GEORGIA INSTITUTE OF TECHNOLOGY

School of Civil & Environmental Engineering

CEE 2300 – Environmental Engineering Principles

Instructor: S. G. Pavlostathis **Spring 2013**

EXAM 1 – Closed Book & Notes

DATE: Wednesday, February 13, 2013

TIME: 1:35 to 2:55 PM

NAME: ___________________________

Student ID #: _____________________

1. ________/25
2. ________/25
3. ________/25
4. ________/25

TOTAL: ________/100

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1. **(25 points)** Briefly explain/answer the following:

1-a) The meaning of "the tragedy of the commons"; provide an example related to environmental degradation/pollution.

1-b) What were/are the environmental and socio-economic impacts of the April 20, 2010 BP oil spill?

1-c) When was the US Environmental Protection Agency (US EPA) established, who was the US President at that time, and what was/were the purpose/reasons for the establishment of the US EPA?

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1-d) Globally speaking, what are the environmental and social consequences of large-scale biofuel production? List at least four (4) such impacts.

1-e) Explain why in the last two decades the CO_2 emissions due to consumption of goods and services in developed countries exceeded the CO_2 emissions due to production of goods and services.

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2. **(25 points)** Methane (CH_4) can be produced by microorganisms by the reduction of CO_2 by molecular hydrogen (H_2) as follows:

$$H_2 \quad + \quad CO_2 \quad \rightarrow \quad CH_4 \quad + \quad \text{product}$$

A. Balance the above equation and name the product on the right.

B. If H_2 and CO_2 are supplied in a gas mixture of N_2, H_2, and CO_2 at a total pressure of 1 atm and in which the partial pressure of N_2 (i.e., pN_2) is 0.5, calculate the partial pressures of H_2 and CO_2 according to the balanced stoichiometric equation you completed in part A, above.

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3. **(25 points)** A wastewater with nitrogen in the form of dissolved ammonia (NH_3) and ammonium (NH_4^+) has a total nitrogen (i.e., $[NH_4^+] + [NH_3]$) concentration of 7.1×10^{-4} mol/L. The Henry's constant (K_H) at 25°C is 57 mol/L • atm. The equilibrium equation is:

$$NH_4^+ \leftrightarrow H^+ + NH_3 \qquad K_a = 10^{-9.26}$$

The fraction of nitrogen in the ammonia form, which is strippable, as a function of pH is given by the following equation:

$$NH_3\, fraction = \frac{[NH_3]}{[NH_3]+[NH_4^+]} = \frac{1}{1+10^{(9.26-pH)}}$$

The wastewater pH is raised to 10 and the incoming air used for stripping of ammonia out of the wastewater has an ammonia partial pressure of 5×10^{-10}.

A. What would be the equilibrium concentration of total nitrogen (i.e., $[NH_4^+] + [NH_3]$) in the wastewater after air stripping? Assume equilibrium between air and wastewater and total gas pressure equal to 1 atm.

B. Under the above conditions, what percentage of the total wastewater nitrogen would be removed?

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4. **(25 points)** Ozone (O_3) is a highly reactive oxidant used for the disinfection of drinking water. It is found that the ozone destruction in water follows fist-order kinetics with respect to the aqueous ozone concentration, such that its concentration decreases by 50% in 12 minutes (i.e., $t_{1/2}$ = 12 minutes). Estimate the initial ozone concentration in mg/L necessary to treat water for 40 minutes and result in a residual ozone concentration of 1 mg/L.

EMPTY PAGE

NAME: ______________________________

APPENDIX – USEFULL EQUATIONS & DATA

Atomic weights: H =1, O = 16, C = 12, N = 14, S = 32, P = 31, Ca = 40, F = 19, Al = 27, Na = 23
Mg = 24.3

Oxidation states: H = +I, O = -II, C = -IV to +IV, N = -III to +V, S = -II to +VI

Ideal gas law: $PV = nRT$ $\quad R = 0.082\ 06$ atm • L/mol • K

Absolute temperature: $K = {}^{o}C + 273.15$
${}^{o}R = {}^{o}F + 459.67$

Water: $[H^+]\,[OH^-] = K_w = 10^{-14}$ $(mol/L)^2$ @ 298 K

pH: $pH = -\log [H^+]$ $\quad [H^+]$ in units of mol/L

Acetic acid: $AcH \Leftrightarrow Ac^- + H^+$ $\quad pK_a = 4.7$

Carbonate system (@ 298 K):
- $[CO_2]_{aq} = K_H\, pCO_2\, P_{total}$ $\quad K_H = 0.0334$ mol/L · atm
- $CO_{2,\,aq} + H_2O \Leftrightarrow H^+ + HCO_3^-$ $\quad K_1 = 4.47 \times 10^{-7}$ mol/L
- $HCO_3^- \Leftrightarrow H^+ + CO_3^{2-}$ $\quad K_2 = 4.68 \times 10^{-11}$ mol/L

Gibbsite (@ 298 K): $Al(OH)_{3\,(s)} \Leftrightarrow Al^{3+} + 3\ OH^-$ $\quad K_{sp} = 1 \times 10^{-32}$ mol^4/L^4

Henry's law

Gas to Liquid transfer: $pA_{gas} = k_H\, [A]_{aq}\, 1/P_T$
- pA_{gas} = partial pressure of A gas, dimensionless
- k_H = Henry's law constant, L • atm/mol
- $[A]_{aq}$ = aqueous-phase concentration of A, mol/L
- P_T = total pressure, atm

Liquid to Gas transfer: $[A]_{aq} = K_H\, pA_{gas}\, P_T$ $\quad K_H$ = Henry's law constant, mol/L • atm

Kinetics

Zero order:	$dC/dt = \pm k$	$C_t = C_o \pm k\,t$
First order:	$dC/dt = \pm k\,C$	$C_t = C_o \exp(\pm k\,t)$
Second order:	$dC/dt = \pm k\,C^2$	$C_t = C_o/(1 -/+ C_o\,k\,t)$