Questions for examination from Unit Operations of Chemical Engineering I – academic year 2014/2015

1. Principle of balance equations. What quantities can be balanced? Discuss the terms: system and its boundaries, time (period) of balancing, stream, accumulation, source/sink (or generation/consumption), fictitious stream, base of balancing. Formulation of material balance equations, overall balance, component balances, number of independent balance equations. Auxiliary (additional) equations: conversion, yield, excess/surplus. Data matrix, usage. Recommended steps in setting up and solving balances.
2. Fluids and continuum. Forces acting in fluids, normal and shear stresses, pressure. Newton viscosity law. Ideal fluid. Laminar and turbulent flows, Reynolds number. Velocity profile in a pipe. Equation of continuity.
3. Balance of mechanical energy of fluid - Bernoulli equation for a pipeline without and with a pump. Equation of hydrostatics. Relations for energy loss in flowing fluids: friction factor for laminar and turbulent flow, loss coefficient, equivalent length. Hydraulic (equivalent) pipe diameter.
4. Transportation of fluids: basic types of pumps. Power input and output of a pump, pump efficiency. Suction and displacement height (heads), maximum suction height. Cavitation. Characteristic (or performance) curve of a pump and of a pipeline, working point.
5. Fluid flow through a bed of solid particles; explain the terms: voidage (porosity) of the bed, specific surface of particles, interstitial and superficial liquid velocity. Principles of the determination of pressure drop along the bed (qualitative description only). Principles of filtration, applications, basic types of filters. Mass balance of a filter. Filtration rate, filtration equation. Filtration at constant velocity and filtration at constant pressure difference. Cake washing.
6. Enthalpy balance (without chemical reaction). Reference state, specific/molar enthalpy of a pure substance and of a mixture. Enthalpy of phase transitions.
7. Mechanisms of heat transfer: heat conduction and heat convection. Fourier law, heat conductivity, temperature profile. Heat flux due to heat conduction in planar and cylindrical walls.
8. Heat convection, natural convection and forced convection. Newton law of cooling. Temperature profile in the vicinity of heat exchange interface. Heat transfer coefficient and its evaluation.
9. Overall heat transfer coefficient. Heat transfer resistances. Temperature profile. Heat transfer in heat exchangers, temperature distributions in heat exchangers, types of heat exchangers. Evaluation of heat flux, heat transfer area. Logarithmic mean temperature difference.
10. Evaporators and their applications. Types and arrangements of evaporation units. Mass and enthalpy balances of a single-stage (or single-effect) evaporator. Calculation of temperature in the evaporator. Calculation of the heat exchange area.
11. Liquid-liquid extraction with immiscible solvents. Graphical representation of phase equilibrium. Description of single extraction stage. Efficiency. Balance equations for repeated extraction. Show the use of McCabe-Thiele diagram (graphical solution) for the case of equilibrium and real stages. Principles of repeated (cross-flow) and counter-current extraction, basic mass balances, graphical solution.
12. Distillation. Description of liquid-vapor equilibrium, vapor pressure, relative volatility. Flash distillation, use of mass balance equations in combination with equilibrium relations to calculate the composition of the out-flowing vapor and liquid. Equations describing batch distillation in a single stage.
13. Rectification I: Describe the operation of a staged rectification column. Write down the equations necessary for its description. Using these equations to describe the McCabe-Thiele diagram for determining the number of ideal (equilibrium) plates in the simplest case of the feed at its boiling point.
14. Rectification II: Operating limits - minimum reflux ratio and minimum number of stages. Effects of preheated feed, McCabe-Thiele diagram including the feed-line.
15. Characterize drying. Describe various types of dryers. Humidity chart. Phase equilibrium, bound and unbound liquid. Batch drying – mass and enthalpy balance. Rate of drying curves, constant and falling-rate period. Calculation of drying time.
16. Mass and enthalpy balances of a continuous dryer without recycling the drying gas. What is specific heat duty and ideal dryer? Show the state of the drying gas in the humidity chart. Describe some dryer equipment.
17. Introduction to reactors: define conversion and extent, their mutual relation. Explain the terms: reaction enthalpy, equilibrium constant. Define reaction rate and give examples of kinetic expressions. Stirred batch reactor – mass balance in the case of single reaction. Calculation of reaction time at constant temperature.
18. Continuous stirred tank reactor – mass balance in the case of single reaction. Determination of mean residence time/ reactor volume. Tubular reactor – mass balance, calculation of mean residence time/reactor volume for liquids. Relation to the batch reactor.