Birla Institute of Technology & Science, Pilani – K. K. Birla Goa Campus

Second Semester, 2022–23

CHEM F327 Comprehensive Examination (Closed Book) Total Marks: 70

Electrochemistry: Fundamentals and Applications Date: 10/05/2023

180 min

Part A (40 Marks, 120 min)

Q1. (a) Explain the relationship between standard potential and formal potential of a redox couple? **[3]**

(b) Write the Levich equation of hydrodynamic voltammetry and explain all the terms. **[3]**

(c) Explain the difference between the behavior of cyclic voltammograms of reversible and quasireversible processes on increasing the scan rates (with required diagrams). **[4]**

(d) Explain in detail the technique isoelectric focusing. **[5]**

(e) Explain the difference between the techniques hydrodynamic voltammetry and cyclic voltammetry. **[5]**

Q2. Identify *True/False* in the following statements. **[6]**

(i) Electrochemical capacitors work in GHz frequency range. (True/False)

(ii) In battery electrode fabrication, PVDF is used to improve the electronic conductivity. (True/False)

(iii) Low Tafel slope indicates high electroactivity (True/False)

(iv) Specific capacitance of carbon electrodes can be improved if one modifies the carbon electrode with redox molecules. (True/False)

(v) The electrochemical process can be made kinetically-controlled process rather than diffusion-controlled by recording voltammograms at very low scan rates. (True/False)

(vi) During the discharging of the battery, chemical energy is converted into electrical energy. (True/False)

Q3. Write the electrochemical reaction involving oxygen reduction reaction (ORR) to water? Write the number of electrons transferred during this electrochemical reaction? **[3]**

Q4. A fuel M of molar mass 200 g/mol is used as anodic fuel in PEM fuel cells whose theoretical cell voltage (E^o) is found to be 2.0 V. The energy density (in kWh/kg) of fuel X is

(Note: Number of electrons involved during fuel oxidation are 8; 1 F = 96500 C/mol) **[3]**

Q5. Calculate the electrochemically active surface area (ECSA) in cm^2/mg of PtNi catalyst that yield a charge of 0.05 C during hydrogen desorption in 0.5 M H_2SO_4. Given the loading of the catalyst is 0.01 g. **[3]**

Q6. Answer the following. **[5]**

(i) Arrange the following in decreasing order of energy density (Wh/kg)

Ni-Cd batteries, Lead-Acid batteries, Li-ion batteries

(ii) Arrange the following in the decreasing order of power density (W/kg)

Batteries, Fuel cells, Supercapacitors

(iii) Write the expressions for the energy stored in a capacitor.

(iv) What is the condition of good approximation in voltammetry that eliminates mass-transfer effects from the given options.

(a) $i < 10\%$ of i_L (b) $i > 10\%$ of i_L (c) $i = i_L$ (d) $i = i_L/2$

(Here i_L represent limiting current)

(v) In fuel cell polarization measurements, which of the following polarization losses are more significant at high current densities?

(a) Ionic polarization loss (b) Concentration polarization loss

(c) Activation polarization loss (d) All the above

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Part B (30 Marks, 60 min)

Q1. Determine the theoretical specific capacity (in Ah/g) of TiO_2 and $LiFePO_4$ using the following reactions.
(i) $MO_2 + 0.5\ Li^+ + 0.5\ e^- \rightarrow Li_{0.5}MO_2$
(ii) $LiMO_4 \rightarrow Li_{0.5}MO_4 + + 0.5\ Li^+ + 0.5\ e^-$
Given molecular weight of MO_2 is 100 g/mol and $LiMO_4$ is 175 g/mol. **[3+3=6]**

Q2. Write at least two ways of improving maximum energy stored in capacitors? Use suitable graphs/examples to explain your answer. **[6]**

Q3. Answer the following. **[3+3=6]**
(i) Write the conditions in which you expect *good* tafel relationships?
(ii) Write the condition and expression that relates charge-transfer resistance and exchange current density?

Q4. Explain memory effect in batteries? **[6]**

Q5. Why electrochemical capacitors are termed as supercapacitors. What are ultracapacitors? Explain your answer with suitable graphs. **[6]**

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