Chemical Engineering 3 – Oral Examination Questions 2013/2014

1. Sketch the phase diagrams for solid-liquid equilibria of two- (s-l) and three-component (s-l-l) systems and use them to explain the principle of crystallisation. Explain the terms: polymorphism, solid solution, co-crystal, eutectic system.
2. Define supersaturation. What are the means of achieving supersaturation and by what criteria are they chosen? Sketch one chosen type of an industrial crystalliser and describe its operation. Discuss the dependence of nucleation and crystal growth kinetics on supersaturation. What are the two commonly used ways of expressing crystal growth rate and what is the relationship between them?
3. Write down the population balance of an ideally mixed continuous flow crystalliser (MSMPR) at steady state. List any assumptions used and briefly discuss their validity limits.
4. Write down the coupled population and mass balances of a batch cooling crystalliser and describe an algorithm for calculating the evolution of crystal size distribution on the cooling rate. Display the system's trajectory in a c-T diagram.
5. Describe the physical mechanism of liquid penetration into a porous structure formed by bulk powder. Based on the Washburn equation, discuss the influence of the following parameters on the penetration rate and particle dispersibility: mean particle size, contact angle, liquid viscosity and surface tension.
6. Write down the mass balance and describe an algorithm for calculating the dissolution time of an isolated particle in a liquid. Discuss any assumptions you have made and their validity limits.
7. Explain the principle of gas separation by adsorption. What types of adsorption equilibrium isotherms do you know and how does the adsorption equilibrium depend on temperature? Give examples of practically important adsorption-based separations and the adsorbents they use.
8. Write down the mass and enthalpy balance of a differential segment of an adsorption column in the non-equilibrium case and in the case of isothermal operation with instantaneous equilibrium. Use the resulting formula for estimating the concentration wave velocity through the column. What is breakthrough curve? Discuss its importance for the practical operation of an adsorption column.
9. What methods for adsorbent regeneration do you know and when should they be chosen? Describe the principle of Pressure Swing Adsorption, including the evolution of pressure and composition profiles in each step.
10. Discuss the similarities and differences in the behaviour of liquids and powders at rest and during flow. Explain the meaning of the angle of internal friction and its importance for calculating stress distribution in a cylindrical vessel for powder storage. What other powder characteristics do you know? Describe how they are measured and explain their meaning.
11. Explain the concept of equivalent particle diameter. What is the shape factor of a particle and how is it calculated? Explain the difference between discrete and continuous, cumulative and differential particle size distribution. What is the relationship between the distribution by number, length, area, volume?
12. Give examples of process equipment and the underlying physical mechanisms used for particle size reduction (milling). What criteria are used to select the appropriate mill type with respect to the material properties of the milled substance? How can the energy requirements for milling be estimated? Provide a definition and explain the meaning of the selection and the breakage functions S(x) and B(x,y), respectively.

13. Write down the mass balance of an individual size fraction during passage through a continuous mill. Explain the construction of the mill matrix from the breakage function B(x,y). When is it necessary to recycle material during milling, and how is the recycle carried out practically?

14. What are the main reasons for carrying our particle size enlargement (agglomeration) and what types of process equipment are used for this purpose? Describe the principle of wet granulation and the elementary steps that take place at the single-particle level. Explain the meaning of the viscous Stokes number and its use for granulation process control. Discuss the influence of individual physical parameters on the granulation kinetics.

15. Write down the population balance of a batch and a continuous flow ideally mixed granulator. List any simplifying assumptions made and discuss their validity limits. Explain the meaning of the agglomeration kernel β_{ij}.

16. Explain the operating principle of spray drying. Which methods of spray formation (liquid atomisation) do you know? Write down the overall mass and enthalpy balance of a spray drying tower. Describe the algorithm for calculating the single droplet drying time and discuss the influence of individual parameters on the drying time. What are the practical limitations on the temperature and the flowrate of the inlet air?

17. Describe the operating principle of a cyclone. Write down the forces acting on a particle in a cyclone. What is the separation efficiency of a cyclone and which parameters does it depend on? Describe the design procedure of a cyclone and the criteria for connecting multiple cyclones in series or in parallel.

18. Describe the sedimentation of concentrated suspensions. What modifications need to be made in the case of hindered settling compared to sedimentation of an isolated particle? Derive the dependence of the settling flux on suspension concentration and sketch the functional dependence graphically. What type of concentration profiles can evolve during batch settling of a concentrated suspension?