Preparatory Assignment for Quiz 1—**Key**

CENG 340–Introduction to Environmental Engineering
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1. $\rho_{water} = 1 \frac{\mathrm{g}}{\mathrm{mL}} = 1000 \frac{\mathrm{g}}{\mathrm{L}}$

$$[VC] = 0.002\ \frac{\mathrm{mg\,VC}}{\mathrm{L\,total}} \times \frac{1\,\mathrm{g\,VC}}{1000\,\mathrm{mg\,VC}} \times \frac{1\,\mathrm{L\,solution}}{1000\,\mathrm{g\,solution}} = 2 \times 10^{-9}\ \frac{\mathrm{g\,VC}}{\mathrm{g\,solution}}$$

$$[VC] = 2 \times 10^{-9}\ \frac{\mathrm{g\,VC}}{\mathrm{g\,solution}} \times \frac{10^6\,\mathrm{ppm_m}}{\frac{\mathrm{g}}{\mathrm{g}}} \times \frac{10^3\,\mathrm{ppb_m}}{\mathrm{ppm_m}} = 2\,\mathrm{ppb_m}$$

2. Molecular weight of N $= 14\ \frac{\mathrm{g}}{\mathrm{mole}}$
   Molecular weight of $\mathrm{NO_3^-} = 62\ \frac{\mathrm{g}}{\mathrm{mole}}$
   $\mathrm{MCL}_{NO_3^-} = 10\ \frac{\mathrm{mg-N}}{\mathrm{L}}$

   - Does the concentration of $\mathrm{NO_3^-}$ violate the MCL?

     $$[\mathrm{NO_3^-}] = 10 \frac{\mathrm{mg}}{\mathrm{L}} \times \frac{14\,\mathrm{mg\,N}}{62\,\mathrm{mg\,NO_3^-}} = 2.3\ \frac{\mathrm{mg\text{-}N}}{\mathrm{L}} < 10\ \frac{\mathrm{mg\text{-}N}}{\mathrm{L}}$$

     MCL not violated.

   - MCL Concentration in units of ppm_m:

     $$[\mathrm{NO_3^-}]_{\mathrm{MCL}} = 10\ \frac{\mathrm{mg\text{-}N}}{\mathrm{L}} = 10\,\mathrm{ppm_m\,as\,N}$$

   - MCL Concentration in units of $\frac{mole}{L}$:

     $$[\mathrm{NO_3^-}]_{\mathrm{MCL}} = 10\ \frac{\mathrm{mg\text{-}N}}{\mathrm{L}} \times \frac{1\,\mathrm{g}}{1000\,\mathrm{mg}} \times \frac{1\,\mathrm{mole}}{14\,\mathrm{g}} = 7.1 \times 10^{-4}\ \frac{\mathrm{mole}}{\mathrm{L}}$$

   - MCL Concentration in units of ppb_m:

     $$[\mathrm{NO_3^-}]_{\mathrm{MCL}} = 10\,\mathrm{ppm_m} \times \frac{10^3\,\mathrm{ppb_m}}{1\,\mathrm{ppm_m}} = 10,000\,\mathrm{ppb_m}\ \text{as N}$$

3. Outdoor air-quality 1-h standard: [CO] = 35 $\frac{\text{mg}}{\text{m}^3}$
At Lynah Rink: $[\text{CO}]_{low}$ = 35 ppm$_v$, and $[\text{CO}]_{high}$ = 115 ppm$_v$

Part One:

- **Step 1: Convert $[\mathbf{CO}]_{std}$ from $\frac{\text{mg}}{\text{m}^3}$ to $\frac{\text{mole}}{\text{m}^3}$**

  Molecular weight of CO = 12 + 16 = 28 $\frac{\text{g}}{\text{mole}}$

$$[\text{CO}]_{\text{std}} = 35\,\frac{\text{mg}}{\text{m}^3} \times \frac{1\,\text{mole}}{28\,\text{g}} \times \frac{1\,\text{g}}{1000\,\text{mg}} = 1.25 \times 10^{-3}\,\frac{\text{mole}}{\text{m}^3}$$

- **Step 2: Convert $[\mathbf{CO}]_{std}$ from $\frac{\text{mole}}{\text{m}^3}$ to $\frac{\text{m}^3}{\text{m}^3}$**

  Use the ideal gas law: PV = nRT, where (1) temperature in Kelvin (K) = temperature in Celsius (^{0}C) + 273.15, (2) the ideal gas constant R = $8.205 \times 10^{-5}\,\frac{\text{m}^3\times\text{atm}}{\text{mole}\times\text{Kelvin}}$, and (3) P = 1 atm.

$$[CO]_{std} = \frac{1.25 \times 10^{-3}\,\text{moles CO} \times \frac{\text{R}\times\text{T}}{\text{P}}}{\text{m}^3\,\text{air}} =$$

$$= \frac{1.25 \times 10^{-3}\,\text{moles CO} \times \frac{8.205\times10^{-5}\,\frac{\text{m}^3\times\text{atm}}{\text{mole}\times\text{K}}\times 293.15\,\text{K}}{1\,\text{atm}}}{\text{m}^3\,\text{air}} = 3.01 \times 10^{-5}\,\frac{\text{m}^3\,\text{CO}}{\text{m}^3\,\text{air}}$$

- **Step 3: Convert $[\mathbf{CO}]_{std}$ from $\frac{m^3}{m^3}$ to ppm$_v$:**

$$[\text{CO}]_{\text{std}} = 3.01 \times 10^{-5}\,\frac{\text{m}^3\,\text{CO}}{\text{m}^3\,\text{air}} \times 10^6\,\frac{\text{ppm}_\text{v}}{\frac{\text{m}^3}{\text{m}^3}} = 30\,\text{ppm}_\text{v}$$

At Lynah [CO] ranges from 35 to 115 ppm$_v$—violates the air quality standard all of the time. Prof. Sills might want to bring a gas mask.

Part Two:

[CO] in units of ppm$_v$ = $\frac{P_i}{P_{air}} \times 10^6$

$$\text{P}_\text{i}(\text{low}) = \frac{35\,\text{ppm}_\text{v} \times 1\,\text{atm}}{10^6} = 3.5 \times 10^{-5}\,\text{atm}$$

$$\text{P}_\text{i}(\text{high}) = \frac{115\,\text{ppm}_\text{v} \times 1\,\text{atm}}{10^6} = 1.15 \times 10^{-4}\,\text{atm}$$

The partial pressure of CO at Lynah Rink ranges from 3.5×10^{-5} atm to 1.15×10^{-4} atm.

4. Convert 10 $\frac{g}{L}$ to $\frac{mole}{L}$:

$$[\mathrm{NaOH}] = 10\,\frac{\mathrm{g}}{\mathrm{L}} \times \frac{1\,\mathrm{mole}}{40\,\mathrm{g}} = 0.25\,\frac{\mathrm{mole}}{\mathrm{L}}$$

$$[\mathrm{Na_2SO_4}] = 10\,\frac{\mathrm{g}}{\mathrm{L}} \times \frac{1\,\mathrm{mole}}{142\,\mathrm{g}} = 0.07\,\frac{\mathrm{mole}}{\mathrm{L}}$$

$$[\mathrm{K_2Cr_2O_7}] = 10\,\frac{\mathrm{g}}{\mathrm{L}} \times \frac{1\,\mathrm{mole}}{294\,\mathrm{g}} = 0.03\,\frac{\mathrm{mole}}{\mathrm{L}}$$

$$[\mathrm{KCl}] = 10\,\frac{\mathrm{g}}{\mathrm{L}} \times \frac{1\,\mathrm{mole}}{74.5\,\mathrm{g}} = 0.13\,\frac{\mathrm{mole}}{\mathrm{L}}$$

5. $\mathrm{MW}_{[HCO_3^-]} = 61\ \frac{g}{mole}$

$$[\mathrm{HCO_3^-}] = 50\,\frac{\mathrm{mg}}{\mathrm{L}} \times \frac{1\,\mathrm{mole}}{60\,\mathrm{g}} \times \frac{1\,\mathrm{g}}{1000\,\mathrm{mg}} = 8.2 \times 10^{-4}\,\frac{\mathrm{mole}}{\mathrm{L}}$$

$$[\mathrm{HCO_3^-}] = 8.2 \times 10^{-4}\,\frac{\mathrm{mole}}{\mathrm{L}} \times \frac{1\,\mathrm{equivalent}}{\mathrm{mole}} = 8.2 \times 10^{-4}\,\frac{\mathrm{eq}}{\mathrm{L}}$$

$$[\mathrm{HCO_3^-}] = 8.2 \times 10^{-4}\,\frac{\mathrm{eq}}{\mathrm{L}} \times \frac{50\,\mathrm{g\,CaCO_3}}{\mathrm{eq}} \times \frac{1000\,\mathrm{mg}}{\mathrm{g}} = 41\,\frac{\mathrm{mg}}{\mathrm{L}}$$

6. *Step One: Convert [Ca^{2+}], [Mg^{2+}], and [Mn^{2+}] from units of $\frac{mg}{L}$ to hardness as $\frac{meq}{L}$.*

$$[\mathrm{Ca^{2+}}] = 42\,\frac{\mathrm{mg}}{\mathrm{L}} \times \frac{1\,\mathrm{mole}}{40\,\mathrm{g}} \times \frac{2\,\mathrm{eq}}{\mathrm{mole}} = 2.1\,\frac{\mathrm{meq}}{\mathrm{L}}$$

$$[\mathrm{Mg^{2+}}] = 12\,\frac{\mathrm{mg}}{\mathrm{L}} \times \frac{1\,\mathrm{mole}}{24\,\mathrm{g}} \times \frac{2\,\mathrm{eq}}{\mathrm{mole}} = 1.0\,\frac{\mathrm{meq}}{\mathrm{L}}$$

$$[\mathrm{Mn^{2+}}] = 10\,\frac{\mathrm{mg}}{\mathrm{L}} \times \frac{1\,\mathrm{mole}}{55\,\mathrm{g}} \times \frac{2\,\mathrm{eq}}{\mathrm{mole}} = 0.36\,\frac{\mathrm{meq}}{\mathrm{L}}$$

Step Two: Calculate total hardness in units of $\frac{\mathrm{meq}}{\mathrm{L}}$.

Total Hardness = [Ca^{2+}] + [Mg^{2+}] + [Mn^{2+}] = 2.1 + 1.0 + 0.36 = 3.46 $\frac{meq}{L}$

Step Three: Convert total hardness from units of $\frac{\mathrm{meq}}{\mathrm{L}}$ to $\frac{\mathrm{mg{-}CaCO_3}}{\mathrm{L}}$:

$$\mathrm{TotalHardness} = 3.46\,\frac{\mathrm{meq}}{\mathrm{L}} \times \frac{50\,\mathrm{g\,CaCO_3}}{\mathrm{eq}} = 173\,\frac{\mathrm{mg\,CaCO_3}}{\mathrm{L}}$$

7.

$$[\text{Coliforms}] = 9000\,\frac{\text{coliform}}{\text{m}^3} \times \frac{1\,\text{m}^3}{1000\,\text{L}} \times \frac{1\,\text{L}}{1000\,\text{mL}}$$

$$[\text{Coliforms}] = 9 \times 10^{-3}\,\frac{\text{coliform}}{\text{mL}}$$

Therefore, in 100 mL, there are $9 \times 10^{-3}\,\frac{\text{coliform}}{\text{mL}} \times 100\,\text{mL} = 0.9\,\text{coliforms}$

8. Global warming potential of methane from

- Landfills:

$$6709\ \text{Gg}\ \text{CH}_4 \times 25\frac{\text{g}\,\text{CO}_2\text{-eq}}{\text{g}\,\text{CH}_4} = 167,725\ \text{Gg}\ \text{CO}_2\text{-eq}$$

- Wastewater Treatment Plants (WWTPs):

$$1758\ \text{Gg}\ \text{CH}_4 \times 25\frac{\text{g}\,\text{CO}_2\text{-eq}}{\text{g}\,\text{CH}_4} = 43,950\ \text{Gg}\ \text{CO}_2\text{-eq}$$

- Percent of annual methane emissions that come from landfills and WWTPs:

$$\frac{(167725 + 43950)\,\text{Gg}\ \text{CO}_2\text{-eq} \times \frac{1\,\text{Tg}}{1000\,\text{Gg}}}{556.7\ \text{Tg}\ \text{CO}_2\text{-eq}} \times 100\,\% = 38\,\%\ \text{of annual methane emissions}$$

- Percent of annual greenhouse gas (GHG) emissions that come from landfills and WWTPs:

$$\frac{(167725 + 43950)\,\text{Gg}\ \text{CO}_2\text{-eq} \times \frac{1\,\text{Tg}}{1000\,\text{Gg}}}{7074\ \text{Tg}\ \text{CO}_2\text{-eq}} \times 100\,\% = 3\,\%\ \text{of annual GHG emissions}$$

9.

$$\text{TS} = \frac{(13.020 - 12.819)\text{g}}{0.2\,\text{L}} \times \frac{1000\,\text{mg}}{\text{g}} = 1005\,\frac{\text{mg}}{\text{L}}$$

$$\text{FS} = \frac{(12.982 - 12.819)\text{g}}{0.2\,\text{L}} \times \frac{1000\,\text{mg}}{\text{g}} = 815\,\frac{\text{mg}}{\text{L}}$$

$$\text{VS} = \text{TS} - \text{FS} = 1005 - 815 = 190\,\frac{\text{mg}}{\text{L}}$$