ENGG 201 – MASS BALANCE EXAMPLE PROBLEMS

Question 1

5. A sink tap is dripping at a rate of 3 mL per 10 minutes, and the plug is accidentally left in. How long would it take to fill up a 5 L sink? What would the outlet flow rate be (in SI units) when the sink was full? (/2)

IN + ~~GEN~~ = ~~OUT~~ + ACCUM (on sink)

Rate = $\frac{3\,mL}{10\,min}$ = 0.3 mL/min → total volume = 5000 mL

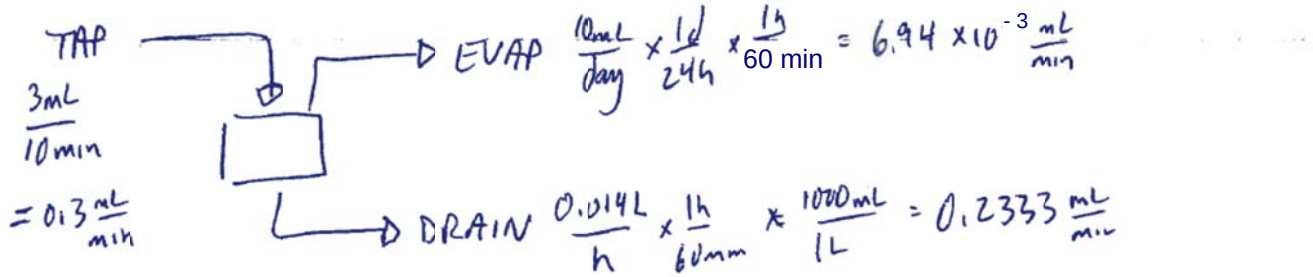
$\frac{5000\,mL}{0.3\,mL/min}$ = 16,667 min (277.8 h) → If sink was full IN = OUT

↳ $\frac{0.3\,mL}{min} \times \frac{1\,cm^3}{1\,mL} \times \left(\frac{m}{100\,cm}\right)^3 \times \frac{1\,min}{60\,s}$

$= 5 \times 10^{-9}\ m^3/s$

Question2

5. A sink tap is dripping at a rate of 3 mL per 10 minutes into a sink that initially holds 5 L of water, and the drain is partially blocked only allowing 0.014 L/h out. If water is evaporating at a rate of 10 mL per day, how long (h) would it take to fill up the entire sink (total volume = 10L)? (/2)



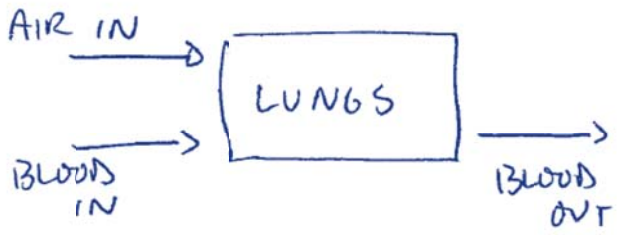
IN + ~~GEN~~ = OUT + ACCUM

0.3 = 6.94 x10^-3 + 0.2333 + ACCUM

ACCUM = 0.05972 mL/min → $\frac{5000\,mL}{0.05972\,mL/min}$ = 83720 min → 1395 h

Question 3

3. In the human body, the oxygen level in the blood just before it enters the lungs is 0.15 mL_{O2} / mL_{blood} and the oxygen level in blood just after the lungs is 0.20 mL_{O2} / mL_{blood}. In addition, the uptake rate of oxygen in the lungs is 270 mL $_{O2}$/min from the air. Determine the flow rate of blood in L/min. (/2 Marks)



1

OXYGEN BALANCE ON LUNGS

INPUT + GENERATION = OUTPUT + ACCUMULATION

IN = OUT

$$\frac{270\,mL_{O2}}{min} + \frac{0.15\,mL_{O2}}{mL\ blood} \cdot X\ \frac{mL_{blood}}{min} = \frac{0.20\,mL_{O2}}{mL_{blood}} \cdot X\ \frac{mL_{blood}}{min}$$

1/2

$$270 = (0.2 - 0.15)X \rightarrow X = \frac{270}{0.2-0.15}$$

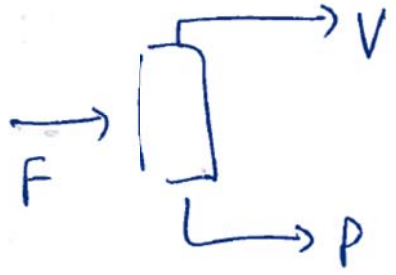
$$X = 5400\ mL_{blood}/min$$

$$X = 5.4\ L/min\ blood$$

1/2

Question 4

2. An evaporator is a unit operation that concentrates a liquid solution by evaporating pure water as vapour. A liquid stream flowing at a rate of 500 kg/h containing 25% by mass NaOH is fed to an evaporator, and the concentration of the resulting liquid output is 40%. Calculate the rate of product formation (kg/h) and vapour production (kg/h) at steady state. ***(/2)***



$F = 500$ kg/h $\quad P = ?$

$w_F = 0.25 \quad V = ?$

$w_P = 0.40$

$F = P + V \rightarrow 500 = P + V$

$F w_F = P w_P$

$500 \times 0.25 = P \times 0.40$

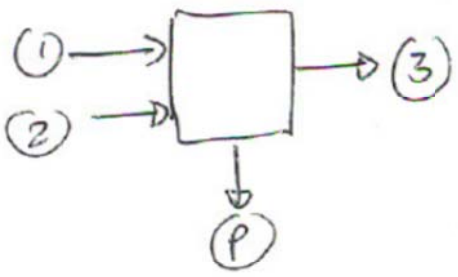
$\boxed{P = 312.5 \text{ kg/h}}$

$500 = 312.5 + V$

$\boxed{V = 187.5 \text{ kg/h}}$

Question 5

2. A process mixes Stream 1 (400 kg/h of a solution containing 10% by mass salt) with another, Stream 2 (flowing at a rate of 0.1 kg/s containing 20% by mass salt) to generate a mixed salt water Stream 3. During the process, a total of 120 kg of salt precipitates and is removed as solid each day. What is the flow rate of the salt water and concentration of salt in the exit Stream 3 at steady state? *(/2)*



Total mass ~~bla~~ balance (per hour)

(1) 400 kg/h

(2) $0.1\ kg/s \times 3600\ s/h = 360\ kg/h$

(P) $\frac{120\ kg}{day} \times \frac{1\ day}{24\ h} = 5\ kg/h$

$IN + GEN = OUT + ACCUM$

$IN = OUT$

Total $400\ kg/h + 360\ kg/h = 5\ kg/h + (3) \rightarrow$ **(3) = 755 kg/h**

salt $0.1(400\ kg/h) + 0.2(360\ kg/h) = 5\ kg/h + (3) \times X$ (107 kg/h)

$X = 0.1417 \rightarrow$ **14.2 % by mass**

Use the back if you need space →