4. Reactivity series and electrochemistry

Let us Assess

1. Question

The solutions of $ZnSO_4$, $FeSO_4$, $CuSO_4$, and $AgNO_3$ are taken in four different test tubes. Suppose, an iron nail is kept immersed in each one.

• In which test tube the iron nail undergoes a colour change?

• What is the reaction taking place here?

• Justify your answer. (Refer reactivity series of metals).

Answer

(i) The iron nail undergoes a colour change in that test tube which has $CuSO_4$ solution.

Since Fe is more reactive than Cu and Ag but less reactive than Zn because in reactivity series Fe is above to Cu and Ag. So, Fe will displace Cu and Ag from their salts. But colour will change in a test tube of $CuSO_4$ solution from blue to green. Because $AgNO_3$ is colourless and $Fe(NO_3)_2$ is also colourless so there is no colour change in test tube of $AgNO_3$.

(ii) $Fe(s) + CuSO_4(aq) \longrightarrow FeSO_4(aq) + Cu(s)$

(iii) Since Fe is more reactive than Cu and Ag but less reactive than Zn because in reactivity series Fe is above to Cu and Ag. So Fe will displace Cu and Ag from their salts. But colour will change in test tube of CuSO4 solution from blue to green. Because AgNO3 is colourless and Fe(NO3)2 is also colourless so there is no colour change in a test tube of AgNO3.

2. Question

Compare the electrolysis of molten potassium chloride and solution of potassium chloride. What are the processes taking place at the cathode and the anode?

Answer

On electrolysis of molten potassium chloride, potassium chloride dissociates into K^+ and Cl^-. The anode is connected to positive terminal and cathode to the negative terminal of the battery. So, the oxidation occurs at anode and reduction occurs at the cathode. At the cathode, there are only K^+ ions so they reduced and potassium will deposit on the cathode. And at the anode, there are only Cl^- ions so they will oxidized and chlorine gas will evolve at the anode.

At anode- $2Cl^-(aq) \longrightarrow Cl_2(g) + 2e^-$

At cathode- $K^+(aq) + e^- \longrightarrow K(s)$

On electrolysis of a solution of potassium chloride, potassium chloride dissociates into K^+ and Cl^-. The anode is connected to positive terminal and anode to the negative terminal of the battery. So, the oxidation occurs at anode and reduction occurs at the cathode. At the cathode, there are K^+ ions and water. So, while comparing K^+ ions and water, water has greater tendency to get reduced. Hence hydrogen gas is liberated at the cathode. Similarly, at anode, there are Cl^- ions and water. So, on comparing Cl^- ions, and water, oxidation occurs to Cl^-. Hence chlorine gas is liberated at the anode.

At anode- $2Cl^- \longrightarrow Cl_2 + 2e^-$

At cathode- $2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$

3. Question

You are given a solution of $AgNO_3$, a solution of $MgSO_4$, an Ag rod and an Mg ribbon. How can you arrange a Galvanic cell using these? Write down the reactions taking place at the cathode and the anode.

Answer

First we take 100 ml solution of $MgSO_4$ in one beaker and 100 ml solution of $AgNO_3$ in the second beaker.

Immerse Mg ribbon in $MgSO_4$ solution and Ag rod in $AgNO_3$ solution. Connect the negative terminal of a voltmeter to the Mg ribbon and positive terminal to the Ag rod. Connect the solutions in two beakers by a salt bridge.

Oxidation will occur at anode and reduction will occur at the cathode.

Reaction at anode - $Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^-$

Reaction at cathode - $Ag^+(aq) + e^- \longrightarrow Ag(s)$

$Mg(s) + 2Ag^+(aq) \longrightarrow Mg^{2+}(aq) + Ag(s)$

Note- Salt bridge is a U-tube filled with a paste made by mixing gelatin or agar gel and a salt like KCl or KNO_3. This completes the circuit by transfer of ions and maintains the electrical neutrality of the cell.

Extended Activities

1. Question

Keep two carbon rods immersed in a copper sulphate solution. Then pass electricity through the soon.

(i) At which electrode does a colour change occur-anode or cathode?

(ii) Is there any change in the blue colour of the copper sulphate solution?

(iii) Write down the chemical equations for the changes occurring here.

Answer

(i) The colour change occurs at the cathode. The electrolyte $CuSO_4$ dissociates into Cu^{2+} and SO_4^{2-}. So at cathode Cu^{2+}converts into Cu which deposited on the cathode and the colour will change at the cathode.

$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$

(ii) Yes, the intensity of the blue colour of $CuSO_4$ will decrease as the copper ions are converted to the copper deposit on the cathode.

(iii) Reaction at cathode: $Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$

Reaction at anode: The negative sulphate ions (SO_4^{2-}) and the hydroxide ions (OH^-) are attracted to the positive electrode. But the sulphate ion is too stable and nothing happens. So either hydroxide ions or water molecules are oxidised to form oxygen.

$4OH^-(aq) \longrightarrow 2H_2O(l) + O_2(g) + 4e^-$

Or $2H_2O(l) \longrightarrow 4H^+(aq) + O_2(g) + 4e^-$

2. Question

When acidified copper sulphate solution is electrolyzed oxygen is obtained at the anode. What arrangements are to be made for this? Find the element deposited at the cathode.

Answer

Take copper sulphate ($CuSO_4$) in a beaker. Add some acid (H_2SO_4) to it and make a copper solution. Immerse two carbon rods in a beaker. Connect a battery to the rods. Oxidation occurs at anode and reduction occurs at the cathode. And we can observe that oxygen is produced at the anode.

$4OH^-(aq) \longrightarrow 2H_2O(l) + O_2(g) + 4e^-$

Or $H_2O(l) \longrightarrow 4H^+(aq) + O_2(g) + 4e^-$

And at cathode, copper will deposit due to conversion of Cu^{2+} ions to Cu.

$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$

3. Question

How many Galvanic cells can be made by using the metals Ag, Cu, Zn, and Mg? When Galvanic cells are made using the metals given, what will be the nature of reactions in each cell? (Reactivity: Mg>Zn>Cu>Ag).

Answer

In Galvanic cell, the anode is always more reactive than the cathode.

Total 6 Galvanic cells can be made.

(i) Mg-Zn – Anode = Mg and Cathode = Zn

(ii) Mg-Cu – Anode = Mg and Cathode = Cu

(iii) Mg-Ag – Anode = Mg and Cathode = Ag

(iv) Zn-Cu – Anode = Zn and Cathode = Cu

(v) Zn-Ag – Anode = Zn and Cathode = Ag

(vi) Cu-Ag – Anode = Cu and Cathode = Ag

All the reactions in each Galvanic cell are redox in nature because oxidation occurs at anode and reduction occurs at the cathode.

4. Question

You are familiar with some materials which are used in various secondary cells.

Make a list of different types of chemical cells. Analyse how they influence the environment.

Answer

Types of chemical cells-

1- Simple chemical cell

2- Dry cell

(i) Primary cells

a- Leclanche cells

b- Alkaline cells

c- Lithium cells

d- Mercury cells

e- Silver oxide cell

(ii) Secondary cells

a- Nickel-cadmium cell

b- Lithium-ion cell

c- Nickel metal-hydride cell

3- Wet cell

4- Fuel cell

(i) Phosphoric Acid fuel cell (PAFC)

(ii) Proton Exchange Membrane fuel cell

5- Solar cell

6- Electric cell

The effects of chemical cells on the environment are negative. As chemical cells are burned they pollute the air. And when they are thrown into dump areas then their toxic chemicals are absorbed by soil and damaging our natural eco system. These toxic chemicals damages to plant and animal life. These chemical cells also have a large impact on air acidification. The three worst chemical toxins found in chemical cells are lead,

cadmium, and mercury. And these have the worst effect on the environment.