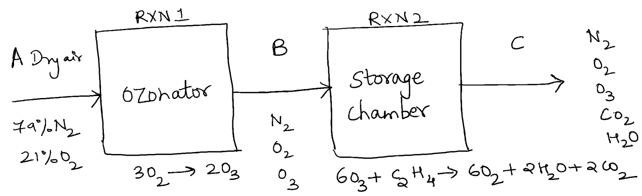
Question 14 : Incomplete Conversion of Ethylene



Let's start with a basis for dry air, $\dot{n}_{DA} = 100$ mol air/h in stream A

Balances around the ozonator,

$\boxed{N_2}$: ACC = IN - OUT + GEN

$$0 = 79\,\text{mol/h} - \dot{n}_N^B + 0$$

$$\boxed{\dot{n}_N^B = 79\ \text{mol}\ N_2/h}$$

$\boxed{O_2}$: ACC = IN - OUT + GEN

$$0 = 21\,\text{mol/h} - \dot{n}_{ox}^B - \dot{n}_{ox}^{RXN1} \quad -(1)$$

$$\text{Conversion} = \frac{\text{mol } O_2 \text{ consumed}}{\text{mol } O_2 \text{ fed}}$$

$$0.07 = \frac{\dot{n}_{ox}^{RXN1}}{21}$$

$$\boxed{\dot{n}_{ox}^{RXN1} = 1.47\ \text{mol}\ O_2/h}$$

from 1, $\Rightarrow$ $0 = 21 - \dot{n}_{ox}^B - 1.47$

$$\boxed{\dot{n}_{ox}^B = 19.53\ \text{mol}\ O_2/h}$$

$\boxed{O_3}$: ACC = IN - OUT + GEN

$$0 = 0 - \dot{n}_{oz}^B + \dot{n}_{oz}^{RXN1} \quad -(2)$$

$$\dot{n}_{oz}^{RXN1} = \frac{2 \text{ mol } O_3 \text{ generated}}{3 \text{ mol } O_2 \text{ consumed}} \times 1.47 \text{ mol } O_2 \text{ cons/h}$$

$$\boxed{\dot{n}_{oz}^{RXN1} = 0.98\ \text{mol}\ O_3/h}$$

From 2, $0 = 0 - \dot{n}_{oz}^B + 0.98 \rightarrow \boxed{\dot{n}_{oz}^B = 0.98\ \text{mol}\ O_3/h}$

Balance around the storage chamber,

$\boxed{N_2}$: ACC = IN - OUT + GEN

$$0 = 79\,\text{mol/h} - \dot{n}_N^C + 0$$

$$\boxed{\dot{n}_N^C = 79\ \text{mol}\ N_2/h}$$

$\boxed{O_3}$: ACC = IN - OUT + GEN

$$0 = 0.98\,\text{mol/h} - \dot{n}_{oz}^C - \dot{n}_{oz}^{RXN2} \quad -(3)$$

Percentage excess of O_3 is 80%

$$XS = \frac{\text{mol } O_3 \text{ fed} - \text{mol } O_3 \text{ consumed}}{\text{mol } O_3 \text{ consumed}}$$

$$0.8 = \frac{0.98 \text{ mol/h} - \dot{n}_{OZ}^{RXN2}}{\dot{n}_{OZ}^{RXN2}}$$

$$\boxed{\dot{n}_{OZ}^{RXN2} = 0.54 \text{ mol } O_3/h}$$

From 3,

$$0 = 0.98 - \dot{n}_{OZ}^{C} - \dot{n}_{OZ}^{RXN2}$$

$$0 = 0.98 - \dot{n}_{OZ}^{C} - 0.54$$

$$\boxed{\dot{n}_{OZ}^{C} = 0.44 \text{ mol } O_3/h}$$

$\boxed{C_2H_4}$: How much C_2H_4 can we remove?

$$= \frac{1 \text{ mol } C_2H_4 \text{ cons}}{6 \text{ mol } O_3 \text{ cons}} \times 0.54 \text{ mol } O_3 \text{ cons/h}$$

Sarada Sripada at 11/1/2021 8:14 PM

$$= \underline{0.09 \text{ mol } C_2H_4/h}$$

$\boxed{O_2}$: ACC = IN − OUT + GEN

$$0 = 19.53 \text{ mol/h} - \dot{n}_{OX}^{C} + \dot{n}_{OX}^{RXN2} \quad -(4)$$

$$\dot{n}_{OX}^{RXN2} = \frac{6 \text{ mol } O_2 \text{ generated}}{6 \text{ mol } O_3 \text{ consumed}} \times 0.54 \text{ mol } O_3 \text{ cons/h}$$

$$\boxed{\dot{n}_{OX}^{RXN2} = 0.54 \text{ mol } O_2/h}$$

From 4, $0 = 19.53 - \dot{n}_{OX}^{C} + 0.54$

$$\boxed{\dot{n}_{OX}^{C} = 20.07 \text{ mol } O_2/h}$$

$\boxed{CO_2}$: ACC = IN − OUT + GEN

$$0 = 0 - \dot{n}_{CD}^{C} + \dot{n}_{CD}^{RXN2} \quad -(5)$$

RXN 2 ... cons/h

$$0 = 0 - \dot{n}_{CD}^{c} + \dot{n}_{CD} \qquad -(5)$$

$$\dot{n}_{CD}^{RXN\,2} = \frac{2 \text{ mol } CO_2 \text{ gen}}{6 \text{ mol } O_3 \text{ cons}} \times 0.54 \text{ mol } O_3 \text{ cons/h}$$

$$\boxed{\dot{n}_{CD}^{RXN\,2} = 0.18 \text{ mol } CO_2/h}$$

from 5, $0 = 0 - \dot{n}_{CD}^{c} + 0.18 \text{ mol/h}$

$$\boxed{\dot{n}_{CD}^{c} = 0.18 \text{ mol } CO_2/h}$$

$\boxed{H_2O}$: ACC = IN − OUT + GEN

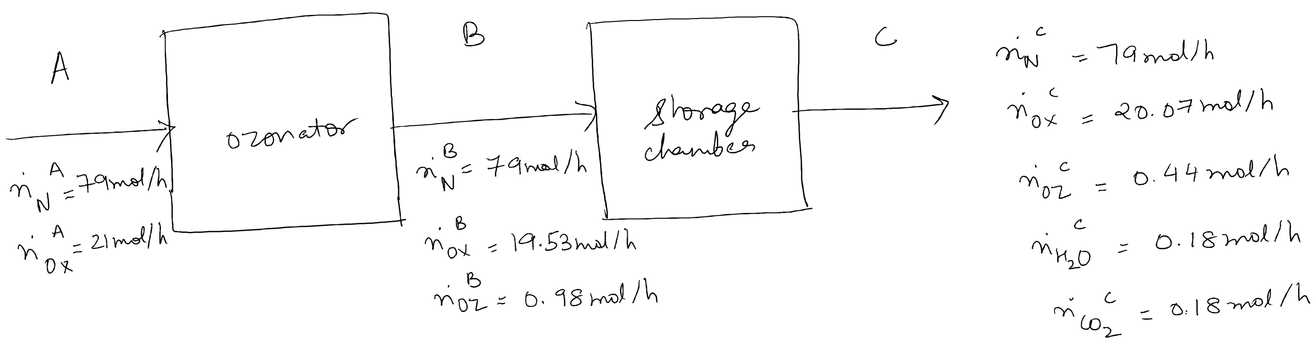
$$0 = 0 - \dot{n}_{W}^{C} + \dot{n}_{W}^{RXN2} \qquad -(6)$$

$$\dot{n}_{W}^{RXN\,2} = \frac{2 \text{ mol } H_2O \text{ gen}}{6 \text{ mol } O_3 \text{ cons}} \times 0.54 \text{ mol } O_3/h$$

$$\boxed{\dot{n}_{W}^{RXN2} = 0.18 \text{ mol } H_2O/h}$$

from 6, $0 = 0 - \dot{n}_{W}^{c} + 0.18 \text{ mol/h}$

$$\boxed{\dot{n}_{W}^{c} = 0.18 \text{ mol/h}}$$



Summary of gases out in stream c,

	ni (mol/h)	xi
N_2	79	0.79
O_2	20.07	0.201

O_2	20.07	0.201
O_3	0.44	0.0044
CO_2	0.18	0.0018
H_2O	0.18	0.0018
Total $\rightarrow$	99.87	

Scale $\rightarrow$ for $\dot{n}^A_{DA} = 100\ mol/h$, $0.09\ mol\ C_2H_4/h$ is removed.

$\Rightarrow$ 16 tons of apples $\times \frac{6.5 g\ C_2H_4}{ton.h} \times \frac{mol}{28.05 g} = 3.71\ mol\ C_2H_4/h$

which means our basis of 100 mol/h is $3.71/0.09 \rightarrow 41.2$ times too small.

(i) Quantity of ozone generated:

$\dot{n}^B_{OZ} = 0.98\ mol/h$

$\Rightarrow \left(\frac{0.98\ mol\ O_3}{h}\right)(41.2) = 40.4\ mol\ O_3/h$ or

$\left(\frac{40.4\ mol\ O_3}{h}\right)\left(\frac{48 g\ O_3}{1\ mol\ O_3}\right) = \boxed{1.94\ kg\ O_3/h}$

(ii) Quantity of dry air to be supplied to the ozonator:-

$\dot{n}^A_{DA} = 100\ mol\ D.A/h$

$\Rightarrow \left(\frac{100\ mol\ DA}{h}\right)(41.2) = 4120\ mol\ DA/h$

$\Rightarrow \left(\frac{4120\ mol\ DA}{h}\right)\left(\frac{29 g\ DA}{1\ mol\ DA}\right) = \boxed{119.5\ kg\ DA/h}$

$(101.4\ m^3\ DA/h$ at $25°C)$

(iii) Composition of the exit gas (mole fraction calculated above)

Total flow out $= \left(\frac{99.87\ mol}{h}\right)(41.2) = \boxed{4115\ mol/h}$