ANSWERS

1. Elementary ideas in environmental engineering

(a) Divide mass concentration by atomic mass (40 g/mol) to obtain $[Ca^{2+}]$ = 50 μM = 0.050 mM.
(b) Divide mass concentration by molecular mass (96 g/mol) and multiply by 2 (net charges per ion) to obtain 125 μeq/L = 0.125 meq/L.
(c) Density is mass concentration and for air density equals (P×MW)/(R×T). With fixed P and T, increasing the RH causes the MW to decrease, since MW_{H2O} = 18 g/mol < $MW_{dry\ air}$ = 29 g/mol. With a lower mass for each mole of air, the density decreases.
(d) Clean background air contains CO_2 at about 380 ppm. Some CO_2 dissolves into the raindrop (according to Henry's law) and forms carbonic acid, H_2CO_3*, a weak, diprotic acid. Some of the acid dissociates, liberating H^+ and lowering the pH.
(e) The partial pressure of water vapor is the total air pressure multiplied by the mole fraction of water vapor in the gas. The mole fraction is obtained from stoichiometry: Y_{H2O} = 2/10.56 = 0.189. So P_{H2O} = 0.189 atm.

2. Kinetics in a batch reactor

(a) R = k [A]
(b) $\tau \sim 1/k$
(c) d[A]/dt = -R = -k[A] so $[A](t) = A_o \exp(-kt)$. For t = 1/k, $[A] = A_o/e$.
(d) Use stoichiometry: $[A](t) - A_o = [B](t) - B_o$. Therefore, at t = 1/k, $[B] = B_o - A_o + A_o/e$.
(e) Use stoichiometry. The reaction is complete when all [A] has been consumed. (Some [B] will remain since $A_o < B_o$.) Each mole of A consumed produces one mole of C. Therefore $[C] = C_o + A_o$.

3. Naphthalene: No NAPL

The approach: Figure out how many moles of naphthalene are in the water when it is saturated and in the air when it is saturated. Add the results to obtain the desired *M*.

In water: 31 mg/L ÷ 128 g/mol = 0.24 mM; 0.24 mM × 2 L = 0.48×10^{-3} mol
In air: P_s = 10.6 Pa = 0.000105 atm; $n_s = P_sV/(RT) = 0.21 \times 10^{-3}$ mol

Total: 0.69×10^{-3} moles

4. Acid-mine drainage is a redox phenomenon

(a) S must be at –I, since the molecule is neutral and Fe is +II.
(b) S must be at +VI, since the molecule is neutral, O is –II and H is +I.
(c) Note that S is going from –I to +VI, which is a change of 7, and O is going from 0 to –II, a change of -2. A balanced reaction will have 2 S atoms for every 7 O atoms. Working with integers, we can begin by writing:

$$2\ FeS_2 + 7\ O_2 + \ldots \rightarrow 2\ Fe^{2+} + 4\ H_2SO_4 + \ldots$$

We have balanced Fe, S and the oxidation states. It remains to balance H, O, and +/-:

H: 0 → 8
O: 14 → 16
+/-: 0 → +4

Remedies: add 4 H^+ to the left and add 2 H_2O to the left. Then everything balances:

$$2\ FeS_2 + 7\ O_2 + 4\ H^+ + 2\ H_2O \rightarrow 2\ Fe^{2+} + 4\ H_2SO_4$$

Superficially, we don't see acidification here, since the reaction seems to consume, rather than produce H^+. The resolution is in the fact that sulfuric acid is strong and diprotic. So all of the H_2SO_4 will fully dissociate to H^+ and SO_4^{2-} ions. A better way to write the balanced reaction is like this:

$$2\ FeS_2 + 7\ O_2 + 2\ H_2O \rightarrow 2\ Fe^{2+} + 4\ H^+ + 4\ SO_4^{2-}$$