GEORGIA INSTITUTE OF TECHNOLOGY
School of Civil & Environmental Engineering
CEE 2300 – Environmental Engineering Principles
Instructor: S. G. Pavlostathis **Spring 2014**

EXAM 1 – SOLUTIONS

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

1-a) Who was Dr. John Snow and what was his contribution relative to public health?
In 1854, during the cholera epidemic, M.D. John Snow linked the cholera fatalities to water supply in a district of London around the Broad Street Pump, which supplied contaminated water from the Thames River. It is the earliest epidemiological study which provided a demonstration of the relationship between contaminated water and a disease (cholera). His work is remarkable as it proceeded the discovery of the germ theory of disease by Koch in 1876 (see D+M, p. 5; slide 7).

1-b) What was the environmental impact of the chemical spill this past January near Charleston, West Virginia? What hampered/complicated the response of the local authorities? What action did the CDC take?
For extra 5 pts, name and draw the structure of the main chemical in the spill.
- A chemical storage tank, owned by Freedom Industries, which contained 4-methylcyclohexanemethanol (MCHM), a chemical used to process coal, leaked and contaminated the nearby Elk River, which is about 1 mile upstream from the intake pipe for Charleston's water supply system, thus contaminating the city's drinking water.
- Lack of hazard and toxicity data hampered the response of the authorities to the chemical spill.
- The CDC established a short-term screening level of 1 part per million (ppm) for the MCHM spill in the Elk River.
- Extra 5 pts:
4-methylcyclohexanemethanol (MCHM)

1-c) What is the difference between environmental laws and environmental regulations?
- Laws are passed by the Congress, signed by the President; they are very general, mainly stating the purpose.
- Regulations set specific requirements about what is legal and what isn't; they set limits that are enforced. Environmental regulations are developed by the Environmental Protection Agency

1-d) Globally speaking, what are the two drivers of environmental change? Briefly explain how each of these drivers exerts pressure on the environment.
Drivers: population growth and economic development
Pressure:
- Population growth leads to increased demand on resources, even to satisfy basic human needs (e.g., food, water, etc.).
- Economic development aims at improving the living standards, thus increasing the demand on resources beyond the basic human needs.

1-e) Describe Photochemical Smog and name the main air pollutants involved listed by the type of source.
Photochemical Smog: The production of secondary (photochemical) air pollutants, such as ozone, fine PM, etc., by the reaction of sunlight with primary air pollutants emitted to the atmosphere from three sources:
- Biogenic sources (mainly plants): VOCs (e.g., isoprene)
- Stationary sources (mainly industry, power plants): PM, SO_2, NO_x
- Mobile sources (mainly cars and trucks): PM, CO, NO_x, VOCs

2. **(25 points)** Calculate the volume (in mL) of liquid pure sulfuric acid (H_2SO_4) needed to make 100 L of an aqueous solution with pH of 2.7. What is the molar concentration of the solution? The density of sulfuric acid is 1.84 g/mL.

Solution:

pH = - log [H^+] ➔ [H+] = 10^{-pH} = $10^{-2.7}$ = 0.002 M

$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$ (Note: valence, z = 2)

Based on the valence, z = 2 ➔ the sulfuric acid solution should be equal to 0.001 M

Sulfuric acid MW = 2(1) + 32 + 4(16) = 98 g/mol

Thus, to make 100 L of 0.001 M you need: 0.001 mol/L x 98 g/mol x 100 L = 9.8 g

In terms of volume, you need: 9.8 g x (1/1.84 mL/g) = **5.33 mL pure sulfuric acid**

Molar concentration of the solution: **0.001 M**

3. (25 points) Calculate the concentration in moles/L (or M) of each ion released when excess dolomite [$CaMg(CO_3)_2$] is dissolved in pure water at 25°C in a closed to the atmosphere system at equilibrium. Consider only dissolution and assume that the carbonate ion does not participate in the carbonate system equilibrium. The solubility product for dolomite at 25°C is $K_{sp} = 10^{-17.1}$.

Solution:

$CaMg(CO_3)_2 \longrightarrow Ca^{2+} + Mg^{2+} + 2CO_3^{2-}$

For s moles of dolomite dissolved, the product ions will be:

$Ca^{2+} = s$
$Mg^{2+} = s$
$CO_3^{2-} = 2s$

Write the equilibrium equation:

$[Ca^{2+}] [Mg^{2+}] [CO_3^{2-}]^2 = K_{sp} = 10^{-17.1}$

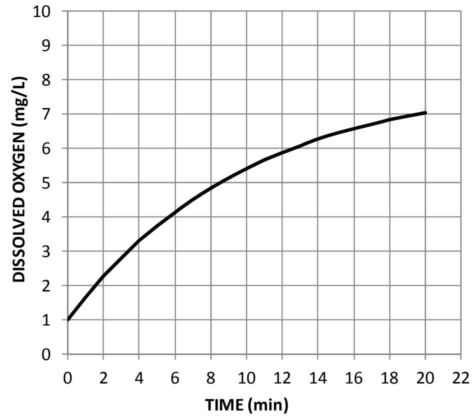
Or $(s)(s)(2s)^2 = 4 s^4 = 10^{-17.1}$

Solve for s: $s = (10^{-17.1}/4)^{1/4} = 3.75 \times 10^{-5}$ M

Thus, the ion concentrations will be:

Ca^{2+} = **3.75×10^{-5} M**
Mg^{2+} = **3.75×10^{-5} M**
$CO_3^{2-} = 2 (3.75 \times 10^{-5}$ M$)$ = **7.51×10^{-5} M**

4. (25 points) An oxygenation test of wastewater performed at a total gas pressure of 1 atm using air containing 21% oxygen, resulted in the graph shown on the right (dissolved oxygen, mg/L versus time, min). Under the conditions of this test, the Henry's law constant (K_H) was 0.00119 mol/L • atm. Calculate the DO saturation concentration (C_s) value in mg/L and the oxygen mass transfer coefficient (k_a, min^{-1}).



Solution:

$[O_2]_{aq} = K_H\, pA_{gas}\, P_T$ = (0.00119 mol/L • atm)(0.21)(1 atm) = 0.00025 mol/L

MW of O_2 = 2(16) = 32 g/mol

DO = (0.00025 mol/L)(32 g/mol)(1000 mg/g) = **8 mg/L**

The equation for gas transfer to water is: $\ln [(C_s-C_t)/(C_s-C_o)] = -k_a\, t$ (1)

Or solving for k_a: $k_a = - \ln [(C_s-C_t)/(C_s-C_o)]/t$ (2)

Based on the graph:

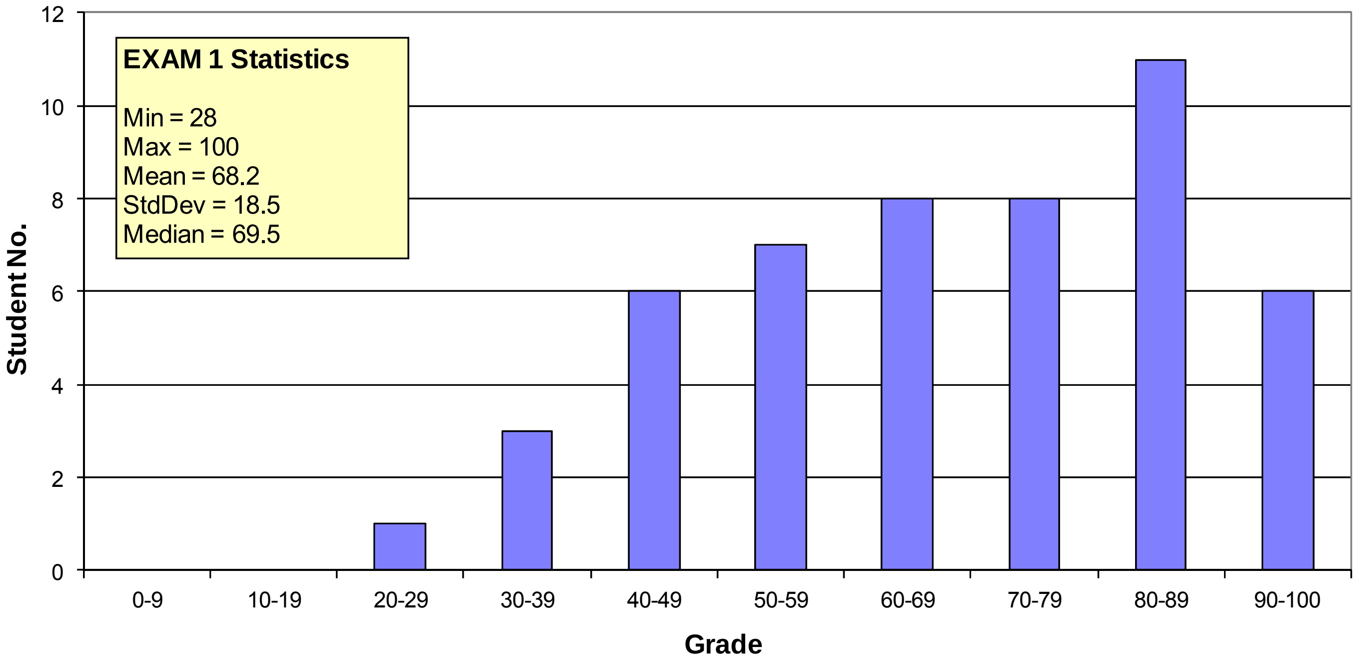
at t = 0 min, C_o = 1 mg/L

at t = 10 min, C_t = 5.4 mg/L

Substitute these values to equation (2):

$k_a = - \ln [(8 - 5.4)/(8 - 1)]/10$ = **0.1 1/min**

NOTE: Any C_t values from the graph for t > 0 could be used. However, if there was data variability, it would have been statistically more correct to use specific data points and then perform a regression based on equation (1) as was done in HW2-Problem B2.


EXAM 1 Statistics
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Max = 100
Mean = 68.2
StdDev = 18.5
Median = 69.5
Student No.
12
10
8
6
4
2
0
0-9
10-19
20-29
30-39
40-49
50-59
60-69
70-79
80-89
90-100
Grade