Quiz 1
CE 311A: Environmental Quality and Pollution

Date: August 14, 2017 Venue: L16, L17 Time: 9:00 – 9:45 am

Instructions:-

1) Please write your roll number on the main and any supplementary answer sheets used.
2) Answer all questions. The exam is closed book, closed notes type.
3) Only calculators and pens are allowed. Cell phones, bags and accessories are strictly prohibited inside the examination hall. If found, these will be confiscated and a marks penalty will be accorded.

Max. Marks: 40

Q1. **[1+3 marks]** a) What is the pH of $10^{-3.5}$ M H_2SO_4 solution?

Sulfuric acid being a strong acid we assume complete dissociation. The moles of protons released are much larger than those contained in water (10^{-7} M)

$pH = -\log[H^+] = -\log (2*10^{-3.5}) = 3.199$

b) What is the pH of 10^{-8} M H_2SO_4 solution?

$[SO_4^{2-}] = 10^{-8}$ M; CB : $[H^+] = [OH^-] + 2[SO_4^{2-}] = 10^{-14}/ [H^+] + 2 \cdot 10^{-8}$

Solve for H^+, $[H^+] = 1.1x10^{-7}$ M; pH = 6.957

Q2. **[3+1 marks]** a) If the air contains 10 ppb of benzene [C_6H_6], calculate the concentration of benzene in µg m^{-3} at 25 deg C temperature and 1 atm pressure.

Molar volume of air = RT/P = 0.0821 L-atm/mol/K * 298 K/ 1 atm = 24.466 L;

10 ppbv is 10^{-8} mol of benzene / mol of air; Since MW of benz is 12*6+1*6 = 78 g/mol,

Conc = $78*10^{-8}$ g of benz/ 24.466 L of air = 31.88 µg m^{-3};

b) If a typical adult inhales about 20 m^3 d^{-1} of air, what is the exposure to benzene via inhalation (µg inhaled per day)?

Exposure is = 31.88 * 20 m^3/d = 637.6 µg/day

Q3. **(8 marks)** A university campus meets its water demand for its residents (students, faculty, staff) solely from groundwater. With increasing demand over the years and not enough groundwater recharge, the water is being progressively drawn from aquifers deeper into the ground thereby increasing the risk of higher fluoride (F)-containing water being used for consumption. The groundwater source has 10 mg/L F concentration which is much higher than the permissible drinking water limit (1.5 mg/L). Rather than investing money in a treatment plant to reduce F concentrations of the drawn groundwater to the acceptable standard concentration, the university decided to do two things:-

a) Collection of rainwater harvested during monsoon periods in underground storage tanks and use it for consumption throughout the year. This water needs minimal treatment and contains 100 ppb fluoride. The campus area was able to harvest 730 m^3 of rain water during the entire year.

b) Blend a nearby river water that has low F concentrations (0.5 ppm) with their groundwater so that the standard is just met.

Determine the relative amounts of river water and groundwater that should be used, in m^3/d. The university water demand is 10 m^3/d.

For meeting the university water demand (Q), the sum of the harvested rainwater (730/365 = 2 m^3/d), groundwater used (Q1) and river water used (Q2) must be equal to Q; **[1 mark for estimating rainwater available per d]**

$Q = Q1 + Q2 + 2$ (1) **[1 mark for MB eq]**

$8 = Q1 + Q2$ (2) **[0.5 mark for correct inputs and steps]**

Option 1 (as per b above only the groundwater and river water are blended):-

The blended water must have F concentration (C) just meeting the drinking water standard (1.5 mg/L). By F mass balance on the two blending streams,

$C\,Q_b = C1Q1 + C2Q2$ (3) **[2 marks for fluoride MB eq]**

$1.5\cdot(10-2) = 10\cdot Q1 + 0.5\cdot Q2$ (4) **[1 mark for other inputs and steps; 0.5 mark for 0.5 ppm conversion to 0.5 mg/L]**

Solving eqs (2) and (4) simultaneously, Q1 = 0.84 m^3/d and Q2 = 7.16 m^3/d
[2 marks for final answers; 0.5 marks each deducted for not specifying the units]

Alternative Option (if all three types of water were to be blended):-

The blended water must have F concentration (C) just meeting the drinking water standard (1.5 mg/L). By F mass balance on the three blending streams (rainwater also has trace F),

$C\,Q = C1Q1 + C2Q2 + C3Q3$ (3) **[2 marks for fluoride MB eq]**

$1.5\cdot10 = 10\cdot Q1 + 0.5\cdot Q2 + 0.1\cdot2$ (4) **[1 mark for other inputs and steps; 0.5 mark for 0.1 ppm conversion]**

Solving eqs (2) and (4) simultaneously, Q1 = 1.14 m^3/d and Q2 = 6.86 m^3/d
[2 marks for final answers; 0.5 marks deducted for not specifying the units]

Q4. **(6 marks)** Enterprising students of CE department decided to test the groundwater of the IITK campus and found the following properties of water:

pH 8; Total alkalinity 0.1 mg/L $CaCO_3$

Trace amounts of sulfurous acid, pentachlorophenol and chromic acid were also found. Indicate the most dominant chemical species of each of these chemicals. Also calculate the concentration of bicarbonate ions in water.

Sol: Since alkalinity of 1 mg/L $CaCO_3$ in pure water is equivalent to 2 10^{-5} eq/L, the measured alkalinity indicates a total alkalinity of 2 10^{-6} eq/L. At pH 8, Alk ~ $[HCO_3^-]$ + $[OH^-]$

This implies that $[HCO_3^-]$ ~ 10^{-6} M **[3 marks]**

From the table, species are SO_3^{2-}, $C_6Cl_5O^-$, CrO_4^{2-} **[3 marks]**

Q5. **(12 marks)** A water body contains 10^{-3} M potassium benzoate, 10^{-4} M potassium hydroxide and 10^{-2} M sodium chloride. Showing all steps, set up the equation in terms of $[H^+]$ and known values, which, if solved, gives the pH of the solution. You DO NOT have to solve this equation.

Species (H_2O), H^+, OH^-, K^+, $Benz^-$, HBenz, Na^+, Cl^- **[1 mark]**

Components (H_2O), H^+, K^+, $Benz^-$, Na^+, Cl^- **[1.5 marks]**

Acid-base water reaction **[0.5 mark]**;

Acid-base Benz reaction and pKa correct from Table **[2 marks]**

Component mass balances: TOTK = 10^{-3} + 10^{-4} = $1.1 \cdot 10^{-3}$ M = $[K^+]$ **[1 mark]**,

TOTNa = 10^{-2} M = $[Na^+]$, TOTCl = 10^{-2} M = $[Cl^-]$ **[0.5 + 0.5 marks]**

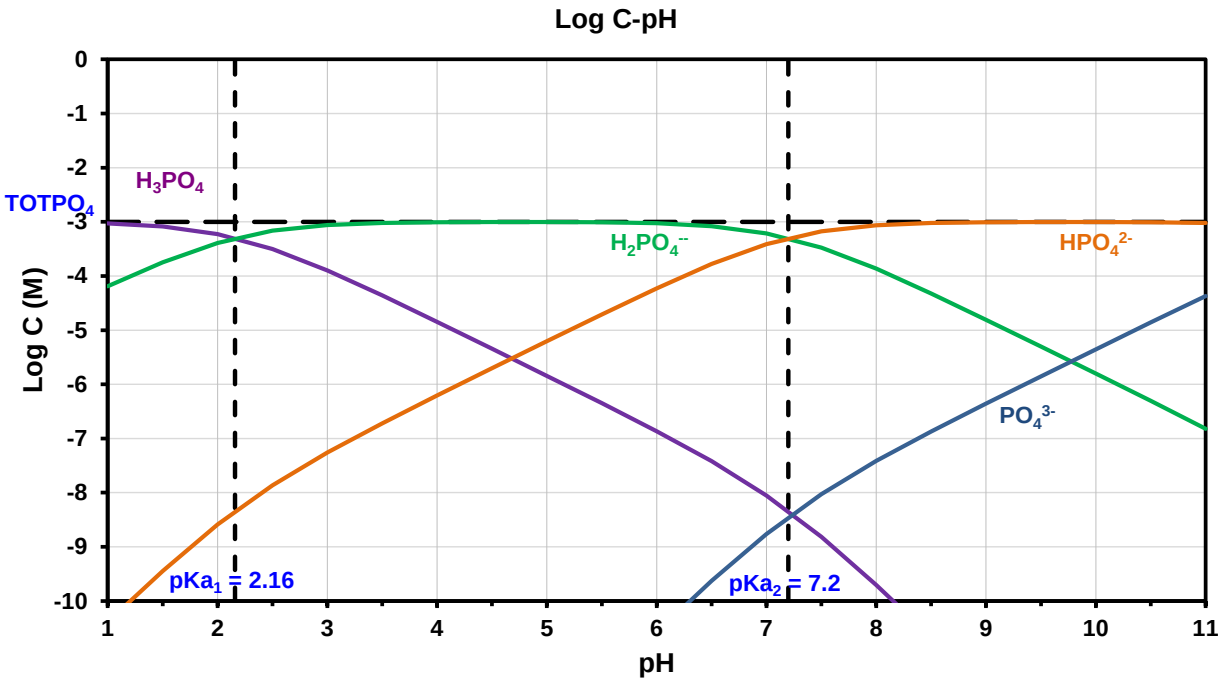
TOTBenz = 10^{-3} M = [HBenz] + $[Benz^-]$ **[1 mark]**

Charge balance:

$[K^+] + [Na^+] + [H^+] = [Cl^-] + [Benz^-] + [OH^-]$ **[2 marks]**

Inputs of OH^- in terms of $[H^+]$ and $[Benz^-]$ in terms of TOTBenz and $[H^+]$ **[0.5 + 1.5 marks]**

Q6. **(6 marks)** On the logC-pH plot given below identify the component and its corresponding acid-base species to which each of the curves belong to. Also, label the necessary properties that help you arrive at your decision.



1 mark to identify the PO_4^{3-} component; 1 mark each for labeling the four PO_4^{3-} species; 0.5 marks each for marking the two pKa values on plot;

Table 3.2 Chemical formulas and acidity constants of some important acids[3]

Name	Formula	pK_{a1}	pK_{a2}	pK_{a3}	pK_{a4}
Nitric acid	HNO_3	−1.30			
Trichloroacetic acid	CCl_3COOH	−0.5			
Hydrochloric acid	HCl	<0			
Sulfuric acid	H_2SO_4	<0	1.99		
Hydronium ion	H_3O^+	0.00	14.00		
Chromic acid	H_2CrO_4	0.86	6.51		
Oxalic acid	$(COOH)_2$	0.90	4.20		
Dichloroacetic acid	$CHCl_2COOH$	1.1			
Sulfurous acid	H_2SO_3	1.86	7.30		
Phosphoric acid	H_3PO_4	2.16	7.20	12.35	
Arsenic acid	H_3AsO_4	2.24	6.76		
Monochloroacetic acid	$CH_2ClCOOH$	2.86			
Salicylic acid	$C_6H_4OHCOOH$	2.97	13.70		
Citric acid	$C_3H_4OH(COOH)_3$	3.13	4.72	6.33	
Hydrofluoric acid	HF	3.17			
Benzoic acid	C_6H_5COOH	4.20			
Pentachlorophenol	C_6Cl_5OH	4.7			
Acetic acid	CH_3COOH	4.76			
Carbonic acid	H_2CO_3	6.35	10.33		