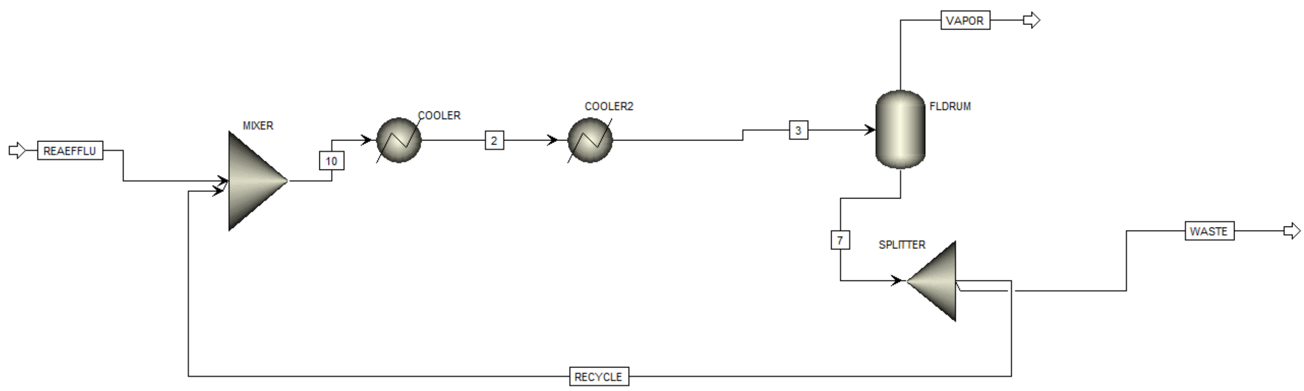
Q.2. (A) The composition of the Vapor from the Flash Drum is as follows:- (Without Quenching)

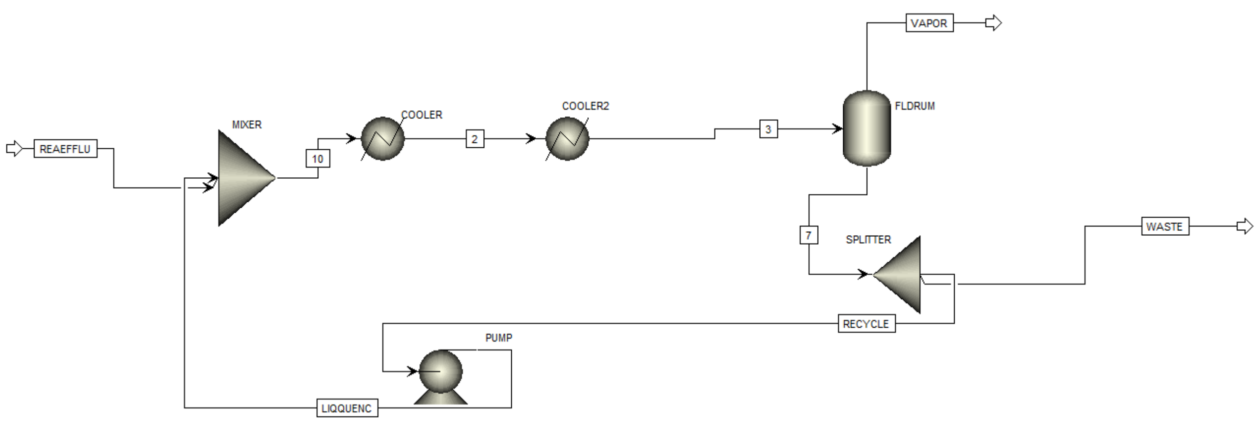
Molar flow rate of vapor is 4006.95 lbmol/hr

With flow rate different components i.e., **for H_2 is 1996.83 lbmol/hr ; For CH_4 is 1976.21 lbmol/hr ; for Benzene is 31.6485 lbmol/hr ; For toluene is 2.26553 lbmol/hr**

Then comes the compositions of the components :-
(a) H_2 (in vapor) = 0.49384
(b) CH_4(in vapor) = 0.49316
(c) Benzene(in vapor) = 0.00789839
(d) Toluene(in vapor) = 0.0005654



(I)



(II)

Both above flowsheets are the Quench(II) and without Quench(I)

With Quenching ,(Table)

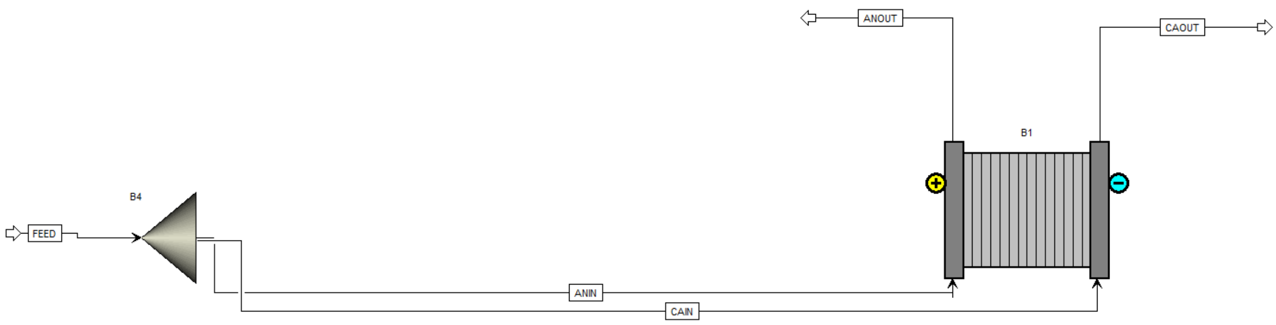
Mole Flows	lbmol /hr	9937.05 9008	9937.05 9008	5930.10 4545	9937.05 9008	5337.09 409	46 00	5337.09 409	**4006.95 4463**	593.010 4545

H2	lbmol/hr	2028.546256	2028.546256	31.71942668	2028.546256	28.54748401	2000	28.54748401	**1996.826829**	3.171942668
CH4	lbmol/hr	2213.937519	2213.937519	237.7239177	2213.937519	213.9515259	2000	213.9515259	**1976.213601**	23.77239177
Benzene	lbmol/hr	4714.998649	4714.998649	4683.350147	4714.998649	4215.015132	500	4215.015132	**31.6485014**	468.3350147
TOLUENE	lbmol/hr	979.5765849	979.5765849	977.3110534	979.5765849	879.579948	100	879.579948	**2.265531492**	97.73110534

(B) As it is seen that **Impact of Quench on Flash Separation**

- The quench reduces the temperature before flashing but does not significantly change the equilibrium separation at 500 psia. The vapor-to-liquid ratio remains nearly the same, confirming that **quenching affects cooling efficiency but not phase separation**.
- There is not much change in the vapor phase mole fraction and molar flow rates of the components.
- The quench stream effectively lowers the process stream temperature but has **minimal impact** on flash separation results.

Q.5. (I)



	Units	ANIN	ANOUT	CAIN	CAOUT	FEED
Pressure	bar	7	6	7	5.8	7
Molar Vapor Fraction		0	0	0	0.0117514	0
Molar Liquid Fraction		1	1	1	0.988249	1
Molar Solid Fraction		0	0	0	0	0
Mass Vapor Fraction		0	0	0	0.00162759	0
Mass Liquid Fraction		1	1	1	0.998372	1
Mass Solid Fraction		0	0	0	0	0
Molar Enthalpy	cal/mol	-71336.6	-71141.5	-71336.6	-70574	-71336.6
Mass Enthalpy	cal/gm	-3287.7	-3277.91	-3287.7	-3273.07	-3287.7
Molar Entropy	cal/mol-K	-34.6944	-34.4851	-34.6944	-34.1364	-34.6944
Mass Entropy	cal/gm-K	-1.59897	-1.58893	-1.59897	-1.58317	-1.59897
Molar Density	mol/cc	0.0510238	0.0505696	0.0510238	0.0127847	0.0510238
Mass Density	gm/cc	1.10711	1.09753	1.10711	0.275663	1.10711
Enthalpy Flow	cal/sec	-1.09727e+09	-1.10024e+09	-3.65757e+08	-3.57896e+08	-1.46303e+09
Average MW		21.698	21.7033	21.698	21.562	21.698
+ Mole Flows	**kmol/hr**	**55373.8**	**55676.1**	**18457.9**	**18256.4**	**73831.7**
+ Mole Fractions						
− Mass Flows	**kg/sec**	**333.75**	**335.654**	**111.25**	**109.346**	**445**
H2O	kg/sec	250.313	251.321	83.4375	81.4205	333.75
O2	kg/sec	0	0.895641	0	0	0
H2	kg/sec	0	0	0	0.112848	0
KOH	kg/sec	83.4375	83.4375	27.8125	27.8125	111.25

Here the Shortcut method was used.

The Rate of production of H_2 is 0.112 kg/sec and The rate of production of O_2 is 0.895 kg/sec. Here the Water that is going to Anode and Cathode is about 333.75 kg/sec**, in which** the In anode the water inlet is 250.313 kg/sec **and** Cathode inlet is 83.4375 kg/sec **, so at the end** the outlet of water at anode is 251.321 kg/sec and Cathode outlet for water is 81.4205 kg/sec.

From the data:

- FEED (Total Inlet): 333.75 kg/sec (H2O)
- ANOUT (Outlet): 251.321 kg/sec (H2O)
- CAOUT (Outlet): 81.4205 kg/sec (H2O)

The total water leaving the system is the sum of the water in the ANOUT and CAOUT streams:

Total Outlet Water = ANOUT (H2O) + CAOUT (H2O) = 251.321 kg/sec + 81.4205 kg/sec = 332.7415 kg/sec

The rate of water consumption is the difference between the total inlet water and the total outlet water:

Water Consumption = FEED (H2O) - Total Outlet Water = 333.75 kg/sec - 332.7415 kg/sec = 1.0085 kg/sec

So, the rate of water consumption is approximately 1.0085 kg/sec.

From the table:

- ANIN (Inlet): 250.313 kg/sec

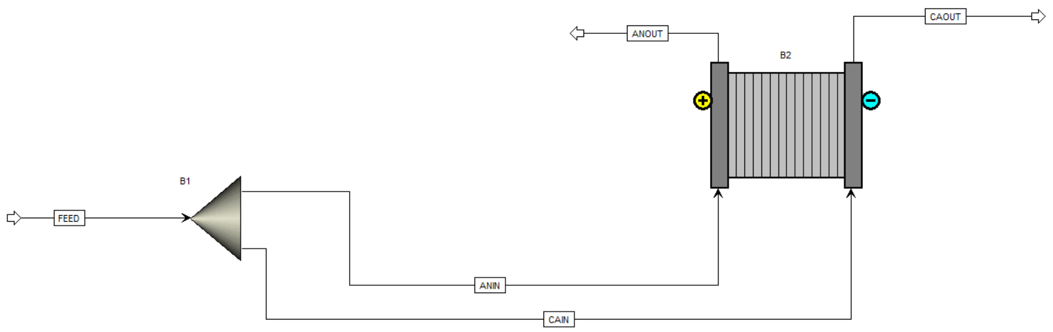
- ANOUT (Outlet): 251.321 kg/sec

The makeup water required would be the difference between the outlet and inlet water flow rates:

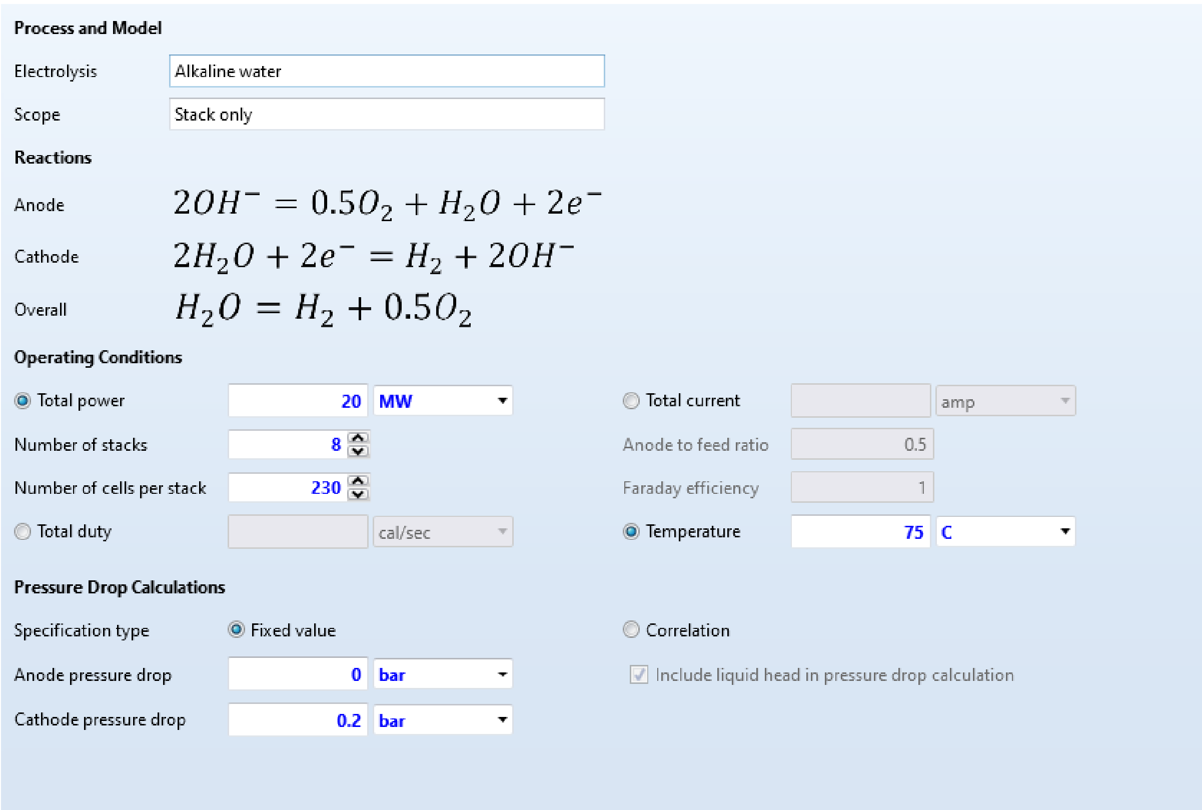
Makeup Water = ANOUT (H2O) - ANIN (H2O) = 251.321 kg/sec - 250.313 kg/sec = 1.008 kg/sec

So, the makeup water required is approximately 1.008 kg/sec.

ii)



Rigorous Method



Process and Model

Electrolysis: Alkaline water

Scope: Stack only

Reactions

Anode: $2OH^- = 0.5O_2 + H_2O + 2e^-$

Cathode: $2H_2O + 2e^- = H_2 + 2OH^-$

Overall: $H_2O = H_2 + 0.5O_2$

Operating Conditions

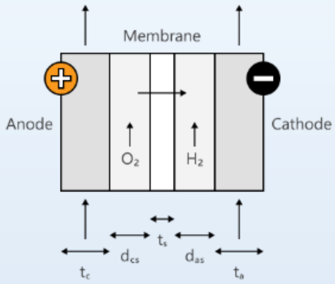
◉ Total power	20	MW	○ Total current		amp
Number of stacks	8		Anode to feed ratio	0.5	
Number of cells per stack	230		Faraday efficiency	1	
○ Total duty		cal/sec	◉ Temperature	75	C

Pressure Drop Calculations

Specification type	◉ Fixed value		○ Correlation	
Anode pressure drop	0	bar	☑ Include liquid head in pressure drop calculation	
Cathode pressure drop	0.2	bar		

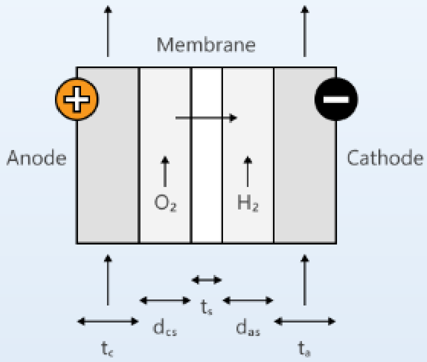
Geometrical Parameters

Parameter	Anode	Units	Cathode	Units
Active area	4	sqm	4	sqm
Width of channel	2	meter	2	meter
Length of channel	2	meter	2	meter
Porosity	0.3		0.3	
Tortuosity	3.8		3.8	
Pore radius	1e-06	meter	1e-06	meter
Separation b/w electrode and separator (das, dcs)	1.25	mm	1.25	mm
Thickness of channel (ta, tc)	2	cm	2	cm
Electrode roughness factor	1.25		1.05	
Thickness of electrode	2	mm	2	cm
Bubble zone width	0.5	mm	0.5	mm
Channel roughness factor	1		1	
Activation free energy	19229.5	cal/mol	12463	cal/mol



Membrane Parameters

Parameter	Value	Units
Active area	4	sqm
Thickness (ts)	0.5	mm
Porosity	0.42	
Tortuosity	2.18	
Wetness factor	0.85	
Oxygen diffusivity	1.81e-05	sqcm/sec
Hydrogen diffusivity	5.63e-05	sqcm/sec



Property options

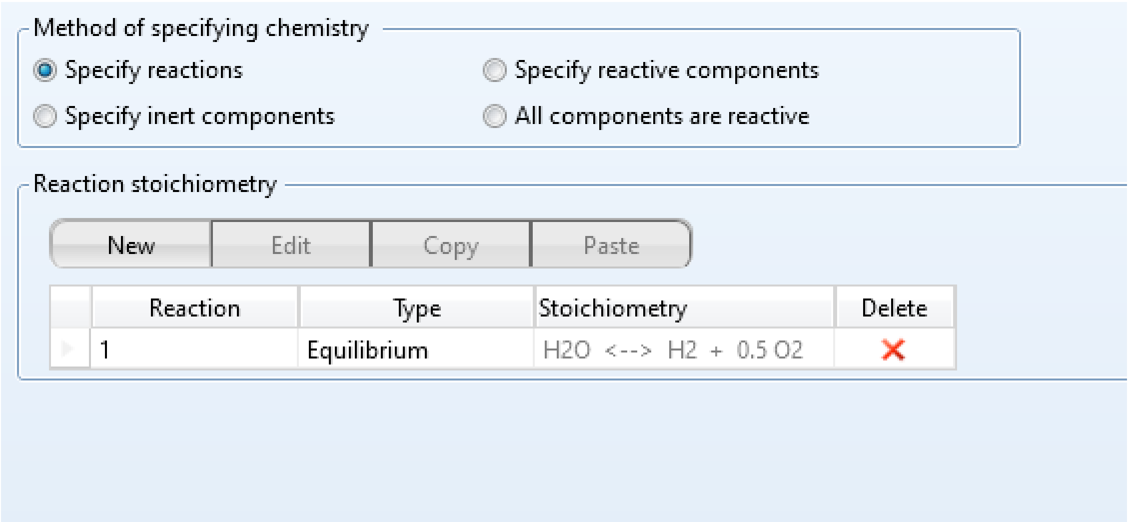
Property method	ELECNRTL
Henry components ID	HC-1

Electrolytes calculation options

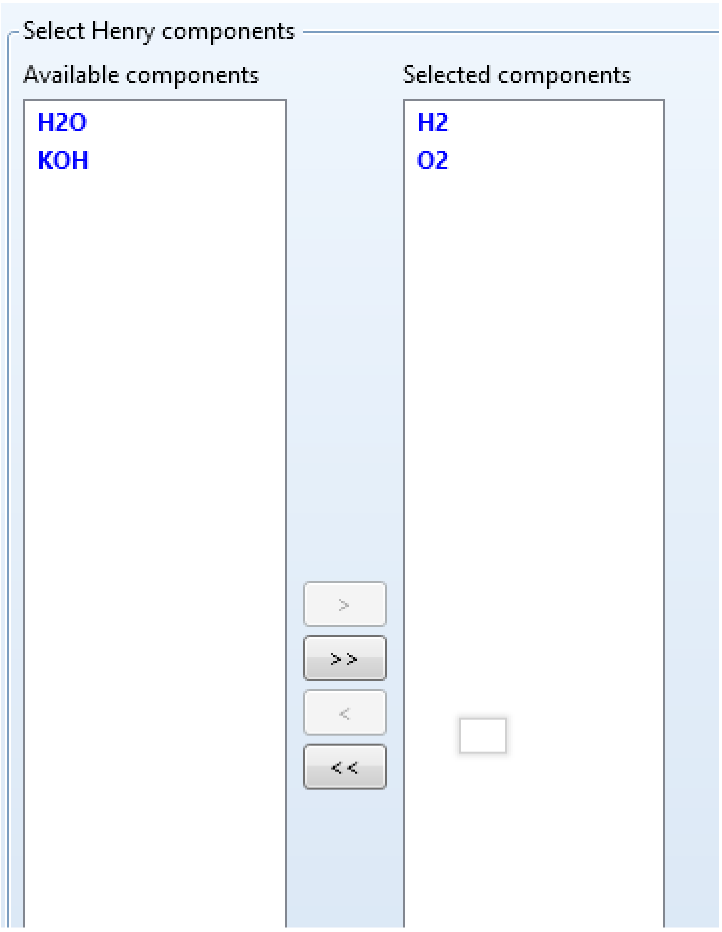
Chemistry ID	C-2
Simulation approach	Apparent components

Petroleum calculation options

Free-water phase properties	STEAM-TA
Water solubility method	3 - No correction



Reaction Components



Henry Components

	Units	ANIN	ANOUT	CAIN	CAOUT	FEED	
Pressure	bar	7	7	7	6.8	7	
Molar Vapor Fraction		0	0.0018225	0	0.0128047	0	
Molar Liquid Fraction		1	0.998178	1	0.987195	1	
Molar Solid Fraction		0	0	0	0	0	
Mass Vapor Fraction		0	0.00263609	0	0.0016656	0	
Mass Liquid Fraction		1	0.997364	1	0.998334	1	
Mass Solid Fraction		0	0	0	0	0	
Molar Enthalpy	cal/mol	-71336.6	-71052.9	-71336.6	-70786.3	-71336.6	
Mass Enthalpy	cal/gm	-3287.7	-3286.08	-3287.7	-3244.35	-3287.7	
Molar Entropy	cal/mol-K	-34.6944	-34.522	-34.6944	-33.9941	-34.6944	
Mass Entropy	cal/gm-K	-1.59897	-1.59658	-1.59897	-1.55805	-1.59897	
Molar Density	mol/cc	0.0510238	0.0369274	0.0510238	0.013482	0.0510238	
Mass Density	gm/cc	1.10711	0.798459	1.10711	0.294155	1.10711	
Enthalpy Flow	cal/sec	-1.09727e+09	-1.12375e+09	-3.65757e+08	-3.34254e+08	-1.46303e+09	
Average MW		21.698	21.6224	21.698	21.8183	21.698	
+ Mole Flows	**kmol/hr**	**55373.8**	**56936.5**	**18457.9**	**16999.3**	**73831.7**	
+ Mole Fractions							
− Mass Flows	kg/sec	**333.75**	**341.974**	**111.25**	**103.026**	**445**	
H2	kg/sec	0	0.000132673	0	0.116429	0	
O2	kg/sec	0	0.925112	0	1.57753e-09	0	
H2O	kg/sec	250.313	257.611	83.4375	75.0975	333.75	
KOH	kg/sec	83.4375	83.4375	27.8125	27.8126	111.25	

a. Electrolyzer Efficiency

The efficiency of an electrolyzer can be calculated using the formula:

Efficiency=[(Energy content of hydrogen produced)/(Electrical energy input)]×100%

The energy content of hydrogen is typically given by its lower heating value (LHV), which is approximately 33.33 kWh/kg.

From the provided data:

- Total power input = 20 MW
- Number of stacks = 8
- Number of cells per stack = 230

First, calculate the total electrical energy input per second:

Electrical energy input=20 MW=20×10^6 W=20×10^6 J/s

Next, determine the mass flow rate of hydrogen produced. From the table, the mass flow rate of H_2 at the cathode is 0.116429 kg/s.

Now, calculate the energy content of the hydrogen produced per second:

Energy content of hydrogen=0.116429 kg/s×33.33 kWh/kg×3600 s/h
Energy content of hydrogen≈13999.8 kJ/s
Now, calculate the efficiency:

Efficiency = [(13999.8 /20×10^3)] ×100%≈70%

b. Energy Requirements per Unit Mass of H_2 Production

The energy requirement per unit mass of hydrogen production can be calculated as:

Energy requirement = Electrical energy input/Mass flow rate of hydrogen

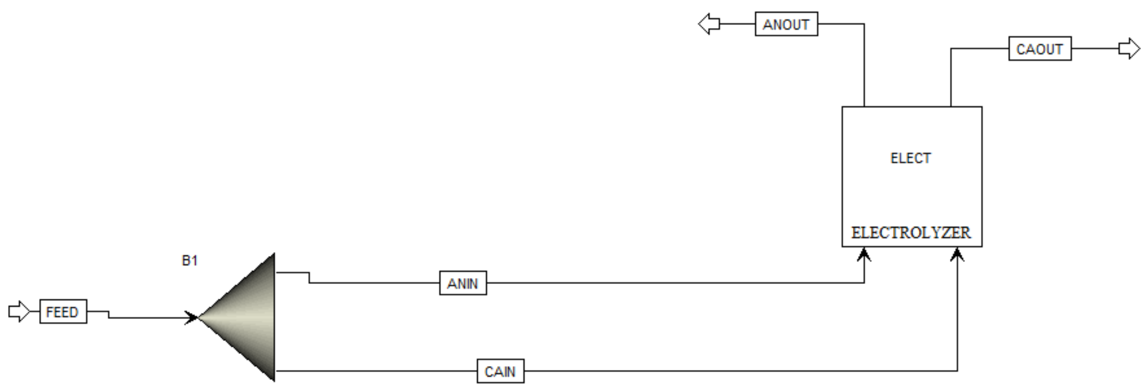
Using the values from above:

Energy requirement=20×10^6 /0.116429≈171.8 MJ/kg

This value can also be expressed in kWh/kg:

Energy requirement=171.8/3.6≈47.7 kWh/kg

(III) Flowsheet as follows:-



	Units	ANIN	ANOUT	CAIN	CAOUT	FEED	
Enthalpy Flow	cal/sec	-1.09727e+09	-1.12389e+09	-3.65757e+08	-3.341e+08	-1.46303e+09	
Average MW		21.698	21.622	21.698	21.819	21.698	
− Mole Flows	**kmol/sec**	**15.3816**	**15.8178**	**5.1272**	**4.72002**	**20.5088**	
H2	kmol/sec	0	6.58123e-05	0	0.058042	0	
O2	kmol/sec	0	0.0290538	0	4.901e-11	0	
H2O	kmol/sec	13.8945	14.3016	4.63149	4.16626	18.5259	
KOH	kmol/sec	1.48715	1.48715	0.495717	0.495718	1.98287	
− Mole Fractions							
H2		0	4.16063e-06	0	0.012297	0	
O2		0	0.00183678	0	1.03834e-11	0	
H2O		0.903316	0.904142	0.903316	0.882678	0.903316	
KOH		0.0966837	0.0940172	0.0966837	0.105025	0.0966837	
− Mass Flows	**kg/sec**	**333.75**	**342.014**	**111.25**	**102.986**	**445**	
H2	kg/sec	0	0.00013267	0	0.117006	0	
O2	kg/sec	0	0.929687	0	1.56826e-09	0	
H2O	kg/sec	250.313	257.647	83.4375	75.0563	333.75	
KOH	kg/sec	83.4375	83.4375	27.8125	27.8126	111.25	
− Mass Fractions							
H2		0	3.87907e-07	0	0.00113613	0	
O2		0	0.00271827	0	1.52279e-11	0	
H2O		0.75	0.753322	0.75	0.728802	0.75	
KOH		0.25	0.243959	0.25	0.270062	0.25	
Volume Flow	l/min	18087.6	25737	6029.19	21089.4	24116.8	
+ Vapor Phase							

The molar mass of H_2 is approximately 2 g/mol or 0.002 kg/mol.

Molar flow rate of H_2 = 0.117006/0.002 = 58.503 mol/s

Since the purity of H_2 is 96%, the actual molar flow rate of H_2 produced is: Actual Mass flow rate of H_2 = 58.503/0.96 = 60.94 mol/s

According to the stoichiometry of the reaction, 1 mole of water is required to produce 1 mole of H_2.

So, Molar flow rate of H2O=60.94 mol/s

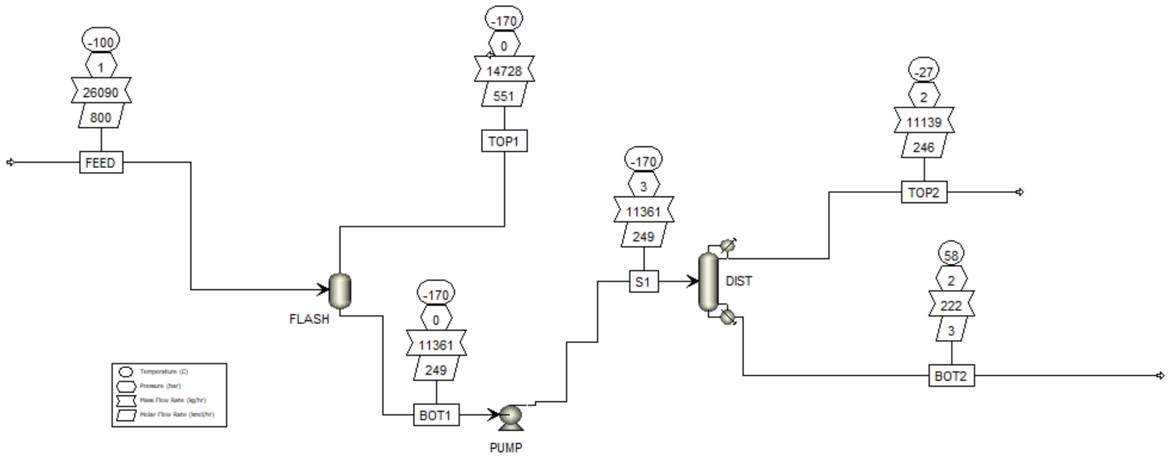
The molar mass of water (H_2O) is approximately 18 g/mol or 0.018 kg/mol.

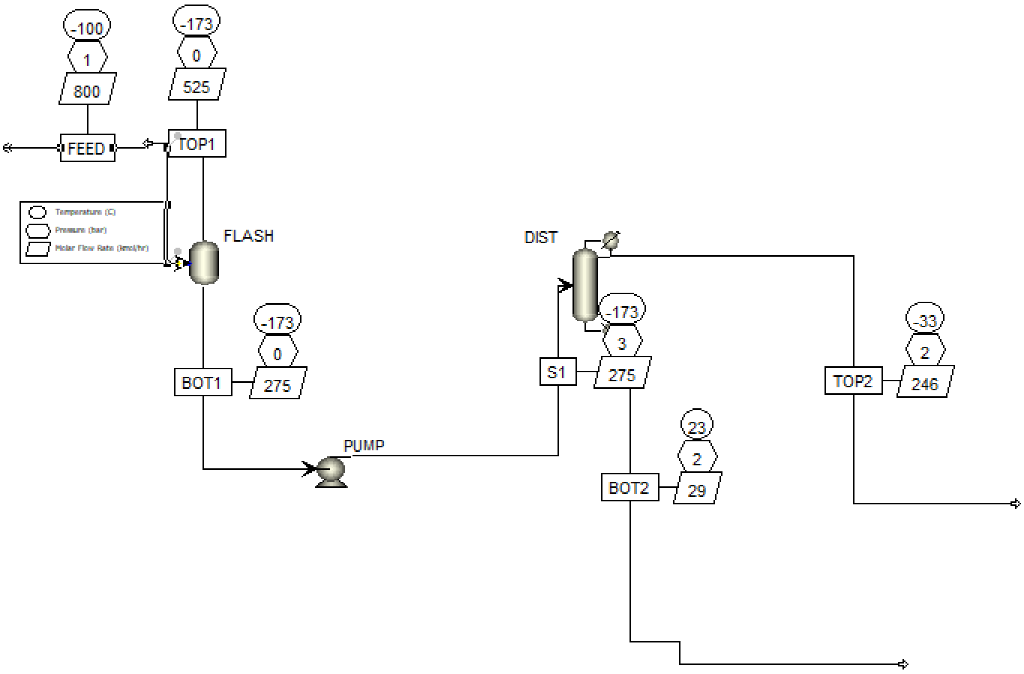
Mass Flow rate of H_2O = 60.94 × 0.018 = 1.096 kg/s

1.

For separation of the C2/C3 (direct separation)

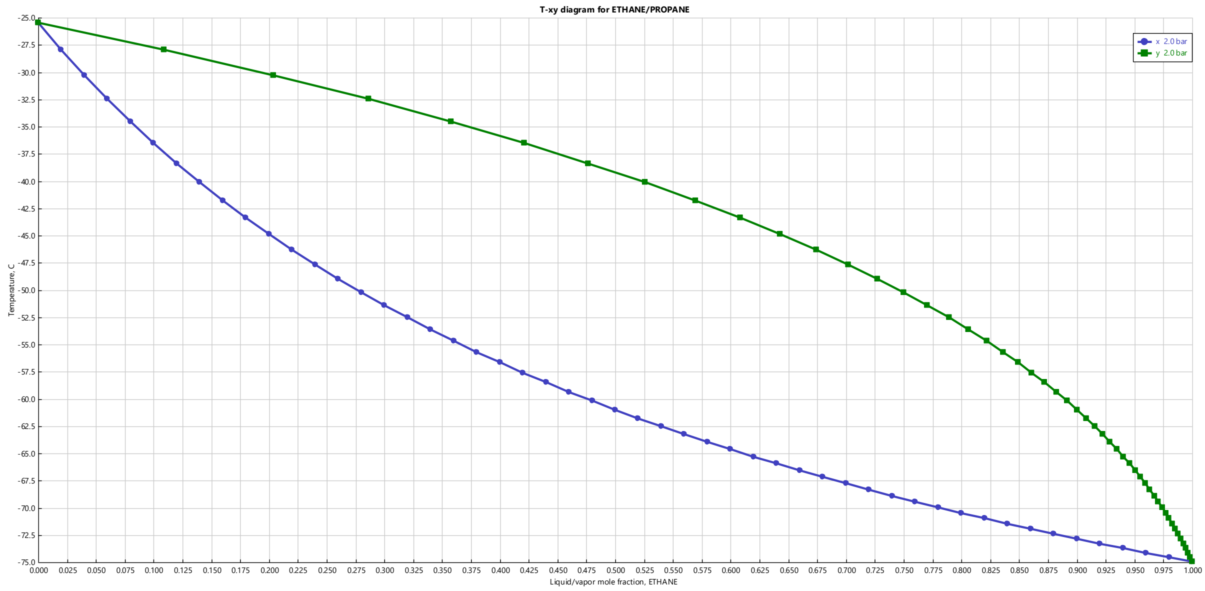
- **Flowsheet for Direct Sequence (C2/C3 separation first)**





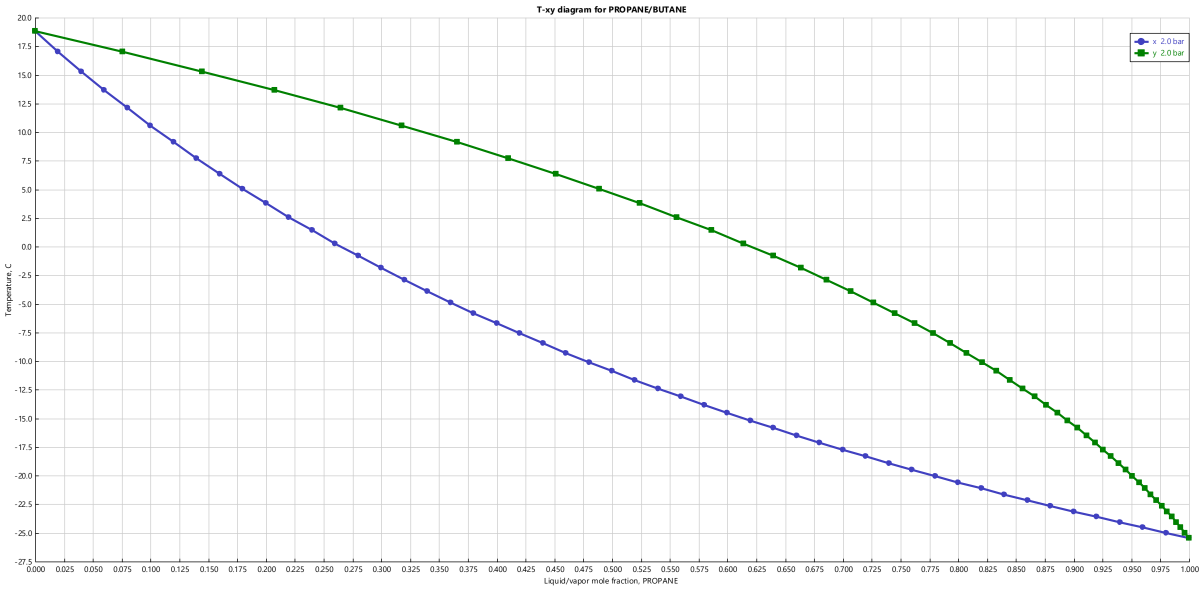
By Binary analysis plot of C2/C3 we get a range of flash temperature to operate

Temperature range for flash = -40 to -47.5 °C



For separation of the C3/C4 (Indirect separation)

- **Binary Analysis of C3/C4**



- By Binary analysis plot of C3/C4 we get a range of flash temperature to operate

Temperature range for flash = -2.5 to -5.0 °C