

SIMULATION OF CUMENE PRODUCTION

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ABSTRACT

The Cumene production process has seen an immense rise in prospects and so better ideas and studies should be continued so that the production cost is reduced. With the modernization of technology like computers and simulating processes such as DWSIM, it is possible to design and optimize the given process. Production cost can be reduced severely by designing it in the most effective way possible hence reducing environment hazards and maintaining proper safety protocols.

AIM

To Simulate the production of Cumene using DWSIM software.

OBJECTIVE

1. To prepare the flow sheet for production of cumene
2. To optimize the contents of the flow sheet for minimization of loss of material along with a greater production of cumene and low requirement of energy
3. To stimulate the process to get a higher yield.

INTRODUCTION

- Cumene also known as Isopropyl benzene is the principal chemical used in the production of phenol and its co-product acetone on an industrial scale.
- Physically, cumene is a colorless, volatile liquid with a gasoline-like odor and it is a natural component of coal tar and crude oil, and also can be used as a blending component in gasoline.
- Cumene is the starting material in the production of acetophenone, methyl styrene, diisopropyl benzene and dicumyl peroxide.
- Minor uses of cumene include as a thinner for paints, enamels, and lacquers. It is also a good solvent for fats and resins and has been suggested as a replacement for benzene in many of its industrial applications.

CATALYST ANALYSIS

Cumene is produced by the alkylation of benzene with propylene over an acid catalyst. Catalysts like aluminum chloride, boron trifluoride, hydrogen fluoride and solid phosphoric acid (SPA) are normally used. Over the years these catalysts have given way to zeolite based catalysts. There are some inherent problems associated with conventional acid catalysts.

1. Disadvantages of using solid phosphoric acid (SPA) Process:- a)The presence of side reactions limits the production of cumene to 95% b)The catalyst is not regeneratable hence it must be replaced with a new amount in each cycle
2. Disadvantages of using Aluminum chloride as catalyst
a)Pretreatment of feeds are essential. b)The occurrence of corrosion.
3. Advantages of using the zeolite based catalyst:
a)Less needed for regeneration which means the process can run for months without worrying about affecting the

selectivity or yield. b) No corrosions. c) More profitable in terms of the capital cost and operating cost since the temperature required is lower, which can also increase the lifetime of the reactors.

CHEMICAL EQUILIBRIUM

One of the challenges is how to minimize the side reaction which forms DIPB to maximize the fraction of cumene in the outlet stream.

The selectivity of cumene can be enhanced greatly by increasing the molar ratio of benzene/propylene. Which means more molecules of benzene are available to react with propylene.

This can be achieved by recycling a great amount of benzene to the reactor. If no recycling is used either the selectivity of cumene will be poor or a larger amount of fresh benzene is needed and then dumping the excess amount after separation which is illogical.

SIMULATION

For the synthesis of Cumene, DWSIM was used for simulating the process. DWSIM is an open-source CAPE-OPEN compliant chemical process simulator. It allows us to conduct experiments and analyze data using advanced models and operations. DWSIM allows chemical engineering students and practicing engineers to model process plants by using rigorous thermodynamic and unit operations models. Since DWSIM is free and open-source, one can see how the calculations are actually being done by inspecting the code behind during execution using free tools available elsewhere.

Steps involved

1. Addition of the components required from the component library and pure components were added for the synthesis of CUMENE, add the property package required (Here Peng-Robinson was used) and select the system of units.

Added	Name	CAS Number	Formula	Source Database
<input checked="" type="checkbox"/>	Cumene	98-82-8	(C ₆ H ₅)CH(CH ₃) ₂	ChemSep
<input checked="" type="checkbox"/>	Benzene	71-43-2	-CHCHCHCHC...	ChemSep
<input checked="" type="checkbox"/>	Propylene	115-07-1	CH ₂ CHCH ₃	ChemSep
<input checked="" type="checkbox"/>	Propane	74-98-6	CH ₃ CH ₂ CH ₃	ChemSep
<input checked="" type="checkbox"/>	P-diisopropylbenzene	100-18-5	(CH ₃) ₂ CH(C ₆ H...	ChemSep
<input type="checkbox"/>	Carbon dioxide	124-38-9	CO ₂	ChemSep
<input type="checkbox"/>	Carbon monoxide	630-08-0	CO	ChemSep
<input type="checkbox"/>	Argon	7440-37-1	Ar	ChemSep
<input type="checkbox"/>	Bromine	7726-95-6	BrBr	ChemSep
<input type="checkbox"/>	Carbon tetrachloride	56-23-5	CCl ₄	ChemSep
<input type="checkbox"/>	Chlorine	7782-50-5	Cl ₂	ChemSep
<input type="checkbox"/>	Hydrogen iodide	10034-85-2	HI	ChemSep

2. Addition of reaction set involved in the process in the settings and choosing the base component of the reaction. Mentioning of the stoichiometric coefficient of the reactants and products.

Identification

Name
Rxn1

Descripti
Benzene+Propylene=Cumene

Components, Stoichiometry and Reaction Orders

Name	Molar Weight	ΔH_f (kJ/kg)	Include	BC	Stoich. Coeff.	DO	RO
Cumene	120.192	33.2802	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1	0	-1
Benzene	78.1118	1061.04	<input checked="" type="checkbox"/>	<input type="checkbox"/>	-1	1	0
Propane	44.0956	-2373.93	<input type="checkbox"/>	<input type="checkbox"/>	0	0	0
Propylene	42.0797	480.754	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	-1	1	0
P-diisopropylbenzene	162.271	-478.211	<input type="checkbox"/>	<input type="checkbox"/>	0	0	0

Stoichiometry
OK
Balance
Heat of Reaction (kJ/kmol_BC)
-99110

Equation
-CHCHCHCHCHCH- + CH₂CHCH₃ <-> (C₆H₅)CH(CH₃)₂

Kinetic Reaction Parameters

Base Component
Propylene
Basis
Molar Concentrations
Tmin (K)
0
Phase
Vapor
Tmax (K)
2000

Kinetics Specification
Simple
Advanced
Python Script
Help

Rate Constants for Direct and Reverse Reactants (k and k')

Direct Reaction
Arrhenius
A
6510
E
52654
kJ/kmol

User-Defined: f(T), T in K

Reverse Reaction
Arrhenius
A'
0
E'
0
J/mol

User-Defined: f(T), T in K

Amount Units
kmol/m³
Rate Units
kmol/[m³.s]

Edit Kinetic Reaction

Identification

Name Rxn2

Descripti Cumene+Propylene=DIPB

Components, Stoichiometry and Reaction Orders

Name	Molar Weight	ΔH_f (kJ/kg)	Include	BC	Stoich. Coeff.	DO	RO
Cumene	120.192	33.2802	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	-1	1	0
Benzene	78.1118	1061.04	<input type="checkbox"/>	<input type="checkbox"/>	0	0	0
Propane	44.0956	-2373.93	<input type="checkbox"/>	<input type="checkbox"/>	0	0	0
Propylene	42.0797	480.754	<input checked="" type="checkbox"/>	<input type="checkbox"/>	-1	1	0
P-diisopropylbenzene	162.271	-478.211	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1	0	-1

Stoichiometry OK
Balance
Heat of Reaction (kJ/kmol_BC) -101830

Equation $(C_6H_5)CH(CH_3)_2 + CH_2CHCH_3 \rightleftharpoons (CH_3)_2CH(C_6H_4)CH(CH_3)_2$

Kinetic Reaction Parameters

Base Component Cumene
Basis Molar Concentrations
Phase Vapor
Tmin (K) 0
Tmax (K) 2000

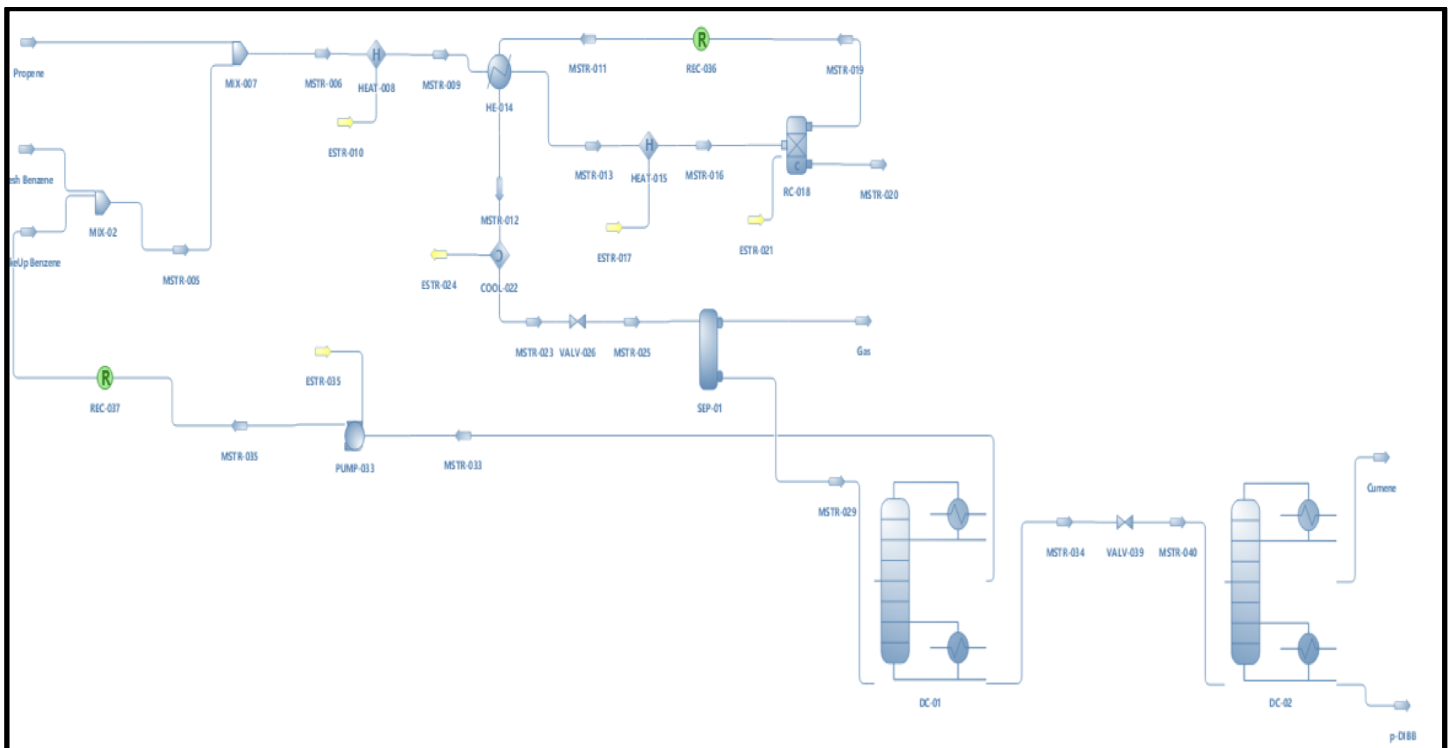
Kinetics Specification ☒ Simple ☐ Advanced
Python Script
Help

Rate Constants for Direct and Reverse Reactons (k and k')

Direct Reaction
☒ Arrhenius
A 450
E 55000
J/mol
☐ User-Defined: f(T), T in K

Reverse Reaction
☒ Arrhenius
A' 0
E' 0
J/mol
☐ User-Defined: f(T), T in K

3. Enter the simulation environment. Add all the required equipment to the flowsheet from the object palette. Addition and defining of inlet and outlet material and energy streams.



4. Defining the properties of the inlet stream.

Propene :

Propene (Material Stream)

Information Connections

General Info

Object: Propene

Status: Calculated (3/3/2022 6:36:49 PM)

Linked to

Property Package Settings

Property Package: PP_1

Input Data Results Annotations Dynamics Floating Tables

Stream Conditions Compound Amounts

Flash Spec: Temperature and Pressure (TP)

Temperature: 298.15 K

Pressure: 24.673082 atm

Mass Flow: 4396.8948 kg/h

Molar Flow: 104.24016 kmol/h

Volumetric Flow: 8.6557332 m3/h

Specific Enthalpy: -368.13831 kJ/kg

Specific Entropy: -1.6493531 kJ/[kg.K]

Vapor Phase Mole Fraction: 0

MSTR-034 (Ma... MSTR-040 (Ma... Fresh Benzene ... Propene (Mate...

Benzene :

Fresh Benzene (Material Stream)

Information Connections

General Info

Object: Fresh Benzene

Status: Calculated (3/3/2022 6:36:49 PM)

Linked to

Property Package Settings

Property Package: PP_1

Input Data Results Annotations Dynamics Floating Tables

Stream Conditions Compound Amounts

Flash Spec: Temperature and Pressure (TP)

Temperature: 298.15 K

Pressure: 24.673082 atm

Mass Flow: 15622.812 kg/h

Molar Flow: 200.00016 kmol/h

Volumetric Flow: 17.848831 m3/h

Specific Enthalpy: -415.13422 kJ/kg

Specific Entropy: -1.1878731 kJ/[kg.K]

Vapor Phase Mole Fraction: 0

MSTR-020 (Ma... MSTR-034 (Ma... MSTR-040 (Ma... Fresh Benzene ...

RESULTS AND DISCUSSION

Conversion reactor :

RC-018 (Conversion Reactor)

Inlet Stream: MSTR-016

Outlet Stream 1: MSTR-019

Outlet Stream 2: MSTR-020

Energy Stream: ESTR-021

Calculation Parameters

Parameters

Reaction Set: Default Set

Calculation Mode: Define Outlet Temperature

Outlet Temperature: 692.15 K

Pressure Drop: 0 kgf/cm2

Property Package: PP_1

External Solver:

Results

General Reactions Conversions

Reaction	Property	Value	Units
Cumene Pro...	Conversion	96.5	%
Diisopropyl...	Conversion	2.6	%

RC-018 (Conversion Reactor)

Inlet Stream: MSTR-016

Outlet Stream 1: MSTR-019

Outlet Stream 2: MSTR-020

Energy Stream: ESTR-021

Calculation Parameters

Parameters

Reaction Set: Default Set

Calculation Mode: Define Outlet Temperature

Outlet Temperature: 692.15 K

Pressure Drop: 0 kgf/cm2

Property Package: PP_1

External Solver:

Results

General Reactions Conversions

Compound	Conversion (%)
Propane	0.00020335973
Propylene	96.591003
Benzene	32.213519

Stream wise results of the simulation

Stream wise Results								
Object	p-DIB	MakeUp Benzene	MSTR-020	Gas	Fresh Benzene	Excess Benzene	Cumene	
Temperature	474.17212	323.91588	692.15	363.15151	298.15	281.49104	424.87021	K
Pressure	0.98692327	24.673098	24.673082	2.3320705	24.673082	24.673082	0.98692327	atm
Mass Flow	14.538979	8316.2754	0	586.32718	15622.812	7796.8958	11516.62	kg/h
Molar Flow	0.089605966	109.06435	0	10.199988	200.00016	99.81432	95.833402	kmol/h
Volumetric Flow	0.022300383	10.318883	0	125.6549	17.848831	8.7457649	22.296875	m3/h
Molar Fraction (Mixture) / Propane	0	0.045223425	0	0.46655797	0	0	1.9930759E-13	
Molar Fraction (Mixture) / Propylene	4.6437046E-20	0.015689235	0	0.16467123	0	0	4.1746403E-14	
Molar Fraction (Mixture) / Benzene	3.3982516E-14	0.93336474	0	0.3408777	1	1	0.00050046751	
Molar Fraction (Mixture) / Cumene	0.00039010455	0.0057225977	0	0.027890776	0	0	0.99949009	
Molar Fraction (Mixture) / P-diisopropylbenzene	0.9996099	3.620992E-11	0	2.3206056E-06	0	0	9.4409417E-06	

CONCLUSION

Cumene is an organic compound that is widely used as a chemical intermediate in the production of phenol and acetone. In our project we have studied the industrial method of production of cumene by the alkylation of benzene and propylene. The simulation of production of cumene will be carried out using DWSIM Software. We will be using a zeolite based catalyst to cut down production cost and also minimize environmental impacts.

REFERENCES

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