Frequently asked questions Fuel Cell Technology
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Module 3: Irreversible losses in fuel cell

Module 3: Frequently asked questions:

Question no. 1. What are the different transport processes that occur in the fuel cell simultaneously?

Question no. 2. Why voltage drops down when charge transport in the fuel cell?

Question no. 3. Compare and discuss about the basic laws of transport processes related to fuel cell.?

Question no. 4. List some of the important reasons for the use of porous ectrodes in fuel cell.?

Question no. 5. Define the mobility of an ion.?

Question no. 6. What is the meaning of migration?

Question no. 7. The mole fractions of hydrogen and water vapor in a humidified hydrogen gas are 0.7 and 0.3, respectively. The pressure and temperature of humidified hydrogen can be taken as 1 atm and 80 ^oC Determine the following, if the velocities of hydrogen and water vapor are 3 m/s and 2 m/s, in the same direction:

(i) molar and mass average velocities

(ii) molar and mass diffusion velocities for hydrogen and water vapor.

(iii) total molar and mass fluxes for hydrogen and water vapor.

(iv) Diffusional molar and mass flux for both hydrogen and water vapor.

Question no. 8. Hydrogen gas fully saturated with water vapor at 1 atm and 80 ^oC flows over an anode electrode, parallel to the anode surface, at a velocity of 1 m/s. If the anode is rectangular and the length along the flow direction is 10 cm, determine the following;

(i) the limiting current density profile corresponding to the rate of convective mass transfer,

(ii) the hydrogen concentration variation at the electrode surface and its average value, if the current density drawn from the electrode if 0.5 A/cm^2.

Question no. 9. Define Nernst-Einstein relation.

Question no. 10. Define transference number of an ionic species.

Question no. 11. Define resistance, specific resistance, conductivity conductance, and specific conductivity.

Question no. 12. Write the Nernst-Planck equation and details the different terms.

Solution3

Solution 7:

Given,

Mass fraction of hydrogen, $\mathbf{x_{H_2} = 0.7}$

Mass fraction of water, $\mathbf{x_{H_2O} = 0.3}$

T = 80^{o}C, P=1 atm

$$\mathbf{v_{H_2} = \frac{3m}{s};\ v_{H_2}O = 2m/s}$$

(i) The molar average velocity can be calculated,

$$v^* = (x_{H_2} * v_{H_2}) + (x_{H_2}O * v_{H_2}O) = (0.7*3) + (0.3*2)$$
$$= 2.1+0.6 = 2.7 \text{ m/s}$$

In order to determine mass-average velocity, mass fractions of H_2 and H_2O need to be determined.

Since, the H_2-H_2O vapor mixture's molecular weight will be required, so first we will find out the molecular weight of the mixture (w_{mix}).

$$\mathbf{w_{mix} = \left(x_{H_2} * w_{H_2}\right) + \left(x_{H_2O} * w_{H_2O}\right)}$$

Where and are the molecular weights (2 kg/kmol and 18 kg/kmol) of H_2 and H_2O, respectively.

$$\mathbf{w_{mix} = (0.7 * 2) + (0.3 * 18)}$$

$$\mathbf{= 1.4 + 5.4 = 6.8 \text{ kg / kmol}}$$

Therefore, the mass fraction will be,

$$y_{H_2} = x_{H_2}\left(\frac{w_{H_2}}{w_{mix}}\right) = 0.7\left(\frac{2}{6.8}\right) = 0.206$$

$$y_{H_2O} = x_{H_2O}\left(\frac{w_{H_2O}}{w_{mix}}\right) = 0.3\left(\frac{18}{6.8}\right) = 0.794$$

Thus, the mass average velocity becomes,

$$\boldsymbol{v = y_{H_2} * v_{H_2} + y_{H_2O} * y_{H_2O}}$$

= 0.206 * 3 + 0.794 * 2 = 2.206 m/s

Diffusion velocity of hydrogen relative to the mass averaged mean motion of the mixture is,

$$\boldsymbol{V_{H_2} = v_{H_2} - v = 3 - 2.206 = 0.794\ m/s}$$

Diffusion velocity of hydrogen relative to the molar averaged mean motion of the mixture is,

$$V_{H_2}^{*} = \boldsymbol{v_{H_2} - v^{*} = 3 - 2.7 = 0.3\ m/s}$$

Diffusion velocity of water relative to the mass averaged mean motion of the mixture is,

$$\boldsymbol{V_{H_{2O}} = v_{H_2O} - v = 2 - 2.206 = -0.206\ m/s}$$

Diffusion velocity of water relative to the molar averaged mean motion of the mixture is,

$$\boldsymbol{V_{H_{2O}}^{*} = v_{H_2O} - v^{*} = 2 - 2.7 = -0.7\ m/s}$$

(iii)

The total density for the mass in the mixture may be formed out from the equation of state by assuming that the mixture follows the ideal gas behavior,

$$\mathbf{P} = \frac{\boldsymbol{P\ w_{mix}}}{\boldsymbol{RT}} = \frac{\mathbf{101.325*10^3*6.8}}{\mathbf{8314*(80+273)}} = \mathbf{0.235\ kg}\ /\boldsymbol{m^3}$$

Thus, the partial density of H_2 and H_2O is,

$$\rho_{H_2} = y_{H_2}\,\rho = 0.206 * 0.235 = 0.0484 \text{ kg}/m^3$$

$$\rho_{H_2O} = y_{H_2O}\,\rho = 0.794 * 0.235 = 0.1866 \text{ kg}/m^3$$

We can also find the corresponding total molar concentration for the mixture,

$$C = \frac{\rho}{w_{mix}} = \frac{0.235 \text{ kg/m}^3}{6.8 \text{ kg/kmol}} = 0.035 \text{ kmol/m}^3 = 0.35 \text{ kmol/m}^3$$

Then the molar concentration of H_2 and H_2O is,

$$C_{H_2} = x_{H_2} C = 0.7 * 35 = 24.5 \text{ mol/m}^3$$

$$C_{H_2O} = x_{H_2O}\ C = 0.3 * 35 = 10.5 \text{ mol/m}^3$$

Thus,

The total mass flux of H_2 = $\rho_{H_2}\ v_{H_2}$ = 0.0484 * 3 = 0.1452 $\text{kg/m}^3\text{s}$

The total molar flux of H_2 = $C_{H_2} v_{H_2} = 24.5 * 3 = 73.5\ mol/\text{m}^2\text{s}$

Similarly,

The total mass flux of H_2O = $\rho_{H_{2O}}\ v_{H_{2O}}$ = 0.1866 * 2 = 0.3732 $\text{kg/m}^2\text{s}$

The total molar flux of H_2O = $C_{H_{2O}}\ v_{H_{2O}}$ = 10.5 * 2 = 21 $mol/\text{m}^2\text{s}$

(iv)

The diffusional mass flux of H_2, $\rho_{H_2}\ v_{H_2}$ = 0.0484 * 0.794 = 0.0384 $\text{kg/m}^3\text{s}$

The diffusional molar flux of H_2 $C_{H_2} V^*_{H_2} = 24.5 * 3 = 73.5\ mol/\text{m}^2\text{s}$

The diffusional mass flux o fH_2O, $\rho_{H_{2O}} v_{H_{2O}}$= 0.1866 *(-0.0206)= - 0.38 $\text{kg/m}^2\text{s}$

The diffusional molar flux of H_2O, $C_{H_{2O}}\ V^*_{H_2O}$ = 10.5 * (- 0.7) = -7.35 mol/m^2