The University of Jordan
Faculty of Engineering & Technology
Chemical Engineering Department

10/10 Great Job!! :)

(0905211) Chemical Engineering Principles	Second Semester – 2016/2017

Quiz # 1 (Chapter 2)

Name: [illegible]   ID # 0156491

Q1: The volume of microbial culture is observed to increase with time, t, according to the formula:

$$V(cm^3) = 3.0e^{1.5t(s)} \text{ where t is in seconds}$$

a) **What are the units of the constants 3.0 and 1.5?**

constant 3 (cm^3) ✓

constant 1.5 (s^{-1}, $\frac{1}{s}$) ✓

b) **What is the value of V at t = 30 seconds?**

$V = 3e^{1.5t}$

$V = 3e^{1.5(30)} = 1.0 * 10^{20}\ cm^3$ ✓

Q2: Using the dimensional equations convert: 921 kg/m³ to lbm/ft³

$\frac{921\ kg}{m^3} \Big| \frac{1\ lb_m}{0.453593\ kg} \Big| \frac{1\ m^3}{35.3145\ ft^3} = 57.5\ lb_m/ft^3$ ✓

~~1~~
~~1.0.0.1 ... 044955~~

Mass	$1\ kg = 1000\ g = 0.001$ metric ton $= 2.20462\ lb_m = 35.27392$ oz $1\ lb_m = 16\ oz = 5 \times 10^{-4}$ ton $= 453.593\ g = 0.453593\ kg$
Length	$1\ m = 100\ cm = 1000\ mm = 10^6$ microns (μm) $= 10^{10}$ angstroms (Å) $= 39.37$ in. $= 3.2808$ ft $= 1.0936$ yd $= 0.0006214$ mile $1\ ft = 12$ in. $= 1/3$ yd $= 0.3048\ m = 30.48\ cm$
Volume	$1\ m^3 = 1000\ L = 10^6\ cm^3 = 10^6\ mL$ $= 35.3145\ ft^3 = 220.83$ imperial gallons $= 264.17$ gal $= 1056.68$ qt $1\ ft^3 = 1728\ in.^3 = 7.4805$ gal $= 0.028317\ m^3 = 28.317\ L$ $= 28{,}317\ cm^3$

$g = 9.8066\ m/s^2$
$= 980.66\ cm/s^2$
$= 32.174\ ft/s^2$

Q3: The following (x, y) data are to be correlated by the relation: $y = ax^b$.

x	0.5	1.4	84
y	2.20	3.00	6.30

a) What you plot to get a straight line?

$y = a x^b$

$\ln y = \ln a + b \ln x$

- $\ln y$ vs $\ln x$ ✓ — $\ln a \rightarrow$ intercept $\rightarrow a = e^{\text{intercept}}$
- $b \rightarrow$ slope

b) Plot the data as you decided in (a) to determine the coefficients *a* and *b*.

$\ln y = \ln a + b \ln x$

x	0.5	1.4	84
y	2.20	3.00	6.30
ln y	0.788	1.098	1.840
ln x	-0.693	0.336	4.430

$b = \frac{\Delta y}{\Delta x} = \frac{1.25 - 1}{1.5 - 0} = \frac{0.25}{1.5}$

$b = 0.16$ ✱

$\ln a = \ln y - b \ln x$

$\ln a = \ln(2.20) - (0.16(\ln 0.5))$

$\ln a = 0.788 - (0.16 * (-0.693))$

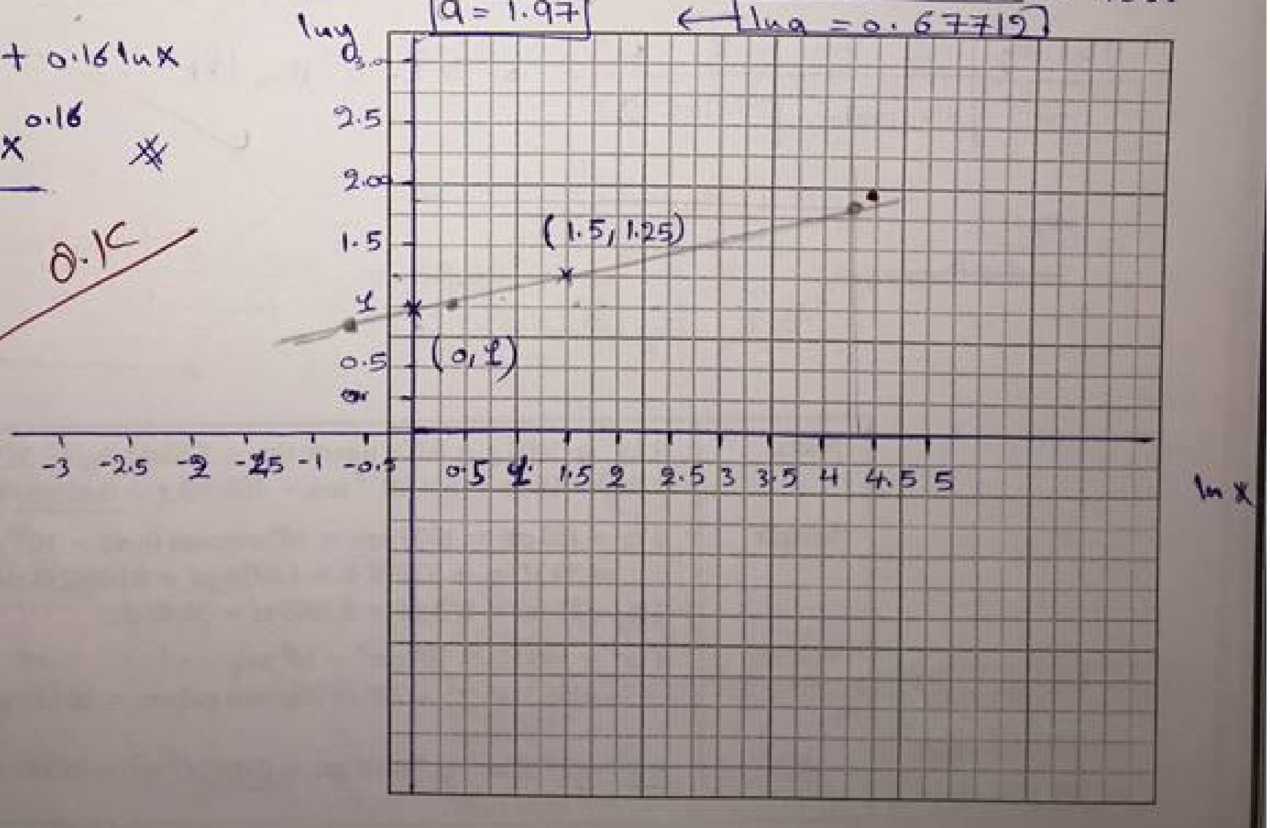
$= 0.11088$

$\ln a = 0.67712$ ⟵ $a = 1.97$

$\ln y = 0.67712 + 0.16 \ln x$

$y = 1.97 * x^{0.16}$ ✱

0.1C



Quiz # 2 (Chapter 3)

Name: [illegible] ID # 0150421

Q1: A mixture of n-heptane and n-hexane contains 20.0 wt% n-heptane.

$x_{hep} = 0.2$

$x_{hex} = \frac{m}{tot} = \frac{80}{100}$

a) **What is the average molecular weight of the mixture?**

$\frac{1}{\bar{M}} = x_{hep} \bar{M} + x_{hex} \bar{M}$

$\frac{1}{\bar{M}} = \frac{0.2 \text{ g hep}}{\text{g tot}} \Big| \frac{100.2 \text{ g tot}}{\text{mol}} +$

b) **How many moles of n-heptane are in 150.0 kg of the mixture?**

$x_{hep} = 0.2$

$x = \frac{\text{mass hep}}{\text{mass mix}}$

mass hep = 30 kg.

$n_{hep} = \frac{m}{Mw}$

$n_{hep} = \frac{30 \text{ kg}}{100.20 \text{ kg}} \Big| \text{Kmol} \Rightarrow n = 0.3 \text{ Kmol}$ #

c) **The flow rate of n-heptane in the mixture is to be 120 lb-mole/h. What must the mixture flow rate be in lb_m/min?**

~~basis 1 lb-mol/h~~

$\dot{n}_{hep} = 120$ lb-mol / h

$\dot{m}_{mix} = ??$ lbm/min

$n = \frac{m}{Mw}$

$\dot{m}_{hep} = \dot{n} * Mw$

$\dot{m}_{hep} = \frac{120 \text{ lbmol}}{\text{h}} \Big| \frac{100.2 \text{ lbm}}{\text{lbmol}} = 12000 \text{ lbm/h}$ #

heptane → in mix = ?

a) $\frac{1}{\bar{M}} = \frac{x_{hep}}{\bar{M}} + \frac{x_{hex}}{\bar{M}}$

$\frac{1}{\bar{M}} = \frac{0.2 \text{ g hep}}{\text{g tot}} \Big| \frac{\text{mol}}{100.2 \text{ g tot}} + \frac{0.8 \text{ g hex}}{\text{g tot}} \Big| \frac{\text{mol}}{86.17 \text{ g}}$

$\frac{1}{\bar{M}} = 1.99 \times 10^{-3} \text{ g/mol} + 9.28 \times 10^{-3} = 0.01127 \Rightarrow \bar{M} = 88.7 \text{ g/mol}$

Compound	Formula	Mol. Wt.	SG (20°/4°)	T_m(°C)[b]	$\Delta\hat{H}_m(T_m)$[c,j] kJ/mol	T_b(°C)[d]	$\Delta\hat{H}_v(T_b)$[e,j] kJ/mol	T_c(K)[f]	P_c(atm)[g]	$(\Delta\hat{H}_f^\circ)$[h,j] kJ/mol	$(\Delta\hat{H}_c^\circ)$[i,j] kJ/mol
n-Heptane	C_7H_{16}	100.20	0.684	−90.59	14.03	98.43	31.69	540.2	27.0	−224.4(l) −187.8(g)	−4816.9(l) −4853.5(g)
n-Hexane	C_6H_{14}	86.17	0.659	−95.32	13.03	68.74	28.85	507.9	29.9	−198.8(l) −167.2(g)	−4163.1(l) −4194.8(g)
Hydrogen	H_2	2.016	—	−259.19	0.12	−252.76	0.904	33.3	12.8	0(g)	−285.84(g)
Hydrogen bromide	HBr	80.92	—	−86	—	−67	—	—	—	−36.23(g)	—
Hydrogen chloride	HCl	36.47	—	−114.2	1.99	−85.0	16.1	324.6	81.5	−92.31(g)	—
Hydrogen cyanide	HCN	27.03	—	−14	—	26	—	—	—	+130.54(g)	—
Hydrogen fluoride	HF	20.0	—	−83	—	20	—	503.2	—	−268.6(g) −316.9(aq, 200)	— —
Hydrogen sulfide	H_2S	34.08	—	−85.5	2.38	−60.3	18.67	373.6	88.9	−19.96(g)	−562.59(g)
Iodine	I_2	253.8	4.93	113.3	—	184.2	—	826.0	—	0(c)	—
Iron	Fe	55.85	7.7	1535	15.1	2800	354.0	—	—	0(c)	—
Lead	Pb	207.21	$11.337^{20°/20°}$	327.4	5.10	1750	179.9	—		0(c)	—
Lead oxide	PbO	223.21	9.5	886	11.7	1472	213	—	—	−219.2(c)	—
Magnesium	Mg	24.32	1.74	650	9.2	1120	131.8	—	—	0(c)	—
Magnesium chloride	$MgCl_2$	95.23	$2.325^{25°}$	714	43.1	1418	136.8	—	—	−641.8(c)	—
Magnesium hydroxide	$Mg(OH)_2$	58.34	2.4		Decomposes at 350°C			—			—
Magnesium oxide	MgO	40.32	3.65	2900	77.4	3600	—	—	—	−601.8(c)	—
Mercury	Hg	200.61	13.546	−38.87	—	−356.9	—	—	—	0(c)	—
Methane	CH_4	16.04	—	−182.5	0.94	−161.5	8.179	190.70	45.8	−74.85(g)	−890.36(g)
Methyl acetate	$C_3H_6O_2$	74.08	0.933	−98.9	—	57.1	—	506.7	46.30	−409.4(l)	−1595(l)
Methyl alcohol (Methanol)	CH_3OH	32.04	0.792	−97.9	3.167	64.7	35.27	513.20	78.50	−238.6(l) −201.2(g)	726.6(l) −764.0(g)
Methyl amine	CH_5N	31.06	$0.699^{-11°}$	−92.7	—	−6.9	—	429.9	73.60	−28.0(g)	−1071.5(l)
Methyl chloride	CH_3Cl	50.49	—	−97.9	—	−24	—	416.1	65.80	−81.92(g)	—

(continued)

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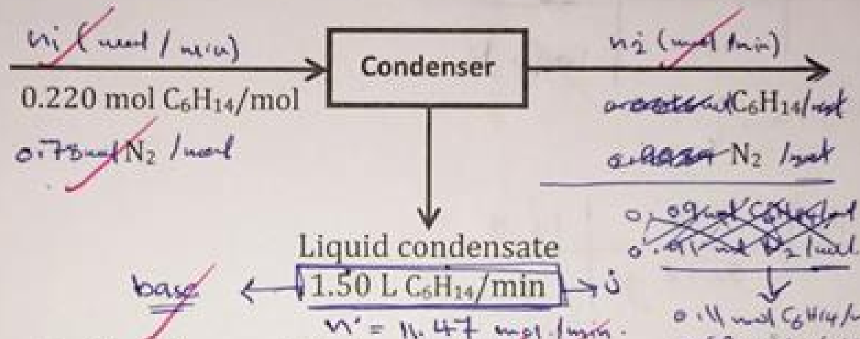
(0905211) Chemical Engineering Principles **Second Semester – 2016/2017**

Quiz # 3 (Chapter 4)

Name: ____________ **ID #** 0156421

A gas stream contains 22.0 mol % hexane, C_6H_{14} (SG = $0.659 \frac{20°}{4°}$, MW = 86.17) and the balance nitrogen (MW = 28.02). The stream flows to a condenser, where some hexane is liquefied. The hexane **mass fraction** in the gas stream leaving the condenser is 0.140 g hexane/g. Liquid hexane condensate is recovered at a rate of 1.50 L/min.



$X_{C_6H_{14}}$ = 0.14 g/g
X_{N_2} = 0.86 g/g
X = mass/Total
- $m_{C_6H_{14}}$ = 0.14 g
- m_{N_2} = 0.86 g

1- Complete labeling the flowchart and do degree-of-freedom analysis.
2- What is the flow rate of the gas stream leaving the condenser in **mol/min**?
3- What percentage of the hexane entering the condenser is recovered as a liquid (mol liquid hexane/mol hexane in feed)?

- $m_{C_6H_{14}} = 0.14 g \rightarrow n_{C_6H_{14}} = \frac{0.14}{86.17} = 1.62 \times 10^{-3} = 0.00162$
- $m_{N_2} = 0.86 g \rightarrow n_{N_2} = 0.0153$ mol
- $y_{C_6H_{14}} = \frac{0.0016}{0.0169} = 0.09$ mol C_6H_{14}/mol
- $y_{N_2} = 0.91$ mol N_2/mol

$\bar{M} = \sum_{\text{all components}} y_i M_i$

$\frac{1}{\bar{M}} = \sum_{\text{all components}} \frac{x_i}{M_i}$

$\frac{1}{M} = \frac{0.14}{86.17} + \frac{0.86}{56.04}$ (28)

$\frac{1}{M} = 0.0169$

$\bar{M} = 59.17$

$\dot{V} = \frac{1.50 L}{min}$ $\rho = \frac{\dot{m}}{\dot{V}} \rightarrow \dot{m} = \rho \times \dot{V}$

$\dot{m} = \frac{1.50 L}{min} \left| \frac{1000 kg}{m^3} \right| \frac{1 m^3}{1000 L} = 1.50 kg/min$

$\dot{n} = \frac{\dot{m}}{Mw} = \frac{1.50 kg}{min}$

$\bar{M} = \sum y_i M$

$59.17 = (y_{C_6H_{14}} \times 86.17) + y_{N_2}$

$y_{C_6H_{14}} + y_{N_2} = 1$

$(1 - y_{N_2})$

$59.17 = y_{C_6H_{14}} \times 86.17 + y_{N_2} (56.04)$

$59.17 = 86.17 - 86.17 y_{N_2} + 56.04 y_{N_2}$

$\dot{V}_{C_6H_{14}} = 1.50\ L/min \longrightarrow d_{C_6H_{14}} = SG * d_{ref}$

$d = \frac{\dot{m}}{\dot{V}}$

$\dot{n} = \frac{\dot{m}}{Mw}$

$d_{C_6H_{14}} = 0.659 * \frac{10^3\ kg}{m^3}$

$\boxed{d = 0.659 * 10^3\ kg/m^3}$

2/2 = 3+9+10

$\dot{m} = d * \dot{V}$

$\dot{m} = \frac{0.659 * 10^3\ kg}{m^3} \Big| \frac{1.50\ L}{min} \Big| \frac{1\ m^3}{1000\ L}$

$\boxed{\dot{m} = 0.989\ kg/min}$

$\dot{n} = \frac{0.989\ kg}{min} \Big| \frac{mol}{86.17\ g} \Big| \frac{10^3\ g}{1\ kg}$

$\boxed{\dot{n} = 11.47\ mol/min}$ #

✓ Y

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1) DoF = no of unknown − no of eqn

DoF = 2(n_1, n_2) − 2(C_6H_{14}, N_2) = zero # O.K 1.5

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2) n_2 = ??

$\boxed{n_1 = 92.83\ mol/min}$ #

→ Total balance

$\boxed{n_1 = n_2 + 11.47}$ ✓ ⟹ ~~n_2 = 80.24 mol/min~~

~~→ N_2 balance~~

~~$0.78 n_1 = 0.91 n_2$~~

~~$0.78 n_2 + 8.947 = 0.91 n_2$~~

~~$0.13 n_2 = 8.947$ ⟹ n_2 = 68.8 mol/min~~ #

N_2 balance ⟹ $\boxed{0.78 n_1 = 0.89 n_2}$ O.K

(n_2 + 11.47)

$0.78 n_2 + 8.95 = 0.89 n_2$

~~$0.64 n_2 = 8.95$~~

$\boxed{n_2 = 81.36\ mol/min}$ # O.K

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3) $\frac{\text{mol liquid Hexane}}{\text{mol Hexane feed}} = \frac{11.47\ mol/min}{(0.22) n_1} = \frac{11.47}{0.22(92.83)}$ = ~~0.143 mol liquid/mol feed~~

(~~80.24~~) 2

= 0.124 mol liquid/mol feed #

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(0905211) Chemical Engineering Principles I — Second Semester – 2015/2016

Quiz # 3 (Chapter 5)

Name: [illegible] ID # 0156491

Q1: A gas consists of 70.0 mol% ethane (C_2H_6) and 30.0% methane (CH_4). Ten moles of this gas is to be compressed to a pressure of 200 bar at 90 °C. Using Kay's rule and the compressibility chart, estimate the final volume of the gas.

$T_c' = \sum y_i T_{ci} = T_c$ for Gas mixture

$P_c' = \sum y_i P_{ci} = P_c$ for gas mixture

$y_{C_2H_6} = 0.7$ mol/mol

$y_{CH_4} = 0.3$ mol/mol

$n_{gas} = 10$ mol

$P = 200$ bar

$T = 90°C$

$T_c' = 0.3 * 190.7 + 0.7 * 305.4 = 270.99$ K (CH4, C2H6)

$P_c' = 0.3 * 45.8 + 0.7 * 48.2 = 47.48$ atm.

$T_r' = \frac{90+273}{271} = 1.34$

$P_r' = \frac{200 \text{ bar}}{47.5 \text{ atm}} \cdot \frac{1 \text{ atm}}{1.0132 \text{ bar}} = 4.17.$

$z = 0.7 \Rightarrow V = \frac{znRT}{P} = \frac{0.7 \cdot 10 \text{ mol} \cdot (90+273) \text{ K} \cdot 0.08314 \text{ L·bar}}{200 \text{ bar} \cdot \text{mol·K}} = 1.05 \text{ L}$

Q2: A 5.0-m^3 tank is charged with 75 kg of propane gas (C_3H_8, M=44) at 25 °C. Use the van der Waals equation of state to estimate:

1- the pressure in the tank,

2- the volume occupied by the propane molecules. = $b = 0.09\ L/mol \times 1.7\ kmol$ 153 L

$P = \frac{RT}{\hat{V} - b} - \frac{a}{\hat{V}^2}$

V = 5 m^3

m = 75 kg

Mw = 44

T = 25 °C

n = 1.7 kmol

$a = 27 \frac{(0.08216\ L \cdot atm/mol \cdot K)(369.9)^2\ K^2}{64 \cdot 42\ atm}$

$a = 27 \frac{(0.0821)^2\ L^2 \cdot atm^2}{mol^2 \cdot K^2} \frac{(396.9)^2\ K^2}{64 \cdot 42\ atm}$

a = 9.3 $L^2 \cdot atm/mol^2$

$b = \frac{RT_c}{8P_c} = \frac{1}{8} \cdot \frac{0.08206\ L \cdot atm}{mol \cdot K} \cdot \frac{369.9\ K}{42.0\ atm} = 0.9\ L/mol$

$\hat{V} = \frac{V}{n} = \frac{5\ m^3}{1.7\ kmol} = 3\ m^3/kmol = 3\ L/mol$

$n = \frac{m}{Mw} = 1.7\ kmol$

P = 7.5 atm #

(0905211) Chemical Engineering Principles (I) — Second Semester – 2016/2017

Quiz # 4 (Chapter 5)

Name: [illegible] ID # 0156421

The analysis of a fuel oil is 86.93 wt% carbon, 11.71% hydrogen, and 1.36% sulfur. This oil is burned in a furnace with 15% excess air. The air is preheated to 175 °C and enters the furnace at 180 mm Hg. The sulfur and hydrogen are completely oxidized to SO_2 and H_2O; 5% of the carbon is oxidized to CO, and the balance forms CO_2.

Calculate the feed ratio (m³ air)/(kg oil).

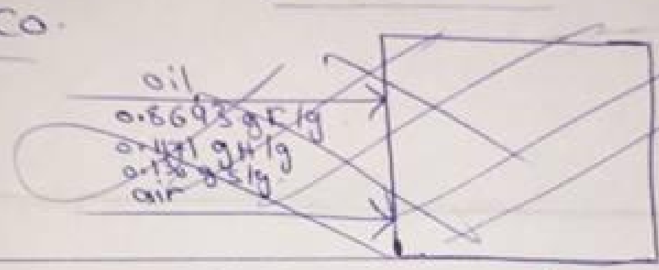
Gas constant	
8.314	m³·Pa/(K · mol)
0.08314	L · bar/(K · mol)
62.36	L · mm Hg/(K · mol)
0.08206	L · atm/(K · mol)

- $S + O_2 \rightarrow SO_2$
- $2H + \frac{1}{2}O_2 \rightarrow H_2O$
- $C + O_2 \rightarrow CO_2$
- $C + \frac{1}{2}O_2 \rightarrow CO$

$S + O_2 \rightarrow SO_2$

~~H + O₂ →~~

$C + O_2 \rightarrow CO_2$



Balance CO_2

0.95 * 86.93 | =

$n_{CO_2} = 82.5$ mol

$S + O_2 \rightarrow SO_2$

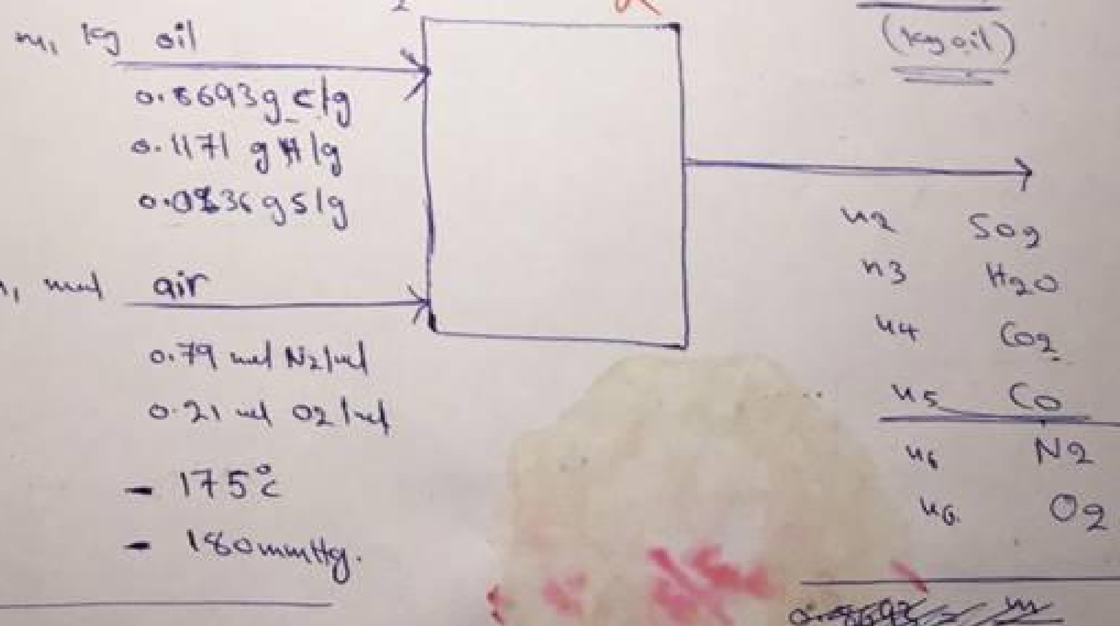
$2H + \frac{1}{2}O_2 \rightarrow H_2O$

$C + \frac{1}{2}O_2 \rightarrow CO_2$

excess air = 15%

5% of C → CO balance CO_2

(m³ air)/(kg oil)



excess air = $\frac{fed - theo}{theo} * 100\%$

$n_5 = 0.05 * 86.93 \left| \frac{1 \text{ mol CO}}{1 \text{ mol C}} \right.$

$n_5 = 4.3$ mol CO

mass fraction → mol fraction

Basis 100 g.

$m_c = X * m_{Total}$

$m_c = 86.93 g$ → $Mw_c = 12$ → $n_c = 7.24$ mol ✓

$m_H = 11.71 g$ → $Mw = 1$ → $n_H = 11.71$ mol ✓

$m_S = 1.36 g$. → $Mw = 32$ → $n_S = 0.043$ mol ✓

theo O_2 :

$C + O_2 \rightarrow CO_2$

1 mol C → 1 mol O_2

7.24 → x

7.24 mol O_2 ✓

$2H + \frac{1}{2} O_2 \rightarrow H_2O$

2 mol H → $\frac{1}{2} O_2$

11.71 → x

2.93 mol O_2 ✓

$S + O_2 \rightarrow SO_2$

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theo O_2 = 10.16 mol O_2 o.k

theo air = 48.4 ✓

$0.15 = \frac{\text{feed} - 48.4}{48.4} * 100\%$

feed air = 55.6 mol ok

$PV = nRT$

$V = \frac{nRT}{P} = \frac{55.6 \text{ mol} \mid 448.15 K \mid 62.36 \text{ L mmHg} \mid 1 m^3}{\mid \mid 180 \text{ mmHg} \mid \text{mol.K} \mid 1000 L}$

$V_{air} = 8.63 m^3$ ✓ → 86.3 m^3/kg air

Atomic Balance

N Balance

$2 * 0.79 * n_1 = 2 n_6$