1. (5 points) For the equation:

$$m * V^{-b} = \frac{T-c}{a}$$ Where V is volume (L), m is mass (kg), T is Temperature (K).

   a. What are the units of the constant, b? Justify your answer.
   b. What are the units of the constant, c? Justify your answer.
   c. What are the units of the constant, a? Justify your answer.

Replace Variable w/ respective units as: $Kg * L^{-b} = \frac{K-c}{a}$
↳ We know units on both sides must be equivalent!

a) V has units (L) as given, and b is an exponent acting on this quantity, so it can be assumed $\boxed{\text{b is unitless.}}$

b) T has units of K as it is temperature. In order to subtract quantities, they must agree within their units. Therefore $\boxed{\text{c must have units of K}}$

c) Suppose b=1, unitless as explained in (a). Analyzing the equation with units:

$Kg * L^{-1} = \frac{K}{a}$, we can rearrange for a as:

$a = \frac{K}{Kg * L^{-1}}$, simplifying to $\boxed{a = K * L * Kg^{-1}}$ ← unitted expression, quantities not needed

2. (5 points) A student filled a 1 L flask with maple syrup (density = 1.34 g/mL) in 2 minutes through a funneling spigot. The time to fill the same flask with water using at the same mass flow rate would be __________. Without doing any calculations, justify your answer. You may use equations but do not do a numerical calculation.
   a. Shorter than with maple syrup
   b. Longer than with maple syrup
   c. The same as maple syrup

$$\text{Mass} = \text{Volume} \times \text{Density}$$

$$\dot{\text{Mass}} = \frac{\text{Mass}}{\text{Time}}$$

$$\text{Time} = \frac{\text{Mass}}{\dot{\text{Mass}}} = \frac{\text{Volume} \times \text{Density}}{\dot{\text{Mass}}}$$

$\boxed{\text{Time is shorter than maple syrup}}$

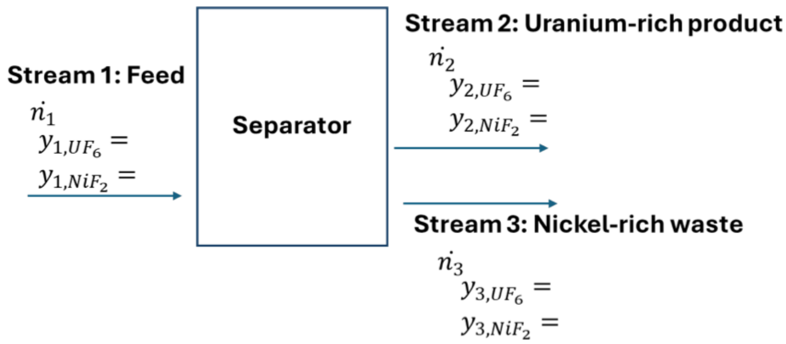
Assuming cross-sectional area is constant as well as the mass flowrate, water would take a shorter time. Water's density is about 1 g/mL, which is less than maple syrup. Lowering the density in the equation in blue causes the time to decrease.

3. (5 points) Rank the following from least number of significant figures to most number of significant figures. You can use inequalities and equalities (> and =).
   a. π ← infinite
   b. Ideal gas constant, R = 0.821 L·atm/mol·K ← 3 sf
   c. 3,000 ← 1 sf
   d. 3.0×10^{-5} ← 2 sf

$$\boxed{3{,}000 < 3.0\times10^{-5} < 0.821 < \pi}$$

π has infinite digits and is infinitely precise!

4. (30 points) At a nuclear fuel fabrication facility, uranium oxide is converted to gaseous uranium hexafluoride (UF_6). Unfortunately, some undesired species are also volatilized (made gaseous) like nickel fluoride (NiF_2). The mixture of UF_6 and NiF_2 are fed to a separator which is shown below.



a) Given Quantities

mol fraction: $y_{1,UF6} = 0.82$

$y_{1,NiF_2} = 0.18$

Molecular Weights:

$UF_6 = 238.03 + 6(19.00) = 352.03$ g/mol

$NiF_2 = 58.69 + 2(19.00) = 96.69$ g/mol

Mass UF_6: $\frac{0.82 \text{ mol}}{1 \text{ mol}} \times \frac{352.03 \text{ g UF6}}{\text{mol UF6}} = 288.6646 \text{ g UF6/mol mixture}$

Mass NiF_2: $\frac{0.18 \text{ mol}}{\text{mol}} \times \frac{96.69 \text{ g } NiF_2}{\text{mol } NiF_2} = 17.4042 \text{ g } NiF_2\text{/mol mixture}$

Mass Mixture: $288.6646 + 17.4042 = 306.0688$ g

Rounding done @ end for accuracy

Mass Fraction UF_6: $\frac{288.6646}{306.0688} = 0.9431 \rightarrow \boxed{\text{Mass Fraction } UF_6 : 0.94}$

b) Given Quantities

Mixed Gas @ T = 298 K

Molar Flowrate $\dot{n} = 100 \frac{mol}{s}$

Assume Ideal Gas

Important Quantities

$bar = \frac{mbar}{1000}$

$P\dot{V} = \dot{n}RT$ Use Ideal Gas law to relate $\dot{V}$ to $\dot{n}$

$\dot{V} = \frac{\dot{n}RT}{P}$, $\dot{n} = 100 \frac{mol}{s}$, $T = 298$ K

Variable

$R = 8.31 \times 10^{-2} \frac{L \cdot bar}{mol \cdot K}$

Pressure increments of 10 mbar, from 10 mbar to 100 mbar. Done in excell, reported to 1 sf as $\dot{n}$ is limiting.

mbar	10	20	30	40	50	60	70	80	90	100
$\dot{V}$	2×10^{-5}	1×10^{-5}	8×10^{-4}	6×10^{-4}	5×10^{-4}	4×10^{-4}	4×10^{-4}	3×10^{-4}	3×10^{-4}	2×10^{-4}

c) Given Quantities

Specific Activity (SA): decay rate / unit mass

Becquerels ↳ $Bq/g = {}^{1\,decay}/_{second}/_{gram}$ ← 1 Bq

- $UF_6 = 8{,}000\ Bq/g$
- $NiF_2 = 500\ Bq/g$

Masses of species from (a)

Mass UF_6: 288.6646 g

Mass NiF_2: 17.4042 g

Want to use weighted Average

$$SA_{Avg} = \frac{SA_{UF_6} m_{UF_6} + SA_{NiF_2} m_{NiF_2}}{m_{UF_6} + m_{NiF_2}}$$

$$= \frac{8000\ Bq/g\,(288.6646\ g) + 500\ Bq/g\,(17.4042)}{288.6646 + 17.4042} = 7573.52\ Bq/g$$

SA given are reported to 1 sf, so $\boxed{SA_{Feed} = 8.0 \times 10^{-3}}$

5. (5 points) Review the learning objectives from Unit 1. In which problems on the HW were the objectives tested? You can make a list.

After this unit, students are expected to be able to:

- Identify process variables
- Convert between mass, moles, and volumetric flowrate for liquids
- Convert between mass, moles, and volume for ideal gases
- Calculate a the average property of a mixture (weighted average)
- Use Excel to perform mathematical operations
- In Excel, use cell referencing techniques for fixed properties

For this Homework Assignment, all of the above topics were tested but identifying process variables. While problem 1 did evaluate our ability to perform dimensional analysis and ensure units were accurate, It did not explicitly ask for a list of process variables. The same can be said for problem 5, though that problem did present a process flow diagram, which was helpful in showing how a PFD might be used to identify process variables in future problems. Problem 4 attacked every other objective listed above in blue. Part (a) required a conversion between moles and masses, which led to developing a mass fraction for a specific species. Part (b) required looking at the relationship between volume flow rate and molar flow rate for ideal gases. Part (c) tackled the weighted average idea, which was used to accurately determine the specific activity average of the feed stream. Excel was used for each of these parts in order to perform quick mathematical operations, which required special cell referencing to do.