Seoul National University

457.621.001

Biological Processes in Environmental Engineering

FINAL EXAMINATION

TIME ALLOWED: 75 MINUTES

November 10, 2015

---

1. Students may use two double-sided, A4 notes prepared in their own handwriting. Mechanical or electronic reproduction of any notes are not allowed.

2. Students should bring their own calculator which is not pre-programmed with formulae from the class.

3. Be aware that the cheated student will get 80% of the lowest score in class! There is no tolerance at all.

4. Make sure your answers include units if appropriate. Watch your units! Prepare your answers in a logical, easy-to-follow format.

5. This exam contains 5 questions. Each full question is worth 20 to 25 points. Total points = 110.

Use following values for physical constants and properties, if needed:

Atomic weights: C, 12; H, 1; N, 14; O, 16

1. Mark O or X for the following statements.

Note: This is a bet! +2.5 points for correct answers, -2 points for incorrect answers, and 0 point if you choose not to answer.

i) 16S rRNA is used for phylogenetic classification (i.e., classification based on phylogeny) of all prokaryotes and eukaryotes.

ii) For an enzyme reaction following the Michaelis-Menten kinetics, the reaction speed is 1/3 of the maximum value (i.e., $v=v_m/3$) when the substrate concentration is half the value of K_M (i.e., $[S]=K_M/2$).

iii) Under a sufficiently high concentration of a substrate, the enzyme reaction is not significantly affected by a competitive inhibitor.

iv) Bacterial cells are generally assumed to be 100% biodegradable.

v) If a reaction is at zero order, a PFR (plug flow reactor) shows better performance than a CSTR (continuously stirred tank reactor).

vi) If a reaction is at second order, a PFR (plug flow reactor) shows better performance than a CSTR (continuously stirred tank reactor).

vii) A/O process is generally applied for the biological treatment of nitrogen and phosphorus.

viii) One of the advantage of a membrane bioreactor over a conventional activated sludge process is that a higher biomass concentration can be maintained in the aeration basin.

2. *Dehaloccoides ethenogens* is a bacterial strain that is isolated in a TCE (trichloroethylene) contaminated site. The strain is found to use TCE (CCl_2=CHCl) as an electron acceptor, converting it to vinyl chloride (VC; CHCl=CH_2) or ethylene (CH_2=CH_2).

   i) It is also found that the strain obtains energy by oxidizing H_2 and carbon from organic matter. When exposed to oxygen, the strain is completely inactivated. According to the information above, classify the bacterial strain in the following categories:

      a) By energy source: phototroph, organochemotroph, or lithochemotroph

      b) By carbon source: autotroph or heterotroph

      c) By growth in the presence/absence of O_2: obligate anaerobe, aerotolerant anaerobe, obligate aerobe, or facultative aerobe

(10 points)

   ii) Write electron donor and acceptor half reactions, and the overall energy reaction for the biological conversion of TCE into ethene by this strain. (10 points)

3. You are thinking of applying aerobic biodegradation by microorganisms to treat petroleum waste. By elemental analysis, you found that the waste can be represented by C_3H_5. With the information, answer questions below.

i) Write electron donor and acceptor half reactions. (10 points)

ii) Using the following cell formation half reaction and an f_s value of 0.15, calculate the carbon-to-nitrogen ratio (g waste carbon / g NH_4-N) that should be maintained to support microbial growth. (15 points)

$$\frac{1}{5}CO_2 + \frac{1}{20}HCO_3^- + \frac{1}{20}NH_4^+ + H^+ + e^- = \frac{1}{20}C_5H_7O_2N + \frac{9}{20}H_2O$$

4. You constructed a laboratory chemostat (CSTR) for the aerobic treatment of wastewater. Using the following parameters, answer the questions.

$\theta = 1\ d$

$S^0 = 1000\ mg\ COD/L = 1000\ mg\ BOD_L/L$ (all soluble)

$X_a^0 = 0,\ \ X_i^0 = 0$

$\hat{q} = 10\ mg\ COD/mg\ VSS_a - d$

$K = 10\ mg\ COD/L$

$b = 0.1/d$

$Y = 0.5\ mg\ VSS_a/mg\ COD$

$f_d = 0.8$

i) Calculate the percent removal of i) total COD, ii) total BOD_L, and iii) soluble COD by the chemostat. Neglect the production of SMPs (soluble microbial products). (15 points)

ii) The dissolved oxygen (DO) concentration of the influent wastewater is 7 mg/L. How much oxygen (in g O_2/m^3-d) should be provided into the chemostat to maintain the DO level of the chemostat at 3 mg/L? (10 points)

5. You are applying an attachment growth process for the nitrification of wastewater containing ammonia. For this process, sketch the concentration profile of ammonia and nitrate of a biofilm composed of nitrifying bacteria for i) a deep biofilm and ii) a shallow biofilm. Include the effective diffusion layer.

   * If you think your drawing is unclear, please indicate the shape in words (e.g., curvilinear, linear, constant, etc.)

(20 points)