Problem 1 : Units (5 points)

For the equation $m \cdot V^{-b} = \frac{T-c}{a}$ where $m = Kg$, $V \equiv L$, $T \equiv K$

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

$\boxed{\text{b is unitless because it is an exponent}}$

b. What are the units of c? Justify.

$\boxed{\text{Kelvin (K), because it is subtracted from T which has units of K}}$

c. What are the units of a? Justify

The equation must be dimensionally homogeneous.

Units of the RHS $= Kg \cdot L^{-b}$

and units RHS = LHS so $Kg \cdot L^{-b} = \frac{K-K}{a}$

rearranging, solving for a. $a = \frac{K-K}{Kg \cdot L^{-b}} \Rightarrow \boxed{\frac{K \cdot L^{b}}{Kg}}$

Problem 2: Maple Syrup (5 points)

To convert from volumetric flowrate to mass flowrate, we multiply by the density.

$$\dot{m}_{syrup} = \dot{V}_{syrup}\,\rho_{syrup} = \frac{V_{syrup}}{t_1}\cdot\rho_{syrup}$$

Then we do the same thing for water:

$$\dot{m}_{oil} = \dot{V}_{water}\,\rho_{water} = \frac{V_{water}}{t_2}\cdot\rho_{water}$$

The problem statement says that the mass flowrates are the same:

$$\dot{m}_{syrup} = \dot{m}_{water}$$

$$\frac{V_{syrup}}{t_1}\cdot\rho_{syrup} = \frac{V_{water}}{t_2}\,\rho_{water}$$

Now we can solve for t_2, the time it takes for the water to pass through the funnel.

$$\frac{\dot{V}_{syrup}}{t_1}\cdot\rho_{syrup} = \frac{\dot{V}_{water}}{t_2}\,\rho_{water}$$

$$t_2 = \frac{V_{water}}{V_{syrup}}\cdot\frac{\rho_{water}}{\rho_{syrup}}\cdot t_1$$

And, the problem statement asks about 1L of both liquids so

$V_{water} = V_{syrup}$ and $\frac{V_{water}}{V_{syrup}} = 1$.

Simplifying:

$$t_2 = \frac{\rho_{water}}{\rho_{syrup}}\cdot t_1$$

If we look up the density of the water, we find it is less than maple syrup. Therefore $\frac{\rho_{water}}{\rho_{syrup}} < 1$ and $t_2 < t_1$

$\boxed{\text{a. Shorter than with maple syrup}}$

$\boxed{\text{Problem 3}}$ Rank the following from least to most significant figures.

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

$$c < d < b < a$$

Explanation

π has infinite

R has 3

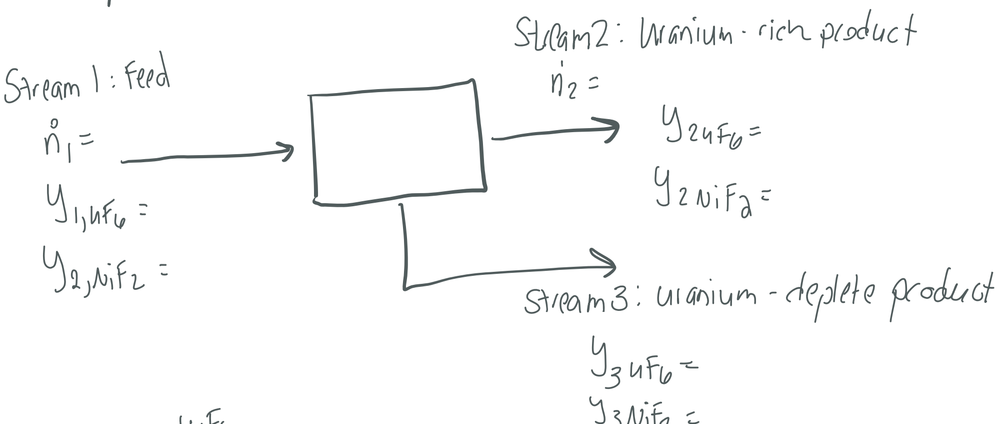
3.0×10^{-5} has 2

3,000 has 1 because trailing zeros to the left of a decimal place are not significant

Problem 4

30 points

UF_6 / NiF_2 mixture is fed to an enrichment plant



a. The feed is 0.82 $\frac{mol\ UF_6}{mol}$. What is the mass fraction of UF_6 in the feed? (10 points)

mol fraction: $\frac{82\ mol\ UF_6}{100\ mol\ feed} = \frac{82\ mol\ UF_6}{82\ mol\ UF_6 + 20\ mol\ NiF_2}$

Want to know mass fraction: $\frac{g\ UF_6}{g\ UF_6 + g\ NiF_2}$

1. assume a basis: 1 mol feed then calc. mass UF_6
2. Calculate $MW_{UF_6} = MW_U + 6 \cdot MW_F = 352\ g/mol$
3. Convert mol $UF_6 \rightarrow$ mass UF_6. $\Rightarrow 100\ mol \cdot y_{UF_6} \left(\frac{mol\ UF_6}{mol\ feed}\right) \cdot MW_{UF_6}\left(\frac{g}{mol}\right)$
4. Calculate $MW_{NiF_2} = MW_{Ni} + 2MW_F = 96.69\ g/mol$
5. Convert mol $NiF_2 \rightarrow$ mass $NiF_2 = 100\ mol \cdot y_{NiF_2}\left(\frac{mol\ NiF_2}{mol\ feed}\right) \cdot MW_{NiF_2}\left(\frac{g}{mol}\right)$
6. calculate the mass fraction, $y_{UF_6} = \frac{m_{UF_6}}{m_{UF_6} + m_{NiF_2}}$

all Calculations done in excel.

$$\boxed{y_{UF_6} = 0.94}$$

b. $T = 298K$, $\dot{n}_1 = 100$ mol/s, $P = 10 - 100$ mbar (10 points)

Use ideal gas law, $P\dot{V} = \dot{n}RT$

$$\dot{V} = \frac{\dot{n}RT}{P} \quad (*)$$

To solve

1. Convert mbar to bar for all P
2. use equation (*) with $R = 8.31 \times 10^{-2} \frac{L \cdot bar}{mol \cdot K}$ to calc $\dot{V}$ for all P

$\boxed{\text{See excel for } \dot{V}(L/s) \text{ calculated for all P}}$

c. What is the specific activity of the feed? (Bq/g) (5 points)

$SA_{UF_6} = 8{,}000$ Bq/g

$SA_{NiF_2} = 500$ Bq/g

Calculating the SA of a mixture is analogous to calculating the density of a mixture. Both are specific properties i.e. on a per mass or per mol basis.

In excel

1. $SA_{mixture} = y_1 SA_1 + y_2 SA_2$

y_1 = mass fraction of species 1
y_2 = mass fraction of species 2

Calculated in part A.

$$\boxed{SA_{feed} = 7600 \text{ Bq/g}}$$

Two significant figures because the initial mol fraction was given with two significant figures.