1. Environmental engineering basics (4 points; 1 each)

Provide a brief, accurate response to each of the following problems or questions. Your responses should demonstrate your clear understanding of key concepts.

(a) Consider a parcel of air that has a fixed temperature, T, and pressure, P, and composition. The temperature increases. Does the air density increase, decrease, or stay the same? Explain.

(b) Tetrachloroethylene (C_2Cl_4, MW = 166 g/mol), also known as PE, is an organic solvent used for dry cleaning clothes. It is regulated in the US as a drinking water contaminant. The drinking water standard is 0.005 mg/L. What is the corresponding level of PCE in water, expressed in units of ppb?

(c) What is transferred from one species to another in a *redox* reaction?

(d) A cloud droplet in the unpolluted atmosphere has pH = 5.6. Why isn't the pH equal to 7?

2. NAPL of naphthalene (4 points)

A sealed vessel contains liquid water and air. A quantity of $M = 3$ millimoles of naphthalene ($C_{10}H_8$, MW = 128 g/mol) is injected into container. Given the data below, determine the equilibrium quantity of NAPL naphthalene in this vessel. Express your answers in millimoles. [*Hint*: The final solution does indeed have a NAPL.]

Data:

$K_H = 2.3$ M atm^{-1}	Henry's law constant for naphthalene
$P_{sat} = 10.6$ Pa	(saturation) vapor pressure of naphthalene
$C_{sat} = 31$ mg/L	water solubility of naphthalene
$T = 298$ K	temperature
$V_a = 45$ L $= 0.045$ m^3	volume of air in the container
$V_w = 5$ L	volume of liquid water in the container

3. Environmental redox: Industrial boilers (4 points)

In industrial boilers, dissolved oxygen can be a potent corrosive agent, causing iron to rust. Write a stoichiometrically balanced reaction in which solid iron metal (Fe(s)) is converted to iron rust (Fe^{3+}) in water with dissolved oxygen (O_2) as the oxidizer.

4. Combustion of a synthetic fuel (4 points)

Dimethyl ether (DME, CH_3OCH_3, MW = 46 g/mol) is a synthetic liquid fuel that can be produced from natural gas or coal and used in motor vehicles. What is the air-to-fuel mass ratio for complete, stoichiometric combustion of DME in air? In other words, how many grams of air are required for complete, stoichiometric combustion of one gram of DME? [*Hint*: As usual, represent air as a two-component mixture, $O_2 + 3.78\ N_2$, MW = 29 g/mol.]

5. Neutralizing a strong acid with a strong base (4 points)

Aqueous wastes with a pH ≥ 12.5 or ≤ 2 are classified as hazardous because they are corrosive. They must be treated before disposal. Consider pure water to which is added a strong acid such that the initial solution has pH = 2.0. What dose of the strong base, NaOH (MW = 40.0 g/mol), is required to neutralize the acid so that the final solution has pH = 7.0? Express your answer in g/L.