Ref. No.: Ex/FET/OE/CHE/T/201/2023

B.E. MECHANICAL ENGINEERING FOURTH YEAR SECOND SEMESTER EXAM 2023

COLLOID AND SURFACE ENGINEERING

Time : 3 hours **Full Marks : 50**

Part -I

Use Separate Answer scripts for each Part

Answer Any Two Questions

Clearly mention all the assumptions
Assume any missing data and mention it clearly

1. a) Write short notes (any three) **[5x3=15]**

a) photo lithography
b) Microcontact printing
c) electron beam lithography
d) Scanning probe induced oxidation

b) Explain in detail one gas-phase and one liquid-phase bottom-up process for 0-D nanomaterials fabrication. **[5x2=10]**

2. a) Derive Poisson-Boltzman Equation. What is Debye-Huckle approximation. **[8+7]**

b) A coating consists of consisting of 55 vol% TiO_2 (spherical, surface-treated pigment particles), 32 vol% emulsion, and 13 vol% water (containing some dissolved compounds). The oil content of the emulsion is 50 vol.%. The oil droplet and TiO_2 particle diameters are 1.2 and 0.3 μm, respectively. The temperature is 25°C and the viscosity of the medium (thickened aqueous phase) is 1 kg m^{-1} s^{-1}. The Hamaker constants of the oil and of TiO_2 in vacuum are 5×10^{-20} and 15×10^{-20} J, respectively. The Hamaker constant of the aqueous medium in vacuum is 3.75×10^{-20} J. The medium concentration of salt, NH_4OH (applied to control pH to basic conditions), in the coating formulation is 10^{-5} M. The relative permittivity of the medium is 80. The medium is water with a salt, NH_4OH (1 : 1 salt) at 10^{-5} M and κ^{-1} is calculated using the formula $\kappa^{-1}=0.304/\sqrt{C}$.

i) Calculate the attractive Van der Waals interaction energy between two oil droplets, between two TiO_2 particles, and between an oil droplet and a TiO_2 particle in the coating when the distance between the colloids (in all cases) is 15 nm. Comment on the result.

[Turn over

ii) It has been decided to stabilize both pigments and oil droplets electrostatically. The surface potential for both colloids is –50 mV. Calculate the electrostatic and composite (overall) interaction energies between an oil droplet and a TiO_2 particle in the coating when the distance between them is 10 nm. Based on these calculations, what can you conclude more generally about the interaction of oil droplets and TiO_2 particles in the coating? **[10]**

3. a) Derive an expression of heat of immersion relating surface tension. **[7]**
b) What is deryaguin's approximation. How salt concentration affect interaction energies? **[10+3]**

c) The following data are available from a measurement of the zeta potential in an aqueous suspension of kaolin
particles at 25°C:
- diameter of the spherical particles: 0.75 micrometre (μm);
- concentration of NaCl in water: 0.003 M;
- movement of the particle: 350 μm;
- time for movement of particle: 4.2 s;
- potential of the field in a 10 cm cell: 200 V.

Moreover, the following values are available for the f correction parameter of the Henry equation for various values of κR (κ^{-1} is the Debye length and R is the radius of the particle):

κR	$f(\kappa R)$	κR	$f(\kappa R)$
0	1.000	5	1.160
1	1.027	10	1.239
2	1.066	25	1.370
3	1.101	100	1.460
4	1.133	∞	1.500

i) Calculate the electrophoretic mobility of the colloid particles.
ii) Provide an estimation of the zeta potential of the particles. **[5]**

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Part-II **FM-50**

Use Separate Answer script for each part

Assume any missing data

1. (i) Calculate the electrophoretic mobility of a 50 nm diameter spherical colloid particle in an aqueous solution of NaCl at 298 K. The ξ-potential is 0.02 V. The concentration of NaCl in the solution is 100 mol/m^3. Given: The Debye length is ~1 nm at this concentration of the salt. Given: $\epsilon = 80$. (7)

   (ii) What is streaming potential? How is it developed? (1+2)

   (iii) Write short notes on (any two): Peclet Number, Krafft Point, Donnan Equilibrium (10)

2. (i) The aggregation number of the surfactant $C_{10}H_{21}N(CH_3)_3Br$ has been reported to be 36. Can its micelle be spherical? (7)

   or

   The variation of osmotic pressure of a polystyrene solution in toluene with its concentration at 298 K is given below.

c (kg/m^3)	0.2	0.4	0.6	0.8	0.9
π_o (cm of toluene)	0.04	0.09	0.16	0.22	0.28

   Determine the molecular weight of the polymer from these data. Given: density of toluene at 298 K = 860 kg/m^3.

   (iii) How the critical micelle concentration depends upon electrolyte concentration and pH of the solution? (4)

   (iv) State Fowkes modification over Girifalco and Good Correlation regarding interfacial tension. (4)

3. (i) Discuss how How the pressure difference to the shape of the planar, cylindrical and spherical surface. (10)

   (ii) Write down the Assumptions made in BET adsorption isotherm. Differentiate chemisorption from physisorption. (3+2)