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CVG 2132
Fundamentals of Environmental Engineering
MIDTERM 2013

Professor: R. M. Narbaitz
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- **CLOSED BOOK TEST**
- **READ and REREAD the QUESTIONS CAREFULLY**
- WRITE LEGIBLY AND NEATLY
- **CLEARLY INDICATE THE AREA AROUND WHICH THE MASS BALANCE IS BEING CARRIED OUT AND THE NATURE OF THE MASS BALANCE.**
- **If conducting a mass balance write it first in terms of the variables. Carry out all the calculations with at least three significant digits**
- **ONLY NON-PROGRAMMABLE CALCULATORS ARE ALLOWED.**
- CLEARLY STATE ALL ASSUMPTIONS
- CLEARLY EXPLAIN EVERY STEP

PART A. Short Questions (35 points)

1. (2 points) Environmental problems are caused by a number of different things, but ultimately the cause can reduced to a number of key things. T**he most** important socio-economic factor at the root of environmental problems Is population growth. What is the second most important factor?
2. (5 points) How do we determine the inorganic suspended solids in a solution?
3. (5 points) A bathroom cleaning liquid has a density of 1 kg/L and consist of 10 wt% hydrochloric acid (HCl) and 90 wt% water. HCl is a strong acid which has pK = -3. The MW of HCl is 35.5. In cleaning a toilet, you add 10 ml of this cleaning liquid to the 0.5 L of water at the bottom of the

toilet bowl. What will be the pH of the water at the bottom of the toilet bowl when it is well mixed?

4. (3 points) Define alkalinity in words, not the terms in the equation.

5. (5 points) Calculate the concentrations of the substances shown in the table below in mg/L-$CaCO_3$ (show your work in the space below). The molecular weight of Ca^{2+} is 40 g/mol.

Substance	**Conc. (g/m^3)**	**MW (g/mol)**	**Conc. (mg/L - $CaCO_3$)**
CO_3^{2-}	55	60.0	
HCO_3^-	43	61.0	
H^+	1.2	1.0	

6. (5 points) Atrazine (MW = 215 g/mol) is a pesticide which has a herbicide effect. While it has been banned in the European Union, atrazine is used in a large number of countries (United States and Canada) for the treatment of weeds. Samples of water of an aquifer had a concentration of atrazine of 0.05 µg/L and soil samples had a concentration of 2×10^{-6} g/g. The concentrations and mass fraction of atrazine top of 3×10^{-7} mM in water and 5 ppb in ground are toxic and problematic. **(i)** in water, what is the aqueous concentration of atrazine in units of mM and is it toxic? **(ii)** in soil samples, what is the concentration of atrazine in ppb is it toxic?

7. (5 points) The reaction rate constant for a reaction is given as 2 $\frac{L^3}{mg^3 \cdot d}$. The reaction order is

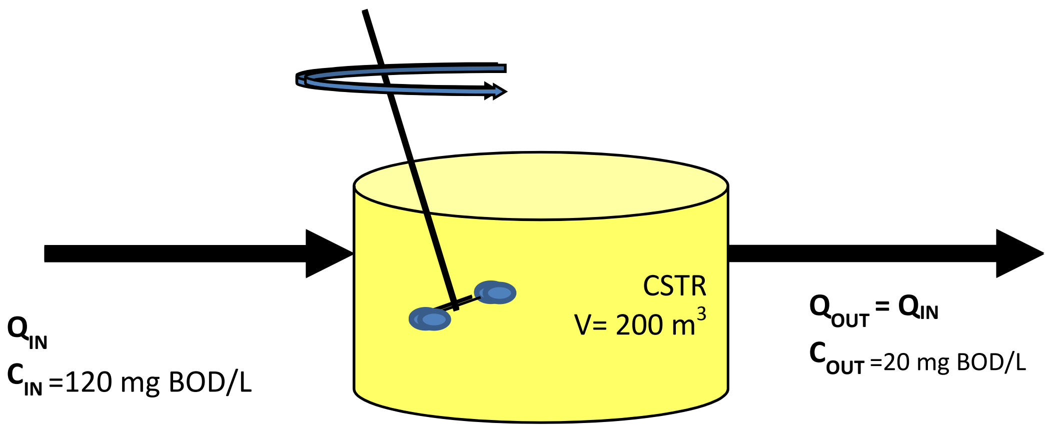
a) a zero order reaction
b) a first order reaction
c) a second order reaction
d) a third order reaction
e) none of the above

8. (5 Points) To determine if a reaction is described by second order rate expression, the batch kinetics experimental data (time and concentration (C)) should be plotted by which of the following graphs:

a) C^2 versus time
b) $1/C^2$ versus time
c) C versus time
d) 1/C versus time
e) None of the above

PART B. Longer Questions (65 points)
Complete Problems B1+ B2 or B3

B1. (35 points) A wastewater treatment system consists of a CSTR with a volume of 200 m^3 which treats a wastewater with a concentration of 120 mg/L BOD. The system has to produce an effluent with an effluent concentration of 20 mg/L BOD. The kinetic coefficient for the BOD treatment is 27 mg/(L*hr).



(i) DERIVE an equation of design for the hydraulic retention time of a basin CSTR using an equation of mass balance in steady state which incorporates the BOD removal kinetics,

(ii) Use this design equation to CALCULATE THE flowrate that the CSTR can accommodate.

(iii) Knowing that the PFR can outperform the CSTRs at some kinetic orders, you realize that by removing the mechanism of mixing and adding baffles to the CSTR basin, you can convert it into a PFR basin. Note that baffles reduce the volume of the basin of 15% (the volume of basin PFR = 0.85 times the volume of basin of CSTR). DERIVE an equation of design for the hydraulic retention time of a PFR using an equation of mass balance in steady state which incorporates the kinetics of removal of BOD.

(iv) Use this design equation to CALCULATE THE flow of a PFR basin that can accommodate the BOD treatment stated above.

(v) Does this make sense? And why?

B2 (30 points). The analysis of a river water yielded the following characteristics:

Parameter	Concentration (meq/L)
Ca^{+2}	4.5
Mg^{+2}	1
Na^{+1}	1.2
CO_3^{-2}	0.05
HCO_3^{-1}	6.2
SO_4^{-2}	0.24
Cl^{-1}	0.2

FIND

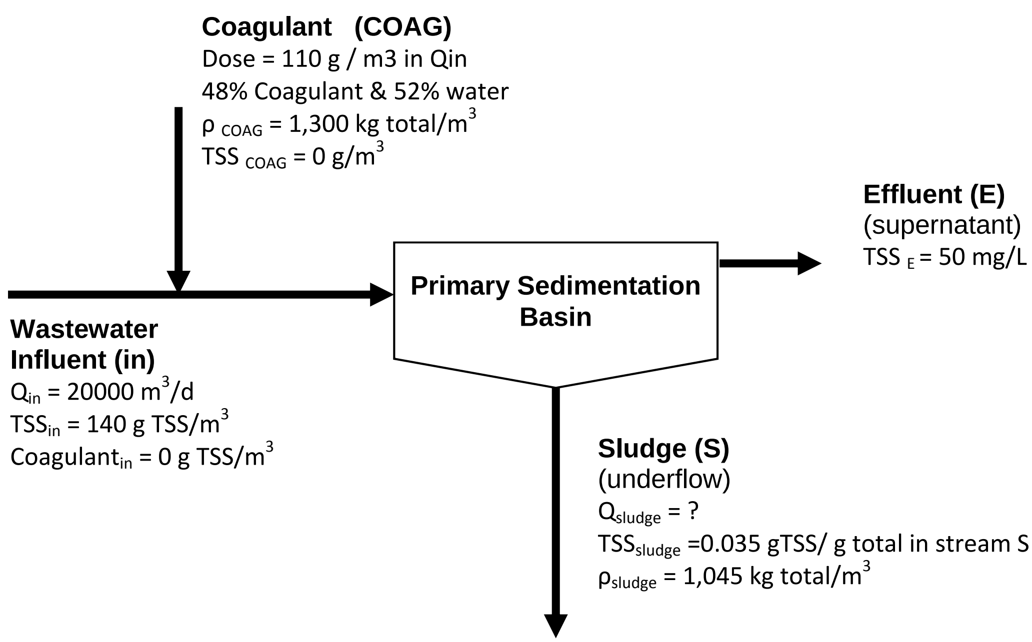
a) pH assuming the carbonate system is controlling buffering system
b) The OH- concentration (in mole/L)
c) The phenolphthalein alkalinity (in mg/L as $CaCO_3$)
d) The total alkalinity (in mg/L as $CaCO_3$)
e) The total hardness (in mg/L as $CaCO_3$)
f) How would this water be classified in terms of hardness?
g) The carbonate hardness (in mg/L as $CaCO_3$)
h) The non-carbonate hardness (in mg/L as $CaCO_3$)
i) Is this analysis accurate?

B3. (65 points) **The town of Riverside has a** primary sedimentation basin with an influent flow of 20000 m^3/d, which has an influent total suspended solids concentration of 140 mg TSS/L. To improve this process, stream COAG adds a coagulating chemical to remove phosphorus plus to bind particles, colloidal solids and dissolved substances (such as phosphorus) allowing them to grow and form settleable TSS and that are removed by the settling. The amount of coagulating chemical added is the equivalent to 110 g coagulant per m^3 of the influent wastewater (Qin). Assume all the coagulant reacts to create additional TSS, and the mass of this new TSS equals 0.8 of the mass of coagulant added. The resulting sludge stream has a density of 1,045 kg total/m^3 and its total suspended solids concentration is 0.035 gTSS/g total. The coagulant stream (COAG) has a density of 1,300 kg total/m^3, 48wt% of it is coagulant and 52 wt% water. COAG does not contain TSS or phosphorus. Assume the mass contribution of coagulant stream (COAG) to the system total mass balance is negligible. Note the coagulant added does not count as solids, but after it reacts it forms solids.

Calculate

(a) Q_{COAG}, the *volumetric flowrate of coagulant stream COAG (m^3/d);*

(b) Q_S, the *volumetric flow rate of sludge (m^3/d)* produced in the *underflow from this tank*,



Formula sheet

$$N = meq/L = \frac{mg/L}{eq.wt} = \frac{mg/L}{MW} z$$

$K_1 = \frac{[H^+]\cdot[HCO_3^-]}{[H_2CO_3^*]} = 4.47 \times 10^{-7}\ mol/L$	
$K_2 = \frac{[H^+]\cdot[CO_3^{-2}]}{[HCO_3^-]} = 4.68 \times 10^{-11}\ mol/L$	
$P_A = k_H^A \cdot x_A$	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$$\frac{dC}{dt} = r = -kC^n \qquad \frac{dC_A}{d\theta} = r_A = -kC_A^n$$

$$Acc. = (Q \cdot C_{A_{IN}}) - (Q \cdot C_{A_{OUT}}) - V \cdot r_A$$

C- 12, Ca- 40, Cl- 35.5, H- 1,

K- 39.1, Mg- 24.3, Na- 23, O- 16, S- 32.1