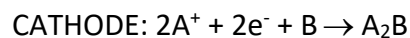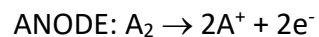**Fuel Cell Science and Technology**
Final Exam
Jun 14 2021 18:00~20:00

1. [30 pts] Explain following terms in fuel cells.

a) Arrhenius plot in fuel cells

b) Hydrophobic treatment in MEA

c) Electro-osmatic drag

d) Platinum loading of anode and cathode in PEMFC

e) Ni-YSZ cermet

f) Heterogeneous process in fuel cell catalyst

g) Concentration cell

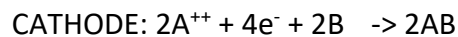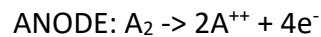h) Effective diffusivity

i) Anode supported SOFC

j) Tafel fitting

2. [20 pts] Consider the following reactions.

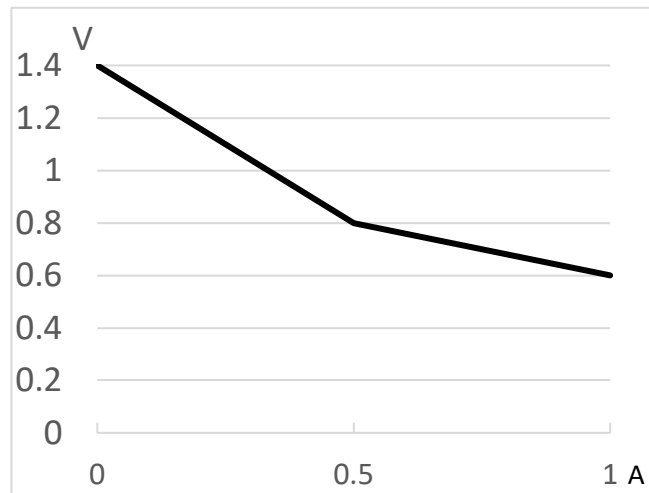$$A_2 + B \rightarrow A_2B \qquad - (1)$$
$$A_2 + 2B \rightarrow 2AB \qquad - (2)$$
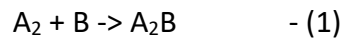
It is known that reaction (1) releases more Gibb's free energy. For these reactions, following fuel cell reactions are possible.

$$\text{ANODE: } A_2 \rightarrow 2A^+ + 2e^-$$
$$\text{CATHODE: } 2A^+ + 2e^- + B \rightarrow A_2B$$

or,

$$\text{ANODE: } A_2 \rightarrow 2A^{++} + 4e^-$$
$$\text{CATHODE: } 2A^{++} + 4e^- + 2B \rightarrow 2AB$$

Now, we made a fuel cell with a special electrolyte that can conduct both A^+ and A^{++}. The following IV curve was obtained from the reaction of A_2 and B.

The fuel cell operates under very high stoichiometry number of A_2 and B – in other words, the concentration overvoltage is negligible. Also, the fuel cell reactions involve negligible activation overvoltages. Answer the following questions.

a) Estimate the Gibb's free energy of the reaction (1) and (2)

b) Estimate the ohmic resistance of the electrolyte for A^+ and A^{++} respectively.

3. [15 pts] The following EIS obtained from a well humidified PEMFC at OCV under constant temperature, say 343 K. Hydrogen and air with 100% relative humidity were used as reactants under ambient pressure in stoichiometric ratios of 1.5 and 2.0, respectively.

a

b
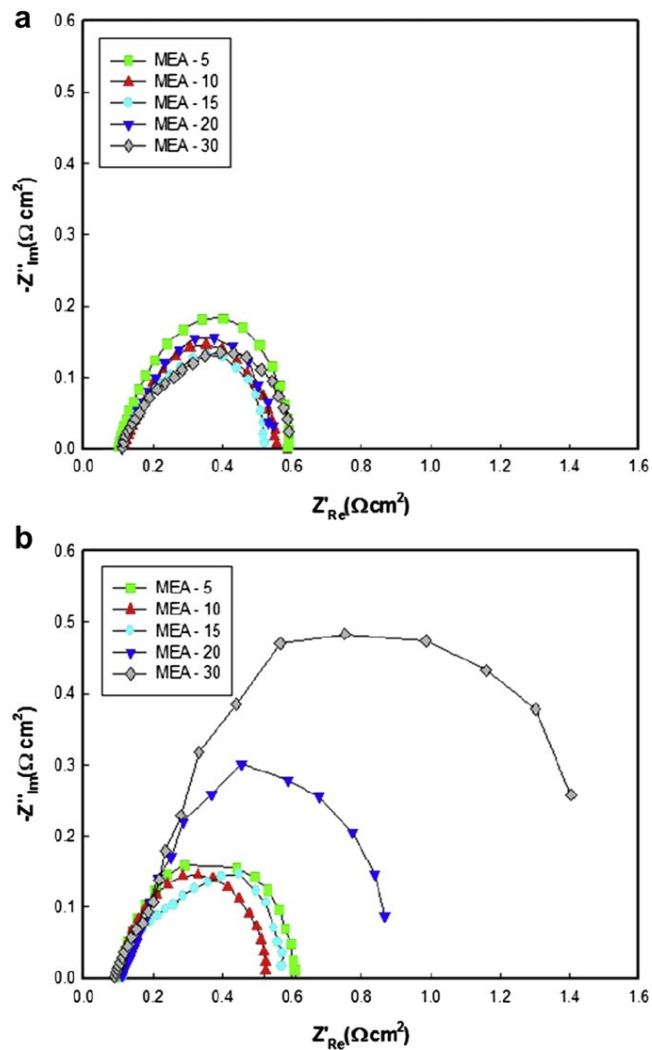
Everything else being equal, the Nafion loading at the catalyst layer of both anode and cathode were change from low (5 wt% of catalyst) to high (30 wt% of catalyst) value. a) and b) were measured at low current density, say 0.2Acm-2, and high current density, say 0.8A cm-2, respectively. Please answer the following questions

a) What is the optimum Nafion loading values for this fuel cell at low current density and high current density respectively?

b) Please explain why optimum loading value is different for low current density and high current density.

c) Please explain the impedance behavior of high Nafion loading at high current density. Why do you observe such behavior?

5. [15 pts] The following figure shows the change of gas mole fractions at the anode along the channel direction in an SOFC. The SOFC uses methane fuel directly through internal stream reforming – methane reacting with water vapor turns in to hydrogen directly at the anode. Identify five gas streams in the figure and label them with proper explanation for each stream.
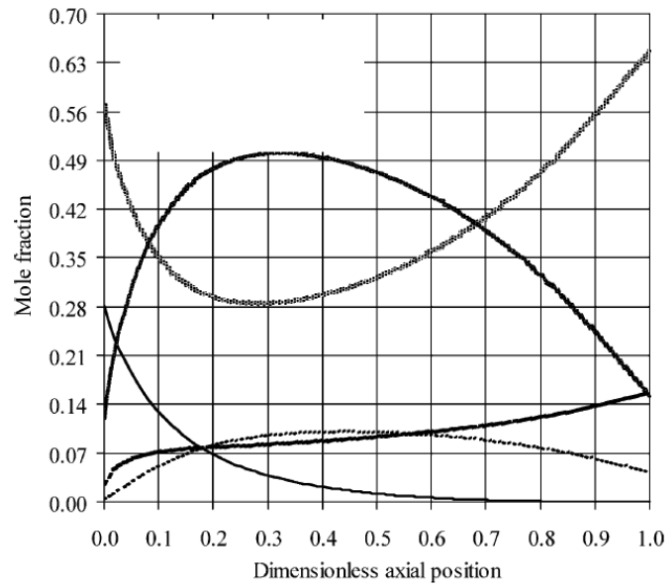
7. [15 pts] We operated an "electrolyte-supported" SOFC to obtain following IV curves with hydrogen-ozone and hydrogen-oxygen respectively (Conveniently, you can ignore all internal losses except Ohmic loss for electrolyte-supported cell). The cell was provided with constant hydrogen flux equivalent to 10 A and constant oxygen (or ozone) flux equivalent to 4 A. Assume all gases as ideal gases. Assume STP conditions.
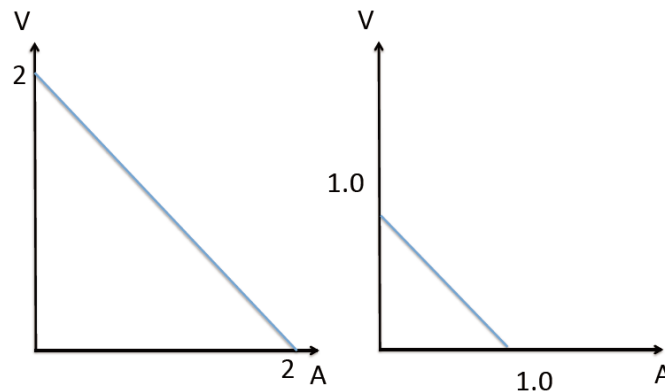
IV curve for ozone operation   IV curve for oxygen operation

a) Roughly sketch an IV curve when the mixture of 25 vol % ozone and 75 vol % "helium" is supplied. Assume all other conditions are unchanged. Explain your answer briefly. (Remember total flux of gas is unchanged.)

b) Roughly sketch an IV curve when the mixture of 10 vol % ozone and 90 vol % oxygen is supplied. Assume all other conditions are unchanged. Explain your answer briefly. (Remember total flux of gas is unchanged.)

c) Roughly sketch an IV curve when the mixture of 50 vol% ozone and 50 vol% oxygen is supplied. Assume all other conditions are unchanged. Explain your answer briefly.