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Electrolysis of tap water in chemical synthesis using pure and rectified D.C. allowing detection of A.C. components in a pulsating D.C. source

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Abstract
Distilled water is a weak electrolyte due to very low concentration of mobile ions. It is rather a dielectric due to its poor conductivity (since dielectrics are mainly insulators). However tap water contains dissolved impurities which conduct on application of electric field. This water is rarely soft as it contains $Ca^{2+,}$ Mg^{2+}, SO_4^{2-} etc. When tap water is electrolyzed (with or without addition of other electrolytes) numerous compounds may be obtained. Here the source of current (a battery or a transformer with a rectifier) is very important as it affects the products greatly. This paper has attempted to describe electrolysis of tap water in synthesizing compounds like CuOH (stable only for about 1-2 seconds), $Cu(OH)_2$, Cu_2O, $CuCO_3.Cu(OH)_2$, colloidal solution of graphite and that of copper. We used tap water, copper wire, NaCl, $Pb(CH_3COO)_2$ as the raw materials. As for the source of current we used a 9V battery and a step down transformer (12V/3A) depending on the products. The same solution (e.g. NaCl solution) when electrolyzed by two different currents, one pure D.C. and the other containing A.C. components gives totally different products. Thus A.C. components in a source of D.C. can be detected.

Keywords: water, electrolyte, colloidal solution, nascent oxygen

1. Introduction

Water is a universal solvent and a weak electrolyte in its pure state. Distilled water is electrolyzed with a few drops of dilute H_2SO_4 to give H_2 at cathode and O_2 at anode. The equations are:-

$2H^+ + 2e^- \rightarrow H_2\uparrow$ (At cathode)
$4OH^- - 4e^- \rightarrow 2H_2O + O_2\uparrow$ (At anode)

The SO_4^{2-} ions do not take part in the reaction. This reaction takes place when the electrodes used are inert (e.g. graphite). Tap water containing dissolved impurities can be electrolyzed to obtain various chemicals.

We electrolyzed tap water having various concentrations of electrolytes (both strong and weak) with reactive electrodes i.e. Cu. In each case H_2 and O_2 were not liberated. CuOH, $Cu(OH)_2$, e.t.c were formed in the cases. Cu_2O and colloidal solution of graphite and that of copper required use of a transformer and a rectifier. Here components of A.C. play a part. If this D.C. is tried to filter using a 25V 4700µF capacitor, the capacitor explodes due to excessive charge. As electrolysis draws a very large current (about 3A), filtration becomes difficult. Hence pure D.C. is never obtained. However it helps in synthesizing colloidal solution of graphite and copper and synthesis of Cu_2O. Since water has high resistance, electrolysis can also be done using 220V rectified D.C. But it leads to excessive production of heat and sparking. As water is an electrolyte, resistance decreases with temperature and even more heat is produced. The mixture spurts out violently and the reaction can not be controlled.

Apparatus and Chemicals:

1. Sodium Chloride (NaCl)
2. Lead Acetate trihydrate
3. Sodium hydroxide
4. Tap water
5. 1.5mm^2 copper wire (to be used as electrodes)
6. Graphite rod
7. Transformer 230/12V, 3A
8. 4700µF/25V, ELECTROLYTE caPAcitor.
9. 9V Battery.

Experimental

CuOH, $Cu(OH)_2$, $CuCO_3.Cu(OH)_2$, Cu_2O, colloidal graphite solution and colloidal Cu solution may be prepared. The first three require a 9V battery while the remaining require transformer (12V, 3A). They are explained in detail below:-

CuOH

A solution of brine (NaCl solution) is electrolyzed with Cu electrodes. The source of current is a 9V battery. The current drawn is about 1.5A-2A i.e. it is fairly large indicating the low resistivity of the solution. Whitish CuOH is formed at the anode and H2 is liberated at cathode. Thus the anode loses mass and bubbles are seen to form at the cathode. It is stable for only about 1-2seconds. After that it changes in to pale blue due to oxidation. The reaction is:-

$Cu – e^- \rightarrow Cu^+ + OH^-$ (from water) $\rightarrow$ CuOH (At anode)

Cu $(OH)_2$

The same solution of brine electrolyzed for a longer period (about 1 minute or so) gives Cu(OH)2. This is basically CuOH getting oxidized to Cu(OH)2 due to atmospheric O2.
$Cu – e^- \rightarrow Cu^+ + OH^-$ (from water) $\rightarrow$ CuOH (At anode)
CuOH + O_2 (From atmosphere) $\rightarrow$ $Cu(OH)_2$ (Pale blue insoluble mass)
At cathode H2 is liberated which is seen as bubbles. The equation is already given above in the introduction parts.

$CuCO_3$.Cu $(OH)_2$

Cu(OH)2 reacts with CO2 forming the said compound. The reaction mechanism may be explained as:-

$Cu(OH)_2 + CO_2$ (from air) $\rightarrow CuCO_3 + H_2O$

$Cu(OH)_2 + CuCO_3 \rightarrow Cu(OH)_2.CuCO_3$ (Bright green)

The above formation can be checked by adding NaOH to newly formed Cu(OH)2. This will absorb CO2 and hence prevent it from reacting with Cu(OH)2.

Cu_2O

This will require a step down transformer and a rectifier. 220V rectified D.C. may be used but the reaction becomes extremely vigorous and uncontrollable. Hence use of such high voltage should be avoided. Bubbles are formed at the cathode indicating the formation of H2. The Cu^+ ions formed at the anode react with nascent oxygen leading to the formation of brick red precipitate of cuprous oxide i.e. Cu_2O.

The Cu2O has an orange red appearance. If allowed to stand for some time, it changes to pale blue Cu(OH)2 and finally CuCO3.Cu(OH)2 are formed.

Colloidal solution of graphite

When brine solution is electrolyzed using graphite electrodes, NaOH is formed. Since the rectified D.C. has A.C. components, heat is produced. Cl2 is also produced at anode. The heat along with Cl2 is enough to dissolve graphite in to tiny particles black in color. The equations are:-

$2Cl^- - 2e^- \rightarrow Cl_2\uparrow$ + C (graphite) $\xrightarrow{Heat}$ C (Colloidal solution)

$2H^+ + 2e^- \rightarrow H_2\uparrow$ (At cathode)

As a result the carbon anode gradually corrodes and has to be replaced periodically.

NaOH solution on electrolysis with rectified D.C. and graphite electrodes also gives colloidal graphite solution. Here O2 is liberated at anode which plays the role of Cl2.

$2H^+ + 2e^- \rightarrow H_2\uparrow$ (At cathode)

$4OH^- - 4e^- \rightarrow 2H_2O + O_2\uparrow$ (At anode)

** The above products are also formed if the current source is a battery. But as it does not contain A.C. components, no heat is produced and hence no colloidal solution is formed.

Colloidal solution of Cu

$Pb(CH_3COO)_2$ ionizes as $Pb(CH_3COO)_2 \rightarrow Pb^{2+}$ + $CH3COO^-$. But a bulk amount of it remains unionized since it is a weak electrolyte. When current is passed the reaction at anode is: Cu – 2e- $\rightarrow Cu^{2+}$. But this Cu^{2+} does not react with CH3COO- forming pale blue Cu(CH3COO)2. At cathode some Pb^{2+} is discharged as: $Pb^{2+} + 2e^- \rightarrow$ Pb. Cu^{2+} present in the solution again gains electron and thereby dissolves as a colloidal solution. Some CH3COOH is formed along with Pb(OH)2 due to hydrolysis of

$Pb(CH_3COO)_2.3H_2O$.

$Pb(CH_3COO)_2 + 2H_2O \rightarrow Pb(OH)_2 + 2CH_3COOH$ (Vinegar smell)

Results and discussions

The above experiments show how water which is a weak electrolyte can be used to synthesize various substances. The choice of the source of current plays an important role. The above reactions help in detecting whether a source of D.C. is pure or not. If it contains A.C. components electrolysis of brine solution with Cu electrodes gives Cu2O, while pure D.C. gives CuOH having stability of about 1-2 seconds. The table below shows the summary:-

Table 1

Solution	Electrode	Current source	Color	Product
NaCl	Cu	9V battery	White to pale blue, finally green	CuOH, $Cu(OH)_2$,$CuCO_3.Cu(OH)_2$ respectively
NaCl	Graphite	9V battery	Colorless	NaOH
NaCl	Graphite	Step down transformer	Black	Colloidal graphite solution and NaOH
NaOH	Graphite	Step down transformer	Black	Colloidal graphite solution
$Pb(CH_3COO)_2$	Cu	Step down transformer	Brown	Colloidal Cu solution

All these reactions can be carried out using tap water. Thus it can be shown that dissolved impurities have no effect on the products of electrolysis but the current source certainly has.

In case of battery the current drawn per 100 m.l NaCl solution is close to 2.6A (actual value 2.591A). Therefore the resistance of the solution comes to be 9/2.6 ohm = 3.461 =3.5 ohm.

In case of transformer, the current drawn increases the temperature of the solution slightly. Hence the resistance falls a bit. As a result current drawn is more in this case i.e. close to 4A.

Conclusion

Tap water and some common chemicals like NaCl can be used in the manufacture of chemicals and colloidal solutions. Here the dissolved impurities play no part. The voltage applied in each case must be 9-12V for best performance. If cells are connected in series to give higher potential, the current drops due to increase of internal resistance. The formation of bubbles of H_2 at the cathode can be accelerated by placing the cathode between the poles of a horse shoe magnet. But the discussion of this phenomenon is beyond the scope of this paper. Pure A.C. may be used to produce CuO (black) using a solution of an oxidizing agent like KNO_3 and Cu electrode. But it takes a very long time (about 4 hours or more). This is due to the combined effect of A.C. and the heat produced. Therefore we can see how the products of electrolysis help in detecting whether a D.C. source is pure or not.

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