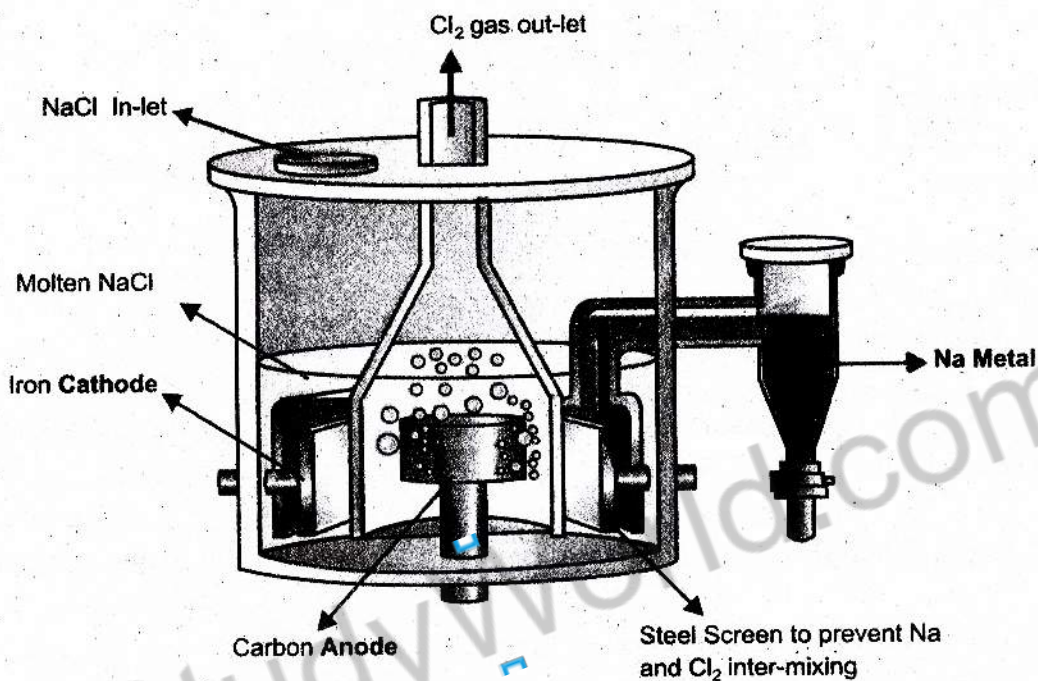
**Q3. How sodium metal is extracted from fused sodium chloride in Down's cell?**

**Ans. Principle**

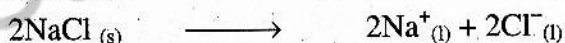
On the industrial scale molten sodium metal is obtained by the electrolysis of fused NaCl in the Downs cell.

**Construction of Down's cell**

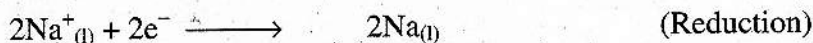
This electrolytic cell is a circular furnace. In the center there is a large block of graphite, which acts as an anode while cathode around it is made of iron.



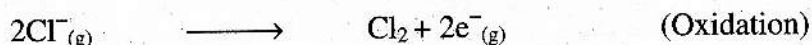
#### Ionization of fused NaCl:



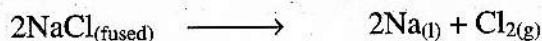
#### Reaction at Cathode:



#### Reaction at Anode:



#### Overall Reactions:



#### Conclusion

Chlorine gas is liberated from anode electrode as a by-product, while sodium metal is collected at cathode electrode.

#### Working of Downs Cell

The fused NaCl produces  $\text{Na}^+$  and  $\text{Cl}^-$  ions, which migrate to their respective electrodes on the passage of electric current. The electrodes are separated by steel gauze to prevent the contact between the products. The  $\text{Cl}^-$  ions are oxidized to give  $\text{Cl}_2$  gas at the anode. It is collected over the anode within an inverted cone-shaped structure. While  $\text{Na}^+$  ions are reduced at cathode and molten sodium metal floats on the denser molten salt mixture from where it is collected in a side tube. Following reactions take place during the electrolysis of the molten sodium chloride.

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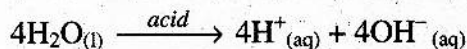
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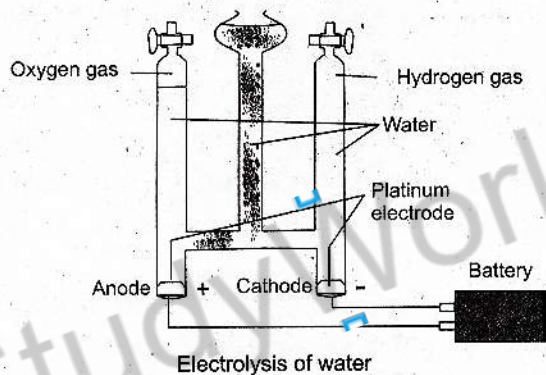
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**Q4. Write a note on the electrolysis of water in detail.**

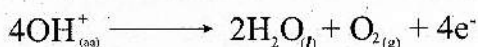
**Ans.** Pure water is a very weak electrolyte. It ionizes to a very small extent. The concentrations of hydrogen ions ( $H^+$ ) and hydroxyl ions ( $OH^-$ ) are both at  $10^{-7}$  mol  $dm^{-3}$  respectively. When a few drops of an acid are added in water, its conductivity improves.



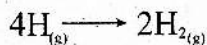
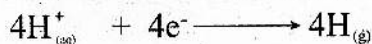
When an electric current is passed through acidified water, water splits up into  $H^+$  ions and  $OH^-$  ions.  $OH^-$  ions move towards positive electrode (anode) and  $H^+$  ions move towards negative electrode (cathode) and discharge takes place at these electrodes.



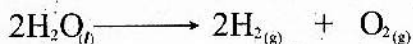
Oxidation reaction at anode:



Reduction reaction at cathode:



Overall reaction:



**Conclusion**

Oxygen is evolved at anode electrode, while hydrogen is evolved at cathode electrode.

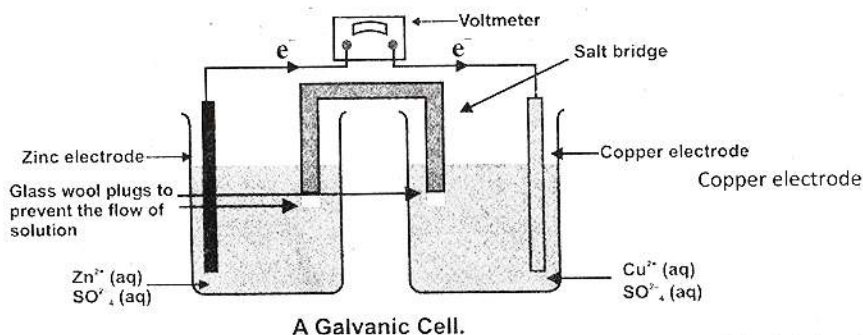
**Q5. What is meant by Galvanic cell? Write construction and working of Daniel cell**

**Ans. Galvanic cell:**

“The electrochemical cell in which a spontaneous chemical reaction takes place and generates electric current is called Galvanic or Voltaic cell”.

**Construction of Daniel cell**

A galvanic cell consists of two cells, each called as half cell, connected electrically by a salt bridge. In each of the half-cell, an electrode is dipped in 1M solution of its own salt and connected through a wire to an external circuit.



The left half cell consists of an electrode of zinc metal dipped in 1 M solution of zinc sulphate. The right half cell is a copper electrode dipped in 1M solution of copper sulphate.

### Salt bridge

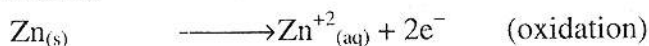
Salt bridge is a U shaped glass tube. It consists of saturated solution of strong electrolyte supported in a jelly type material. The ends of the U tube are sealed with a porous material like glass wool. The function of the salt bridge is to keep the solutions of two half cells neutral by providing a pathway for migration of ions.

### Working of the cell

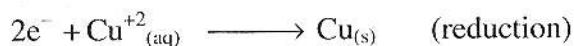
The zinc metal has tendency to lose electrons more readily than copper. As a result oxidation takes place at Zn-electrode. The electrons flow from Zn-electrode through the external wire in a circuit to copper electrode. These electrons are gained by the copper ions of the solution and copper ions deposit at the electrode.

The respective oxidation and reduction processes going on at two electrodes are as follows.

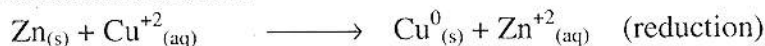
### At Anode



### At Cathode



### Overall cell reaction



### Conclusion

It is an indirect Redox reaction, in which electrons flow in a particular direction through an external conductivity wire connecting the two electrodes. Thus, in an indirect Redox reaction, the decrease in the chemical energy is liberated in the form of electrical energy.

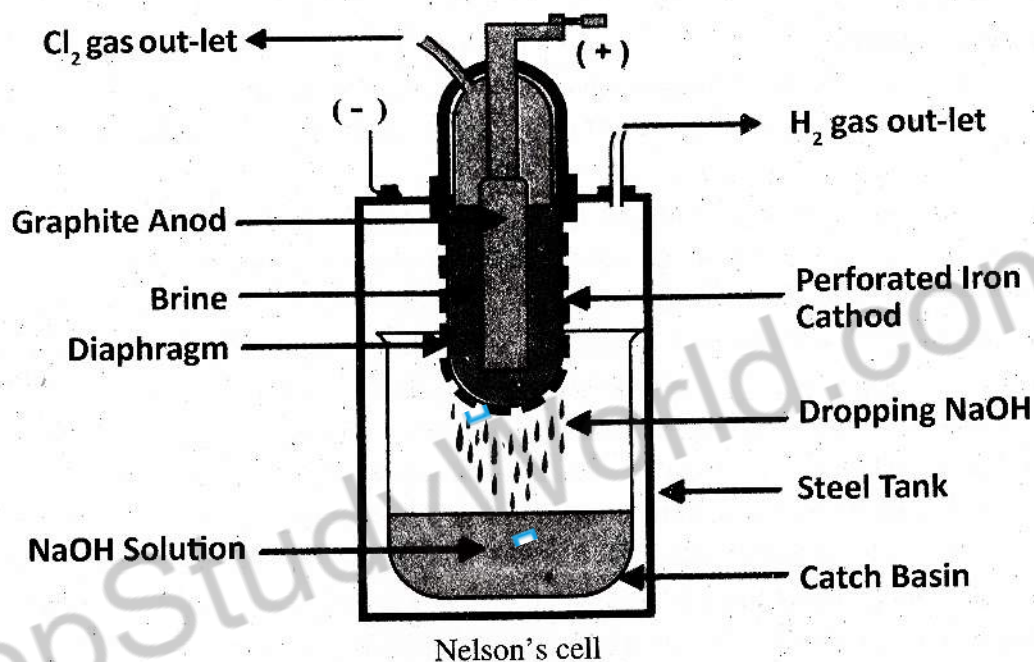
**Q6. How can we prepare NaOH on commercial scale? Discuss its chemistry along with diagram? How sodium hydroxide is manufactured from brine solution in Nelson's cell?**

**Ans. Principle**

On industrial scale sodium hydroxide NaOH, is produced in Nelson's cell by the electrolysis of aqueous solution of NaCl called brine.

### Construction of Nelson's cell

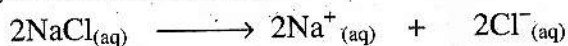
Nelson's cell consists of a steel tank in which graphite anode is suspended in the center of a U-shaped perforated iron cathode. This iron cathode is internally lined with asbestos diaphragm. Electrolyte brine is present inside the iron cathode.



### Working of Nelson's cell

Aqueous solution of sodium chloride consists of Na<sup>+</sup>, Cl<sup>-</sup>, H<sup>+</sup> and OH<sup>-</sup> ions. These ions move towards their respective electrodes and redox reactions take place at these electrodes. When electrolysis takes place Cl<sup>-</sup> ions are discharge at anode and Cl<sub>2</sub> gas rises into the dome at the top of the cell. The H<sup>+</sup> ions are discharged at cathode and H<sub>2</sub> gas escapes through a pipe. The sodium hydroxide solution slowly percolates into a catch basin.

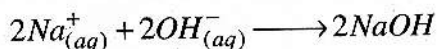
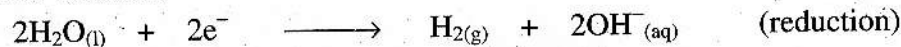
### Electrolysis of Brine solution



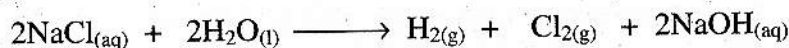
### Reaction at Anode



### Reaction at Cathode



### Overall reaction



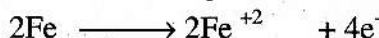
### Q7. How the process of rusting takes place?

#### Ans. Introduction to rusting

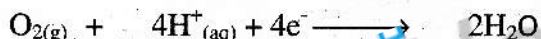
Corrosion of iron is called rusting. The important condition for rusting is moist air (air having water vapours in it). There will be no rusting in water vapours free of air or air free of water.

#### Process of rusting

Stains and dents on the surface of the iron provide the sites for this process to occur. This region is called anodic region and following oxidation reaction takes place here:



This loss of electrons damages the object. The free electrons move through iron sheet, until they reach to a region of relatively high oxygen concentration near the surface surrounded by water layer as shown in figure. This region acts as cathode and electrons reduce the oxygen molecule in the presence of  $\text{H}^{+}$  ions.

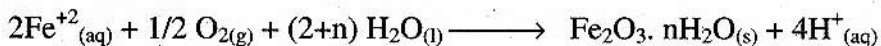


The  $\text{H}^{+}$  ions are provided by the carbonic acid, which is formed because of presence of  $\text{CO}_2$  in water. That is why acidic medium accelerates the process of rusting.

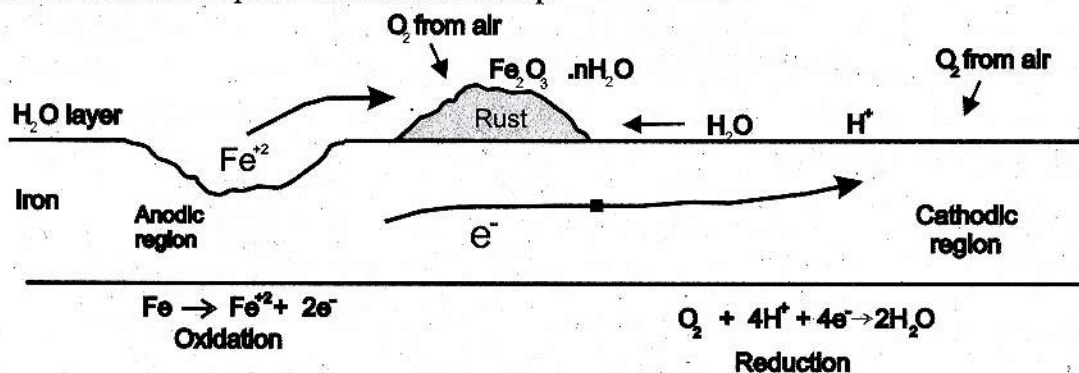
The overall Redox process is completed without the formation of rust.



The  $\text{Fe}^{+2}$  formed spreads throughout the surrounding water and react with  $\text{O}_2$  to form the salt  $\text{Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O}$  which is called rust. It is also a Redox reaction.



The rust layer of iron is porous and does not prevent further corrosion. Thus rusting continues until all the piece of irons is eaten up



### Q8. What are the methods for the prevention of corrosion?

Ans. Following are some of the methods for the prevention of corrosion.

#### i) Removal of stains

The regions of stains in an iron rod act as the site for corrosion. If the surface of iron is properly cleaned and stains are removed, it would prevent corrosion.



## ii) Paints and greasing

Greasing, polishing or painting of the surface can prevent the corrosion of iron. With development of technologies, modern paints contain a combination of chemicals called stabilizers that provide protection against the corrosion in addition to prevention against the weathering and other atmospheric effects.

## iii) Alloying

Alloy is a homogeneous mixture of one metal with one or more other metals or non metals. Alloying of iron with other metals has proved to be very successful technique against rusting. The best example of alloying is the 'stainless steel'.

## iv) Metallic coating

The best method for protection against the corrosion of metals exposed to acidic conditions is coating the metal. With other metal corrosion resistant metals like Zn, Sn, and Cr are coated on the surface of iron to protect it from corrosion. It is the most widely applied technique in the food industry where food is tin-packed'. The containers of iron are coated with tin or chromium to give it a longer life. Metallic coating can take place by physical as well as electrolytic methods.

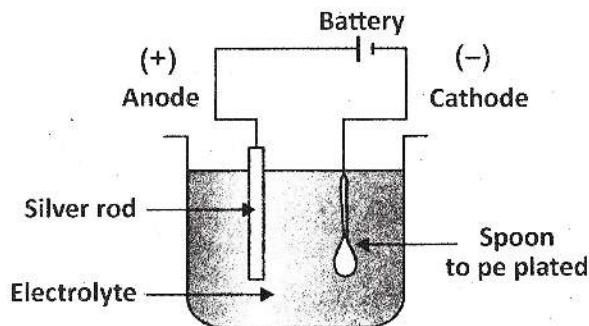
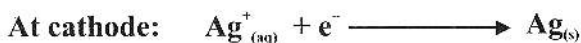
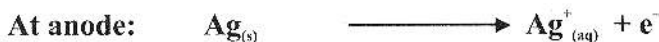
**Q9. Define electroplating. Explain electroplating of silver.**

**Ans.** "Electroplating is depositing of one metal over the other by means of electrolysis".

### Electroplating of silver

The electroplating of silver is carried out by establishing an electrolytic cell. The pure piece of silver strip acts as anode that is dipped in silver nitrate solution. The cathode is the metallic object to be coated such as silver spoon. When the current is passed through the cell, the  $\text{Ag}^+$  ions dissolve at the anode, and migrate towards the cathode where they discharge on the object e.g. spoon.

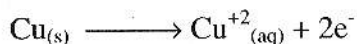
The chemical reaction can be represented as:



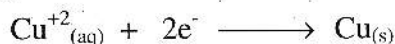
Common example of silver plating is table wares, cutlery, jewelry and steel objects.

### Q10. How copper is refined?

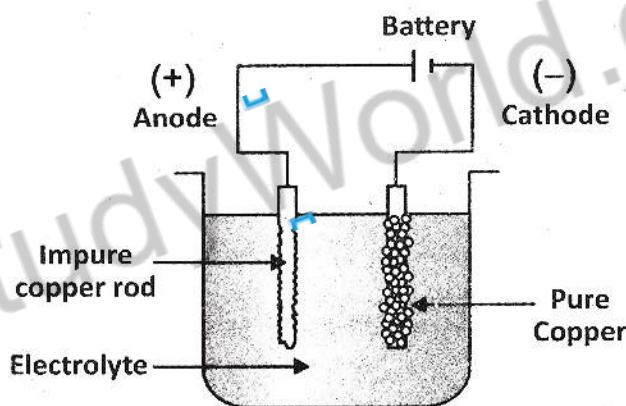
Ans. Impure copper is refined by the electrolytic method in the electrolytic cell. Impure copper acts as anode and pure copper plate acts as cathode. Copper sulphate solution is used as an electrolyte. Oxidation reaction takes place at the anode. Copper atoms from the impure copper lose electrons to the anode and dissolve in solution as copper ions.



Reduction reaction takes place at the cathode. The copper ions present in the solution are attracted to the cathode. Where they gain electrons from the cathode and become neutral and deposit on the cathode.



In the process impure copper is eaten up and purified copper atoms deposit on the cathode.



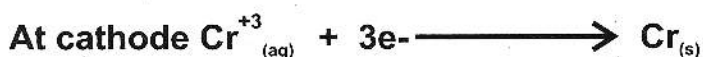
### Q11. Write a note on electroplating of chromium.

Ans. In chromium electroplating, the object to be electroplated is dipped in aqueous solution of chromium sulphate containing a little amount of sulphuric acid, which acts as an electrolyte. The object which is to be electroplated acts as cathode while, antimonial lead acts as anode. The electrolyte ionizes and provides  $\text{Cr}^{3+}$  ions, which reduce and deposit at cathode.

Electrolyte produces the following ions:



Reactions at the electrodes are as follows:



For practical convenience, the steel is usually plated first with nickel or copper and then by chromium because it does not adhere well on the steel surface. Moreover, it allows moisture to pass through it and metal is stripped off. The nickel or copper provides adhesion and then chromium deposited over the adhesive layer of copper lasts longer. This type of electroplating resists corrosion and gives as bright Silvery appearance to the object.

## Short Answer Questions

**Q1. What is meant by electrochemistry?**

**Ans.** The branch of chemistry that deals with the relationship between electricity and chemical reactions is called electrochemistry.

**Q2. Define oxidation.**

**Ans.** Oxidation is defined as the addition of oxygen or removal of hydrogen or loss of electron or increase in oxidation number during a chemical reaction.



**Q3. Define reduction.**

**Ans.** Reduction is defined as the removal of oxygen or addition of hydrogen or gain of electron or decrease in oxidation number during a chemical reaction.



**Q4. What is meant by Redox?**

**Ans.** Chemical reactions in which the oxidation state of one or more substances changes are called oxidation-reduction or Redox reactions.



**Q5. What is meant by oxidizing agent? Give examples.**

**Ans.** An oxidizing agent is a species that oxidizes a substance by taking electrons from it. The substance (atom or ion) which is reduced itself by gaining electrons is called oxidizing agent. For example

- i) Concentrated sulphuric acid.  $\text{H}_2\text{SO}_4$
- ii) Potassium permanganate.  $\text{KMnO}_4$  etc

**Q6. What is meant by reducing agent? Give examples.**

**Ans.** Reducing agent is the species that reduces a substance by donating electron to it. The substance (atom or ion) which is oxidized by losing electrons is called reducing agent. For example

- i) Hydrogen (H)
- ii) Hydrogen sulphide ( $\text{H}_2\text{S}$ ) etc

**Q7. What are spontaneous reactions?**

**Ans.** Spontaneous reactions are those which take place on their own without any external agent.

**Q8. What are non-Spontaneous reactions?**

**Ans.** Non-spontaneous reactions are those which take place in the presence of external agent.

**Q9. What is meant by Oxidation State?**

**Ans.** Oxidation state or oxidation number is the apparent charge assigned to an atom of an element in a molecule or in an ion. For example in HCl, the oxidation number of hydrogen is +1 and chlorine is -1.

**Q10. Define valency.**

**Ans.** The apparent charge on an atom, ion or molecule is called valency, is written as the sign followed by the number i.e., 2+.

OR

The combining power of an atom to another atom is called its valency

**Q11. What is meant by electrochemical cell?**

**Ans.** Electrochemical cell is a system in which two electrodes are dipped in the solution of an electrolyte which is connected to the battery.

OR

Electrochemical cell is an energy storage device in which either a chemical reaction takes place by using electric current or chemical reaction produces electric current.

**Q12. What are electrolytes?**

**Ans.** The substances, which can conduct electricity in their solutions or molten states, are called electrolytes. For example, solutions of salts, acids or bases are good electrolytes.

**Q13. What are strong electrolytes?**

**Ans.** The electrolytes which ionize completely in aqueous solution and produces more ions, are called strong electrolytes. For example, NaCl, NaOH, H<sub>2</sub>SO<sub>4</sub> are strong electrolytes.

**Q14. What are weak electrolytes?**

**Ans.** The electrolytes which ionize to a small extent when dissolved in water and could not produce more ions are called weak electrolytes. For example, CH<sub>3</sub>COOH, Ca(OH)<sub>2</sub> etc.

**Q15. What are non-Electrolytes?**

**Ans.** The substances, which do not ionize in solution and do not allow the current to pass through their solutions, are called non-electrolytes. For example, sugar solution, benzene etc.

**Q16. What is meant by electrolytic cell?**

**Ans.** The type of electrochemical cell in which a non-spontaneous chemical reaction takes place when electric current is passed through the solution, is called an electrolytic cell e.g., Down's cell.

**Q17. Define cation.**

**Ans.** Chemical specie which carries a positive charge. e.g.,  $\text{Na}^+$ ,  $\text{K}^+$  etc.

**Q18. Define anion.**

**Ans.** Chemical specie which carries a negative charge. e.g.,  $\text{O}^{2-}$ ,  $\text{Cl}^-$  etc.

**Q19. Differentiate between Oxidation and reduction.**

**Ans.**

Oxidation	Reduction
Addition of oxygen	Removal of oxygen
Removal of hydrogen	Addition of hydrogen
Loss of electrons	Gain of electrons
Increase in oxidation number	Decrease in oxidation number

**Q20. What is meant by galvanic cell?**

**Ans.** The electrochemical cell in which a spontaneous chemical reaction takes place and generates electric current is called galvanic or voltaic cell e.g., Daniel cell.

**Q21. What is half cell?**

**Ans.** A galvanic cell consists of two cells one having cathode while the other having anode end and which are connected with a salt bridge. Each of these known as half cell.

**Q22. Differentiate between Cathode and anode.**

Cathode	Anode
Reduction always takes place at cathode	Oxidation always takes place at anode
Cathode carries negative charge in electrolytic cell	Anode carries positive charge in electrolytic cell
Cathode carries positive charge in galvanic cell	Anode carries negative charge in galvanic cell

**Q23. What is meant by salt bridge?**

**Ans.** Salt-bridge is a U-shaped glass tube which consists of a saturated solution of strong electrolyte supported in a jelly type material. The ends of the U-shaped glass tube are sealed with a porous material like glass wool. The function of the salt bridge is to keep the solutions of two half cells neutral by providing a pathway for migration of ions.

**Q24. Define corrosion.**

**Ans.** It is a Redox reaction that takes place by the action of air and moisture with the metals. For example rusting of iron

**Q25. Differentiate between cation and anion.**

**Ans.**

Cation	Anion
A chemical specie which carries a positive charge	A chemical specie which carries a negative charge

During electrolysis it always move towards cathode electrode	During electrolysis it always move towards anode electrode
Examples: $\text{Na}^+$ , $\text{Ca}^{2+}$	Examples: $\text{Cl}^-$ , $\text{O}^{2-}$

**Q26. What is meant by rust?**

**Ans.** It is a Redox reaction that takes place when iron is exposed to air and moisture. The chemical formula of rust is  $\text{Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O}$ .

**Q27. Define electroplating.**

**Ans.** Electroplating is depositing of one metal over the other by means of electrolysis.

**Q28. Define alloy.**

**Ans.** Alloy is a homogenous mixture of one metal with one or more other metals or non-metals. For example stainless steel is an alloy of iron, chromium and nickel.

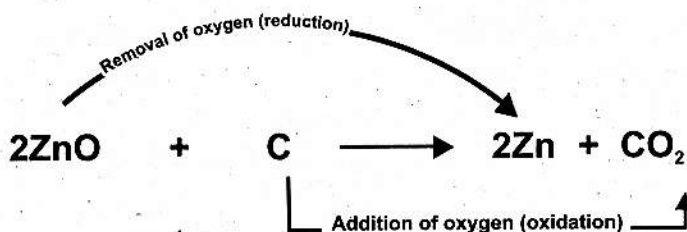
**Q29. Differentiate between Oxidizing agent and reducing agent.**

**Ans.**

Oxidizing agent	Reducing agent
A specie that oxidizes a substance by taking electrons from it.	A specie that reduces a substance by donating electrons to it.
A substance which is reduced itself by gaining electrons.	A substance which is oxidized by losing electrons.
A substance that reduces itself and oxidizes other.	A substance that oxidizes itself and reduces other.
Examples are non-metals.	Examples are metals.

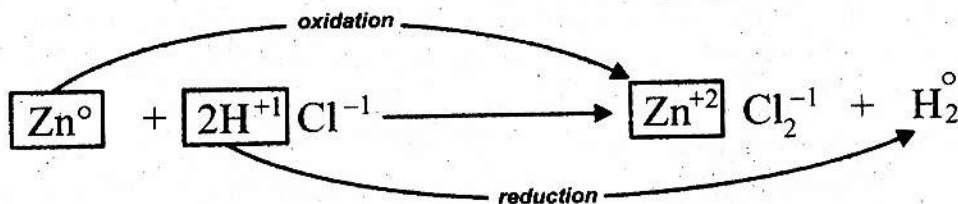
**Q30. Justify the reaction between ZnO and C is Redox reaction.**

**Ans.**



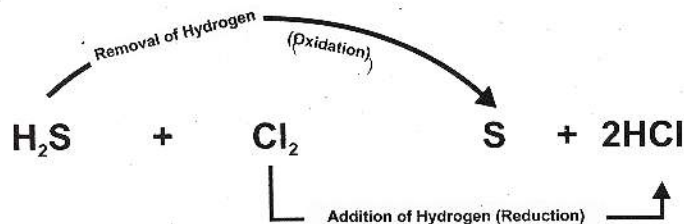
**Q31. Justify the reaction between Zn and HCl is Redox reaction.**

**Ans.**



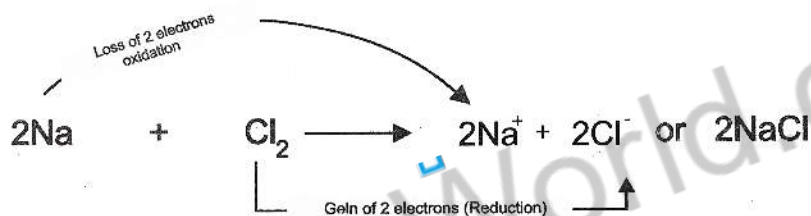
**Q32. Justify the reaction between H<sub>2</sub>S and Cl<sub>2</sub> is Redox reaction.**

Ans.



**Q33. Justify the reaction between Na and Cl<sub>2</sub> is Redox reaction.**

Ans.



**Q34. Write oxidation numbers of oxygen in its binary compounds?**

Ans.

- i) Normal oxides -2
- ii) Peroxides -1
- iii) OF<sub>2</sub> +2

**Q35. Name different types of electrochemical cells.**

- i) Electrolytic cell.
- ii) Galvanic or voltaic cell.

**Q36. How the oxidation number and valency are assigned?**

Oxidation Number	Valency
While assigning oxidation number the sign precedes the number i.e. + 2.	While assigning valency the sign followed by the number i.e. 2+
For example, the oxidation number of sodium is +1	For example, the valency of sodium is 1+

**Q37. Write construction of an electrolytic cell?**

Ans. An electrolytic cell consists of a solution of an electrolyte, two electrodes (cathode and anode) that are dipped in the electrolytic solution and connected to the battery. The electrode connected to positive terminal is called anode and electrode connected to the negative terminal is called cathode.

**Q38. Who was A. Volta?**

Ans. Volta (1745-1827) was an Italian physicist known especially for the development of the first electric cell in 1800.

**Q39. Write construction of Down's cell?**

**Ans.** This electrolytic cell is a circular furnace. In the center there is a large block of graphite, which acts as an anode while cathode around it is made of iron.

**Q40. Differentiate between Spontaneous and non-spontaneous reactions**

**Ans.**

Spontaneous reactions	Non-spontaneous reactions
Those reactions which takes place on their own without any external agent	Those reactions which takes place in the presence of an external agent
Example: Galvanic cell	Example: Electrolytic cell

**Q41. Give overall reaction for the preparation of sodium hydroxide.**

**Ans.**  $2\text{NaCl} + 2\text{H}_2\text{O} \longrightarrow \text{H}_2 + \text{Cl}_2 + 2\text{NaOH}$

**Q42. Why the process of rusting does only occur on iron and not on the surface of aluminum?**

**Ans.** Aluminum corrodes but it does not rust. Rust refers only to iron and steel corrosion. A very hard material aluminum oxide protects the aluminum from further corrosion. In comparison to that when iron corrodes. Its color changes and produces large red flakes known as rust. Unlike aluminum oxide, the expanding and flaking of rust exposes new metal to further rusting.

**Q43. Differentiate between Strong and Weak electrolytes.**

**Ans.**

Strong electrolytes	Weak electrolytes
The electrolyte which ionizes completely in solution is called strong electrolyte.	The electrolyte which do not ionize completely in solution is called weak electrolyte.
It produces more ions in water	It produces less ions in water
Examples: NaOH, HCl etc	Examples: $\text{CH}_3\text{COOH}$ , $\text{Ca}(\text{OH})_2$

**Q44. What is meant by stainless steel?**

**Ans.** It is an alloy which is made up of iron, chromium and nickel. Which does not corrode.

**Q45. What is meant by galvanizing?**

**Ans.** The process of coating a thin layer of zinc on iron is called galvanizing.

**Q46. How galvanizing process takes place?**

**Ans.** This process is carried out by dipping a clean iron sheet in a zinc chloride bath and then heating it. After this iron sheet is removed, rolled into molten zinc metal bath and finally air cooled.

**Q47. Write advantages of galvanizing.**

**Ans.** A major advantage of galvanizing is that zinc protects the iron against corrosion even after the coating surface is broken.



**Q48. What is the principle of electroplating?**

**Ans.** The principle of electroplating is to establish an electrolytic cell in which anode is made of the metal to be deposited and cathode of the object on which metal is to deposit. The electrolyte is an aqueous solution of a salt of the respective metal.

**Q49. Differentiate between Electrolytes and non-electrolytes.**

**Ans.**

<b>Electrolytes</b>	<b>Non-Electrolytes</b>
The substances, which can conduct electricity in their solutions or molten states, are called electrolytes	The substances, which cannot conduct electricity in their solutions or molten states, are called non-electrolytes
Examples: NaOH, HCl etc	Examples: Glucose solution, Benzene etc

**Q50. Write a note on zinc electroplating.**

**Ans.** A target metal is cleaned in alkaline detergent type solutions, and it is treated with acid, in order to remove any rust or surface scales. Next, the zinc is deposited on the metal by immersing it in a chemical bath containing electrolyte zinc sulphate. A current is applied which results in zinc being deposited on the target metal i.e., cathode.

**Q51. Write a note on tin electroplating.**

**Ans.** Tin usually electroplated on steel by placing the steel into a container containing a solution of tin salt. The steel is connected to an electrical circuit acting as cathode. While the other electrode made of tin metal acts as anode. When an electrical current passes through the circuit, tin metal ions present in the solution deposit on steel.

**Q52. Which material is used to make cathode in electroplating?**

**Ans.** The cathode is made up of the object that is to be electroplated like some sheet made up of iron.

**Q53. Why is the anode made up of a metal to be deposited during electrolysis?**

**Ans.** When current is passed, the metal from anode dissolves in the solution and metallic ions migrate to the cathode and discharge or deposit on the cathode.

**Q54. What is the difference between corrosion and rusting?**

**Ans.** Corrosion is slow and continuous eating away of a metal by the surrounding medium. It is a Redox chemical reaction that takes place by the action of air and moisture with metals. While, rusting is an example of corrosion. The condition for rusting is the moist air (air having water vapours in it).

**Q55. Differentiate between Electrolytic and galvanic cell.**

<b>Electrolytic cell</b>	<b>Galvanic cell</b>
It consists of one complete cell, connected to a battery	It consists of two half cells connected through a salt bridge

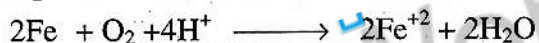
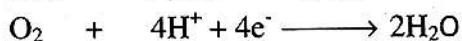
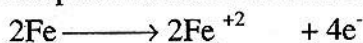
Anode has positive charge while cathode has negative charge	Anode has negative charge while cathode has positive charge
Electrical energy is converted into chemical energy	Chemical energy is converted into electrical energy
Current is used for a non-spontaneous chemical reactions to take place	Redox reaction takes place spontaneously and produces electric current
Examples: Nelson cell, Down cell	Example: Daniel cell, fuel cell

**Q56. What happen to iron in the rusting process?**

**Ans.** The rusting process continues until all the pieces of iron is eaten up.

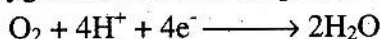
**Q57. Rusting completes in how many Redox reactions?**

**Ans.** Rusting completes in three Redox reactions



**Q58. Explain the role of O<sub>2</sub> in rusting?**

**Ans.** The free electrons move through iron sheet; until they reach to a region of relatively high oxygen concentration, near the surface surrounded by water layer. This region acts as cathode and electrons reduce the oxygen molecule in the presence of H<sup>+</sup> ions.



**Q59. State the best method for protection of metal from corrosion.**

**Ans.** The best method for protection against the corrosion of metals exposed to acidic conditions is coating the metal. Corrosion resistant metals like Zn, Sn and Cr are used for this method.

**Q60. Why tin plated iron is rusted rapidly when tin layer is broken?**

**Ans.** When tin layer is broken and iron is exposed to the air and water, a galvanic cell is established and iron rusts rapidly.

**Q61. Name the metal which is used for galvanizing iron?**

**Ans.** Zinc metal is used for galvanizing iron.

**Q62. Anode of Down's cell is made of a non-metal, what is its name? What is the function of this anode?**

**Ans.** In Down's cell anode is made up of carbon (graphite). The Cl<sup>-</sup> ions are oxidized to give Cl<sub>2</sub> gas at the anode.

**Q63. Where does the sodium metal is collected in Down's cell?**

**Ans.** In Down's cell Na<sup>+</sup> ions are reduced at cathode and molten sodium metal floats on the denser medium salt mixture from where it is collected in a side tube.

**Q64. What is the name of the by-product produced in the Down's cell?**

**Ans.** Chlorine gas is produced as a by-product in the Down's cell.

**Q65. Are anodes of Down's cell and Nelson's cell made of same element? If yes, what is its name?**

**Ans.** Yes, anodes of both Down's cell and Nelson's cell are made up of same element known as graphite.

**Q66. What is the shape of cathode in Nelson's cell? Why is it perforated?**

**Ans.** In Nelson's cell, cathode is internally lined with asbestos diaphragm. Cathode is a U-shaped perforated iron from where sodium hydroxide solution slowly percolates in a catch basin.

**Q67. Which ions are discharged at cathode in Nelson's cell and what is produced at cathode?**

**Ans.**  $\text{Cl}^-$  are discharged at cathode in Nelson's cell and chlorine gas is evolved from that electrode.

**Q68. Why are the strong electrolytes termed as good conductors?**

**Ans.** Strong electrolytes are termed as good conductors because they ionize completely in their solutions.

**Q69. Does non-electrolyte form ions in solution?**

**Ans.** No, non-electrolytes do not ionize in solution and do not allow the current to pass through their solutions.

**Q70. Identify a strong or weak electrolyte among the following compounds.**

**Ans.**

i)  $\text{CuSO}_4$  (Strong electrolyte)

ii)  $\text{H}_2\text{CO}_3$  (Weak electrolyte)

iii)  $\text{Ca}(\text{OH})_2$  (Weak electrolyte)

iv)  $\text{HCl}$  (Strong electrolyte)

v)  $\text{AgNO}_3$  (Strong electrolyte)

**Q71. Which force drives the non-spontaneous reaction to take place?**

**Ans.** Non-spontaneous reactions are those which take place in the presence of external agent. This external agent is known as electrical energy.

**Q72. Which type of chemical reaction takes place in electrolytic cell?**

**Ans.** Non-spontaneous chemical reaction takes place with the help of electricity in electrolytic cell.

**Q73. What type of reaction takes place at anode in electrolytic cell?**

**Ans.** The process of oxidation takes place at anode in electrolytic cell.

**Q74. Why the positively charged electrode is called anode in electrolytic cell?**

**Ans.** The electrode connected to positive terminal of the battery is called anode.

**Q75. In the electrolysis of water, towards which terminal  $\text{H}^+$  ions move?**

**Ans.** In the electrolysis of water,  $\text{H}^+$  ions move towards cathode and reduced to hydrogen gas and liberates.

**Q76. In the electrolysis of water, where is the oxygen produced?**

**Ans.** In the electrolysis of water, oxygen is produced at anode electrode.

**Q77. Towards which electrode of the electrolytic cell moves the cations and what do they do there?**

**Ans.** In electrolytic cell, cations move towards cathode electrode and they are reduced there.

**Q78. How the half cells of a galvanic cell are connected? What is function of salt bridge?**

**Ans.** The half cells of a galvanic cell are connected electrically by a salt bridge. It is used to keep the solutions of two half cells neutral by providing a pathway for migration of ions.

**Q79. In the following reaction, how can you justify that H<sub>2</sub>S is oxidized and SO<sub>2</sub> is reduced**



**Ans.** As hydrogen is removed from H<sub>2</sub>S, therefore H<sub>2</sub>S is oxidized, while removal of oxygen takes place in SO<sub>2</sub>, therefore SO<sub>2</sub> is reduced.

**Q80. The reaction between MnO<sub>2</sub> and HCl is a Redox reaction written as balance chemical equation.**



**Find out.**

- The substance oxidized
- The substance reduced
- The substance which acts as oxidizing agent
- The substance which acts as reducing agent

- Ans.** (a) Cl is oxidized  
(b) Mn is reduced  
(c) MnO<sub>2</sub> is oxidizing agent  
(d) HCl is reducing agent

**Q81. The following reactions are Redox reaction**

**Find out the element which has been reduced and the element which has been oxidized.**

- $\text{Zn} + \text{CuSO}_4 \longrightarrow \text{ZnSO}_4 + \text{Cu}$
- $\text{Cu} + 2\text{AgNO}_3 \longrightarrow \text{Cu(NO}_3)_2 + 2\text{Ag}$
- $\text{H}_2\text{S} + \text{Cl}_2 \longrightarrow 2\text{HCl} + \text{S}$

- Ans.** (a) Zn is oxidized and Cu is reduced  
(b) Cu is oxidized and Ag is reduced  
(c) Sulphur (s) is oxidized and Cl is reduced

**Q82. Why the following reaction is not a redox reaction. Explain with reasons?**



Ans. Because, acid- base reactions are considered to be neutralization reactions. Whenever, acid reacts with bases, they form salt and water.

Q83. Find out the oxidation numbers of the following elements marked in bold in the formulae.  $\text{Ba}_3(\text{PO}_4)_2$ ,  $\text{CaSO}_4$ ,  $\text{Cu}(\text{NO}_3)_2$ ,  $\text{Al}_2(\text{SO}_4)_3$ ,  $\text{Na}_2\text{SO}_4$ ,  $\text{HNO}_3$ ,  $\text{KClO}_3$ ,  $\text{AgNO}_3$ ,  $\text{KMnO}_4$ ,  $\text{K}_2\text{Cr}_2\text{O}_7$ ,  $\text{HNO}_2$ ,  $\text{H}_2\text{S}$ ,  $\text{SO}_2$ ,  $\text{H}_2\text{SO}_4$

Ans.



$$3[\text{O.N of Ba}] + 2[\text{O.N of P}] + 8[\text{O.N of O}] = 0$$

$$3[+2] + 2[\text{P}] + 8[-2] = 0$$

$$+6 + 2\text{P} - 16 = 0$$

$$2\text{P} - 10 = 0$$

$$2\text{P} = +10$$

$$\text{P} = +5$$



$$[\text{O.N of Ca}] + [\text{O.N of S}] + 4[\text{O.N of O}] = 0$$

$$[+2] + [\text{S}] + 4[-2] = 0$$

$$+2 + \text{S} - 8 = 0$$

$$\text{S} - 6 = 0$$

$$\text{S} = +6$$



$$[\text{O.N of Cu}] + 2[\text{O.N of N}] + 6[\text{O.N of O}] = 0$$

$$[+2] + 2[\text{N}] + 6[-2] = 0$$

$$+2 + 2\text{N} - 12 = 0$$

$$2\text{N} - 10 = 0$$

$$2\text{N} = +10$$

$$\text{N} = +5$$



$$2[\text{O.N of Al}] + 3[\text{O.N of S}] + 12[\text{O.N of O}] = 0$$

$$2[+3] + 3[\text{S}] + 12[-2] = 0$$

$$+6 + 3\text{S} - 24 = 0$$

$$3\text{S} - 18 = 0$$

$$3\text{S} = +18$$

$$\text{S} = +6$$



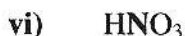
$$2[\text{O.N of Na}] + [\text{O.N of S}] + 4[\text{O.N of O}] = 0$$

$$2[+1] + [\text{S}] + 4[-2] = 0$$

$$+2 + \text{S} - 8 = 0$$

$$S-6=0$$

$$\mathbf{S=+6}$$



$$[\text{O.N of H}] + [\text{O.N of N}] + 3[\text{O.N of O}] = 0$$

$$[+1] + [N] + 3[-2] = 0$$

$$+1 + N - 6 = 0$$

$$N - 5 = 0$$

$$\mathbf{N=+5}$$



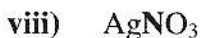
$$[\text{O.N of K}] + [\text{O.N of Cl}] + 3[\text{O.N of O}] = 0$$

$$[+1] + [\text{Cl}] + 3[-2] = 0$$

$$+1 + \text{Cl} - 6 = 0$$

$$\text{Cl} - 5 = 0$$

$$\mathbf{Cl=+5}$$



$$[\text{O.N of Ag}] + [\text{O.N of N}] + 3[\text{O.N of O}] = 0$$

$$[+1] + [N] + 3[-2] = 0$$

$$+1 + N - 6 = 0$$

$$N - 5 = 0$$

$$\mathbf{N=+5}$$



$$[\text{O.N of K}] + [\text{O.N of Mn}] + 4[\text{O.N of O}] = 0$$

$$[+1] + [\text{Mn}] + 4[-2] = 0$$

$$+1 + \text{Mn} - 8 = 0$$

$$\text{Mn} - 7 = 0$$

$$\mathbf{Mn=+7}$$



$$2[\text{O.N of K}] + 2[\text{O.N of Cr}] + 7[\text{O.N of O}] = 0$$

$$2[+1] + 2[\text{Cr}] + 7[-2] = 0$$

$$+2 + 2\text{Cr} - 14 = 0$$

$$2\text{Cr} - 12 = 0$$

$$2\text{Cr} = +12$$

$$\mathbf{Cr=+6}$$



$$[\text{O.N of H}] + [\text{O.N of N}] + 2[\text{O.N of O}] = 0$$

$$[+1] + [N] + 2[-2] = 0$$

$$+1 + N - 4 = 0$$

$$N-3=0$$

$$N=+3$$



$$2[\text{O.N of H}] + [\text{O.N of S}] = 0$$

$$2[+1] + [S] = 0$$

$$+2 + S = 0$$

$$S + 2 = 0$$

$$S = -2$$



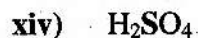
$$[\text{O.N of S}] + 2[\text{O.N of O}] = 0$$

$$[S] + 2[-2] = 0$$

$$S - 4 = 0$$

$$S - 4 = 0$$

$$S = +4$$



$$2[\text{O.N of H}] + [\text{O.N of S}] + 4[\text{O.N of O}] = 0$$

$$2[+1] + [S] + 4[-2] = 0$$

$$+2 + S - 8 = 0$$

$$S - 6 = 0$$

$$S = +6$$

**Q84. In a compound  $MX_3$ , find out the oxidation number of M and X.**

Ans.  $M = +3$

$$X = -1$$

**Q85. Why the oxidation number of oxygen in  $OF_2$  is +2?**

Ans. The oxidation number of oxygen on  $OF_2$  is +2, because fluorine has a high electronegative value as compared to oxygen. Therefore, fluorine will carry negative (-1) charge while oxygen will carry (+2) charge on it.

**Q86. An element X, has oxidation state 0. What will be its oxidation state when it gains three electrons?**

Ans. When X will gain three electrons in its valence shell its oxidation state will become  $X^{-3}$

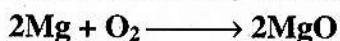
**Q87. An element in oxidation state +7 gains electrons to be reduced to oxidation state +2. How many electrons did it accept?**

Ans. When an element in oxidation state +7 gains electrons and reduced to oxidation state +2, it shows that it has accepted +5 electrons in its valence shell.

**Q88. If the oxidation state of an element changes from +5 to -3. Has it been reduced or oxidized? How many electrons are involved in this process?**

**Ans.** When the oxidation state of an element changes from +5 to -3, it is considered to be reduced. There are eight electrons involved in this process.

**Q89.** How can you justify that a reaction between magnesium and oxygen is a Redox reaction, while the reaction shows only addition of oxygen (oxidation).



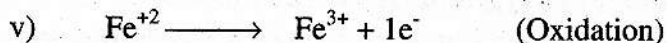
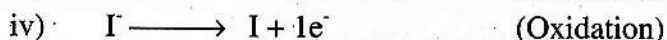
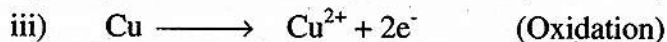
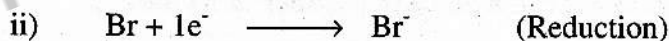
**Ans.** The above reaction is a Redox one, because oxygen tends to gain electron which is known as reduction, while magnesium tends to remove electron which is known as oxidation. The simultaneous oxidation-reduction process is known as Redox.

**Q90.** A reaction between carbon and oxygen involved only addition of oxygen (oxidation), but it is called a Redox reaction. Comment on this.

**Ans.**



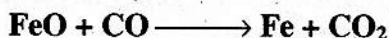
**Q91.** Identify which of the following is oxidation or reduction reaction.



**Q92.** An element M reacts with another element X to form  $\text{MX}_2$ . In terms of loss or gain of electrons, identify the element which is oxidized and which is reduced.

**Ans.** When an element M loses its electron, oxidation process takes place. When this electron is gained by element X, reduction process takes place. Therefore, element M is oxidized while element X is reduced.

**Q93.** How can you justify that the following reaction is not only an oxidation reaction but also a complete Redox reaction.

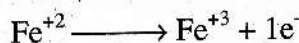
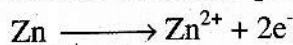


**Ans.** When FeO reacts with CO, oxygen is removed from FeO which shows reduction process. On the other hand when oxygen is added to CO it shows oxidation process. Therefore, it is a complete redox reaction.

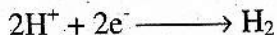
**Q94.** Explain the term oxidation and reduction on the basis of electronic concept with an example.



**Ans. Oxidation:** A process in which loss of electrons takes place is called oxidation.



**Reduction:** A process in which gain of electrons takes place is called reduction.



**Q95. Write applications of galvanic cell?**

**Ans.** As a result of Redox reaction, electric current is produced. The batteries which are used for starting automobiles, running calculators and toys and to lit the bulbs work on the same principle.

## Multiple Choice Questions

**1. The branch of chemistry which deals with the relationship between electricity and chemical reactions.**

- (a) Electrochemistry
- (b) Thermochemistry
- (c) Analytical chemistry
- (d) Industrial chemistry

**2. Oxidation involves**

- (a) Removal of oxygen
- (b) Addition of oxygen
- (c) Gain of electron
- (d) Addition of hydrogen

**3. In HCl, oxidation number of H is:**

- (a) -1      (b) +1
- (c) +2      (d) -2

**4. The oxidation number of all elements in free state is:**

- (a) One      (b) Two
- (c) Three    (d) Zero

**5. The oxidation number of Group-I elements is:**

- (a) +1      (b) +2
- (c) +3      (d) +4

**6. The oxidation number of hydrogen in metal hydrides is:**

- (a) +1      (b) -1
- (c) +2      (d) -2

**7. The oxidation number of oxygen is +2 in:**

- (a)  $\text{H}_2\text{O}$       (b)  $\text{OF}_2$
- (c)  $\text{Na}_2\text{O}$       (d)  $\text{HNO}_3$

**8. In neutral molecules, the algebraic sum of the oxidation numbers of all the elements is:**

- (a) One      (b) Two
- (c) Three    (d) Zero

**9. The oxidation number of sulphur in  $\text{H}_2\text{SO}_4$  is:**

- (a) +1      (b) +4
- (c) +6      (d) +8

**10. Oxidizing agent is a substance which**

- (a) Reduces itself and oxidizes other
- (b) Reduces itself and also reduces other
- (c) Oxidizes itself and reduces other
- (d) Oxidizes itself and also oxidizes other

**11. Chemical reaction in which the oxidation state of one or more substances changes are called**

- (a) Catenation (b) Reduction  
(c) Redox (d) Oxidation

**12. Which of the following is a good electrolyte**

- (a) NaCl (b) H<sub>2</sub>SO<sub>4</sub>  
(c) NaOH (d) All of them

**13. Which of the following is a weak electrolyte?**

- (a) NaCl (b) CH<sub>3</sub>COOH  
(c) KCl (d) NaOH

**14. Which ionizes in small extent in water**

- (a) Ca(OH)<sub>2</sub> (b) NaCl  
(c) NaOH (d) H<sub>2</sub>SO<sub>4</sub>

**15. The substances which do not ionize in solution and do not allow to pass current through them are called:**

- (a) Strong electrolytes  
(b) Weak electrolytes  
(c) Non-electrolytes  
(d) Electrolytes

**16. Example of electrolytic cell is:**

- (a) Down's cell (b) Nelson's cell  
(c) Daniel cell (d) Both a and b

**17. Which of the following is a non-electrolyte?**

- (a) Benzene  
(b) Sodium chloride  
(c) Sulphuric acid  
(d) Sodium hydroxide

**18. Oxidation always takes place at:**

- (a) Anode (b) Cathode  
(c) Both of them (d) None of them

**19. Which gas is evolved during the electrolysis of fused sodium chloride?**

- (a) Hydrogen (b) Chlorine  
(c) Oxygen (d) All of them

**20. Pure water is a**

- (a) Non-electrolyte  
(b) Strong electrolyte  
(c) Weak electrolyte  
(d) All of them

**21. During electrolysis of sodium chloride in aqueous state, which gas is evolved from the cathode electrode?**

- (a) Hydrogen (b) Chlorine  
(c) Oxygen (d) All of them

**22. Who invented first electrolytic cell?**

- (a) Berzelius (b) A. Volta  
(c) J. Dalton (d) Newton

**23. In which cell electrical energy is converted into chemical energy?**

- (a) Galvanic cell  
(b) Voltaic cell  
(c) Electrolytic cell  
(d) All of them

**24. Which is produced as a result of Redox reaction?**

- (a) Electric current  
(b) Chemical current  
(c) Both a and b  
(d) None of them

**25. In galvanic cell cathode electrode carries:**

- (a) Positive charge  
(b) Negative charge  
(c) No charge  
(d) Neutral charge

**26. Which cell is used in the manufacturing of sodium metal from fused NaCl?**

- (a) Down's cell (b) Nelson's cell  
(c) Both of them (d) None of them

27. Which acts as anode in Down's cell?  
 (a) Iron (b) Carbon  
 (c) Silver (d) Steel
28.  $\text{Cl}_2$  gas is formed, when  $\text{Cl}^-$  ions are  
 (a) Reduced (b) Oxidized  
 (c) Removed  
 (d) Reacted with metals
29. In Nelson's cell, cathode is made up of:  
 (a) Iron (b) zinc  
 (c) Graphite (d) steel
30. Which ion is not formed during electrolysis of aqueous sodium chloride?  
 (a)  $\text{Na}^+$  (b)  $\text{H}^+$   
 (c)  $\text{K}^+$  (d)  $\text{OH}^-$
31. Sodium hydroxide is manufactured in  
 (a) Nelson's cell (b) Down's cell  
 (c) Galvanic cell (d) Voltaic cell
32. Chemical formula of rust is  
 (a)  $\text{Fe}_2\text{O}_3$  (b)  $\text{Fe}_3\text{O}_4 \cdot 2\text{H}_2\text{O}$   
 (c)  $\text{Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O}$  (d)  $\text{Fe}_3\text{O}_4$
33. Corrosion of iron is called  
 (a) Rusting (b) Smelting  
 (c) Roasting (d) All of them
34. Which medium accelerates the process of rusting?  
 (a) Acidic (b) Basic  
 (c) Buffer (d) Neutral
35. A region on iron surface when rusting takes place is known as  
 (a) Cathodic region  
 (b) Anodic region  
 (c) Both of them  
 (d) None of them
36. Rusting occurs on  
 (a) Iron (b) Steel  
 (c) Aluminium (d) Both a and b
37. Stainless steel contains  
 (a) Nickel (b) Iron  
 (c) Chromium (d) All of them
38. Which of the following is a corrosion resistant metal?  
 (a) Fe (b) Zn  
 (c) Sn (d) Sr
39. In order to give longer life, the containers of iron are coated by:  
 (a) Tin (b) Chromium  
 (c) Carbon (d) Both a and b
40. A process of coating a thin layer of Zn on iron is called:  
 (a) Catenation (b) Rusting  
 (c) Smelting (d) Galvanizing
41. The electrolytic cell is made up of:  
 (a) Cement (b) Glass  
 (c) Wood  
 (d) All of the above
42. Which of the following is a common example of silver plating?  
 (a) Wares (b) Cutlery  
 (c) Jewellery (d) All of them
43. Which metal has a great tendency to corrosion?  
 (a) Potassium (b) Sodium  
 (c) Aluminium (d) All of them
44. In early nineteenth century photographers produce crude images using papers covered with  
 (a) Chromium sulphate  
 (b) Nickel sulphate  
 (c) Silver nitrate  
 (d) Potassium nitrate
45. Chemical formula of sodium hyposulphite is:  
 (a)  $\text{Na}_2\text{SO}_4$  (b)  $\text{Na}_2\text{S}_2\text{O}_3$   
 (c)  $\text{Na}_2\text{SO}_3$  (d)  $\text{NaSO}_4$

**46. Sodium hyposulphite dissolves:**

- (a) Mercury iodide
- (b) Silver iodide
- (c) Potassium iodide
- (d) Sodium iodide

**47. Which is not a property of fine silver?**

- (a) It is soft
- (b) It is not malleable
- (c) It is easily damaged
- (d) All of them

**48. The percentage of any metal can make up the non-silver portion of sterling is:**

- (a) 2.7
- (b) 4.5
- (c) 7.5
- (d) 8.4

**49. The percentage of silver in sterling silver is:**

- (a) 22.1
- (b) 44.7
- (c) 99.2
- (d) 92.5

**50. Sterling silver is an alloy of silver and:**

- (a) Iron
- (b) Copper
- (c) Chromium
- (d) Aluminium

**51. Spontaneous chemical reactions take place in:**

- (a) Electrolytic cell
- (b) Galvanic cell
- (c) Nelson's cell
- (d) Down's cell

**52. Formation of water from hydrogen and oxygen is:**

- (a) Redox reaction
- (b) Acid-base reaction
- (c) Neutralization
- (d) Decomposition

**53. Which of the following is NOT an electrolytic cell?**

- (a) Down's cell
- (b) Galvanic cell
- (c) Nelson's cell
- (d) Both a and c

**54. The oxidation number of chromium in  $K_2Cr_2O_7$  is:**

- (a) +2
- (b) +6
- (c) +7
- (d) +14

**55. Which of the following is NOT an electrolyte?**

- (a) Sugar solution
- (b) Sulphuric acid solution
- (c) Lime solution
- (d) Sodium chloride solution

**56. The most common example of corrosion is:**

- (a) Chemical decay
- (b) Rusting of iron
- (c) Rusting of aluminum
- (d) Rusting of tin

**57. Nelson's cell is used to prepare caustic soda along with gases. Which of the following gas is produced at cathode?**

- (a)  $Cl_2$
- (b)  $H_2$
- (c)  $N_2$
- (d)  $O_2$

**58. During the formation of water from hydrogen and oxygen, which of the following does not occur?**

- (a) Hydrogen has oxidized
- (b) Oxygen has reduced
- (c) Oxygen gains electrons
- (d) Hydrogen behaves as oxidizing agent

**59. In the Redox reaction between Zn and HCl, the oxidizing agent is:**

- (a) Zn
- (b)  $H^+$
- (c)  $Cl^-$
- (d)  $H_2$

## Answer Key

1.	a	2.	b	3.	b	4.	d	5.	a
6.	b	7.	b	8.	d	9.	c	10.	a
11.	c	12.	d	13.	b	14.	a	15.	c
16.	d	17.	a	18.	a	19.	b	20.	c
21.	a	22.	b	23.	c	24.	a	25.	a
26.	a	27.	b	28.	b	29.	a	30.	c
31.	a	32.	c	33.	a	34.	a	35.	b
36.	d	37.	d	38.	a	39.	d	40.	d
41.	d	42.	d	43.	c	44.	c	45.	b
46.	b	47.	b	48.	c	49.	d	50.	b
51.	b	52.	a	53.	b	54.	b	55.	a
56.	b	57.	b	58.	d	59.	b		