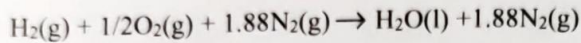


EEN-E1030, Thermodynamics in energy technology
Exam, December 4, 2023

You can answer the questions either in English or Finnish

PROBLEM 1

A fuel cell is an electrochemical system where chemical energy is converted to electrical work and heat through chemical reactions (see Fig. 1). The overall reaction for the fuel cell in Fig. 1 may be written as follows:



A) How much heat is generated in the fuel cell, if the cell produces 34 kW of electrical work and the molar flow rate of H_2 is 0.25 mol/s. Enthalpy of formation for liquid water is -285.8 kJ/mol , and specific heat capacity of liquid water is $75.4 \text{ Jmol}^{-1}\text{K}^{-1}$. You find other necessary values in Figure 1.

B) What is the efficiency of the fuel cell per LHV?

C) What is the entropy of formation for $\text{H}_2(\text{g})$ at 77°C at the standard state?

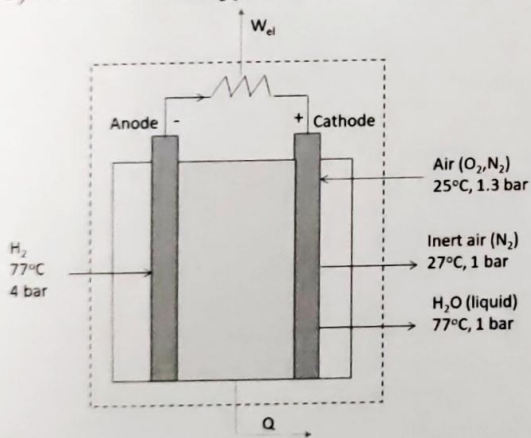


Figure 1. Fuel cell

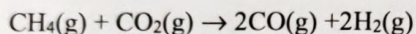
PROBLEM 2

Temperature of the outdoor air is 15°C, relative humidity 72% and total pressure 100 kPa. Air is first heated to 85°C in a heat exchanger. After the heating, water is sprayed into the air to decrease the air temperature to 45°C. The mass flow rate of air through the heat exchanger is 0.12 kg_{da}/s, and the temperature of the spraying water is 8°C. Calculate:

- A) How much heat (kW) is needed to heat the air in the heat exchanger?
- B) What is the dew point temperature of the air after the heating?
- C) How much water must be sprayed into the air after heating to cool it down to 45°C?

PROBLEM 3

CH₄ and CO₂ convert to CO and H₂ according to the following reaction:



- A) What is the equilibrium constant of the reaction when it occurs at 1000K and 5bar?
- B) Mole inputs of CH₄ and CO₂ into the reactor are 2.4 mol and 2.4 mol, respectively. The composition of the reaction mixture at equilibrium (1000K and 5bar) is calculated by minimizing the Gibbs energy of the system. At equilibrium, mole amounts of CH₄ and CO₂ are 1.092 mol and 1.092 mol, respectively. What is the equilibrium constant on the basis of this information?

PROBLEM 4

Research scientist Laukkanen has got two tanks of salt lake water, tanks A and B. One of the tanks contains water from Lake Alberta (salt content 136 g/l_{H2O}) and the other one from salt lake Salton Sea (salt content 46 g/l_{H2O}). Unfortunately, no one has written on the tanks from which salt lake the water has been taken. To find this out, research scientist Laukkanen freezes a water sample from tank A and measures its freezing point. The measured freezing point of the sample is -3.05°C. From which lake is the water in tank A most probably? You can assume that water sample behaves like an ideal solution.