Matching. (2 points each) Put the letter of the description on the right which best describes one of the terms on the left. No letter may be used more than once.

_ F _ Alkalinity A. Soluble oxygen concentration in a water sample.
_ I _ Carbonic acid B. Theoretical reactor with no mixing in flow direction, with flow in and out.
_ J _ Equilibrium constant C. Theoretical reactor completely mixed throughout, with no flow in or out.
_ C _ Batch reactor D. Theoretical reactor completely mixed throughout, with flow in and out.
_ L _ Henry’s Law Constant E. Balance of positive and negative equivalent concentrations.
_ N _ Phosphoric acid F. Acid neutralizing capacity measured by equivalent concentrations.
_ E _ Electroneutrality G. Hydrocarbon produced by living organism with a COOH group.
_ K _ Protein H. Hydrocarbon produced by living organism with both COOH and NH₂ groups.
_ G _ Organic acid I. Weak diprotic acid.
_ M _ Hardness J. Molar concentration ratio determined at each solution temperature.
_ A _ DO K. Chemically bonded chain of amino acids.
_ H _ Amino acid L. Constant relating direct proportion between dissolved gas concentration and the gas partial pressure in the gas phase.
_ B _ CMFR M. Sum of equivalent concentrations of soap interfering metals.
_ D _ PFR N. Strong triprotic acid.

True of False (2 points each). Circle T if the statement is entirely true and F is any part of the statement is false.

T F Natural waters tend to remain between pH 6 and 7, because of buffering from carbonate species.
T F A logarithmic or first order growth constant has units of mole/L.
T F Carbonic acid is a weak acid, because it does not dissociate to the carbonate and bicarbonate forms easily.
T F As pOH increases in a water, the hydroxyl ion concentration decreases.
T F Producers are at the lowest trophic level.
Multiple Choice. (2 points each) Circle the letter of the phrase which **best completes** each sentence below.

1. The outflow concentration of a CMFR is the same as all material inside the reactor, because
   A. there is little reaction inside the reactor.
   B. **mixing is so vigorous inside the reactor.**
   C. the process inside the reactor is a growth rather than decay process.
   D. it is a batch process.

2. The Henry’s Law may be appropriately used for
   A. only pure liquid substances dissolved in a gas.
   B. **mixtures of gases of constant composition dissolved in a liquid.**
   C. mixtures of gases of changing composition in a compressible liquid.
   D. incompressible liquids dissolved in incompressible gases.

3. RCRA set up a system to track hazardous wastes through something called
   A. an NPDES permit.
   B. multimedia pollution.
   C. bioaccumulation.
   D. a **hazardous waste manifest.**

4. Resonant ring structure organics are more stable than chain structures because of
   A. ionic bonds.
   B. sharing of carbons by hydrogen bonds.
   C. **electron sharing between carbon bonds.**
   D. more than 4 covalent bonds shared by each carbon.

5. Halogenated organic chemicals are important environmentally because
   A. **many of them are carcinogenic.**
   B. they have peptide bonds.
   C. they are present in gasoline.
   D. they contain carboxyl and amine structures.

6. The partial pressures of oxygen and nitrogen in air at sea level are approximately
   A. 79 atm carbon dioxide and 21 atm oxygen.
   B. 0.5 atm nitrogen and 0.5 atm oxygen.
   C. **0.79 atm nitrogen and 0.21 atm oxygen.**
   D. 79 atm nitrogen and 11 atm oxygen.
Problem 1 (10 points)
The atmospheric pressure on a winter day in Boulder, Colorado is 0.82 atm. A nearby mountain stream carrying water at 10 °C has a Henry’s law constant of 0.00169 mol/(L⋅atm) for that temperature. Estimate the saturation DO for the stream water in units of mg/L.

\[
\Gamma_{O_2} = K_H \frac{P_{O_2}}{P_{tot}} = 0.21 \quad \text{at} \quad P_{tot} = 0.82 \text{ atm}
\]

\[
P_{O_2} = 0.21 \times (0.82 \text{ atm}) = 0.172 \text{ atm}
\]

\[
\Gamma_{O_2} = (0.00169 \text{ mol/L} \cdot \text{atm}) \times 0.172 \text{ atm} = 2.91 \times 10^{-4} \text{ mol/L}
\]

\[
C_{O_2} = \left(2.91 \times 10^{-4} \text{ mol/L}\right) \left(32 \frac{g \text{O}_2}{\text{mol} \text{O}_2}\right) = 0.093 \frac{g \text{O}_2}{L}
\]

\[
C_{O_2} = \left(0.093 \frac{g \text{O}_2}{L}\right) \left(1800 \frac{mg \text{O}_2}{g \text{O}_2}\right) = 9.3 \frac{mg \text{O}_2}{L}
\]
Problem 2 (15 points)
A water at 25 °C and pH 8.2 has 120 mg/L bicarbonate ion (HCO\textsubscript{3}^-) as CaCO\textsubscript{3} and 20 mg/L of carbonate ion (CO\textsubscript{3}\textsuperscript{2-}) as CaCO\textsubscript{3}. Calculate the alkalinity of the sample in mg/L as CaCO\textsubscript{3}.

\[
\text{alkalinity} = \frac{50 \text{ mg CaCO}_3}{\text{mg}} \left( \frac{2 \text{ HCO}_3^-}{3} + \frac{1 \text{ CO}_3^{2-}}{5} + \frac{5 \text{ OH}^-}{2} - \frac{3 \text{ H}^+}{2} \right)
\]

\[
\frac{5 \text{ HCO}_3^-}{3} = \frac{120 \text{ mg/L CaCO}_3}{50 \text{ mg CaCO}_3/\text{mg}} = 2.4 \text{ meq/L}
\]

\[
\frac{1 \text{ CO}_3^{2-}}{5} = \frac{20 \text{ mg/L}}{50 \text{ mg/meq}} = 0.4 \text{ meq/L}
\]

\[
[\text{OH}^-] = 10^{-7} \text{ (pH - 14)} = 10^{-8.2} = 1.58 \times 10^{-6} \text{ meq/L}
\]

\[
\frac{5 \text{ OH}^-}{2} = \left( \frac{1.58 \times 10^{-6} \text{ mol/L}}{\text{L}} \right) \left( \frac{1 \text{ meq}}{1 \text{ mmol}} \right) = 0.1 \text{ D/100 meq/L}
\]

\[
[\text{H}^+] = 10^{-8.2} = 6.31 \times 10^{-9} \text{ mol/L} = 6.31 \times 10^{-6} \text{ mmol/L}
\]

\[
\frac{3 \text{ H}^+}{2} = \left( \frac{6.31 \times 10^{-6} \text{ mmol/L}}{\text{L}} \right) \left( \frac{1 \text{ meq}}{1 \text{ mmol}} \right) = 6.31 \times 10^{-6} \text{ meq/L}
\]

\[
\text{alkalinity} = 2.4 + 0.4 + 0.016 - 6.31 \times 10^{-6} = 2.802 \text{ meq/L}
\]

\[
\text{CaCO}_3 = \left( \frac{2.802 \text{ meq/L}}{\text{L}} \right) \left( \frac{50 \text{ mg CaCO}_3}{\text{meq}} \right) = 140.1 \text{ mg/L as CaCO}_3
\]
Problem 3 (10 points)
The EPA regulated level of carbon monoxide is 10 mg/m$^3$ at 1 atm and 25 °C. To what level of ppm$_v$ does this correspond?

$$
\text{ppm}_v = \left( \frac{10 \text{ mg CO}}{1 \text{ m}^3 \text{ air}} \right) \left( \frac{1 \text{ m}^3 \text{ air}}{1000 \text{ L air}} \right) \left( \frac{24.4 \text{ L CO}}{1 \text{ mol CO}} \right) \left( \frac{1 \times 10^6 \text{ ppm}}{28,000 \text{ mg CO}} \right) = 9.71 \text{ ppm}_v \text{ CO}
$$
Problem 4 (15 points)
The time in a batch reactor necessary to drop pathogen concentration by dosing with chlorine to one half the original pathogen concentration is 5 minutes. How long should it take to drop a pathogen concentration from 100 organisms per 100 mL to 1 organism per 100 mL with the same chlorine dose?

\[
\frac{N}{N_0} = e^{-kt}
\]

\[
0.5 = e^{-k(5 \text{ min})}
\]

\[
\ln(0.5) = -k(5 \text{ min})
\]

\[
k = \frac{-\ln(0.5)}{5 \text{ min}} = 0.139 \frac{1}{\text{min}}
\]

\[
\frac{1}{100} = e^{-\left(0.139 \frac{1}{\text{min}}\right)t}
\]

\[
\ln(0.01) = -\left(0.139 \frac{1}{\text{min}}\right)t
\]

\[
t = \frac{-\ln(0.01)}{0.139 \frac{1}{\text{min}}} = 33.2 \text{ min}
\]