# Preparatory Assignment for Quiz 1—**Key**

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

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

$$[VC] = 2 \times 10^{-9}\ \frac{\text{g VC}}{\text{g solution}} \times \frac{10^6\,\text{ppm}_\text{m}}{\frac{\text{g}}{\text{g}}} \times \frac{10^3\,\text{ppb}_\text{m}}{\text{ppm}_\text{m}} = 2\,\text{ppb}_\text{m}$$

2. Molecular weight of N $= 14\ \frac{\text{g}}{\text{mole}}$
   Molecular weight of $\text{NO}_3^-$ $= 62\ \frac{\text{g}}{\text{mole}}$
   $\text{MCL}_{NO_3^-} = 10\ \frac{\text{mg}-\text{N}}{\text{L}}$

   - Does the concentration of $\text{NO}_3^-$ violate the MCL?

   $$[\text{NO}_3^-] = 10\frac{\text{mg}}{\text{L}} \times \frac{14\,\text{mg N}}{62\,\text{mg NO}_3^-} = 2.3\ \frac{\text{mg-N}}{\text{L}} < 10\ \frac{\text{mg-N}}{\text{L}}$$

   MCL not violated.

   - MCL Concentration in units of $\text{ppm}_m$:

   $$[\text{NO}_3^-]_\text{MCL} = 10\ \frac{\text{mg-N}}{\text{L}} = 10\,\text{ppm}_\text{m}\ \text{as N}$$

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

   $$[\text{NO}_3^-]_\text{MCL} = 10\ \frac{\text{mg-N}}{\text{L}} \times \frac{1\,\text{g}}{1000\,\text{mg}} \times \frac{1\,\text{mole}}{14\,\text{g}} = 7.1 \times 10^{-4}\ \frac{\text{mole}}{\text{L}}$$

   - MCL Concentration in units of $\text{ppb}_m$:

   $$[\text{NO}_3^-]_\text{MCL} = 10\,\text{ppm}_\text{m} \times \frac{10^3\,\text{ppb}_\text{m}}{1\,\text{ppm}_\text{m}} = 10,000\,\text{ppb}_\text{m}\ \text{as N}$$

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

*Part One:*

- **Step 1: Convert $[\text{CO}]_{std}$ 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 $[\text{CO}]_{std}$ 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.

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

$$= \frac{1.25 \times 10^{-3}\,\text{moles CO} \times \frac{8.205\times10^{-5}\,\frac{\text{m}^3\times\text{atm}}{\text{mole}\times\text{K}}\times293.15\,\text{K}}{1\,\text{atm}}}{\text{m}^3\,\text{air}} = 3.01 \times 10^{-5}\,\frac{\text{m}^3\,\text{CO}}{\text{m}^3\,\text{air}}$$

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

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

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

*Part Two:*

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

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

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

The partial pressure of CO at Lynah Rink ranges from $3.5 \times 10^{-5}$ atm to $1.15 \times 10^{-4}$ 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 = $[\mathrm{Ca^{2+}}] + [\mathrm{Mg^{2+}}] + [\mathrm{Mn^{2+}}] = 2.1 + 1.0 + 0.36 = 3.46\ \frac{meq}{L}$

*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.

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

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

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