Question 1 Solution

- Crystallization involves the formation of a solid product from a homogeneous liquid mixture by using difference in solubility. Heat removed is the ESA. A seed crystal may be added to facilitate nucleation and growth of the crystal (MSA).
- Adsorption involves the adhesion of molecules (adsorbate) to the surface of a solid adsorbent. The adsorbent is the MSA.
- Steeping (brewing) tea exploits differences in solubility by leaching soluble tea constituents from the insoluble tea leaves. Water is the MSA, and heat in the water can hasten brewing (ESA).
- Using monoethanolamine (MEA) in a carbon dioxide scrubber exploits the relative solubility of CO_2 in the MEA solvent (MSA).
- Flotation is a gravity separation process that exploits differences in surface properties of particles, where the species of interest are preferentially attached to the bubbles (MSA). The ESA is the gravitational field.

Question 2 Solution

- Relative volatility is used in fractional distillation (e.g.: crude oil distillation). Product streams are separated based on boiling point.
- Evaporation is used in desalination of sea water. Water molecules are evaporated, leaving behind the salt content.
- Condensation is used in a condenser during distillation. The overhead vapour is condensed using an air-cooled and/or water-cooled condenser, and then sent to a reflux drum.
- Relative solubility differences are used in liquid-liquid extraction. For example, hydrogen sulphide is removed from liquefied petroleum gas using methyl diethanolamine (MDEA).
- Particle size differences are used in quarries. A vibrating screen has multiple tiers of increasingly fine mesh size, resulting in product streams of different particle size ranges.

Question 3 Solution

- A mechanical deboner is used to separate animal meat from bone. The crushed meat and bones are pressed against a sieve, where the edible tissue is forced through the screen, leaving behind the bone.
- Flotation columns separate desired mineral particulates from slurry made up of water and ground ore. Air bubbles are introduced at the bottom of the column, floating upwards and collecting mineral particles which adhere to the bubble surface. A resulting froth is formed on the slurry surface for collection.
- Pressure swing adsorption is a gas separation technique used in applications such as nitrogen or hydrogen generation. A solid adsorbent preferentially adsorbs certain gases (typically impurities) from the mixture at high pressure, allowing the product stream to be obtained at

high purity. Following that phase, the adsorbed gases are released at low pressure, and the next cycle would start.

- Evaporators apply heat to a solution to vaporize the solvent, which is usually water (e.g.: treating waste water containing organic and inorganic impurities). Components in the mixture with a higher volatility will vaporize, while components of a lower volatility remain in the liquid/solid phase.

Question 4 Solution

Assume Re<1 (Stokes' region):

$$v_{TSV} = \frac{(\rho_p - \rho_f)gD_p^2}{18\mu_f} = \frac{(1530 - 0.83)(9.81)(500 \times 10^{-6})^2}{(18)(2.309 \times 10^{-5})} = 9.02 \text{m.s}^{-1}$$

Calculating Reynolds number:

$$Re = \frac{\rho_f v_{TSV} D_p}{\mu_f} = \frac{(0.83)(9.02)(500 \times 10^{-6})}{2.309 \times 10^{-5}} = 162.20$$

Reynolds assumption was not true, so estimate drag coefficient:

$$C_D = \frac{24}{Re}(1 + 0.15Re^{0.687}) = \frac{24}{162.2}(1 + 0.15 \times 162.2^{0.687}) = 0.88$$

Update estimate of terminal velocity:

$$v_{TSV} = \sqrt{\frac{4(\rho_p - \rho_f)gD_p}{3C_D\rho_f}} = \sqrt{\left(\frac{4(1530 - 0.83)(9.81)(500 \times 10^{-6})}{3(0.88)(0.83)}\right)} = 3.70 \text{m.s}^{-1}$$

New estimate results in a Reynolds number of $\frac{(0.83)(3.70)(500 \times 10^{-6})}{2.309 \times 10^{-5}} = 66.51$

Using Re=66.51, C_D=1.33 and v_{TSV}=3.01m.s^{-1}

Continue iterations of calculating C_D, v_{TSV} and Re until convergence: terminal settling velocity is approximately 2.81m.s^{-1}

Question 5 Solution

- Milling rolls: this unit uses mechanical shear forces (ESA) applied by the rolls (MSA) to extract juice from the cane.
- Filter: uses particle size differences. Residual juice passes through the filter (MSA).
- Clarifier/lime-tanks: uses density differences to perform separation of solid impurities from the juice. Milk of lime (MSA) is added to form insoluble lime salts which settle. The gravitational field is the ESA.

- Vacuum crystallizer uses evaporation to remove water by adding heat (ESA). A seed sugar crystal (MSA) is added to the supersaturated sugar solution to initiate crystallization.
- Centrifuge: uses particle size differences. The molasses passes through the centrifuge wall lining (MSA), leaving behind the larger sugar crystals. Centrifugal force is the ESA.