16-CHEM-A2, UNIT OPERATIONS and SEPARATION PROCESSES

December 2018

3 hours duration

NOTES

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. The examination is an **open book exam.** One textbook of your choice with notations listed on the margins etc., but no loose notes are permitted into the exam.
3. Candidates may use any **non-communicating** scientific calculator.
4. All problems are worth 25 points. At least **two problems** from **each** of parts **A** and **B** must be attempted.
5. **Only the first two** questions as they appear in the answer book from each section will be marked.
6. State all assumptions clearly.

PART A: UNIT OPERATIONS

A1. A slurry containing 5 kg of water/kg of solids is to be thickened to a sludge containing 1.5 kg of water/kg of solids in a continuous operation. Laboratory tests using five different concentrations of the slurry yielded the following data:

Concentration (kg of water/kg of solids)	**Rate of Sedimentation** (mm/s)
5.0	0.20
4.2	0.12
3.7	0.094
3.1	0.07
2.5	0.05

Calculate the minimum area of a thickener required to effect the separation for a flow of 4788 kg/hr of solids.

A2. A liquid flows through two pipes connected in series at a rate of 12,000 kg/hr. The two pipes consist of 100 meters of horizontal smooth-walled 50-mm straight pipe followed by a reducer to 38 mm with 60 meters of horizontal smooth-walled straight pipe. Frictional loss for the reducer amounts to 0.2 velocity heads. Determine the frictional pressure drop across the pipe system.

DATA: Viscosity of liquid = 3×10^{-3} N.s/m^2
Density of liquid = 850 kg/m^3

A3. There is a requirement for the power demand to be kept to a minimum when designing a fluidized bed. A 1-meter diameter fluidized bed is filled with 1800 kg of 2-mm diameter spherical particles to a depth of 1.6 meters. The density of spherical particles is 2100 kg/m^3. The fluidizing gas, flowing at a rate of 830 m^3/hr, has a density of 1.21 kg/m^3 and a viscosity of 1.42×10^{-5} $N.s/m^2$. The Kozeny constant can be taken as 5.

(a) **[10 points]** Determine the pressure drop over the fluidized bed.

(b) **[3 points]** Determine the power requirement for flow of gas though the fluidized bed.

PART B: SEPARATION PROCESSES

B1. A feed solution containing 70 moles of benzene and 30 moles of toluene mixture is fed to a distillation column at a total pressure of 1 atm. One third of the feed is vaporized, and average volatility ratio of the system (α) is 2.5. Calculate the composition of distillate and bottoms using the following:

(a) **[13 points]** Flash distillation.

(b) **[12 points]** Differential distillation.

B2. 1400 kg of granular solid is to be dried under constant drying conditions from a moisture content of 0.2 kg/kg of dry solid to a final moisture content of 0.02 kg/kg of dry solid. The material has an effective area of 6.15×10^{-2} m^2/kg. Calculate the time required for drying based on the following data obtained for the material:

Moisture Content (kg/kg of dry solid)	**Rate of Drying** (kg/hr.m^2)
0.3	1.71
0.2	1.71
0.14	1.71
0.096	1.46
0.056	1.29
0.042	0.88
0.026	0.54
0.016	0.376

B3. The adsorption of ethane (C_2H_6) on Linde molecular sieve type 5A was studied at 35 °C and the following data was obtained:

Pressure, in mm Hg	**Ethane Uptake,** in cm^3 (STP)/g
0.17	0.059
0.95	0.318
5.57	1.638
12.09	3.613
111.32	24.236
220.87	34.278
300.05	38.340
401.25	41.779
500.18	44.037
602.74	45.693

(a) **[20 points]** Determine if Langmuir isotherm or Freundlich isotherm can be used to model the data.

(b) **[5 points]** Calculate the total surface area of the solid.

DATA: Avagadro's number = 6.023×10^{23} molecules/mole
Density of liquified ethane = 354.9 kg/m^3

The Periodic Table of the Elements