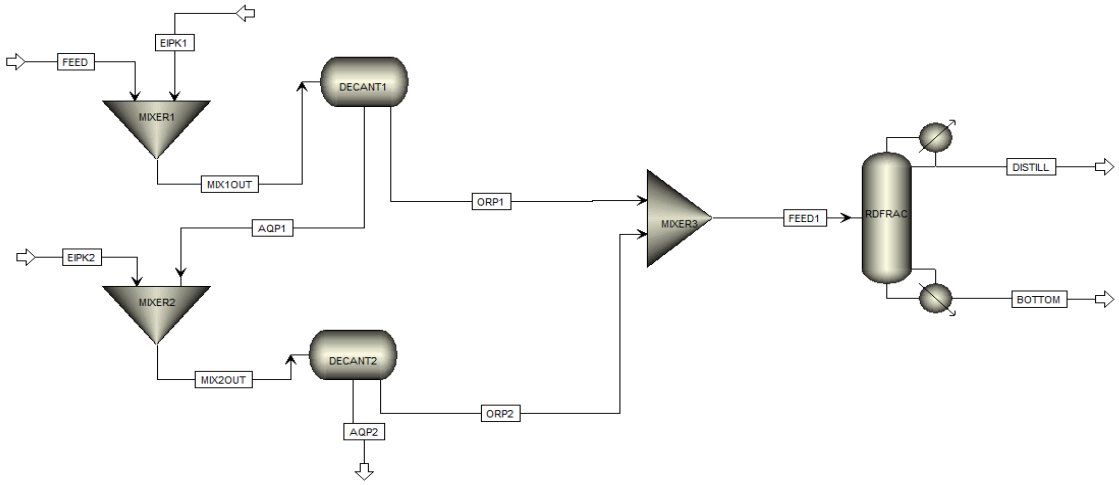
Assignment – 5

Roll no – 234107206

PROBLEM-1

Flowsheet:-



Stream Result of Red-Frac column:-

	Units	FEED1	BOTTOM	DISTILL
Phase		Liquid Phase	Liquid Phase	Liquid Phase
Temperature	C	13.2385	82.173	37.6563
Pressure	bar	1.01325	0.506625	0.506625
Molar Vapor Fraction		0	0	0
Molar Liquid Fraction		1	1	1
Molar Solid Fraction		0	0	0
Mass Vapor Fraction		0	0	0
Mass Liquid Fraction		1	1	1
Mass Solid Fraction		0	0	0
Molar Enthalpy	cal/mol	-73811	-74704.9	-61665.4
Mass Enthalpy	cal/gm	-880.843	-766.854	-1335.24
Molar Entropy	cal/mol-K	-123.13	-135.206	-62.9126
Mass Entropy	cal/gm-K	-1.46941	-1.3879	-1.36225
Molar Density	mol/cc	0.00990293	0.00773036	0.0172166
Mass Density	gm/cc	0.829824	0.753072	0.795112
Enthalpy Flow	cal/sec	-86275.3	-64104.7	-19163.3
Average MW		83.7958	97.4174	46.1829
+ Mole Flows	**kmol/hr**	**4.20793**	**3.08918**	**1.11875**
+ Mole Fractions				
− Mass Flows	**kg/hr**	**352.607**	**300.94**	**51.667**
ACETONE	kg/hr	45.7909	1.16275	44.6281
WATER	kg/hr	7.82612	1.67378	6.15234
ETHYL-01	kg/hr	298.99	298.103	0.886485

(a)

	Units	ORP1
— **MIXED Substream**		
Phase		Liquid Phase
Temperature	C	10
Pressure	bar	1.01325
Molar Vapor Fraction		0
Molar Liquid Fraction		1
Molar Solid Fraction		0
Mass Vapor Fraction		0
Mass Liquid Fraction		1
Mass Solid Fraction		0
Molar Enthalpy	cal/mol	-69656.4
Mass Enthalpy	cal/gm	-999.835
Molar Entropy	cal/mol-K	-101.537
Mass Entropy	cal/gm-K	-1.45745
Molar Density	mol/cc	0.0120229
Mass Density	gm/cc	0.837609
Enthalpy Flow	cal/sec	-20275.1
Average MW		69.6679
+ **Mole Flows**	**kmol/hr**	**1.04786**
+ **Mole Fractions**		
— **Mass Flows**	**kg/hr**	**73.0023**
ACETONE	kg/hr	23.3251
WATER	kg/hr	3.30116
ETHYL-01	kg/hr	46.3761
+ **Mass Fractions**		

- The mass flowrate (kg/hr.) of EIPK from the 1st liquid outlet stream of the 1st flash separator is 46.3761 kg/hr

(b)

Summary | Balance | Phase Equilibrium | Utility Usage | Status

Outlet temperature	15	C
Outlet pressure	1.01325	bar
Heat duty	0.428726	kW
Net duty	102.399	cal/sec
1st liquid / Total liquid	0.565952	
Pressure drop	0	bar

- The heat duty (in kW) of the 2nd flash separator is 0.428726KW

(c)

Reboiler / Bottom stage performance

Name	Value	Units
Temperature	355.323	K
Heat duty	15491.6	cal/sec
Bottoms rate	3.08918	kmol/hr
Boilup rate	5.62119	kmol/hr
Boilup ratio	1.81964	
Bottoms to feed ratio	3.91824	

- The temperature (in K) of the bottom stage of the RADFRAC column is 355.323

(d)

Component	DISTILL	BOTTOM
ACETONE	0.974607	0.0253925
WATER	0.786129	0.213871
ETHYL-01	0.00296493	0.997035

- The split-fraction of water in the water distillate stream is 0.786129

(e)

Reboiler / Bottom stage performance

Name	Value	Units
Temperature	355.323	K
Heat duty	15491.6	cal/sec
Bottoms rate	300.94	kg/hr
Boilup rate	0.117324	kg/sec
Boilup ratio	1.4035	
Bottoms to feed ratio	6.57204	

- The boil up rate (kg/sec) of the reboiler 0.117324 kg/sec

(f) & (g)

View: All Basis: Mole

Stage	Temperature (F)	Pressure (bar)	Heat duty (cal/sec)	Liquid from (Mole) (kmol/hr)	Vapor from (Mole) (kmol/hr)	Liquid feed (Mole) (kmol/hr)	Vapor feed (Mole) (kmol/hr)	Mixed feed (Mole) (kmol/hr)	Liquid product (Mole) (kmol/hr)	Vapor product (Mole) (kmol/hr)	Liquid enthalpy (cal/mol)	Vapor enthalpy (cal/mol)	Liquid flow (Mole) (kmol/hr)	Vapor flow (Mole) (kmol/hr)
1	99.7813	0.506625	-12484.1	5.54803	0	0	0	0	1.11875	0	-59041.4	-51384.8	4.75546	0
2	104.393	0.506625	0	4.30909	5.8742	0	0	0	0	0	-61235.6	-51890	4.30909	5.8742
3	113.924	0.506625	0	3.96365	5.42784	0	0	0	0	0	-64579.6	-53044.7	3.96365	5.42784
4	125.556	0.506625	0	3.76939	5.0824	0	0	0	0	0	-67134.2	-55096.6	3.76939	5.0824
5	132.86	0.506625	0	8.87269	4.88813	4.20793	0	0	0	0	-69821.8	-56688.5	8.87269	4.88813
6	136.251	0.506625	0	8.83874	5.78351	0	0	0	0	0	-70379.2	-57570.6	8.83874	5.78351
7	139.063	0.506625	0	8.81666	5.74956	0	0	0	0	0	-70781.9	-58354.8	8.81666	5.74956
8	140.879	0.506625	0	8.80815	5.72748	0	0	0	0	0	-71278.5	-58929.2	8.80815	5.72748
9	146.517	0.506625	0	8.71037	5.71897	0	0	0	0	0	-73636.2	-59675.4	8.71037	5.71897
10	179.911	0.506625	15491.6	3.08918	5.62119	0	0	0	3.08918	0	-74704.9	-63127.3	3.08918	5.62119

- The temperature (in ^{0}F) of the 7th stage of the column 139.063^{0}F
- The flow ratio (mole basis) for stage 5 is (8.87269/4.88813)=1.815150

(h)

View: All Basis: Mass

Stage	Temperature (F)	Pressure (bar)	Heat duty (cal/sec)	Liquid from (Mass) (kg/hr)	Vapor from (Mass) (kg/hr)	Liquid feed (Mass) (kg/hr)	Vapor feed (Mass) (kg/hr)	Mixed feed (Mass) (kg/hr)	Liquid product (Mass) (kg/hr)	Vapor product (Mass) (kg/hr)	Liquid enthalpy (cal/mol)	Vapor enthalpy (cal/mol)	Liquid flow (Mass) (kg/hr)	Vapor flow (Mass) (kg/hr)
1	99.7813	0.506625	-12484.1	320.536	0	0	0	0	51.667	0	-59041.4	-51384.8	274.745	0
2	104.393	0.506625	0	236.402	326.412	0	0	0	0	0	-61235.6	-51890	236.402	326.412
3	113.924	0.506625	0	210.095	288.069	0	0	0	0	0	-64579.6	-53044.7	210.095	288.069
4	125.556	0.506625	0	174.994	261.762	0	0	0	0	0	-67134.2	-55096.6	174.994	261.762
5	132.86	0.506625	0	558.974	226.661	352.607	0	0	0	0	-69821.8	-56688.5	558.974	226.661
6	136.251	0.506625	0	548.94	258.034	0	0	0	0	0	-70379.2	-57570.6	548.94	258.034
7	139.063	0.506625	0	539.785	248	0	0	0	0	0	-70781.9	-58354.8	539.785	248
8	140.879	0.506625	0	553.049	238.845	0	0	0	0	0	-71278.5	-58929.2	553.049	238.845
9	146.517	0.506625	0	723.308	252.109	0	0	0	0	0	-73636.2	-59675.4	723.308	252.109
10	179.911	0.506625	15491.6	300.94	422.368	0	0	0	300.94	0	-74704.9	-63127.3	300.94	422.368

- The vapour flow (kg/hr) for stage 6 is 258.034kg/hr

(i) & (j)

View: Vapor Basis: Mass

Stage	ACETONE	WATER	ETHYL-01
1	0.993975	0.00336757	0.0026571
2	0.957063	0.0239265	0.0190109
3	0.851996	0.0592018	0.088802
4	0.643279	0.104974	0.251747
5	0.462635	0.180899	0.356466
6	0.351706	0.217151	0.431143
7	0.246476	0.250784	0.50274
8	0.161396	0.281793	0.556812
9	0.0917693	0.264402	0.643829
10	0.026681	0.0687934	0.904526

- The mass fraction of acetone in the vapour phase in the 5th stage 0.462635
- The mass flow rate (in kg/hr) of the 2nd EIPK feed stream from the design specification is 140 kg/hr

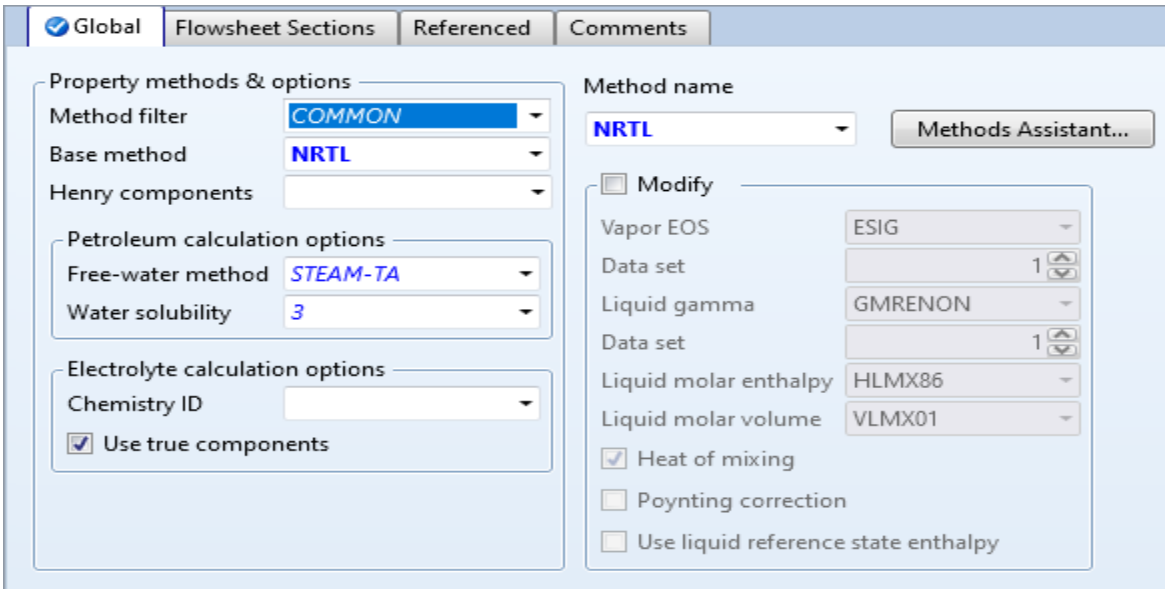
PROBLEM-2

Component:-

Select components

Component ID	Type	Component name	Alias
ETHAN-01	Conventional	ETHANOL	C2H6O-2
N-HEX-01	Conventional	N-HEXANE	C6H14-1

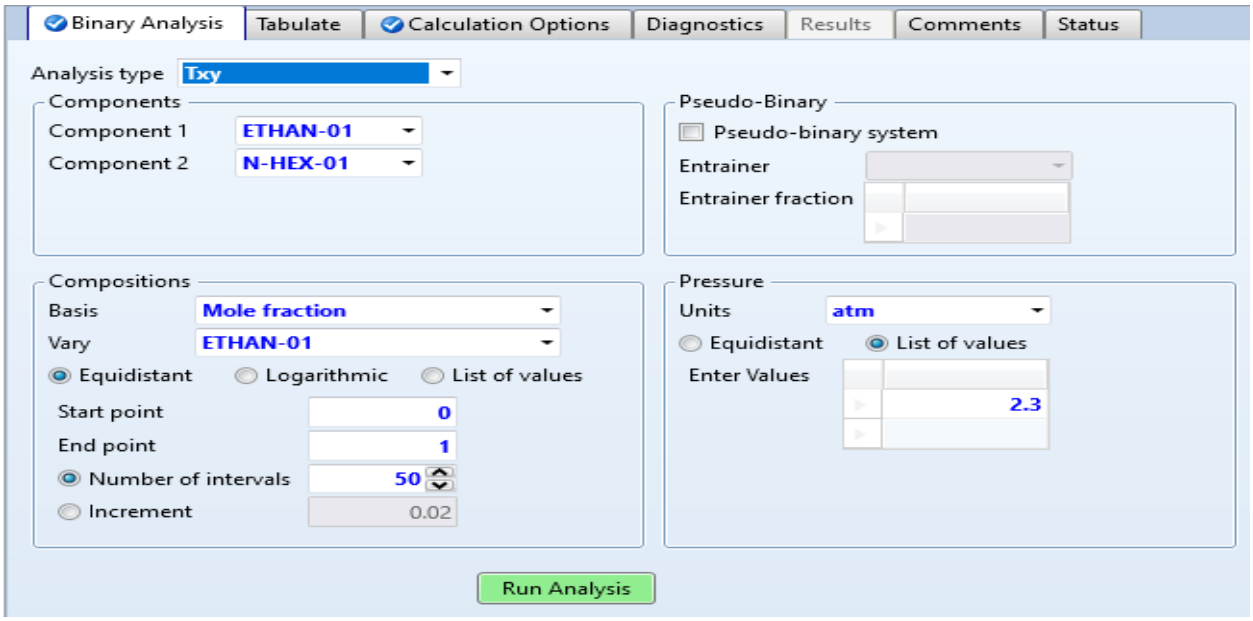
Base Method:-



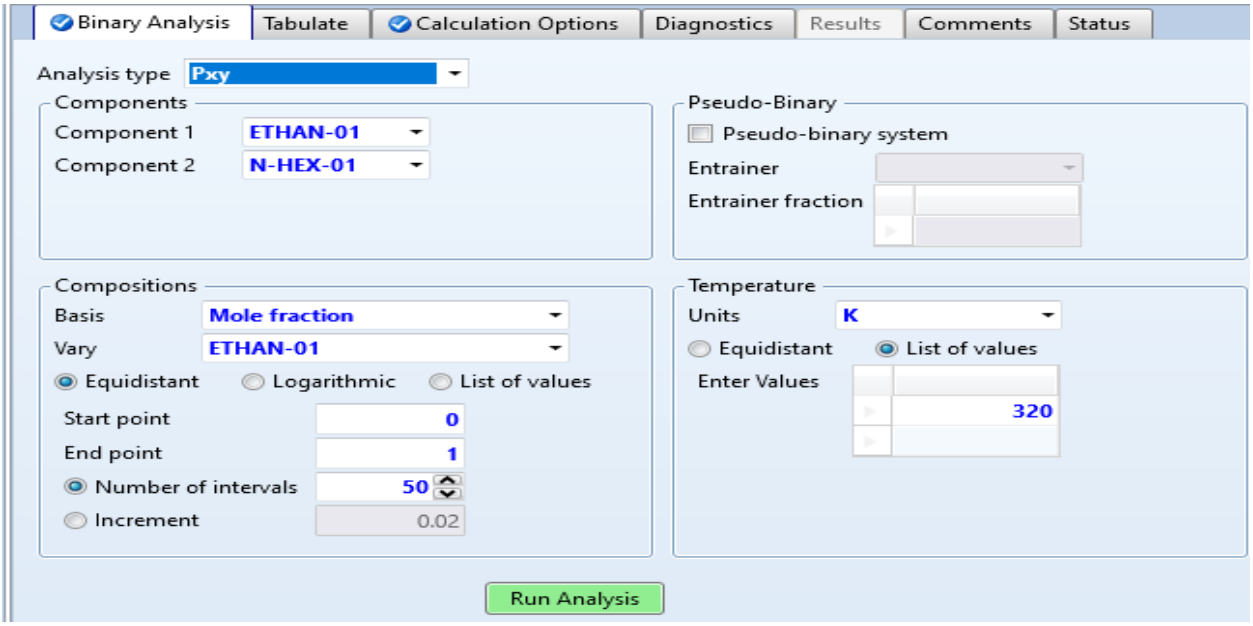
Binary Section:-

Name	Type	Hide	Active	Status	Description	Delete
BINRY-1	BINARY	☐	☑	Input Complete		✗
BINRY-2	BINARY	☐	☑	Input Complete		✗

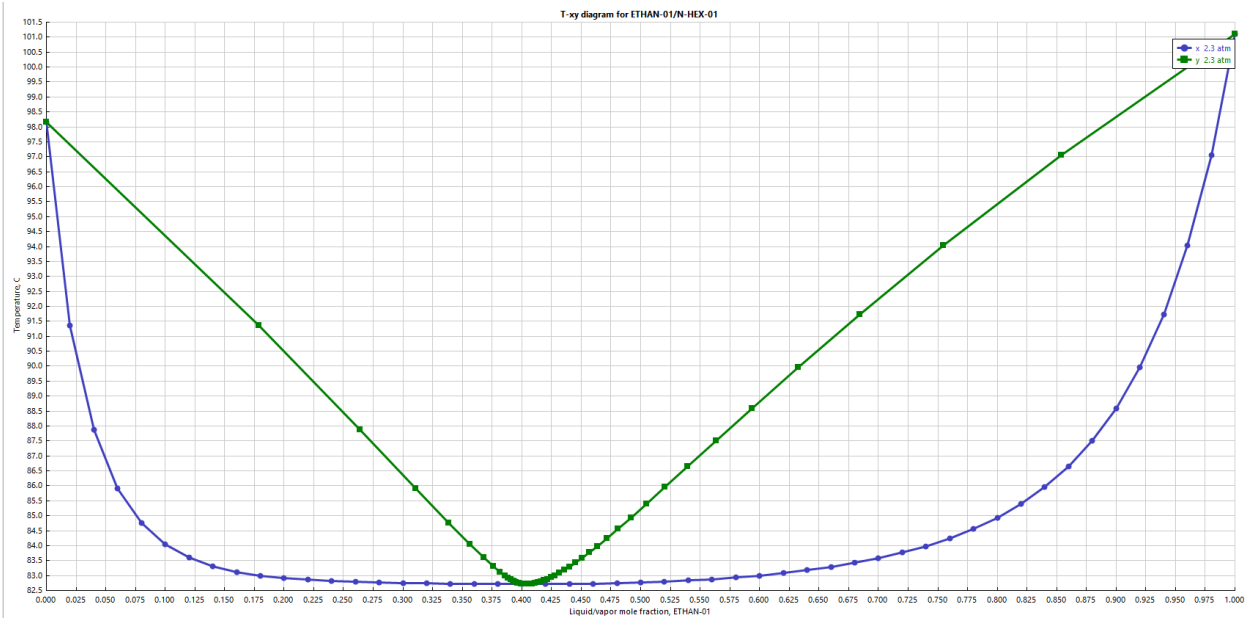
Binary-1 Specification:-



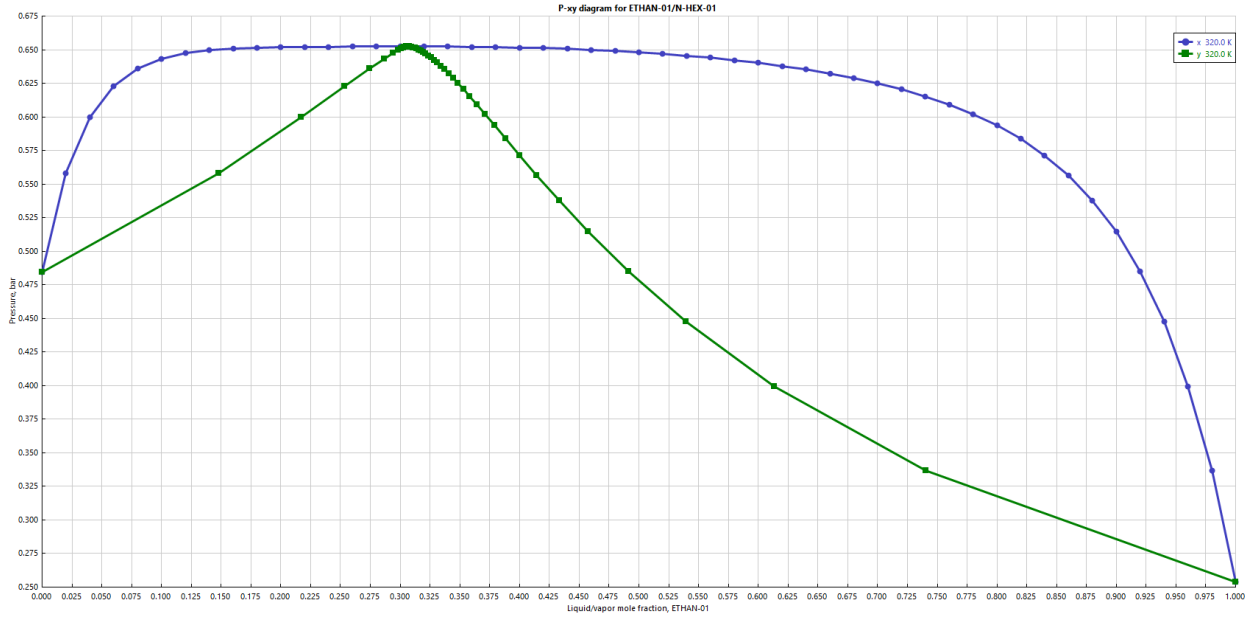
Binary-2 Specification:-



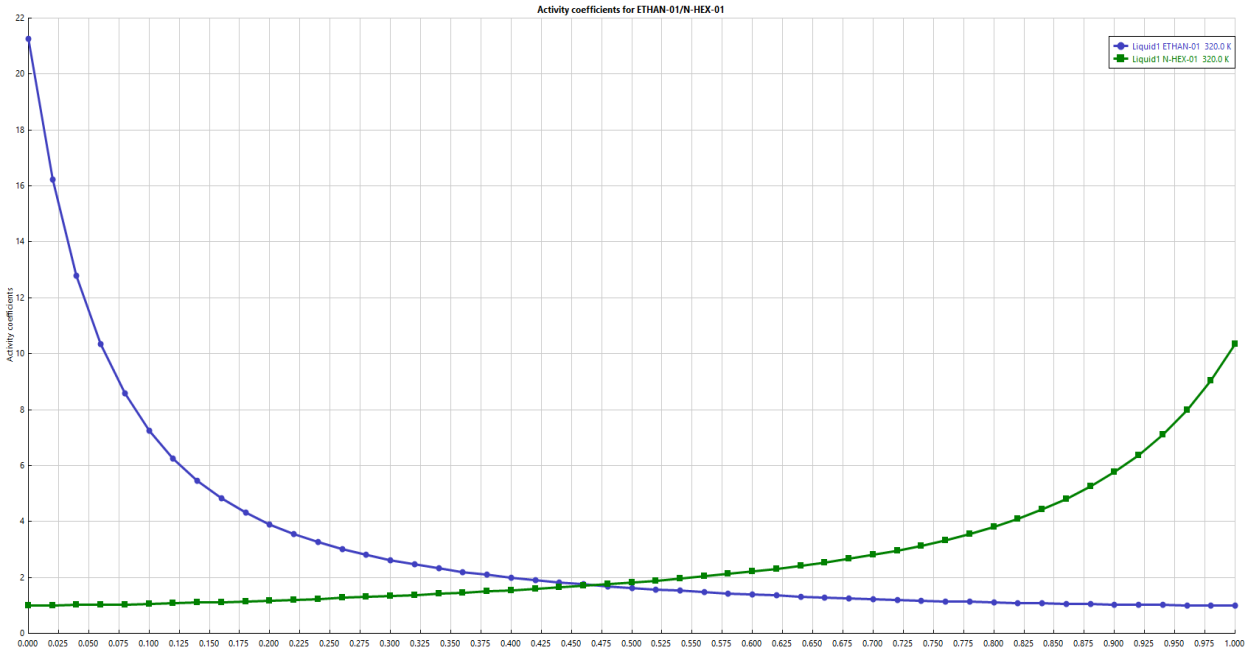
(a) Plot for the ethanol at 2.3 atm



(b) Plot for the ethanol at 320K and (p-x-y)



© Activity coefficients of n-hexane and ethanol



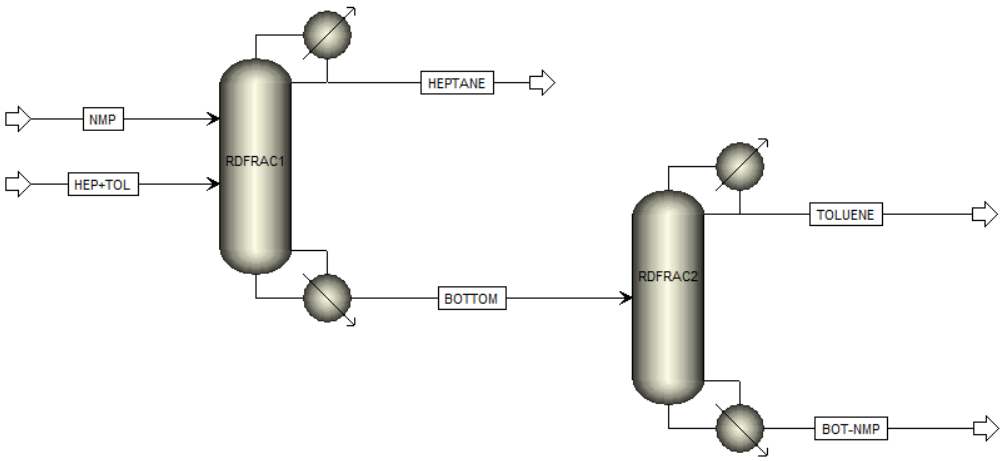
(a) The liquid mole fraction at 360K, 2.3 atm is 0.05 & vapor mole fraction at 360k , 2.3 atm is 0.2875

(b) At 320K the vapour mole fraction of ethanol at 320 K for a liquid mole fraction of 0.9 is 0.46

(c) Liquid mole fraction of hexane (@ 320 K) the activity coefficients of n-hexane and ethanol are same at 0.465

PROBLEM-3

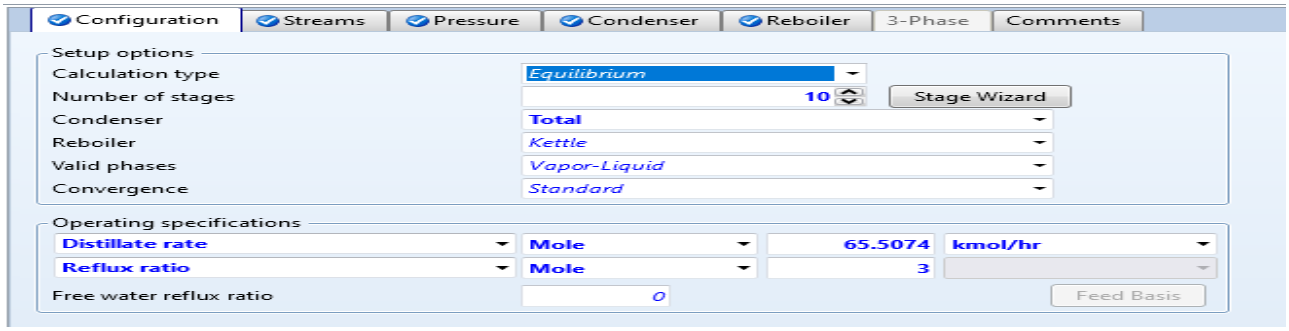
Flowsheet:-

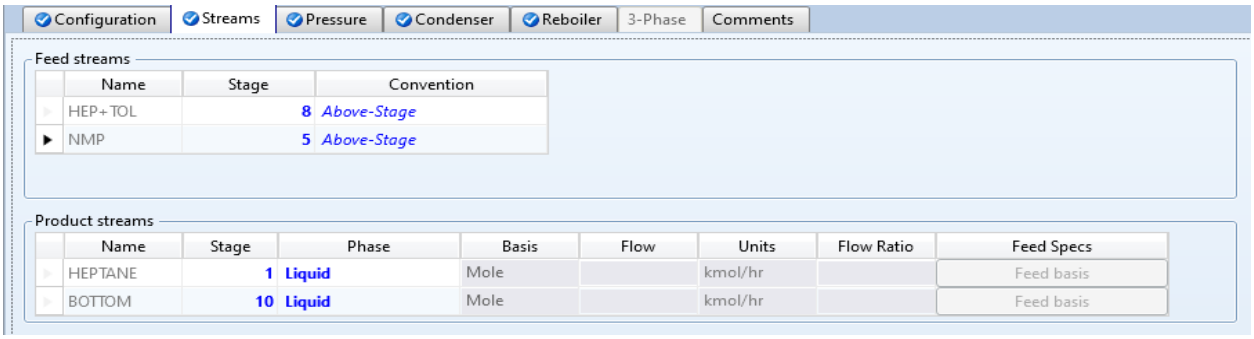


Stream Result:-

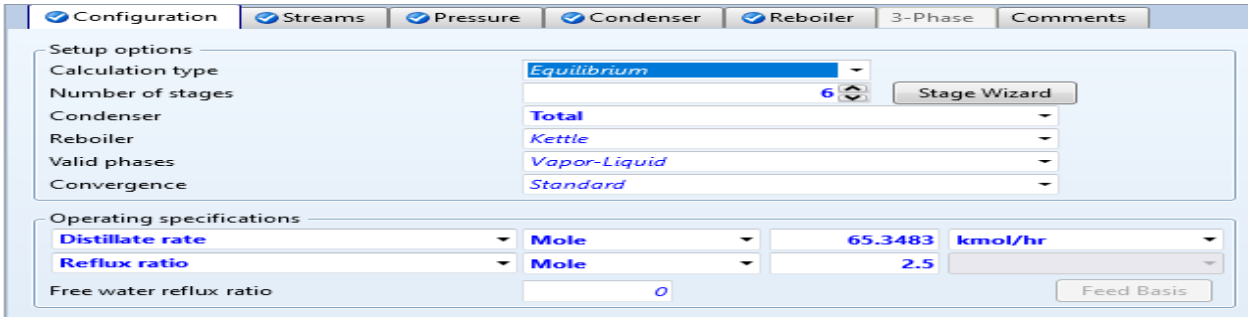
	Units	BOTTOM	HEPTANE	NMP	TOLUENE
To		RDFRAC2		RDFRAC1	
Stream Class		CONVEN	CONVEN	CONVEN	CONVEN
Maximum Relative Error					
Cost Flow	$/hr				
− MIXED Substream					
Phase		Liquid Phase	Liquid Phase	Liquid Phase	Liquid Phase
Temperature	C	175.205	98.4756	100	113.026
Pressure	bar	1.01325	1.01325	1.1	1.01325
Molar Vapor Fraction		0	0	0	0
Molar Liquid Fraction		1	1	1	1
Molar Solid Fraction		0	0	0	0
Mass Vapor Fraction		0	0	0	0
Mass Liquid Fraction		1	1	1	1
Mass Solid Fraction		0	0	0	0
Molar Enthalpy	cal/mol	-50478.7	-49110.9	-60322.6	1065.84
Mass Enthalpy	cal/gm	-512.598	-490.223	-608.504	11.4936
Molar Entropy	cal/mol-K	-116.08	-167.304	-130.844	-75.548
Mass Entropy	cal/gm-K	-1.17876	-1.67002	-1.31989	-0.814678
Molar Density	mol/cc	0.0088576	0.00614568	0.00969936	0.00851177
Mass Density	gm/cc	0.872263	0.615679	0.961523	0.789327
Enthalpy Flow	cal/sec	-9.75231e+06	-893646	-1.05565e+07	19347.5
Average MW		98.4762	100.181	99.1326	92.7336
+ Mole Flows	**kmol/hr**	**695.507**	**65.5074**	**630**	**65.3483**
+ Mole Fractions					
− Mass Flows	**kg/hr**	**68491**	**6562.57**	**62453.5**	**6059.98**
N-HEP-01	kg/hr	39.2454	6524.86	0	39.2452
TOLUENE	kg/hr	6021.23	14.6645	0	5516.04
N-MET-01	kg/hr	62430.5	23.0443	62453.5	504.701

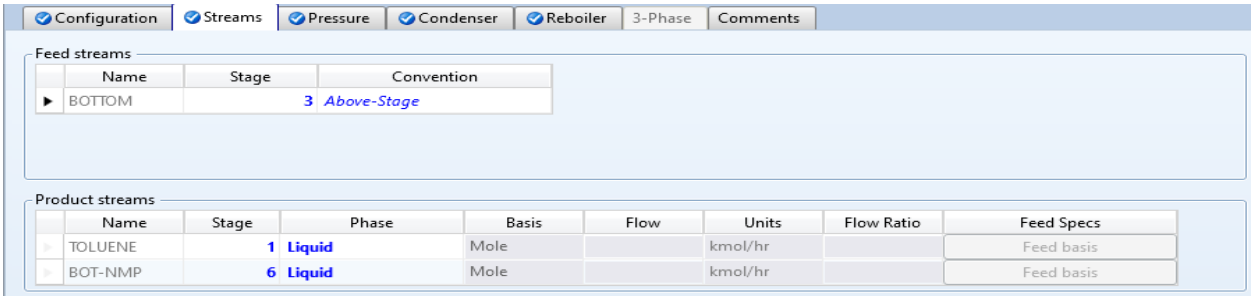
Red-frac 1 Specification:-





Red-Frac 2 Specification:-





Red-Frac 1 Results:-

View: All Basis: Mole

Stage	Temperature (C)	Pressure (bar)	Heat duty (cal/sec)	Liquid from (Mole) (kmol/hr)	Vapor from (Mole) (kmol/hr)	Liquid feed (Mole) (kmol/hr)	Vapor feed (Mole) (kmol/hr)	Mixed feed (Mole) (kmol/hr)	Liquid product (Mole) (kmol/hr)	Vapor product (Mole) (kmol/hr)	Liquid enthalpy (cal/mol)	Vapor enthalpy (cal/mol)	Liquid flow (Mole) (kmol/hr)	Vapor flow (Mole) (kmol/hr)
1	98.4756	1.01325	-552870	262.03	0	0	0	0	65.5074	0	-49110.9	-41527	196.522	0
2	98.5656	1.01325	0	195.977	262.03	0	0	0	0	0	-49125.2	-41515.1	195.977	262.03
3	98.7482	1.01325	0	194.643	261.485	0	0	0	0	0	-49182.8	-41510	194.643	261.485
4	99.2362	1.01325	0	185.258	260.15	0	0	0	0	0	-49402.2	-41514	185.258	260.15
5	104.183	1.01325	0	850.477	250.766	630	0	0	0	0	-56891.4	-41389.4	850.477	250.766
6	104.913	1.01325	0	844.104	285.984	0	0	0	0	0	-55859.8	-40588.1	844.104	285.984
7	108.825	1.01325	0	837.741	279.611	0	2.73971	0	0	0	-52135.7	-37105.2	837.741	279.611
8	118.52	1.01325	0	964.793	270.509	128.275	0	0	0	0	-43048	-25328.3	964.793	270.509
9	143.656	1.01325	0	1010.84	269.286	0	0	0	0	0	-42790.7	-7360.54	1010.84	269.286
10	175.205	1.01325	1.23396e+06	695.507	315.329	0	0	0	695.507	0	-50478.7	-11745.8	695.507	315.329

View: Liquid Basis: Mole

Stage	N-HEP-01	TOLUENE	N-MET-01
1	0.994022	0.00242955	0.0035486
2	0.988717	0.00292042	0.00836236
3	0.978082	0.00347605	0.0184419
4	0.947871	0.00433245	0.0477969
5	0.241382	0.00576176	0.752856
6	0.214814	0.0255137	0.759672
7	0.138483	0.0927497	0.768767
8	0.0736794	0.235503	0.690817
9	0.011173	0.232789	0.756038
10	0.000563121	0.0939577	0.905479

Red-Frac 2 Results:-

View: All Basis: Mole

Stage	Temperature (C)	Pressure (bar)	Heat duty (cal/sec)	Liquid from (Mole) (kmol/hr)	Vapor from (Mole) (kmol/hr)	Liquid feed (Mole) (kmol/hr)	Vapor feed (Mole) (kmol/hr)	Mixed feed (Mole) (kmol/hr)	Liquid product (Mole) (kmol/hr)	Vapor product (Mole) (kmol/hr)	Liquid enthalpy (cal/mol)	Vapor enthalpy (cal/mol)	Liquid flow (Mole) (kmol/hr)	Vapor flow (Mole) (kmol/hr)
1	113.026	1.01325	-574589	228.719	0	0	0	0	65.3483	0	1065.84	13317.2	163.371	0
2	135.872	1.01325	0	122.924	228.719	0	0.000955016	0	0	0	-29308.7	10106.8	122.924	228.719
3	172.698	1.01325	0	814.849	188.271	695.507	0	0	0	0	-49380.2	-7779.15	814.849	188.271
4	182.235	1.01325	0	832.904	184.689	0	0	0	0	0	-51738	-16194.7	832.904	184.689
5	193.275	1.01325	0	861.378	202.744	0	0	0	0	0	-53747.4	-28837.1	861.378	202.744
6	200.609	1.01325	762866	630.159	231.219	0	0	0	630.159	0	-54748	-39143	630.159	231.219

View: Liquid Basis: Mole

Stage	N-HEP-01	TOLUENE	N-MET-01
1	0.00599331	0.916098	0.0779082
2	0.00045616	0.444636	0.554908
3	4.20386e-05	0.112732	0.887226
4	2.54343e-06	0.069353	0.930644
5	1.1064e-07	0.0299092	0.970091
6	3.65558e-09	0.00870067	0.991299

Senstivity Analysis:-

Row/Case	Status	VARY 1 NMP MIXED TOTAL MOLEFLOW KMOL/HR	TOLUENE KMOL/HR
1	OK	25	53.2931
2	OK	50	57.5465
3	OK	75	59.928
4	OK	100	61.2995
5	OK	125	62.1063
6	OK	150	62.5822
7	OK	175	62.8546
8	OK	200	62.9927
9	OK	225	63.0402
10	OK	250	63.0222
11	OK	275	62.9557
12	OK	300	62.8522
13	OK	325	62.7189
14	OK	350	62.5611
15	OK	375	62.3829
16	OK	400	62.1877
17	OK	425	61.977
18	OK	450	61.7518
19	OK	475	61.5161
20	OK	500	61.2701
21	OK	525	61.0147
22	OK	550	60.7509
23	OK	575	60.4795
24	OK	600	60.2013
25	OK	625	59.917
26	OK	630	59.8655
27	OK	650	59.6269
28	OK	675	59.332
29	OK	700	59.0325

Answers:-

(a) the mol fraction of toluene at stage 5 in column 1= 0.0058 & column 2 = 0.0299

(b) The temperature of column 1 at stage 6 is 220.844 ºF

(c) The heat duty of the 1st stage of the column 1 is -2314.76 kW

(d) The boil-up ratio for the column 1 is 0.4534

(e) The mol fraction of n-heptane in the distillate for column 1 is 0.9940

(f) The mol flowrate of toluene in the distillate stream of column 2 are 62.9557 and 61.0147for NMP flow rates of 275 and 525 kmol/hr respectively.

(g) The enthalpy flow rate of the distillate stream from 2nd column is 81.0043 kW

(h) The heat duty of the reboiler of the 2nd distillation column is 3193.97 kW

(i) The boil up rate of the reboiler of the 2nd column is 3.8537 kmol/min