

## Homework #1 - SOLUTIONS

**Due: Apr 05, 23:59**

1. Read the following article to provide a brief summary (1-2 paragraphs).

D. G. J. Larsson and C. -F. Flach, Antibiotic resistance in the environment. Nature Reviews Microbiology, 20, 257-269, 2022.

available at: <https://www.nature.com/articles/s41579-021-00649-x>

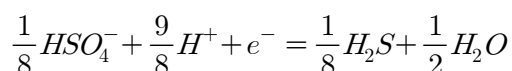
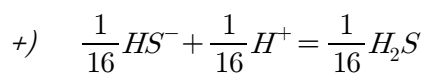
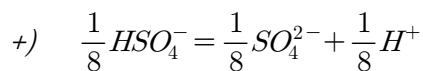
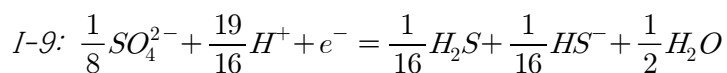
(30 points)

2. Follow the instructions below to rewrite half reactions given in the lecture note.

1) Sulfide-Sulfate couple (Reaction # I-9): Use bisulfate ( $\text{HSO}_4^-$ ) as the only oxidized sulfur species and hydrogen sulfide ( $\text{H}_2\text{S}$ ) as the only reduced sulfur species [may represent highly acidic conditions].

(15 points)

*Solution)*



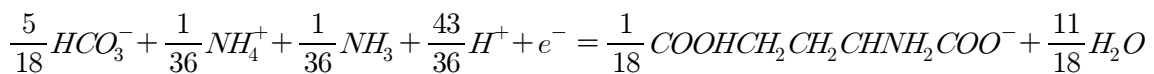
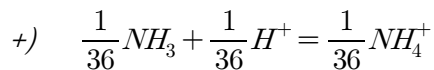
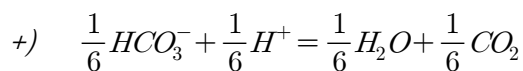
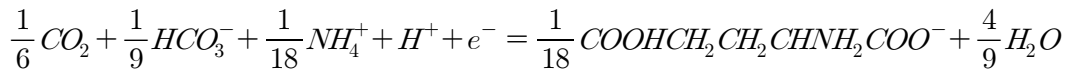
2) Carbon dioxide-Glutamate couple (Reaction # O-8): Use bicarbonate ( $\text{HCO}_3^-$ ) as the only oxidized carbon species, free ammonia ( $\text{NH}_3$ ) and

ammonium ion ( $\text{NH}_4^+$ ) at a molar ratio of 1:1 as reduced nitrogen species, and the deprotonated form for glutamate [may represent a condition of  $\text{pH} = \text{pK}_a$  of ammonia].

(15 points)

*Solution)*

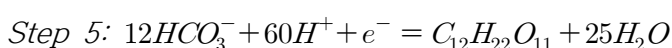
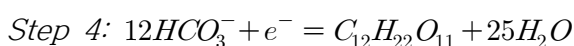
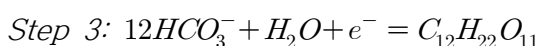
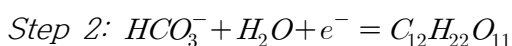
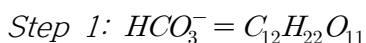
*O-8:*

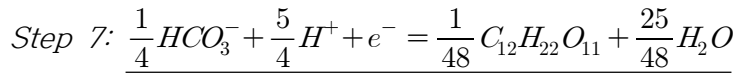
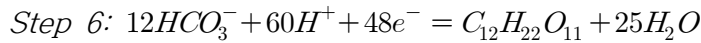


3. You want to develop an eco-friendly and cost-effective process for removal of nitrate ( $\text{NO}_3^-$ ) from groundwater. Your plan is to supply molasses, a byproduct of sugar manufacturing, as an  $\text{e}^-$  donor to enhance denitrification in groundwater. Assuming that the molecular formula of molasses can be represented by  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$  (same as that for sugar), answer the following.

1) Write the electron donor half reaction,  $R_d$ , in an electron-equivalent form. Use  $\text{HCO}_3^-$  as an only form of an oxidized carbon species. (20 points)

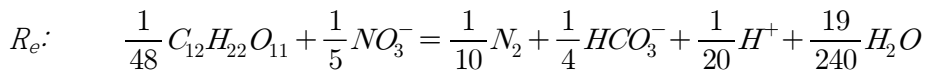
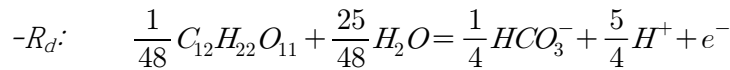
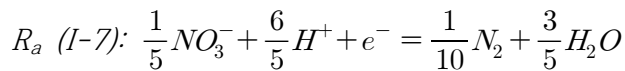
*Solution)*





2) Write the energy reaction,  $R_e$ , in an electron-equivalent form. How much grams of molasses are needed per g of  $\text{NO}_3\text{-N}$  consumed for the energy reaction? (20 points)

*Solution)*

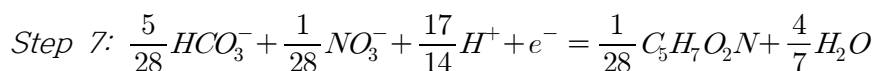
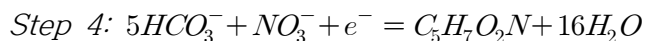
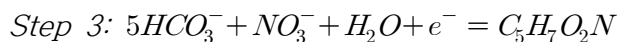
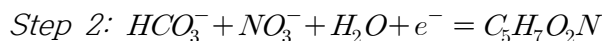


*Molasses molecular weight:*  $12 \times 12 + 1 \times 22 + 16 \times 11 = 342$

$$g \text{ molasses needed/g } \text{NO}_3\text{-N consumed} = \frac{\frac{1}{48} \text{ mole} \times 342 \text{ g molasses/mole}}{\frac{1}{5} \text{ mole} \times 14 \text{ g } \text{NO}_3\text{-N/mole}} = 2.54$$

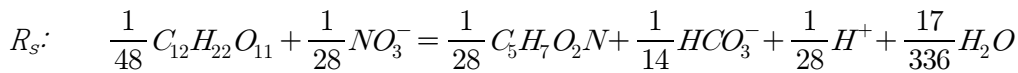
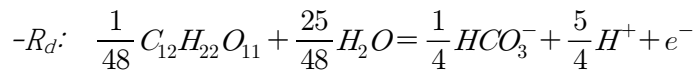
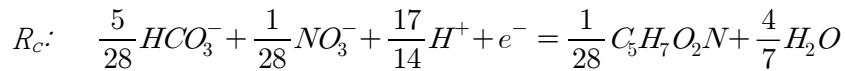
3) Write the cell formation half reaction,  $R_c$ , in an electron-equivalent form. Use the cell formula of  $\text{C}_5\text{H}_7\text{O}_2\text{N}$  and  $\text{NO}_3^-$  as a source of nitrogen (not  $\text{NH}_4^+$ ). Also use  $\text{HCO}_3^-$  as an only form of oxidized carbon species. (20 points)

*Solution)*



- 4) Write the overall cell synthesis reaction,  $R_s$ , in an electron-equivalent form. Use the  $R_d$  derived from 1) and the  $R_c$  derived from 3). How much grams of molasses are needed per g of  $\text{NO}_3\text{-N}$  consumed for the cell synthesis reaction? (20 points)

*Solution)*



$$g \text{ molasses needed/g } \text{NO}_3\text{-N consumed} = \frac{\frac{1}{48} \text{ mole} \times 342 \text{ g molasses/mole}}{\frac{1}{28} \text{ mole} \times 14 \text{ g } \text{NO}_3\text{-N/mole}} = 14.25$$

- 5) From the calculations you did for 2) and 4), which growth state do you think is more favorable for efficient use of molasses? (A) a rapidly growing state or (B) a slowly growing state? Briefly describe the reason for your selection. (10 points)

*Solution)*

(B)

*At a slowly growing state, the  $f_e$  value is greater, meaning that the overall stoichiometry is more weighted to  $R_e$  than it is for a rapidly growing state. Therefore, at a slowly growing state the amount of molasses needed to remove a gram of  $\text{NO}_3\text{-N}$  will be greater (more efficient use of molasses).*