

CVEN 5534, Fall 2010
Homework 3 solutions

1. Assume influent $COD_s = 400 \text{ g/m}^3$

$$\Delta COD_s \text{ consumed} = 0.95(400) = 380 \text{ g/m}^3$$

$$Q(\Delta COD_s) = \frac{380 \text{ g}}{\text{m}^3} \cdot \frac{70 \text{ m}^3}{\text{min}} \cdot \frac{(1440 \text{ min})}{\text{d}} \cdot 10^{-3} \frac{\text{kg}}{\text{g}} = 3.83 \times 10^4 \frac{\text{kg COD}_s}{\text{d}}$$

$$R_s = -3.83 \times 10^4 \frac{\text{kg COD}_s}{\text{d}}$$

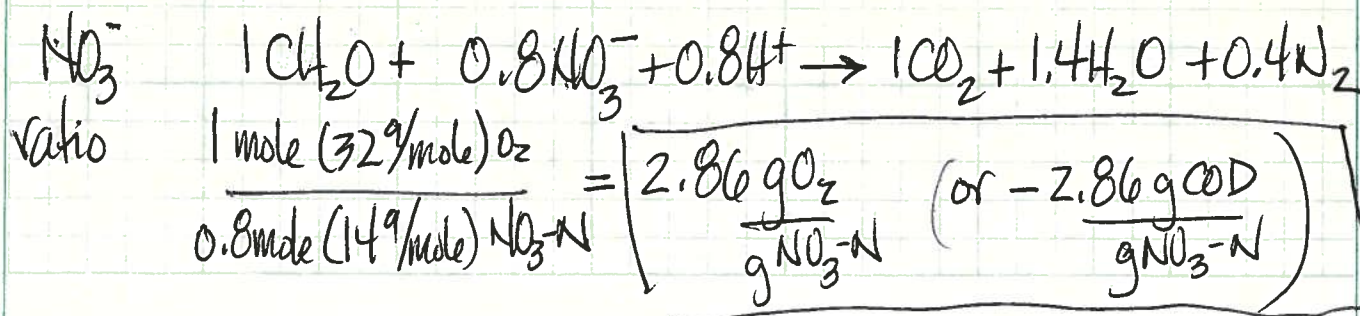
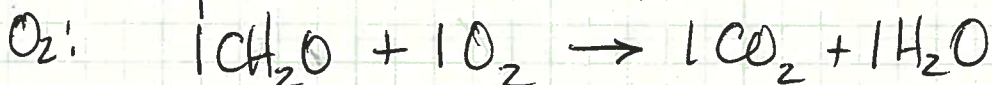
a. $R_{O_2} = (1 - Y) R_s = 0.65(3.83 \times 10^4) = \boxed{2.49 \times 10^4 \frac{\text{kg O}_2}{\text{day}}}$
(Given $1 \text{ kg COD} = 1 \text{ kg O}_2$)

$$R_x = Y R_s = 0.65(3.83 \times 10^4) = 1.34 \times 10^4 \frac{\text{kg COD}_x}{\text{d}}$$

$$R_x = 1.34 \times 10^4 \frac{\text{kg COD}_x}{\text{d}} \cdot \frac{1 \text{ kg cells}}{(1.42 \text{ kg COD})} \cdot \frac{365 \text{ d}}{\text{yr}}$$

b. $R_x = \boxed{3.45 \times 10^6 \frac{\text{kg cells}}{\text{yr}}}$

2. compare O_2 and NO_3^- as electron acceptors in respiration of 1 mole of CH_2O



3. Bad problem statement - credit to all

What I meant:

$$Y = 0.4 \frac{g \text{ COD}_x}{g \text{ COD}_s} \quad \& \quad Y_{obs} = 0.32 \frac{g \text{ COD}_x}{g \text{ COD}_s}$$

a. meant to say 30% of lost cells ($Y - Y_{obs}$) are lysed (and available as substrate)

$$\text{Lost cells} = \frac{0.4 - 0.32}{1} g \text{ COD}_x = 0.08 \frac{g \text{ COD}_x}{g \text{ COD}_s}$$

$$\text{Lysed cells recycled} = 0.3(0.08) = \boxed{0.024 \frac{g \text{ COD}_x}{g \text{ COD}_s}}$$

b. then COD_d (debris) is

$$\text{COD}_d = 0.7(0.08) \frac{g \text{ COD}_d}{g \text{ COD}_s} = \boxed{0.056 \frac{g \text{ COD}_d}{g \text{ COD}_s}}$$

So for biodegradation of 1 gram COD_s you get

0.32 g COD_x (viable cells)

0.024 g COD_x (lysed COD recycled)

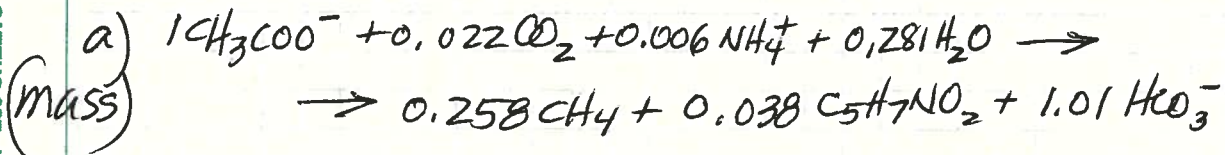
0.056 g COD_d (debris COD)

neglecting further metabolism of COD_d etc, etc...

$$5. \psi_1 = 1, \psi_2 = \frac{0.03(44)}{1(59)} = 0.0224, \psi_3 = \frac{0.02(18)}{1(59)} = 0.006,$$

$$\psi_4 = \frac{0.92(18)}{1(59)} = 0.281, \psi_5 = \frac{0.95(16)}{1(59)} = 0.258, \psi_6 = \frac{0.02(18)}{1(59)} = 0.038$$

$$\psi_7 = \frac{0.98(61)}{1(59)} = 1.01 \quad \text{check } \sum_1 \psi_r = 1.31, \sum_5 \psi_p = 1.31 \checkmark$$



b) (COD) $\gamma_1 = 1, \gamma_3 = \frac{0.258(4)}{1(1.08)} = 0.956, \gamma_4 = \frac{0.038(1.42)}{1(1.08)} = 0.05$

NOTE: NH_4^+ has no COD equivalents in this reaction
 Since NH_4^+ is not oxidized during cell synthesis
 CO_2 also assumed to have no COD even though it is
 e^- acceptor since it is also a product
 of CH_3COO^- oxidation: $\text{CH}_3\text{COO}^- + \text{H}^+ \rightarrow \text{CO}_2 + \text{CH}_4$
 to CH_4

$$\boxed{1 \text{COD}_{\text{CH}_3\text{COO}^-} \rightarrow 0.956 \text{COD}_{\text{CH}_4} + 0.05 \text{COD}_{\text{C}_5\text{H}_7\text{NO}_2}}$$

$$1 - 0.956 - 0.05 = -0.006 \text{ close enough}$$

c) $500 \text{ kg CH}_3\text{COO}^- \left(0.258 \frac{\text{kg CH}_4}{\text{kg CH}_3\text{COO}^-} \right) = 129 \text{ kg CH}_4$

$\frac{129 \text{ kg CH}_4}{16 \frac{\text{kg}}{\text{kmole}}} = 8.06 \text{ kmol CH}_4$, assume CH_4 is ideal gas

$$PV = nRT$$

($\text{C}_5\text{H}_7\text{NO}_2 = \text{VSS}$) $V = 8.06 \text{ kmol} \left(82.05 \frac{\text{L} \cdot \text{atm}}{\text{kmol} \cdot \text{K}} \right) \frac{(273+35) \text{ K}}{1 \text{ atm}} \cdot 10^{-3} \frac{\text{m}^3}{\text{L}}$
 $= 204 \text{ m}^3 \text{ CH}_4$

d) $500 \text{ kg CH}_3\text{COO}^- \left(0.038 \right) \frac{\text{kg VSS}}{\text{kg CH}_3\text{COO}^-} = 19 \text{ kg VSS/d}$

COD AND NITROGEN STOICHIOMETRIC AND KINETIC MATRIX FOR GROWTH AND DECAY

Components								Rates
Process	Soluble COD S_s (mg/L COD)	Soluble NH_4 -N S_{NH} (mg/L N)	Dissolved O_2 , S_o (mg/L O_2)	Heterotrophic biomass, X_{BH} (mg/L COD)	Autotrophic (Nitrifying) Biomass, X_{BA} (mg/L COD)	Debris, X_D (mg/L COD)	Ammonia N in cells X_{NB} (mg/L N)	r_j
Aerobic Heterotrophic Growth	$-\frac{1}{Y_H}$	$-\dot{C}_{NH_3}$	$-\frac{(1-Y_H)}{Y_H}$	/	—	—	$\dot{C}_{N \times B}$	1 and 1a $\mu_H X_{BH}$
Aerobic Growth of Autotrophs (Nitrification)	—	$-\frac{1}{Y_A}$	$-\frac{(4.57-Y_A)}{Y_A}$	—	/	—	—	2 $\mu_A X_{BA}$
Decay and Lysis of Heterotrophs	$1-f_D$	—	—	—/	—	f_D	—	3 $b_H X_{BH}$

And reaction rates are

$\mu_H * X_{BH}$ = growth rate for heterotrophs (d^{-1})

$\mu_A * X_{BA}$ = growth rate for autotrophs (d^{-1})

$b_H * X_{BH}$ = decay rate for heterotrophs (d^{-1})

- c. Give the total rate expressions for ammonia nitrogen, heterotrophic bacteria, autotrophic bacteria, debris, soluble COD, and oxygen considering the reactions 1, 1a, 2, and 3

6c (really b)

$$r_{NH} = -i_{NXB} (\mu_H X_{BH}) - \frac{1}{Y_A} \mu_A X_{BA}$$

$$r_{XBH} = \mu_H X_{BH} - b_H X_{BH}$$

$$r_{XBA} = \mu_A X_{BA} \quad (\text{neglect decay of } X_A)$$

$$r_{XD} = f_D b_H X_{BH}$$

$$r_S = -\frac{1}{Y_H} \mu_H X_{BH} + (1-f_D) b_H X_{BH}$$

$$r_{O_2} = -\left(\frac{1-Y_H}{Y_H}\right) \mu_H X_{BH} - \frac{(4.57-Y_A)}{Y_A} \mu_A X_{BA}$$