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Published in:
Proceedings

Publication date:
2011

Document Version
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA):
Conductivity of Aqueous K$_2$CO$_3$ up to 200 °C

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Electrolysis cells can be used for producing hydrogen and carbon monoxide (syngas) by electrolysis of water and carbon dioxide. Using suitable catalysts syngas can be reacted to form hydrocarbons i.e. synthetic fuels. Today’s electrolysis cells based on oxide ion conductors (SOECs) cannot directly produce hydrocarbons due to the high operating temperature, 750-1000 °C, where the hydrocarbons are not stable [1]. A reduction in temperature to below 300 °C may make it possible to reduce water and carbon dioxide at the same time and form hydrocarbons directly in the cell. However, such a reduction in temperature will require new electrolyte and electrode materials. Furthermore, good electrocatalysts are needed in order to promote the desired reactions.

The electrolyte is a key part of an electrolysis cell, and it is essential to know its properties in order to design a cell properly. Some of the important properties are the ionic conductivity, the thermal expansion and the materials stability at elevated temperatures and in this case also elevated pressures. Aqueous electrolytes are known for their high conductivity at lower temperatures, but are more difficult to handle than solid electrolytes and water management is a big issue. However, pressurized and immobilized aqueous electrolytes, such as K$_2$CO$_3$ (aq), can be used above 100 °C and may be easier to handle.

The conductivity of pure K$_2$CO$_3$ (aq) and immobilized K$_2$CO$_3$ (aq) has been determined from 25 °C up to ~200 °C at 30 bar. Special corrosion resistant sample holders have been designed for measurements on both liquid and immobilized liquid. Initial measurements were performed using the van der Pauw method [2] and electrochemical impedance spectroscopy (EIS). A porous solid disc with a porosity of ~30 vol% was used for the van der Pauw method. This may be due to precipitation of KHCO$_3$. Over the whole temperature range the conductivity was found to be lower in CO$_2$ than in N$_2$. In both gases the conductivity was found to be stable at the maximum temperature. In N$_2$ the temperature was kept constant at 156 °C for 3 hours and in CO$_2$ the temperature was kept constant at 209 °C for 11 hours and the conductivity was 0.0340±0.001 S/cm. In CO$_2$ the conductivity was found to be lower for the symmetrical cell than for the 10 wt% K$_2$CO$_3$ (aq) disc used for the van der Pauw method. This may be explained by the difference in porosity of the solid discs. A drop in conductivity was observed when the gas was changed from N$_2$ to CO$_2$ at room temperature. This may be due to precipitation of KHCO$_3$. Over the whole temperature range the conductivity was found to be lower in CO$_2$ than in N$_2$. In both gases the conductivity was found to be stable at the maximum temperature. In N$_2$ the temperature was kept constant at 156 °C for 3 hours and the conductivity was 0.0507±0.0002 S/cm. In CO$_2$ the temperature was kept constant at 209 °C for 11 hours and the conductivity was 0.0340±0.001 S/cm.

The as-measured conductivity was found to be lower for the symmetrical cell than for the 10 wt% K$_2$CO$_3$ (aq) disc used for the van der Pauw method. This may be explained by the difference in porosity of the solid discs. A drop in conductivity was observed when the gas was changed from N$_2$ to CO$_2$ at room temperature. This may be due to precipitation of KHCO$_3$. Over the whole temperature range the conductivity was found to be lower in CO$_2$ than in N$_2$. In both gases the conductivity was found to be stable at the maximum temperature. In N$_2$ the temperature was kept constant at 156 °C for 3 hours and the conductivity was 0.0507±0.0002 S/cm. In CO$_2$ the temperature was kept constant at 209 °C for 11 hours and the conductivity was 0.0340±0.001 S/cm.

Acknowledgement
This work was financially supported by the Catalysis for Sustainable Energy (CASE) initiative funded by the Danish Ministry of Science, Technology and Innovation, and The European Graduate School (EGS) on Sustainable Energy Technology – THE MOLECULAR APPROACH.

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