CE111 Information Sheet for Exam 1

Atomic Weights (*g/mole*)

H=1	He=4	C=12	N=14	O=16	Na=23	Mg=24	Al=27	Si=28	P=31
S=32	Cl=35	K=39	Ca=40	Cr=52	Mn=55	Fe=56	Cu=63	Zn=65	As=75
Br=80	Ag=108	I=127	Hg=200	Pb=207					

Density: $\rho_{water} = 1000\ kg/m^3 = 1\ kg/L$; $\rho_{air} = 1200\ g/m^3$
Specific heat capacity: $C_{air} = 1\ J/g\text{-}K$; $C_{water} = 4.2\ J/g\text{-}K$
Standard Temperature: $298\ K = 25\ ^oC$

Pressure: $1\ atm = 1.01 \times 10^5\ Pa$; $1\ atm = 14.7\ psi$; $1\ psi = 2.31\ ft\ of\ water$
Energy: $1\ J = 1\ Pa\text{-}m^3 = 1\ kg\text{-}m^2/s^2 = 1\ N\text{-}m$; $1\ kJ = 1000\ J$; $1\ kWh = 3600\ kJ$; $1\ BTU = 1.054\ kJ = 0.000293\ kWh$
Power: $1\ W = 1\ J/s = 1\ Pa\text{-}m^3/s$
Weight: $1\ kg = 1000\ g$; $1\ g = 1000\ mg$; $1\ lb = 454\ g = 0.454\ kg$;
Volume: $1\ m^3 = 1000\ L = 10^6\ mL$; $1\ Gal = 3.78\ L$; $1\ ft^3 = 7.48\ Gal = 28.3\ L$
Length: 1 km = 1000m; $1\ m = 100\ cm = 1000\ mm$; $1\ m = 3.28\ ft$; $1\ ft = 12\ inch$; $1\ inch = 2.54\ cm$
Concentration: $1\ M = 1\ mole/L$; 1 ppm = 1 mg/L
Temperature: $T(K) = 273 + T\ (^oC)$
Time: $1\ h = 60\ min = 3600\ s$; $1\ d = 24\ h$;
Flow rate: $1\ MGD\ (Million\ Gallons\ perday) = 3.78 \times 10^6\ L/d$

Equilibrium Constants for Weak Acids

Acid	Dissociation Reaction	pKa
Acetic acid	$CH_3COOH \Leftrightarrow H^+ + CH_3COO^-$	4.75
Hypochlorous acid	$HOCl \Leftrightarrow H^+ + OCl^-$	7.54
Carbonic acid	$H_2CO_3^* \Leftrightarrow H^+ + HCO_3^-$	6.35
	$HCO_3^- \Leftrightarrow H^+ + CO_3^{2-}$	10.33

* refers to both true acid, H_2CO_3 and dissolved CO_2 because they cannot be distinguished in water.

Equilibrium Solubility Constants

Substances	Dissociation Reaction	pKs
Aluminum hydroxide	$Al(OH)_3\ (s) \Leftrightarrow Al^{3+} + 3OH^-$	32.9
Aluminum phosphate	$AlPO_4\ (s) \Leftrightarrow Al^{3+} + PO_4^{3-}$	20.0
Calcium carbonate	$CaCO_3(s) \Leftrightarrow Ca^{2+} + CO_3^{2-}$	8.3
Calcium sulfate	$CaSO_4(s) \Leftrightarrow Ca^{2+} + SO_4^{2-}$	4.31
Magnesium hydroxide	$Mg(OH)_2\ (s) \Leftrightarrow Mg^{2+} + 2OH^-$	11.25

Equilibrium between Aqueous and Gas Phases

$$C = K_H P$$

Reaction Kinetics and Reactors

Order	Rate Equations	Batch Reactor	PFR	CFSTR
0	$\frac{d[C]}{dt} = -k$	$[C]-[C]_0=-kt$	$C_{out}=C_{in}-kt$	$C_{out}=C_{in}-kt$
1	$\frac{d[C]}{dt} = -k[C]$	$\ln[C]-\ln[C]_0=-kt$	$C_{out}=C_{in}\exp(-kt)$	$Cout = \frac{Cin}{1+kt}$
2	$\frac{d[C]}{dt} = -k[C]^2$	$\frac{1}{[C]} - \frac{1}{[C]_0} = kt$	$C_{out}=\left(\frac{1}{Cin} + kt\right)^{-1}$	$ktC_{out}^2+C_{out}-C_{in}=0$

CE 111 Midterm Exam 1

Total points: 20 Oct 4, 2021

Time: 50 minutes test

Instructions: This is a closed-book/closed-note exam. Communication with other students in any form is prohibited during the exam. Please ***sign the Berkeley Honor Code***.

Please answer questions in the **Answer Sheet** provided. Please write your name on each page. Please only submit the answer sheets without stapling them.

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 full credit.

If you believe insufficient information is provided to answer a question, make reasonable assumptions, and proceed from there.

If not specified in the problem, you can assume standard conditions, i.e., 298 K and 1 atm.

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1. (4 points) A 10 MGD (million gallons per day) plant discharges a wastewater containing 10 mg/L Pb and 0.5 mg/L Hg into Potomac River. The river upstream from the plant already contains 0.1 mg/L Pb and 0.05 mg/L Hg. The Pb concentration in the river downstream from the plant is measured to be 1 mg/L. What is the Hg concentration in the river downstream from the plant?

2. (3 points) Please balance the following reaction:
   $\mathbf{NH_4^+ + HOCl \rightarrow N_2 + Cl^- + H^+ + H_2O}$

3. (4 points) (a) What is the pH of a 10^{-11} M H_2SO_4 solution?
   (b) What is the pH of a 10^{-3} M NaOH solution?
   (c) If you mix a large amount of $Mg(OH)_2$ solid into pure water so that when it reaches equilibrium, there is still undissolved $Mg(OH)_2$. What is the pH of the water at equilibrium?

4. (2 points) A reaction is a first order reaction if (choose **all** that apply)
   a) the reaction rate can be described by $dC/dt = kC$
   b) the reaction rate can be described by $dC/dt = -kt$
   c) the reaction rate can be described by $dC/dt = -k$
   d) the reaction rate constant is 1 mg/L/min
   e) the reaction rate constant is 1 min^{-1}
   f) the reaction rate constant is 1 L/mg/min
   g) there is a linear relationship between C and t
   h) there is a linear relationship between ln(C) and ln(C_0)
   i) there is a linear relationship between ln(C/C_0) and t
   j) there is a linear relationship between C^{-1} and C_0^{-1}

5. (7 points) A lagoon is used to treat 200 m^3/h of sewage containing 100 mg/L of organic matter.
   (a) The volume of the lagoon is not known, so you decided to run a tracer test by continuously dosing a tracer into the influent and monitoring tracer concentration in the effluent from the lagoon. After obtaining the data, you plotted them in Figure 1. Please

determine the volume (V) of the lagoon based on the tracer results.

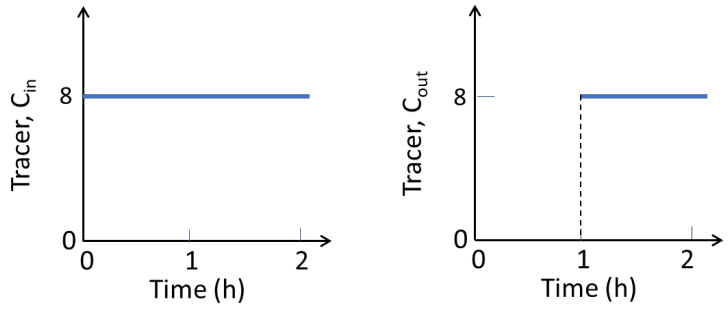

Figure 1. The concentration of tracer in the influent and effluent during the tracer test.

(b) Is the lagoon a PFR or CFSTR?

(c) You used a batch reactor in the lab to determine the degradation rate of the organic matter. By measuring the concentration of organic matter as a function of time and analyzing the results, you generated the three plots in Figure 2. Please use the plots to determine the degradation rate constant (k) and the reaction order.

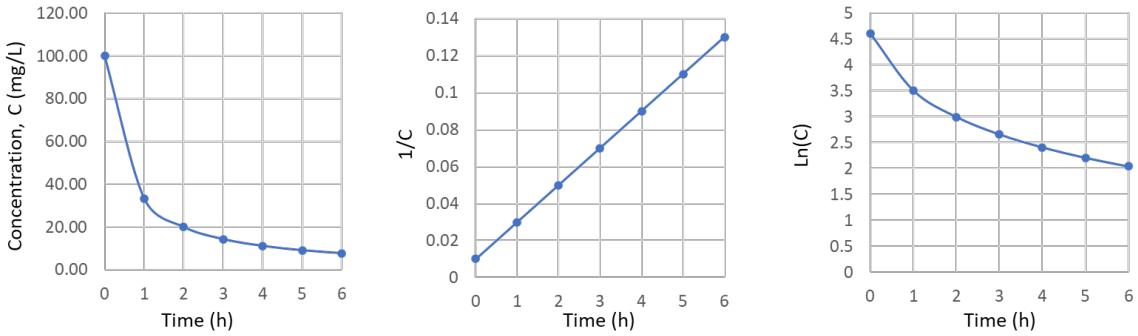

Figure 2. The batch reactor test results.

(d) EPA requires that the organic matter concentration in the wastewater effluent must be below 20 mg/L. What is the organic concentration in the effluent from the lagoon and can it meet the EPA standard?

(e) To smooth out some fluctuation in the sewage flow, a 200 m^3 CFSTR was added in front of the lagoon. What will be the organic concentration in the effluent of the lagoon after adding the CFSTR?

(f) You perform another tracer test after adding the CFSTR. The tracer concentration in the influent is 8 mg/L. Please sketch the effluent tracer concentration as a function of time. Please be as quantitative as possible.

*CE 111 Midterm Exam 1 Answer Sheets Name*_____

Problem 1:

Problem 2:

Problem 3:

Problem 4:

Problem 5:

Signature:_____

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