Practice Set 1

1. A waste treatment pond is 50 m long and 15 m wide, with an average depth of 2 m. The density of the waste is 85.3 lb_m/ft^3. Calculate the weight of the pond contents in lb_f, using a single dimensional equation to do the calculation (think of the grid I use for unit conversions). Ans: 4.5 x 10^6 lb_f

2. A chemical reaction A → B is carried out in a closed vessel. The following data are taken for the concentration of A, C_A (g/L), as a function of time, t(min), from the start of the reaction.

t (min)	0	36	65	100	160	∞
C_A (g/L)	0.1823	0.1453	0.1216	0.1025	0.0795	0.0495

A proposed reaction mechanism predicts that Ca will vary with t according to:

$$\ln \frac{C_A - C_{Ae}}{C_{A0} - C_{Ae}} = -kt$$

Where k is the reaction rate constant.

A) Do the data support this prediction? If so, what is the value of k? Ans: Yes, k = 9.3 x 10^{-3} min^{-1}

B) Also, if the reactor tank volume is 30.5 gallons and there is no B in the tank at t = 0, how much B does the tank have after 2 hours? Ans: 10.7 g

3. A solution containing hazardous waste is charged into a storage tank where it is then chemically treated so that the hazardous material is decomposed. You are told by a colleague that the concentration of the decomposing hazardous waste, C, varies with time according to: C = 1/(a + bt). The contents of the tank are released once the concentration drops below 0.01 g/L. The following data have been obtained:

t (h)	1.0	2.0	3.0	4.0	5.0
C (g/L)	1.43	1.02	0.73	0.53	0.38

A) If the given relationship was correct, plotting what would give you a linear relationship and the ability to calculate a and b from the slope and intercept? Ans: 1/C vs t, slope = b, intercept = a

B) Estimate a and b. Ans: b = 0.477 L/g/h a = 0.082 L/g

C) Estimate the initial concentration in the tank. Ans: 12.2 g/L

D) Estimate the time required to be able to remove the material from the tank (and how confident are you in the estimate). Ans: 209.5 hours

4. Before a rotameter can be used to measure an unknown flow rate, a calibration curve of the flow rate versus the rotameter reading must be prepared. A calibration technique for liquids is to use a pump to force flow through the rotameter, with the outlet of the rotameter going to a graduated cylinder. The flow rate is set by adjusting the pump speed. The following data were collected:

Reading on rotameter	Collection time (min)	Volume collected (cm^3)
2	1	297
2	1	301
4	1	454
4	1	448
6	0.5	300
6	0.5	298
8	0.5	371
8	0.5	377
10	0.5	440
10	0.5	453

A) Assuming the liquid is water at 25C, draw a calibration curve of mass flow rate, m in kg/min, versus rotameter reading, R, and use it to estimate the mass flow rate of water for which you get a reading of R = 5.3. Ans: for R = 5.3, the flow is 0.55 kg/min

B) The mass difference between duplicates, $\overline{D}_i$, provides an estimate of the standard deviation of a single measurement, which was described as s_x earlier.

$$s_x = \frac{\sqrt{\pi}}{2}\overline{D}_i = 0.8862\overline{D}_i$$

Moreover the confidence limits on measured values can be estimated to a good approximation using the mean difference between duplicates. For example, if a single measurement of Y yields a value $Y_{measured}$, then there is a 95% probability that the true value of Y falls within the 95% confidence limits, which are $(Y_{measured} - 1.74\overline{D}_i)$ and $(Y_{measured} + 1.74\overline{D}_i)$

C) For a measured value of 610 g/min, estimate the 95% confidence limit on the true flow rate. Ans: plus or minus 0.018 kg/min

5. A gas chromatograph (GC) separates components of a gas sample into separate components and provides a way of measuring the amounts in the sample. The output is a plot of signal versus time, where the signal corresponds to the amount of the component. The area under the peak formed (signal) is used to calculate the concentration of the component, based on a previously established calibration. The amount can be derived as n_i (mol) = k_iA_i, where A_i is the peak area for species i, and k_i is some proportionality coming from the calibration. Prepare a table as shown below and fill in the blanks:

Sample	Species	MW	k	Peak area	Mole fraction	Mass fraction
1	Methane	16.04	0.150	3.6	0.156	0.062
	Ethane	30.07	0.287	2.8	0.233	0.173
	Propane	44.09	0.467	2.4	0.324	0.353
	Butane	58.12	0.583	1.7	0.287	0.412
2	Methane	16.04	0.150	7.8	0.249	0.111
	Ethane	30.07	0.287	2.4	0.146	0.123
	Propane	44.09	0.467	5.6	0.556	0.685
	Butane	58.12	0.583	0.4	0.050	0.081
3	Methane	16.04	0.150	3.4	0.146	0.064
	Ethane	30.07	0.287	4.5	0.371	0.304
	Propane	44.09	0.467	2.6	0.349	0.419
	Butane	58.12	0.583	0.8	0.134	0.212

6. Perform the following pressure conversions, assuming when needed that atmospheric pressure is 1 atm (unless explicitly stated, the given pressures are absolute):
   a. 2600 mm Hg to psi Ans: 50.3 psi
   b. 275 ft H_2O to kPa Ans:822.0 kPa
   c. 3.00 atm to N/cm^2 Ans: 30.4 N/cm^2
   d. 280 cm Hg to $dynes/m^2$ Ans: 3.733×10^{10} $dynes/m^2$
   e. 20 cm Hg of vacuum to atm (absolute) Ans: 0.737 atm
   f. 25.0 psig to mm Hg (gauge) Ans: 1293 mm Hg (gauge)
   g. 25.0 psig to mm Hg (absolute) Ans: 2053 mm Hg absolute
   h. 325 mm Hg to mm Hg gauge Ans: -435 mm gauge

7. An orifice meter is to be calibrated for the measurement of the flow rate of a stream of liquid acetone. The differential manometer fluid has a specific gravity of 1.10. The following calibration data were taken:

Manometer reading h (mm)	Flow rate (mL/s)	Delta P (mm Hg)
0	0	
5	62	0.114
10	87	0.227
15	107	0.341
20	123	0.455
25	138	0.568
30	151	0.682

A) For each of the readings calculate the pressure drop across the orifice, ΔP (mm Hg).

B) The flow rate through the orifice should be related to the pressure drop across the orifice by the equation $V(mL/s)= K(\Delta P)^n$. Verify graphically that the calibration data are correlated by this relationship and determine the values of K and n. Ans: n = ~0.5, K = 183 (mL/s)/(mm Hg)$0^{.5}$

C) If in use a reading of h = 23 mm is obtained, what are the volumetric, mass and molar flow rates of acetone in the process? Ans: 132 mL/s, 104 g/s, 1.80 mol/s