CE 111 Practice Exam 2

November 1, 2020

Time: 45 minutes

Name ________________________________

Please write your name in the space provided above and sign the Berkeley Honor Code at the end.

This is an open-book/open-note exam. Communication with other students in any form is prohibited during the exam.

Answer questions in the space provided following each question. Use extra blank page if you need more room. Please make sure that you write the final answer in the box when provided.

For problems that require calculations, you must clearly show the steps that you used in arriving at the answer. For such problems, presenting only the final answer without relevant steps will not be given any credit.

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1. (8 points) Please calculate the hardness and alkalinity of the following water.

Component	C (mg/L)
Ca^{2+}	80
Na^{+}	46
Mg^{2+}	12
HCO_3^-	122
SO_4^{2-}	9.6
Fe^{2+}	11.2
K^{+}	11.7
$C_6H_{12}O_6$ (sugar)	270
$C_{10}H_{22}$ (Decane, non-biodegradable)	71
pH7	

(a) Total Hardness: __270__ mg/L as $CaCO_3$.

Tot. hardness = $N_{Ca} + N_{Mg} + N_{Fe}$ = 270 mg/L as $CaCO_3$

$50\ \frac{mg\ CaCO_3}{meq} \times \left(\frac{80\ mg/L}{40\ g/mol} \times 2\ eq/mol + \frac{12\ mg/L}{24\ g/mol} \times 2\ eq/mol + \frac{11.2\ mg/L}{56\ g/mol} \times 2\ eq/mol\right)$

(b) Carbonate Hardness: __100__ mg/L as $CaCO_3$.

CH = $N_{CO_3^{2-}} + N_{HCO_3^-} = \frac{122\ mg/L}{61\ g/mol} \times 1\ eq/mol \times 50\ mg/meq$ = 100 mg/L as $CaCO_3$

(c) Alkalinity: __100__ mg/L as $CaCO_3$.

Alk = $[OH^-] + [HCO_3^-] + 2[CO_3^{2-}] - [H^+]$ = 100 mg/L as $CaCO_3$ ($[OH^-] = 10^{-7}$, $[CO_3^{2-}] \approx 0$, $[H^+] = 10^{-7}$)

(d) There is one major common anion missing from the table. It is __Cl^-__, and the concentration is __195.25__ mg/L.

Anion = $N_{HCO_3^-} + N_{SO_4^{2-}} = 1 \times \frac{122}{61} + 2 \times \frac{9.6}{96}$ = 2.2 meq/L

Cation = $N_{Ca^{2+}} + N_{Mg^{2+}} + N_{Fe^{2+}} + N_{Na^+} + N_{K^+}$ = 5.4 + $1 \times \frac{46}{23}$ + $1 \times \frac{11.7}{39}$ = 7.7 meq/L

$[Cl^-]$ = 35.5 mg/mmol × (7.7 − 2.2) = 195.25 mg/L

(e) The COD of the water is __536__ mg/L, and the BOD of the water is __288__ mg/L.

$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O$

$C_{10}H_{22} + 15.5O_2 = 10CO_2 + 11H_2O$

BOD = $\frac{270\ mg/L}{180\ g/mol} \times 6\ \frac{mol\ O_2}{mol\ sugar} \times 32\ g\ O_2/mol$ = 288 mg/L

COD = BOD + $\frac{71}{142} \times 15.5 \times 32$ = 288 + 248 = 536 mg/L

(f) What process in a drinking water facility could contribute to the removal of decane?

GAC **for small organic molecules**

2. (4 points) A river has a flowrate of 10 m^3/s and reoxygenation rate of 0.5 day^{-1}. The river water contains 10 mg/L BOD and 8 mg/L Disolved Oxygen (DO) before the discharging point of a cheese factory. A cheese factory discharges 10 MGD high-organic wastewater into the river and the wastewater contains 200 mg/L BOD and 0 mg/L DO. The deoxygenation rate of the river after receiving the wastewater is 0.3 day^{-1}. The river water temperature remains constant at 15 °C and the oxygen solubility at 15 °C is 10 mg/L. What is the DO level in the river after the river water travels 100 km downstream at a speed of 1 m/s?

4.75	mg/L

$u = 1 m/s$ → $Q_1 = 10 m^3/s$, $BOD_1 = 10 mg/L$, $DO_1 = 8 mg/L$

↓ $Q_2 = 10 MGD$, $BOD_2 = 200 mg/L$, $DO_2 = 0$

$DO_s = 10 mg/L$

$k_1 = 0.3/d$ deoxygenation rate $k_2 = 0.5/d$ regeneration rate

$$Q_2 = 10 MGD \times 0.044 \frac{m^3/s}{MGD} = 0.44 m^3/s$$

$$BOD_0 = \frac{Q_1 BOD_1 + Q_2 BOD_2}{Q_1 + Q_2} = \frac{10 \times 10 + 0.44 \times 200}{10 + 0.44} = 18 mg/L$$

$$DO_0 = \frac{Q_1 DO_1 + Q_2 DO_2}{Q_1 + Q_2} = \frac{10 \times 8 + 0.44 \times 0}{10 + 0.44} = 7.66 mg/L$$

$$D_0 = DO_s - DO_0 = 10 - 7.66 = 2.34 mg/L$$

$$u = 1 m/s \times 10^{-3} km/m \times 3600 \times 24 \ s/d = 86.4 m/s$$

$$D(100km) = \frac{k_1 BOD_0}{k_2 - k_1} \times \left(e^{-\frac{k_1 x}{u}} - e^{-\frac{k_2 x}{u}}\right) + D_0 \times e^{-\frac{k_2 x}{u}}$$

$$= \frac{0.3 \times 18}{0.5 - 0.3} \times \left(e^{-\frac{0.3 \times 100}{86.4}} - e^{-\frac{0.5 \times 100}{86.4}}\right) + 2.34 \times e^{-\frac{0.5 \times 100}{86.4}} = 5.25$$

$$DO(100km) = DO_s - D(100km) = 4.75 mg/L$$

3. (2 points) Which of the following species in a brackish water contribute the most to the osmotic pressure of the water?

$\Pi = nCRT$

(a) 0.1 M NaCl
(b) 0.07 M Na_2SO_4
(c) 0.08 M $CaCl_2$
(d) 0.2 M $C_6H_{12}O_6$

a) $\Pi = 2 \times 0.1 \cdot RT = 0.2RT$
b) $\Pi = 3 \times 0.07 RT = 0.21RT$
c) $\Pi = 3 \times 0.08 RT = 0.24RT$ ← $CaCl_2$ contributes the most
d) $\Pi = 1 \times 0.2 RT = 0.2RT$

What is the minimum energy to treat this brackish water?

$$E = \sum_1 \Pi_i V = (0.2 + 0.21 + 0.24 + 0.2) mol/L \times 8.314 J/mol\cdot k \times 293k \times 10^{-3} L/m^3$$
$$= 2.07 J/m^3$$

4. (3 points) A wastewater treatment facility has a flowrate of 0.4 m^3/s through a sedimentation tank with L=55m (length), W=10.7m (width), and H=3.0m (depth). For spherical particles with a density of san (2.65 g/cm^3), what is the smallest particle that is removed with 100% efficiency? (g=980 cm/s^2, $\mu = 0.01$ g/cm/s)

27.5 μm

From Stoke's law:

$$v = \frac{d_p^2 \cdot g(\rho - \rho_f)}{18\mu} = \frac{d_p^2 \times 9.8\ m/s^2 \times (2.65-1)\times 10^3\ kg/m^3}{18 \times 10^{-3}\ kg/m\cdot s} = d_p^2 \times 8.98 \times 10^5 /m\cdot s$$

$$V_c = \frac{Q}{A_s} = \frac{Q}{L \times W} = \frac{0.4\ m^3/s}{55m \times 10.7m} = 6.79 \times 10^{-4}\ m/s$$

For 100% removal $\frac{V}{V_c} = 100\% \Rightarrow \frac{d_p^2 \times 8.98 \times 10^5 /m\cdot s}{6.79 \times 10^{-4}\ m/s} = 1$

$d_p = 2.75 \times 10^{-5} m = 27.5\ \mu m$

5. (3 points) A municipal drinking water facility discovers pesticide in the water and decide to use PAC for the pesticide removal. Research found the isotherm for the removal to be $q_e = 266C_e^{0.41}$, where C_e and q_e have the unit of mg/L and mg/g, respectively. The facility needs to treat 0.4 m3/s water, and the untreated water contains 1 mg/L pesticide and MCL for the pesticide in drinking water is 0.04 mg/L. Please calculate the daily PAC consumption in the facility.

4.7×10^5 g/d

$C_e = 0.04\ mg/L$

$q_e = 266 \times 0.04^{0.41} = 71.08\ mg/g_{PAC}$

$$\frac{W}{V} = \frac{C_{init} - C_{fin}}{-(q_{init} - q_{fin})} = \frac{(1 - 0.04)\ mg/L}{-(0 - 71.08)\ mg/g\ PAC} = 0.014\ g\ PAC/L$$

$W = V \times 0.014 = 0.4\ m^3/s \times 10^3$ L/m3 $\times 3600 \times 24\ s/d \times 0.014\ g\ PAC/L$

$= 4.7 \times 10^5\ g/d$

Signature:__________________________________

I pledge my honor that I have not violated the Berkeley Honor Code during this examination.

This is the end of the exam.