ANSWERS

1. Environmental engineering concepts

(a) In water, ppb represents a mass fraction of 10^{-9}. Since the density of water is 1000 g/L, a contaminant at a level of 1 ppb would be present at a concentration of 1 µg/L. In this case, the mass fraction is 10 ppb, which corresponds to a concentration of 10 µg/L.

(b) The clean atmosphere contains 400 ppm of CO_2, a sparingly soluble weak acid. CO_2 dissolves into the raindrops, forming carbonic acid. Some of that dissociates in an acid-base reaction, liberating H^+ and thereby lowering the pH.

(c) SO_2

(d) CO_2

2. Carbon tetrachloride partitioning in air and water

A key point is that the moles of CT added (0.20 mol) is greater than the sum of the gaseous (0.096 moles) and aqueous (0.051 moles) CT at equilibrium. That fact means that there is some CT in the form of a NAPL. It also means that the concentration of CT in water is equal to CT's water solubility.

(a) C_s = 0.051 moles × 153.8 g/mol ÷ 10 L = 784 mg/L

(b) The molar concentration of CT in water is 0.051 moles ÷ 10 L = 0.0051 M. The gas-phase partial pressure comes from the ideal gas law: P = (n/V) RT = (0.096/20) (0.0821) (293) = 0.115 atm. Therefore, K_H = 0.0051/0.115 = 0.044 M/atm.

3. Balancing redox: Nitrification

(a) Oxidation state of N in ammonia is –III

(b) Oxidation state of N in the nitrite ion is +III

(c) Since N changes by 6 electrons and O changes by -2 electrons, the balanced reaction will have 3 O atoms for each N atom.

Trial balanced reaction: $2\ NH_3 + 3\ O_2 \rightarrow 2\ NO_2^- + ?$

Check elements and charge:
N: 2 → 2 okay
O: 6 → 4 need 2 on right
H: 6 → 0 need 6 on right
+/-: 0 → -2 need two – on left (or two + on right)

Let's balance the charge by putting two H^+ on the RHS. Then, to balance the remaining H and O, it looks like we would need 2 H_2O on the RHS. So, the final balanced reaction should be this:

$$2\ NH_3 + 3\ O_2 \rightarrow 2\ NO_2^- + 2\ H^+ + 2\ H_2O$$

Check elements and charge:
N: 2 → 2 okay
O: 6 → 4+2 okay
H: 6 → 2+4 okay
+/-: 0 → -2 + 2 okay

4. Octane combustion

It helps to write a balanced reaction for complete, stoichiometric combustion.

$$C_8H_{18} + \alpha\,(O_2 + 3.78\,N_2) \rightarrow 8\,CO_2 + 9\,H_2O + 3.78\alpha\,N_2$$

Balance the oxygen atoms to determine α:

$$2\alpha = 16 + 9 \Rightarrow \alpha = 12.5$$

So, the balanced combustion reaction is:

$$C_8H_{18} + 12.5\,(O_2 + 3.78\,N_2) \rightarrow 8\,CO_2 + 9\,H_2O + 47.25\,N_2$$

(a) For one mole of octane (mass = 114 g), the combustion reaction will generate 8 moles of CO_2 (mass = 8 × (12 + 32) = 352 g). Therefore for each 1 g of octane, combustion will produce 352/114 = 3.1 g of CO_2 (per g octane).

(b) The air-to-fuel mass ratio, M_{af}, is determined as follows:

M_{af} = 12.5 × (32 + 3.78 × 28) ÷ 114 = 1723/114 = 15.1 (air-to-fuel mass ratio)

5. Sorbing toluene

By material balance, the amount of toluene that must be sorbed is the 1 g initial quantity minus the allowed residual of 50 mg/L × 1 L = 50 mg. That quantity is 950 mg. The mass sorbed per mass of GAC is determined by the sorption isotherm, where C = 50 mg/L is the equilibrium (residual) concentration. So, $q = 100\,(50)^{0.45}$ = 581 mg/g. The quantity of GAC that must be supplied is therefore 950 mg ÷ 581 mg/g = 1.6 g