13. Membrane electrolyzer

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To investigate how a difference of PH-value depends on the pore size of the membrane we have made experiment. It consists in following.

We took a test tube with electrolyte. Electrolyte is sodium sulfate. We placed two inert electrodes (lead and stainless steel) in test tube. There is membrane between them, which has cylinder shape. Membrane is stick by dichloethane glue to acrylic plastic. Both of them are inert.

The current flows to system throw rectifier. During given period of time we measure PH-value in anodic and cathodic parts of system. PH-value we measure by litmus paper. We have some membranes with different pore size. Then we take PH-value and compare them. You can see the graphs on which there is dependence PH-value on the time of electrolyze by given diameter of membrane’s pore.
Graphs

1membrane

2membrane

3membrane

4membrane

5membrane

PH

T(min)
Now let us consider what we have during electrolyses and why we have difference of PH-value in anode cathode.

\[
\text{Na}_2\text{SO}_4 + 4\text{H}_2\text{O} \rightarrow 2\text{H}_2 \uparrow + \text{O}_2 \uparrow + 2\text{NaOH} + \text{H}_2\text{SO}_4
\]

\[
\text{NaOH} \rightarrow \text{Na}^+ + \text{OH}^-
\]

\[
\text{H}_2\text{SO}_4 \rightarrow 2\text{H}^+ + \text{SO}_4^{2-}
\]

So we get liberation of oxygen and hydrogen. We can observe this phenomenon visually.

\[
\begin{array}{c|c}
\text{Na}^+ & \text{OH}^- \\
\hline
\text{Na}^+ & \text{OH}^- \\
\hline
2\text{H}^+ & \text{SO}_4^{2-} \\
\hline
2\text{H}^+ & \text{SO}_4^{2-}
\end{array}
\]

Also we have ions of sodium, hydrogen and ions OH\(^-\) and H\(^+\) pass throw membrane to anode and cathode and ions of Na\(^+\) and SO\(_4^{2-}\) transfer the charge. So the difference of PH-value is made by OH\(^-\) and H\(^+\) ions.

To calculate pore size we have made the second experiment. It consists in following.

We have bottle at one side of which membrane stick. In the bottle we have the same level of electrolyte. And we calculated the hydrostatic pressure and velocity of electrolyte’s leak. Then by this quantities we can calculated the coefficient of leak K.

\[
K = \frac{v^2 \eta}{\rho S_1 \tau}
\]

\[
v = \sqrt{\frac{2gh}{1 - \frac{s_1}{s_2}}}
\]

\[
\begin{align*}
\eta & \quad - \text{viscosity of water} \\
\rho & \quad - \text{density of water} \\
\text{g} & \quad - \text{acceleration of gravity} \\
S_1 & \quad - \text{area of membrane} \\
S_2 & \quad - \text{area of bottle} \\
h & \quad - \text{height of water} \\
\tau & \quad - \text{time} \\
K & \quad - \text{coefficient of leak}
\end{align*}
\]
The following expression is for the pore diameter calculation.

\[ D = 0,003 \beta \sqrt{k/g} \]

\( \beta \) – coefficient of twisting, \( g \) – bulk porosity, \( k \) – coefficient of leak

It is very difficult to calculate coefficient of pore twisting, but we know that it varies from 1 to 2. So to reduce the error, we took the coefficient of twisting equal to 1.5. \( \beta \in (1;2) \)

We can calculate bulk porosity by formula

\[ g = 1 - \frac{d_{ap}}{d_t} \]

\( d_{ap} \) - apparent specific gravity

\( d_t \) - true specific gravity

\[ d_t = \frac{p_d}{p_d - p_w} \]

\( V \) - volume of membrane

\[ d_{ap} = \frac{mg}{Vg\rho} \]

\( P_d \) - mass of membrane in dry state

\( P_w \) - mass of membrane in wet state

All membranes were scaled at the exact electric weight. By this way we can calculate diameters of pore.

You can see diameters of pore by given membranes.

\begin{align*}
D_1 &= 167 \cdot 10^{-6} \ (m) \\
D_2 &= 152 \cdot 10^{-6} \ (m) \\
D_3 &= 115 \cdot 10^{-6} \ (m) \\
D_4 &= 81 \cdot 10^{-6} \ (m) \\
D_5 &= 328 \cdot 10^{-6} \ (m)
\end{align*}

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References

Stender V.V. Electrochemical systems in the synthesis of chemical products.
Phyoshin M.A., Smirnova M.G. Applied Electrochemistry
Reference Book on Elementary Chemistry.