

CVG 2132 Fundamentals of Environmental Engineering
MIDTERM 2015 – v2

PART A. Short Questions (35 points)

1. (5 points)

a) What was the main finding of “Silent Spring”?

Published in 1962 this book presented a great deal of evidence that pesticides were indirectly greatly reducing bird populations. Pesticides were being used in quantities greater than necessary and in many cases were not controlling very well the pests they were intended to control.

The vast use of the pesticide caused the DDT to enter the food chain and resulted in bioaccumulation up the food chain. Resulting in high concentrations of DDT found in tissues of species high in the food chain. The use of DDT has detrimental effects on ecosystems and to humans alike.

OR

b) What happened during the Donora episode?

The Donora incident occurred in the town of Donora, Pennsylvania located on the Monongahela River valley during the fall of 1948. This was a severe smog event lasting six days that was directly responsible for the death of at least 21 individuals and made about 7000 residents sick, many of whom had to be hospitalized. It also killed many pets and plants.

The incident occurred due to: 1) the bowl shape of the river valley; 2) the emissions from a steel plant, a wire mill and zinc plant; and 3) the immersion climatic conditions.

This incident led to the creation of the 1955 Clean Air Act.

2. (5 points) What are fixed solids? How do we determine experimentally the fixed solids?

Fixed solids are the solids of inorganic origin.

We determine the fixed solids by: a) first measuring the total (of total suspended solids)

And b) the placing these solids in a 550 °C oven in which the solids of organic origin burn, leaving only the inorganic solids. After letting the sample cool in a desiccator, the sample is reweighed and these remaining solids are the fixed solids.

3. (6 points) Calculate the concentrations of the substances shown in the table below in mg/L-as CaCO₃. Show your work in detail.

Substance	Conc. (g/m ³)	MW (g/mol)
CO ₃ ⁻²	61	61.0
OH ⁺	51	17

$$EW = \frac{MW}{z}$$

$$MW_{CaCO_3} = \left(40 \frac{g Ca}{mole Ca}\right) + \left(12 \frac{g C}{mole C}\right) + 3moles \times \left(16 \frac{g O}{mole O}\right) = 100 \frac{g CaCO_3}{mole CaCO_3}$$

$$EW_{CaCO_3} = \frac{MW_{CaCO_3}}{z_{CaCO_3}} = \frac{100 \frac{g CaCO_3}{mole CaCO_3}}{2 \frac{eq CaCO_3}{mole CaCO_3}} = 50 \frac{g CaCO_3}{eq}$$

$$EW_{OH^-} = \frac{MW_{OH^-}}{z_{OH^-}} = \frac{17 \frac{g OH^-}{mole OH^-}}{1 \frac{eq OH^-}{mole OH^-}} = 17 \frac{g OH^-}{eq}$$

$$EW_{CO_3^{-2}} = \frac{MW_{CO_3^{-2}}}{z_{CO_3^{-2}}} = \frac{60 \frac{g CO_3^{-2}}{mole CO_3^{-2}}}{2 \frac{eq CO_3^{-2}}{mole CO_3^{-2}}} = 30 \frac{g HCO_3^-}{eq}$$

$$OH^- \text{ conc.} = 51 \frac{g OH^-}{m^3} \times \frac{eq OH^-}{17 g HCO_3^-} \times \frac{50 g CaCO_3}{eq} \times \frac{1000mg}{g} \times \frac{m^3}{1000 L} = 150 \frac{mg}{L} \text{ as } CaCO_3$$

$$CO_3^{-2} \text{ conc.} = 61 \frac{g CO_3^{-2}}{m^3} \times \frac{eq CO_3^{-2}}{30 g CO_3^{-2}} \times \frac{50 g CaCO_3}{eq} \times \frac{1000mg}{g} \times \frac{m^3}{1000 L} = 101.7 \frac{mg}{L} \text{ as } CaCO_3$$

4. (3 points) Determine the pH of the above solution.

$$[OH^-] = 51 \frac{g OH^-}{m^3} \times \frac{mole OH^-}{17 g OH^-} \times \frac{m^3}{1000L} = 3 \times 10^{-3} \frac{mole OH^-}{L}$$

$$K_w = [H^+] \times [OH^-] = 1 \times 10^{-14}$$

$$[H^+] = \frac{K_w}{[OH^-]} = \frac{1 \times 10^{-14}}{3 \times 10^{-3}} = 3.33 \times 10^{-12} mole/L$$

$$and \ pH = -\log_{10}[H^+] = -\log_{10} \left[3.33 \times 10^{-12} \frac{mole H^+}{L} \right] = 11.5$$

5. (6 points) Analytically we cannot easily measure directly the concentrations of the ammonium ion (NH_4^+) and unionized ammonia (NH_3). So we generally measure the total ammonia concentration (i.e., Total ammonia = $[NH_3] + [NH_4^+]$). The concentration of each species is then calculated using following information:



If the unionized NH_3 concentration is 1.25 mg /L as N at $15^\circ C$ and $pH=7.5$, calculate the ionized ammonia (NH_4^+) concentration in mg N/L.

$$MW_{NH_3} = \left(1 \times 14 \frac{g N}{mole N} \right) + \left(3 \times 1 \frac{g H}{mole H} \right) = 17 \frac{g NH_3}{mole NH_3}$$

$$MW_{NH_4^+} = \left(1 \times 14 \frac{g N}{mole N} \right) + \left(4 \times 1 \frac{g H}{mole H} \right) = 18 \frac{g NH_4^+}{mole NH_4^+}$$

But note the concentration is expressed as N, which has an atomic weight of 14.

$$[NH_3] = 1.25 \frac{mg \text{ as } N}{L} \times \frac{g}{10^3 mg} \times \frac{mole N}{14 g N} \times \frac{mole NH_3}{mole N} = 8.93 \times 10^{-5} \frac{mole NH_3}{L}$$

$$K_a = \frac{[H^+] \times [NH_3]}{[NH_4^+]} = 10^{-9.56}$$

$$[H^+] = 10^{-pH} = 10^{-7.5} = 3.16 \times 10^{-8} mole H^+ /L$$

$$[NH_4^+] = \frac{[H^+] \times [NH_3]}{10^{-9.56}} = \frac{[10^{-7.5} \text{ mole } H^+ / L] \times [8.93 \times 10^{-5} \frac{\text{mole } NH_3}{L}]}{10^{-9.56}}$$

$$= 0.0103 \frac{\text{mole } NH_4^+}{L}$$

$$NH_4^+ = 0.0103 \frac{\text{mole } NH_4^+}{L} \times \frac{\text{mole } N}{\text{mole } NH_4^+} \times \frac{14 \text{ g } N}{\text{mole } N} \times \frac{10^3 \text{ mg}}{\text{g}} = 144.2 \frac{\text{mg as } N}{L}$$

6. (3 Points) Select the correct answer. To determine if a reaction is described by 0.5 order rate expression, the batch kinetics experimental data (time and concentration (C)) should be plotted by which of the following graphs:

- a) $C^{1.5}$ versus time
- b) $C^{1.0}$ versus time
- c) $C^{0.5}$ versus time
- d) $\ln C$ versus time
- e) $1/C$ versus time
- f) $1/C^{0.5}$ versus time
- g) $1/C^{1.5}$ versus time
- h) All of the above
- i) None of the above

The correct answer is c)

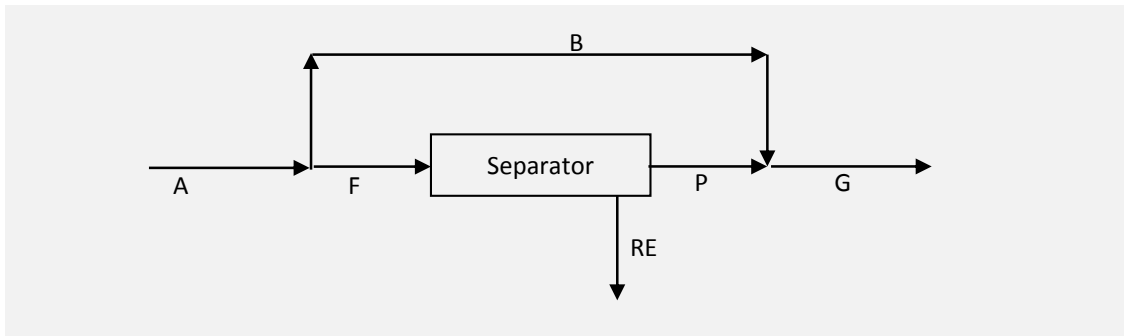
7. (3 points) Select all the correct answers. A reactor that has periodic (intermittent) feed flow and constant effluent flow can be classified as

- a) A CSTR reactor
- b) A tubular reactor
- c) Batch reactor
- d) Semi-batch reactor
- e) Continuous flow reactor
- f) Steady-state reactor
- g) Unsteady-state reactor
- h) All of the above
- i) None of the above

The correct answer is d) and g)

PART B. Long Questions (65 points)

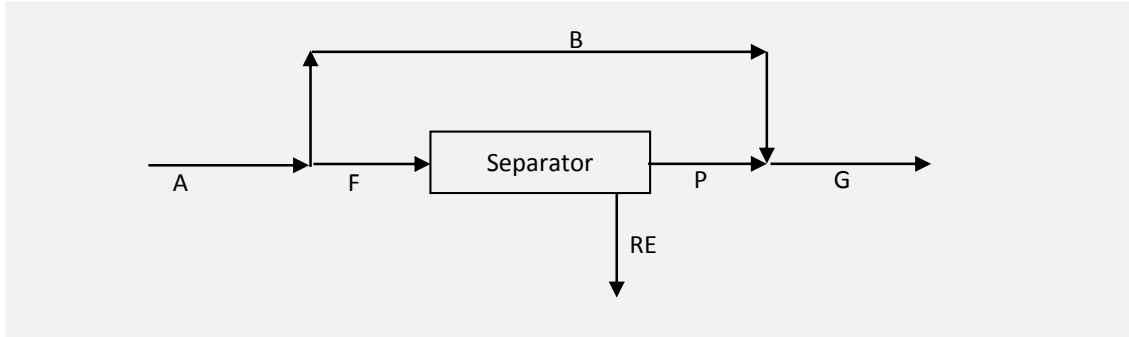
Nanofiltration membranes are used for the removal of hardness from hard surface or groundwaters. The nanofiltration system is a separation process that removes all the hardness from the water (i.e., the hardness in stream P is zero) but it is beneficial to have some hardness in the water so a system with the flow scheme shown below is used. The waters involved are considered to contain a single contaminant, hardness (H). The nanofiltration unit also produces a retentate stream (RE), which has a higher hardness concentration than the feed stream (F). The volumetric flowrate of stream RE is 0.8 the volumetric flowrate of stream F. The system is operated with a by-pass stream (B) so that it produces 10 m³/d of final product (stream G) and this product has a hardness of 80 g CaCO₃/m³. The table below presents the known **volumetric flow rates (Q)** and **concentrations** of H; it also shows the unknowns as dark grey boxes.



		STREAMS					
		A	B	F	RE	P	G
Q	(m ³ /d)						10
H	(g CaCO ₃ / m ³)	300				0	80

Determine:

- a) Determine the unknown volumetric flowrates. Do the calculations in detail and explain every step.



SOLUTION

ASSUMPTIONS

- As there are no apparent changes with time, assume steady state conditions prevail.
- Groundwaters are clean waters, so they are dilute. Accordingly assume that all the streams have the same density as water, i.e., = 1000 kg/m³
- As this is a separation process there are no reactions. Thus, the Generation and Consumption terms equal zero

Since A – B- F is a split, the characteristics of these streams are the same.

- $H_A = H_B = H_F = 300 \text{ g/m}^3$
- The densities of these streams are also the same.

Total MB around joint B-P-G

- Accumulation = $\Sigma M_{IN} - \Sigma M_{OUT} = \Sigma (Q \cdot \rho)_{IN} - \Sigma (Q \cdot \rho)_{OUT}$
- Accumulation = 0 because of steady state conditions

$0 = (Q_B \times \rho_B) + (Q_P \times \rho_P) - (Q_G \times \rho_G)$	Eq.1
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Since the densities of the three streams are the same, divide out the densities

$0 = (Q_B) + (Q_P) - (Q_G)$	Eq.2
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and

$0 = (Q_B) + (Q_P) - \left(10 \frac{m^3}{d}\right)$	Eq.3
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Hardness MB around joint B-P-G

- Accumulation = $\Sigma M_{IN} - \Sigma M_{OUT} = \Sigma (Q \cdot H)_{IN} - \Sigma (Q \cdot H)_{OUT}$
- Accumulation = 0 because of steady state conditions

$0 = (Q_B \times H_B) + (Q_P \times H_P) - (Q_G \times H_G)$	Eq.4
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$0 = \left(Q_B \times 300 \frac{\text{g as CaCO}_3}{\text{m}^3}\right) + \left(Q_P \times 0 \frac{\text{g as CaCO}_3}{\text{m}^3}\right) - \left(10 \frac{\text{m}^3}{\text{d}} \times 80 \frac{\text{g as CaCO}_3}{\text{m}^3}\right)$	Eq.5
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$Q_B = 2.66 \text{ m}^3/\text{d}$

Substituting back into equation 3 one obtains

$0 = \left(2.666 \frac{\text{m}^3}{\text{d}}\right) + (Q_P) - \left(10 \frac{\text{m}^3}{\text{d}}\right)$	Eq.6
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$Q_P = 7.33 \text{ m}^3/\text{d}$

We are given that the flow of stream P will be 0.8 of that of stream A.

$Q_E = 0.8 \times Q_F$	Eq.7
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Total MB around separator

- Accumulation = $\Sigma M_{\text{IN}} - \Sigma M_{\text{OUT}} = \Sigma (Q \cdot \rho)_{\text{IN}} - \Sigma (Q \cdot \rho)_{\text{OUT}}$
- Accumulation = 0 because of steady state conditions

$0 = (Q_F \times \rho_F) - (Q_P \times \rho_P) - (Q_{RE} \times \rho_{RE})$	Eq.9
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Since the densities of the three streams are the same, divide out the densities

$0 = (Q_F) - (Q_P) - (Q_{RE})$	Eq.10
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And substitute in eq. 7

$0 = (Q_F) - (Q_P) - (0.8 \times Q_F)$	Eq.11
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so

$Q_F = \frac{Q_P}{0.2} = \frac{7.33 \frac{\text{m}^3}{\text{d}}}{0.2} = 36.66 \frac{\text{m}^3}{\text{d}}$	Eq.12
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Thus, substituting back into equation 7

$Q_{RE} = 0.8 \times Q_F = 0.8 \times 36.66 \frac{\text{m}^3}{\text{d}} = 29.33 \frac{\text{m}^3}{\text{d}}$	Eq.13
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Total MB around split A-B-F

- Accumulation = $\Sigma M_{IN} - \Sigma M_{OUT} = \Sigma (Q \cdot \rho)_{IN} - \Sigma (Q \cdot \rho)_{OUT}$
- Accumulation = 0 because of steady state conditions

$0 = (Q_A \times \rho_A) - (Q_B \times \rho_B) - (Q_F \times \rho_F)$	Eq.14
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Since the densities of the three streams are the same, divide out the densities

$0 = (Q_A) - (Q_B) - (Q_F)$	Eq.15
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and

$Q_A = (Q_B) + (Q_F)$	Eq.16
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$Q_A = 2.66 \frac{m^3}{d} + \left(36.66 \frac{m^3}{d} \right) = 39.32 \frac{m^3}{d}$	Eq.17
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