

Question 1 [10]

1. Ion Exchange:
 - Separation is due to a difference in charges between the ions in solution and those in the solid phase.
 - MSA (synthetic resins or polymers)
2. Brewing coffee in hot water:
 - Separation of the different components (water, ground coffee, brewed coffee) occurs because of liquid-solid leaching.
 - ESA (heat)
3. Flash Drum:
 - Separation is due to a difference in relative volatilities.
 - ESA (hot and cold utilities)
4. Hemodialysis
 - Separation is due to a difference in diffusion rates between the solutes.
 - ESA – Work done by machine to pump blood from body to dialyzer.
* Note that separation can also be viewed as being due to a difference in particle size. In this case the separating agent is the semipermeable membrane (MSA).
5. Venturi Scrubber
 - Separation is due to a difference in relative solubility (vapour-liquid contact).
 - Either answer accepted: ESA – pressure, MSA – adsorbent.

Question 2 [5]

Difference in particle sizes

- Filters, sieves, sedimentation

Difference in molecule sizes

- Chromatography, gel permeation, dialysis, reverse osmosis, ultra/microfiltration

Difference in liquid densities

- Centrifugation, funnel, fluidized bed, clarifier

Difference in particle surface charge

- Ion exchange, gel electrophoresis, flocculation

Difference in relative solubility

- Precipitation, crystallization

Difference in relative volatilities

- Distillation

Question 3 [8]

Mechanical Deboner

- Meat bone separator whereby mixture is crushed against a screen and the softer meat is extracted. The harder bones are retained on the screen because they are too big to be passed through. A pressure differential is applied to enable the softer meat to pass through.

Flotation Cell

- Enables the separation of hydrophobic and hydrophilic particles by allowing particles to collect in the froth formed at the surface. The particles have a high affinity to air bubbles, and so they attach onto the bubbles and rise to the surface. There are 3 kinds of flotation cells: dissolved air, induced gas, and froth flotation.

Pressure-swing Adsorption

- Allows separation of a gas from a mixture of gases by varying pressure and introducing an adsorbent. Impurities are adsorbed onto the vessel lining (on an adsorbent) allowing purified product to flow through. As the pressure is varied, the impurities are released and can be collected as waste.

Fluidized Bed

- Create an environment where a solid has to behave as a fluid. The fluidized mixture increases the area available for adsorption allowing the higher density particles to settle at the bottom and the lower density particles to rise to the surface.

Question 4 [10]

Any 5 of the following (this is not an exhaustive list):

1. Filtration (<http://en.wikipedia.org/wiki/Filtration#mediaviewer/File:FilterDiagram.svg>)
2. Sedimentation/flocculation (<http://images.tutorvista.com/cms/images/38/coagulation.png>)
3. Centrifugation (<https://www.medicinescomplete.com/mc/rem/2012/images/c29-fig-29-11.png>)
4. Cyclone (http://upload.wikimedia.org/wikipedia/commons/thumb/e/e3/Cyclone_separator.svg/2000px-Cyclone_separator.svg.png)
5. Venturi scrubber (<http://www.scielo.br/img/fbpe/jbsms/v23n4/a08fig01.gif>)
6. Electrostatic precipitator (<http://astarmathsandphysics.com/gcse-physics-notes/gcse-physics-notes-the-electrostatic-precipitator-html-e53bdd7.gif>)
7. Clarifiers (<http://water.me.vccs.edu/concepts/clarifier.jpg>)
8. Evaporation (http://www.plansee.com/media/images/Vacuum_Evaporation_PLANSEE.png)

Question 5 [10]

1. Assume Stoke's law applies, then:

$$v_{TSV} = \frac{(\rho_p - \rho_f)gD_p^2}{18\mu_f} = \frac{(1200 - 1100)(9.81)(100 \times 10^{-6})^2}{18(0.05)}$$
$$\therefore v_{TSV} = 1.09 \times 10^{-5} m/s$$

Checking the Reynolds number, $Re = \frac{\rho_f v_{TSV} D_p}{\mu_f} = \frac{(1100)(1.09 \times 10^{-5})(100 \times 10^{-6})}{0.05} = 2.398 \times 10^{-5}$, which is less than 1 so the assumption holds.

2. In general, the separation unit should be designed based on the smaller particle size because it is the limiting design criterion.

Question 6 [4]

Any 2 of the following:

1. Clarifier
 - Difference in densities
 - MSA (gravity)
2. Evaporator
 - Removal of large amounts of water as vapour from material
 - ESA (heat)
3. Crystallizer (type of evaporator)
 - Difference in solubility
 - ESA(cooling)
4. Filter
 - When considering the filter medium: Difference in particle size - MSA (filter medium)
 - When considering the overall filtration system: Difference in pressure - ESA
5. Centrifuge
 - Difference in liquid densities
 - ESA (artificial gravity)
6. Dryer
 - Removal of relatively small amounts of water from material. *phase change by heat addition
 - ESA (heat)