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CHEMICAL ENGINEERING REFRESHER PROGRAM

CRSTALLIZATION, LECAHING, LIQUID-LIQUID EXTRACTION AND ADSORPTION

1. A packed bed is composed of cubes 0.02 m on a side and the bulk density of the packed bed is 980 kg/m^3. The density of the solid cubes is 1500 kg/m^3. The porosity, ξ is
   a. 0.347
   b. 0.473
   c. 0.267
   d. 0.512

2. The feed to a cooling crystallizer is 1000lb/h at 120°F. The solution is cooled to 70°F. It has a 3 ft2 of cooling surface per foot of running length of crystallizer. The required rate of heat transfer is 44,900 Btu/h. Cooling will be provided by a countercurrent flow of chilled water entering the cooling jacket at 60°F and leaving at 85°F. The overall heat transfer coefficient, U, is expected to be 20 Btu/h-ft2°F. The length of the crystallizer is
   a. 73 ft
   b. 37 ft
   c. 28 ft
   d. 23 ft

3. A 10,000 lb batch of a 32.5% $MgSO_4$ solution at 120˚F is cooled without appreciable evaporation to 70˚F. At 70°F the concentration of solids is 26.3 lb $MgSO_4$ per 100 lb solution. Assuming that the mother liquor leaving is saturated, the mass of $MgSO_4 7H_2O$ crystals that will be formed is
   a. 4174 lb
   b. 6655 lb
   c. 2756 lb
   d. 3345 lb

4. Liquid-liquid extraction schemes practiced in industry may be categorized into a number of several types, what extraction scheme uses dissociation extraction concepts to recover and purify ionizable organic solutes in and forward-and-back extraction scheme?
   a. pH-swing extraction
   b. standard extraction
   c. dissociative extraction
   d. temperature-swing extraction

5. An aqueous solution of acetic acid is to be extracted with isopropyl ether. The solution contains 24.6 kg of acetic acid and 80 kg of H_2O. Water and isopropyl ether may be considered as completely immiscible under these conditions. At the temperature of the extraction, the following equilibrium data apply:

kg acetic acid/kg isopropyl ether	0.03	0.046	0.063	0.07	0.078	0.086
kg acetic acid/kg H2O	0.1	0.15	0.2	0.22	0.28	0.26

   If 100 kg of isopropyl ether is added to the solution, the weight of acetic acid that will be extracted by isopropyl ether if equilibrium conditions are attained is
   a. 18 kg
   b. 15 kg
   c. 24.6 kg
   d. 7 kg

6. Urea is to be crystallized from an aqueous solution that is 90% saturated at 100°C. Ninety percent (90%) of the urea is to be crystallized in anhydrous form and the final temperature is to be 30°C. The solubility of urea in water at 100°C and 30°C are 730 g per 100 g water and 135 g per 100 g water respectively. Taking as a basis 1000 kg of feed, the fraction of water that must be evaporated is
   a. 0.512
   b. 0.125
   c. 0.215
   d. 0.612

7. The change in enthalpy per unit weight of gas adsorbed on gas free or degassed adsorbent to form a definite concentration of adsorbate is called its
   a. Integral heat of adsorption
   b. differential heat of adsorption
   c. heat of wetting
   d. heat of normal condensation

8. A separation process in which a liquid mixture contacts a non-porous perm-selective membrane and one component is transported through the membrane preferentially is called
   a. electrodialysis
   b. ultrafiltration
   c. pervaporation
   d. microfiltration

9. An acetaldehyde-toluene solution containing 6% acetaldehyde by weight is being treated with water in a three stage co-current extraction battery to remove acetaldehyde. Water and toluene are completely immiscible and the equilibrium distribution of acetaldehyde between them is given by the relation: $Y = 2.2 X$

   where: Y = kg acetaldehyde per kg water and X = kg acetaldehyde per kg toluene

   If 60 kg water is used in each stage per 100 kg of feed, the percentage acetaldehyde extracted is
   a. 92.8%
   b. 78.2%
   c. 83.9%
   d. 97.85

10. Formation of large crystals is favored by
    a. a low nucleation rate
    b. a high degree of supersaturation
    c. a high magma density
    d. a low magma density

11. An extractor that can facilitate a liquid-liquid extraction process by reducing diffusion path lengths and increasing the driving force for liquid-liquid phase separation. It can achieve a very high specific throughput with very low liquid residence time.
    a. Rotary Disc Contractor (RDC
    b. Karr Column
    c. Centrifugal extraction
    d. Static Extraction Column

12. Zinc is to be recovered from an ore containing zinc sulfide. The ore is first roasted with oxygen to produce zinc oxide, which is then leached with aqueous sulfuric acid to produce water soluble zinc sulfate and an insoluble, worthless residue called gangue. The decanted sludge of 20,000 kg/h contains 5 weight % water, 10 weight % zinc sulfate and the balance as gangue. This sludge is to be washed with water in a continuous countercurrent washing system to produce an extract, called a strong solution, of 10 weight % zinc sulfate in water with a 98 % recovery of the zinc sulfate. Assume that the underflow from each washing stage contains, by weight, two parts of water (sulfate-free basis) per part of gangue, the number of stages required is
    a. 4
    b. 6
    c. 7
    d. 10

13. With the lowering of equilibrium pressure at a given temperature, the amount of adsorbate on adsorbent
    a. increases
    b. remains the same
    c. decreases
    d. may increase or decrease

14. Partition ratios can be particularly sensitive to temperature when mutual solubility between the feed and extraction solvent involves hydrogen bonding. An interesting example is the extraction of citric acid from water using 1-butoxy-2-propanol as a solvent. Its partition ration at a temperature of 80°C is
    a. 0.65
    b. 0.40
    c. 0.35
    d. 0.20

15. The following equilibrium relationship was obtained during the treatment of an aqueous solution of a valuable solute by decolorizing carbon for removal of coloring impurities: $Y = 8.91 \times 10^{-5} X^{1.66}$
    a. 4.18 kg
    b. 5.6 kg
    c. 7.2 kf
    d. 1.84 kg

16. The mutual solubility of two salts can be plotted on the X and Y axes with temperatures as isotherm lines. If both solid-phase KCl and NaCl are present, the solution composition at equilibrium can only be represented by the invariant point (at constant pressure). The solubility ratios in parts per 100 parts water of KCl and NaCl at 40°C are:
    a. 34.3 and 27
    b. 20.4 and 28.4
    c. 35 and 27.5
    d. 22.6 and 31.4

17. Particles having a size of 0.10 mm, a shape factor of 0.86 and a density of 1200 kg/m^3 are to be fluidized using air at 25°C and 202.65 kPa absolute pressure. Air has a density of 2.374 kg/m^3 and viscosity of 1.845 x 10^{-5} Pa-s at 25°C and 202.65 kPa. The void fraction at minimum fluidizing conditions is 0.43. The bed diameter is 0.60 m and the bed contains 350 kg of solids. The minimum velocity for fluidization is
    a. 4.374 x 10^{-3} m/s
    b. 3.744 x 10^{-3} m/s
    c. 0.04374 m/s
    d. 4.34 m/s

18. For economy in liquid extraction, the partition ratio (or distribution coefficient) must be
    a. less than one
    b. equal to one
    c. greater than one
    d. as large as possible

19. It is desired to extract aniline from water using toluene as extraction solvent at 25°C. The partition ratio is
    a. 39.8
    b. 12.9
    c. 2.2
    d. 36

20. Rate of leaching increases with increasing
    a. temperature
    b. pressure
    c. viscosity of solvent
    d. size of solid

21. A type of fluidization where the fluidized bed resembles a liquid with rising gas bubbles and a sedimentation velocity higher than the bulk of bed with hindered sedimentation.
    a. Turbulent fluidization
    b. Aggregative fluidization
    c. Particulate fluidization
    d. Continuous fluidization

22. A method for the determination of specific surface of a granular material, based on measurement of adsorption of a neutral gas at low temperature
    a. BET
    b. Freundlich
    c. Langmuir
    d. Toth

23. A crystallizer that is characterized by the production of supersaturation in a circulating stream of liquor is
    a. Evaporative
    b. oslo surface cooled
    c. scraped surface
    d. classified suspension

24. A counter-current leaching equipment is to be used to extract NaOH from a feed consisting of 80 kg NaOH, 400 kg water and 100 kg CaCO3 using water as solvent. The final extract solution will contain 10% NaOH with the recovery of 95% of the NaOH. Setting the underflow constant at 3.0 kg solution per kg CaCO3, the number of ideal stages required is
    a. 4.0
    b. 2.0
    c. 7.0
    d. 5.0

25. The data on a leaching system show that the locus of the underflow compositions is a straight line and passes through the vertex representing the solute. Which of the following statement is true?
    a. The solvent retained by the inert in kg per kg of inert is constant.
    b. The solution retained by the inert in kg per kg of inert is constant.
    c. The system is non-ideal and there is solute adsorption by the inert.
    d. The tie lines will not pass through origin in representing inert (I= 1.0)

26. A tower having a diameter of 0.1524 m is being fluidized with water at 20.2°C. Water at 20.2°C has a density = 997.5 kg/m3 and viscosity = 1 x 10-3 Pa-s. The uniform spherical beads in the tower bed have a diameter of 4.42 mm and a density of 1603 kg/m3. The minimum fluidizing velocity is
    a. 0.52 m/s
    b. 0.026 m/s
    c. .312 m/s
    d. 0.082 m/s

27. Two hundred cubic centimeters of an acetone-water mixture that contains 10 wt% acetone are mixed with 400 cm3 of chloroform at 25°C, and the phases are allowed to settle. What percentage of the acetone is transferred from the water to the chloroform? (Densities of acetone, chloroform and water in g/cc are 0.792, 1.489 and 1.0 respectively and k = 1.83)
    a. 86%
    b. 92%
    c. 74%
    d. 80%

28. Consider a 200 kg/h feed stream containing 20 wt.% acetic acid in water that is to be extracted with 400 kg/h of recycle MIBK that contains 0.2 wt.% acetic acid and 0.02 wt.% water. The aqueous raffinate is to be extracted down to 2 wt.% acetic acid. Using Kremser-Souders-Brown (KSB) equation, the number of theoretical stages that will be required assuming that m' = 0.656 and E = 1.85 is
    a. 6
    b. 5
    c. 4
    d. 3

29. Ten kg of a solid containing 45% of a soluble material were treated with 15 kg of a solvent containing the same solute at 2% concentration in a vessel under constant agitation. After a long time, the solution and solid were separated by pressing. The solid analyzed contain 0.8 kg of solvent per kg of inert solid. The extract quantity obtained in kg was therefore
    a. 14.8
    b. 15.1
    c. 13.7
    d. 18.4

30. In a determination of solution retention data, the mass fraction of the solute in the extract was determined to be 0.6. The corresponding underflow analysis showed a retention of 0.6 kg solvent per kg of the inert solid. The mass fraction of the solute in the underflow is most likely
    a. 0.6
    b. 0.225
    c. 0.36
    d. 0.395

31. In ternary liquid equilibria, the apex of the equilateral triangular diagram represents
    a. a pure component
    b. a binary mixture
    c. a ternary mixture
    d. an insoluble binary system

32. Which of the following changes causes a Type II liquid-liquid system to become a Type I system?
    a. an increase in temperature
    b. a decrease in temperature
    c. an increase in pressure
    d. a decrease in pressure

33. In liquid-liquid extraction, if the selectivity (or relative separation) is unity, then
    a. separation of constituent is most effective
    b. no separation is possible
    c. amount of solvent requirement is minimum
    d. solvent flow rate should be very high

34. The following tie line data were obtained for a ternary system of solute B, extract solvent S and raffinate solvent A at a temperature of 25 °C.

	Raffinate Layer, Weight %	Extract Layer, weight%
B	35	52.5
S	57.5	24.6
A	7.5	22.9

    The selectivity at this tie line is very nearly
    a. 3.51
    b. 6.74
    c. 0.68
    d. 1.0

35. We wish to extract nicotine from water using kerosene. If we have 100 kg of 2% nicotine solution extracted once with 200 kg kerosene, what percentage of the nicotine will be extracted? Given that at equilibrium:

    y, (kg nicotine)/(kg kerosene) = 0.9 x, (kg nicotine)/(kg water)

    a. 56.5%
    b. 64.75%
    c. 46.5%
    d. 74.6%

36. The surface area and sorptive capacity of bituminous coal-based carbon adsorbent are between _____km2/kg dry solid and between _____ kg/kg dry solid respectively
    a. 0.9 to 1.2 and 0.4
    b. 0.4 to 0.7 and 0.3
    c. 0.8 to 1.6 and 0.5
    d. 0.8 to 1.6 and 0.4

37. A tube of 0.05 m^2 cross sectional area is packed with spherical particles to a height of 0.25 m. The porosity of the bed is 0.35. It is desired to fluidize the particles with water (ρ = 1000 kg/m3, μ = 10-3 Pa-s). The minimum velocity of fluidization is given by the Ergun's equation:

$$\frac{\Delta P}{L}\frac{D_p}{\rho_f v^2}\frac{\epsilon^3}{1-\epsilon} = \frac{150\,\mu\,(1-\epsilon)}{D_p\,\rho_f\,v} + 1.75$$

Data: Diameter of particles = 0.01 m
Density of solid particles = 2600 kg/m^3

The minimum velocity of fluidization in m/s is

a. 0.059
b. 0.035
c. 0.56
d. 0.0035

38. The oil-solvent solution obtained by leaching of vegetable seeds is

a. miscible liquid
b. adhering solution
c. carrier solvent
d. miscella

39. Purification of a chemical species by solidification from a liquid mixture where no diluent solvent is added to the reaction mixture and the solid phase is formed by cooling is called

a. falling film crystallization
b. melt crystallization
c. fractional crystallization
d. solution crystallization

40. During distribution of a solute between two partially miscible solvents, the selectivity at the plait point is

a. zero
b. less than zero
c. one
d. very large