ENGINEERING CHEMISTRY

Department of Science and Humanities

ENGINEERING CHEMISTRY

Module 5- Energy storage devices – Fuel cells

Class content:

- ***$CH_3OH – O_2$ polymer electrolyte membrane fuel cell***
  - ***Principle***
  - ***Construction and working***
  - ***Advantages***
  - ***Disadvantages***

ENGINEERING CHEMISTRY

Module 5- Energy Storage devices- Fuel cells

Direct CH_3OH-O_2 Polymer electrolyte membrane fuel cells

- Known as **proton exchange membrane fuel cells**
- **Polymer membrane** or proton exchange membrane is used as electrolyte
- **Ease of transport and storage** of methanol, an energy-dense yet reasonably stable liquid at all environmental conditions
- **Low temperature fuel cell** (60- 90 °C)
- Low weight and volume
- **High energy density**
- **Noble metal catalyst** usually Pt
- **CO, if present poisons the catalyst** , so pure fuel and oxidant should be used

ENGINEERING CHEMISTRY

Module 5- Energy Storage devices- Fuel cells

Construction:

- **Anode:** Porous carbon electrode containing platinum
- **Cathode :** Porous carbon electrode containing platinum
- **Fuel:** Solution of CH_3OH
- **Oxidant:** Oxygen gas
- **Electrolyte:** proton conducting polymer membrane
    - Membrane should be an electronic insulator but an excellent conductor of H^+ ions

ENGINEERING CHEMISTRY

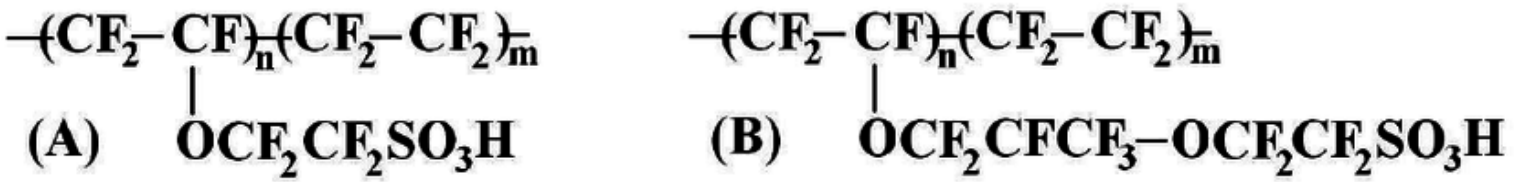
Module 5- Energy Storage devices- Fuel cells

Electrolyte :

• Fluorocarbon backbone (-CF_2-CF_2-) similar to Teflon to which **sulphonic acid groups(-SO_3H)** are attached

•The **protons on sulphonic acid group** are free to migrate through the hydrated membrane

e.g., **Nafion** – most popular because of high proton conductivity, good mechanical strength, good chemical stability



(A) Aquivion **(B) Nafion**

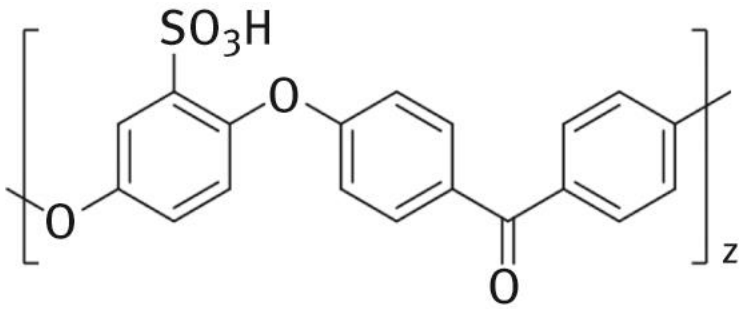
Source:https://www.researchgate.net/figure/Chemical-structures-of-A-AquivionR-or-Hyflon-and-B-NafionR_fig1_234842575

ENGINEERING CHEMISTRY

Module 5- Energy Storage devices- Fuel cells

- For DMFC Nafion not suitable as it has **high permeability for CH_3OH**, hence methanol crossover happens
- **Methanol crossover** – CH_3OH diffuses through the membrane to cathode without undergoing oxidation at anode resulting in low performance
- New membranes are being used - **Poly electrolyte membranes**

  e.g., **SPEEK** - sulphonated poly(ether ether ketone)

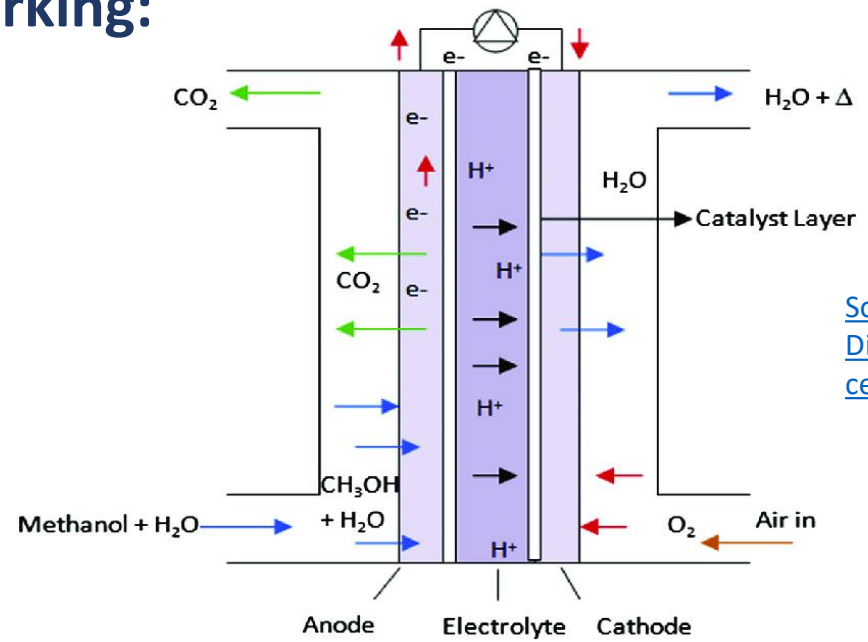


Source:https://www.degruyter.com/view/journals/psr/2/8/article-20170018.xml?language=en

ENGINEERING CHEMISTRY

Module 5- Energy Storage devices- Fuel cells

Working:



Source:https://www.researchgate.net/figure/9-Diagrammatic-representation-of-direct-methanol-fuel-cell_fig5_330049875

At Anode : $CH_3OH + H_2O \longrightarrow 6H^+ + 6e^- + CO_2$

At Cathode : $3/2O_2 + 6H^+ + 6e^- \longrightarrow 3H_2O$

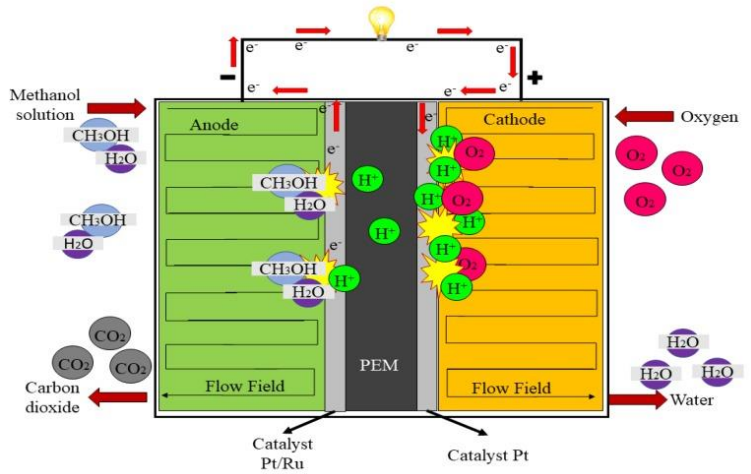
Emf = 1.21 V

Over all reaction : $CH_3OH + 3/2O_2 \longrightarrow 2H_2O + CO_2$

ENGINEERING CHEMISTRY

Module 5- Energy Storage devices- Fuel cells

- A **aqueous solution of methanol** is fed at the anode
- Common operating temperatures are in the range **60- 90 °C**
- Oxidation of methanol on a catalyst layer takes place to form carbon dioxide , protons and electrons
- **Protons (H^+) are transported** across the proton exchange membrane – to the cathode where they react with **oxygen** to produce water
- Water is consumed at the anode and produced at the cathode
- Electrons are forced to travel through an external circuit from anode to cathode, providing power to connected devices



Source:https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7142913/#:~:text=The%20core%20preparation%20for%20electrolyte,anode%20to%20the%20cathode%20side.

ENGINEERING CHEMISTRY

Module 5- Energy Storage devices- Fuel cells

- **Water management** is very important for Proton exchange membrane fuel cells
- **Temperature** has to be maintained constant (60-90^{o}C)
- Polymer membrane **must remain hydrated** to maintain H^+ conductivity
- Water produced from the reaction must be removed from the cathode

  - **High temperatures**
    - may dehydrate the polymer so H^+ conductivity cannot take place
    - the polymer may degrade and crack resulting in short circuit

  - **Low temperatures**
    - will result in flooding of the cell thereby reducing efficiency of the cell
    - a higher catalyst loading will be required

ENGINEERING CHEMISTRY

Module 5- Energy Storage devices- Fuel cells

Advantages:

- High energy density - due to the low weight of the polymer
- Long life - Low temperature operation allows them to start quickly and results in less wear on system components, resulting in better durability
- No free corrosive liquid in the cell

Disadvantages:

- Noble metal catalysts have to be used (Pt) and electrolyte is expensive so cell cost is high
- CO , if present, poisons the Pt catalyst , hence pure reactants should be used
- Management of carbon dioxide created at the anode and water management pose problems

PES UNIVERSITY

CELEBRATING 50 YEARS

THANK YOU

Department of Science and Humanities