國立中央大學 106 學年度碩士班考試入學試題

所別： 環境工程研究所 碩士班 甲組(一般生)　　

科目： 環境化學及環境微生物學

本科考試禁用計算器　須有計算過程　　＊請在答案卷內作答

參考用

1. Define or explain the followings:
   a. Chemical oxygen demand **(5 points)**
   b. Cation-exchange capacity **(5 points)**
   c. The electrical double layer **(5 points)**
   d. Total Kjeldahl nitrogen **(5 points)**
   e. Point of zero charge **(5 points)**

2. Anaerobic bacteria living at the bottom of a shallow inlet to a salt marsh are generating hydrogen sulfide (H_2S) as a by-product of their metabolism. Although this compound (which is responsible for the "rotten egg" smell characteristic of salt marshes and is extremely toxic) is ordinarily found as a gas, it is reasonably soluble in water. (Remember that $\ln K = 2.3 \log K$)

   a. What is the maximum concentration of dissolved hydrogen sulfide species (including H_2S, HS^-, and S^{2-}) that could theoretically accumulate in the waters of the inlet if the pH is 6.0? (This absolute limit would be reached when the pressure of H_2S reached 1 atm and bubbles of pure H_2S formed and escaped. In practice, H_2S concentrations would typically be lower). Some relevant equilibria include: **(15 points)**

   $H_2S <-> H_2S_{(g)}$ $\quad K_H = 10^{0.99}$ atm liter/mol
   $H_2S <-> H^+ + HS^-$ $\quad K_{a1} = 10^{-7.02}$ M
   $HS^- <-> H^+ + S^{2-}$ $\quad K_{a2} = 10^{-13.9}$ M

   b. A small amount of dibromomethane (CH_2Br_2) has been spilled into the inlet. Assume that the partial pressure of H_2S is 0.1 atm. If the principal process that will affect the fate of this species is its reaction with HS^-, for which the relevant rate constant is 5.25×10^{-5} M^{-1} sec^{-1} (note that other dissolved hydrogen sulfide species do not react at measurable rates), how many days will be required for the CH_2Br_2 concentration to decrease to 10% of its initial value? **(15 points)**

3. *Rhodobacter lauracita* is a newly discovered bacterium and is a manganese-based photoautotrophy. Light provides the energy necessary to drive the production of organic carbon. Below are some relevant equations. ($RT = 2477.57$ J mol^{-1})

   $\Delta G° = -RT (\ln K)$
   $\Delta G = \Delta G° + RT (\ln Q)$
   $1/2\ MnO_{2(s)} + 2\ H^+ + e^- = 1/2\ Mn^{2+} + H_2O$ $\quad \log K = +20.8$
   $1/4\ CO_{2(g)} + H^+ + e^- = 1/24\ C_6H_{12}O_6 + 1/4\ H_2O$ $\quad \log K = -0.2$
   $Fe(OH)_{3(am)} + 3\ H^+ + e^- = Fe^{2+} + 3\ H_2O$ $\quad \log K = +16.0$

   a. How much free energy in kJ/mol would be required to form one mole of glucose ($C_6H_{12}O_6$) if reduced manganese (Mn^{2+}) served as the electron donor for *R. lauracita*? Assume that Mn^{2+} is oxidized to the solid MnO_2 (activity = 1), pH = 7, and that Mn^{2+} and glucose are present at 10^{-4} M. The partial pressure of carbon dioxide is $10^{-3.5}$ atm. Be sure to give the answer in kJ per mole of glucose produced. **(15 points)**

   b. This bacterium can also grow with Fe^{2+} as the electron donor, which gets oxidized to the amorphous solid $Fe(OH)_{3(am)}$ (activity = 1). Would you expect *R. lauracita* to require less or greater light intensity for growth when grown on

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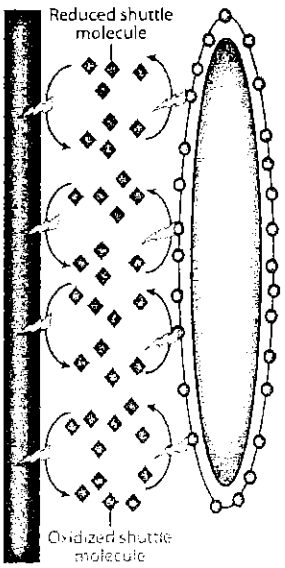
iron (compared to manganese)? Assume pH = 7, and Fe^{2+} and glucose are present at 10^{-4} M. The partial pressure of carbon dioxide is $10^{-3.5}$ atm. Justify this quantitatively. **(15 points)**

c. Another bacterial strain is added to the system that efficiently oxidizes Mn^{2+}, keeping the concentration of this substance very low. Explain qualitatively how this affects your free energy yield for *R. lauracita*. **(5 points)**

4. The following is a defined medium attempted to isolate denitrifying bacteria from soil samples. The isolation is completely carried out in the dark. On the basis of this recipe, explain your rationale of why this experiment will work or not work. Also, which chemical is used as an energy source in this case? **(5 points)**

	m.w.	mass or volume
K_2HPO_4	174	7.0 g
KH_2PO_4	136	2.0 g
NH_4Cl	53.5	1.0 g
$MgCO_3$	84	0.1 g
$CaCl_2$	111	0.05 g
Sodium Acetate	82	1.5 g
Trace elements in chloride forms (Fe, Co, Mn, Zn, Cu, Ni, Mo)		10 μg
Distilled water (pH 7)		1000 mL

5. In the microbial fuel cell (MFC) system, the mechanisms that underlie the extracellularly respiratory electron transfer from cells to the anode have been vigorously researching over the past decades. To date, three pathways have been proposed, and one of them, illustrated as the figure given below, involves small redox-active, dissolved molecules called "flavins" that are self-produced and released to the environment by cells, acting as "electron shuttles" to help cells extracellularly transfer electrons back-and-forth between the insoluble electron acceptor and the cell. Design a simple experiment that you have learned from your study of Environmental Microbiology to validate this hypothesis. **(5 points)**



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