ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 10| Issue: 3| March 2024|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2024: 8.402 || ISI Value: 1.188

PRODUCTION TECHNOLOGY OF ACETONE PRODUCT DERIVED FROM ACETYLENE

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ABSTRACT

Acetone (dimethyl ketone, 2-propanone, CH_3COCH_3) is a clear, colourless, volatile liquid with a sweet odor. The effect of various factors (temperature, volume velocity, acetylene: water ratio, catalyst composition, etc.) on the product yield and process selectivity in the catalytic hydration reaction of acetylene was studied. The kinetic laws of the catalytic hydration reactions of acetylene were studied and the mechanisms of their progress were proposed, and the additive kinetic equations representing the progress of the reactions were proposed (the mean square deviation does not exceed 5%). For the first time, improved and compact technologies for obtaining acetone by hydrating catalytic acetylene have been developed.

KEYWORDS: *Acetone, water, acetylene, catalyst, methyl methacrylate, YKS, selectivity*

INTRODUCTION

About 96% of acetone production worldwide is a by-product of phenol production. Thus, many trends in the phenolic industry also apply to acetone. The global acetone industry is driven by the solvent sector, which accounts for 34% of global demand. Global solvent demand for acetone will continue to maintain a steady growth rate until 2022. Methyl methacrylate (MMA) is the second largest end use of acetone. In 2017, global demand for MMA resin accounted for 25% of total acetone consumption. Bisphenol A is the third largest sector in demand; however, by the end of the forecast period, BPA demand will exceed MMA demand.

Acetone (dimethyl ketone, 2-propanone, CH_3COCH_3) is a clear, colorless, volatile liquid with a sweet odor. It is the simplest aliphatic ketone and the most commercially important. Almost all acetone production in the world occurs by peroxidation of cumene with phenol as a by-product. Its main chemical uses are as an intermediate in the production of acetone, cyanohydrin (MMA), bisphenol A (BPA), aldehyde and alcohol (aldol) for methyl methacrylate. Direct use of solvents accounts for the majority of global demand.

The following users are expected to experience positive growth during the forecast period and overall global acetone demand will continue to improve.

1. European market - Belgium, Finland, France, Germany, Italy, Poland, Russia, Spain
2. Asia-Pacific market - China, India, Japan, Singapore, South Korea, Taiwan, Thailand
3. North American market - USA
4. Latin American market - Argentina, Brazil
5. African and Middle Eastern market - Saudi Arabia, South Africa

EXPERIMENTAL PART

The effect of various factors (temperature, volume velocity, acetylene:water ratio, catalyst composition, etc.) on the product yield and process selectivity in the catalytic hydration reaction of acetylene was studied.

When studying the effect of temperature on the yield of acetone in the presence of catalyst № 9 with high activity and productivity, it was found that the optimal temperature for the acetylene hydration reaction is 425-430°C (Table 1).

Table 1. The effect of temperature on the conversion of acetylene to the yield of acetone and the selectivity of the process (cat №9)

№	Temperature, °C	Total conversion of acetylene, %	Yield of acetone, %	Selectivity to acetone S %
1	300-320	45.1	22,9	50.7
2	325-350	66,2	47,6	71.9
3	355-370	79,4	62.2	78,3
4	375-390	87.2	73.2	83.9
5	395-420	89.9	77.7	86.4
6	**425-430**	**97,2**	**93.6**	**96.3**
7	435-475	90.1	82.4	91.4
8	480-500	82.4	70.5	85.5

As can be seen from the table, when the temperature reaches 425-430℃, the productivity of acetone formation is 93.6%, and the selectivity of the process to acetone is 96.3%.

The effect of partial pressures of reagents on the kinetic laws of the process was carried out by changing the partial pressure of one reagent while keeping the partial pressures of other reagents constant. The required amount of pure argon gas was injected into the reaction zone (area) to keep the linear velocity of the initial mixture constant.

The catalyst volume was adjusted accordingly to keep the specific acetylene flow rate constant. As a result of the study of the influence of the partial pressures of acetylene and water on the kinetic laws of the reaction, it was found that the yield of acetone increases with a decrease in the partial pressure of acetylene. At this time, the total conversion of acetylene increases, while the selectivity of the reaction to acetone decreases. Based on the study of the kinetic laws of the reaction, the following kinetic equation of the reaction of obtaining acetone by catalytic hydration of acetylene was proposed:

$$\boldsymbol{K_p = \frac{P_{C_3H_6O} \cdot P_{CO_2} \cdot P_{H_2}^2}{P_{C_2H_2}^2 \cdot P_{H_2O}^3}}$$

lg K_r the relationship between and temperature is expressed as:

$$lg\,K\,p = \frac{17637}{T} - 2{,}611\ \mathrm{lgT} + 1{,}356 \cdot 10^{-3}T - 0{,}092 \cdot 10^{-6}T^2 - \frac{0{,}223 \cdot 10^5}{T^2} - 3{,}794$$

DISCUSSION PART

(99.8%) Acetylene (1) is delivered from the tank (2) to the upper part of the reactor (hydrolysis unit) for hydration through the compressed acetylene pipeline under a pressure of 0.18 MPa through the compressor. For the safe transportation of compressed acetylene, steam is supplied to the acetylene pipeline, and it is heated to a temperature of 270°C in a heating furnace. To prevent local overheating of the steam acetylene mixture at the point where the transport steam is introduced, the acetylene pipeline is equipped with a shutter for cooling the mixture with circulating water.

The superheater (3) is a rectangular chambered firebox with a stack of steel tubes inside. The furnace consists of 2 parts - radiant, where the steam is superheated due to the combustion of natural gas, and conversion, where the steam is superheated due to exhaust gases.

The steam entering the conversion section of the steam superheater is heated to a temperature of 270°C and split into two streams. A stream is sent to mix it with acetylene for safe transport.

Another steam stream from the conversion part of the furnace enters the coils of the radiation part, where it is heated to a temperature of 500°C.

When the temperature exceeds 350-400°C, catalyst dust starts to come out. Steam heated to 500°C in a heating furnace and (2) acetylene from the compressor are mixed in a ratio (1:4) in a mixer (4) installed at the top of the reactor in order to reduce catalyst expulsion.

Reactor (5) is a vertical apparatus, inside which 10 layers of $ZnO:Fe_2O_3:Cr_2O_3:MnO_2:V_2O_5$/HSZ catalyst are placed and 10 plates are installed above the catalyst layer of each layer. The plates are designed to prevent condensate delivered to the hydrator through the nozzles to dissipate the heat of reaction from reaching the catalyst surface.

The acetylene-steam mixture entering the upper part of the reactor passes through 10 successive layers with a solid catalyst, and the reaction occurs on its surface.
Acetylene hydration is carried out at a temperature of (425-430) °C. At the beginning of the reaction period, the temperature is maintained at 425ºC. As the activity of the catalyst decreases, the temperature of the hydration process gradually increases to 435°C.

Contact gases formed as a result of the reaction from the lower part of the reactor (6) are cooled to a temperature of 185°C in a steam boiler.

After the steam boiler, the gases enter the cooler of the refrigerator (7), where they are cooled by circulating water to a temperature of 100°C and sent to the next cooler (8). Here they are cooled again with circulating water to a temperature of 75°C. In this case, the main part of acetone, acetic acid and crotonic acid dissolved in water in the condenser is condensed. Non-condensable gases with a temperature of 75°C enter the next cooler (9) where they are cooled with cold water to a temperature of 35°C. The obtained acetone water is condensed in coolers (7), (8), (9) and sent to tank (11).

Acetone and flue gases containing carbon dioxide (SO2), nitrogen (N2), oxygen (O2), methane (CH4), carbon monoxide (CO) washed from the reaction products are released into the atmosphere through a 40-meter high chimney (10) .

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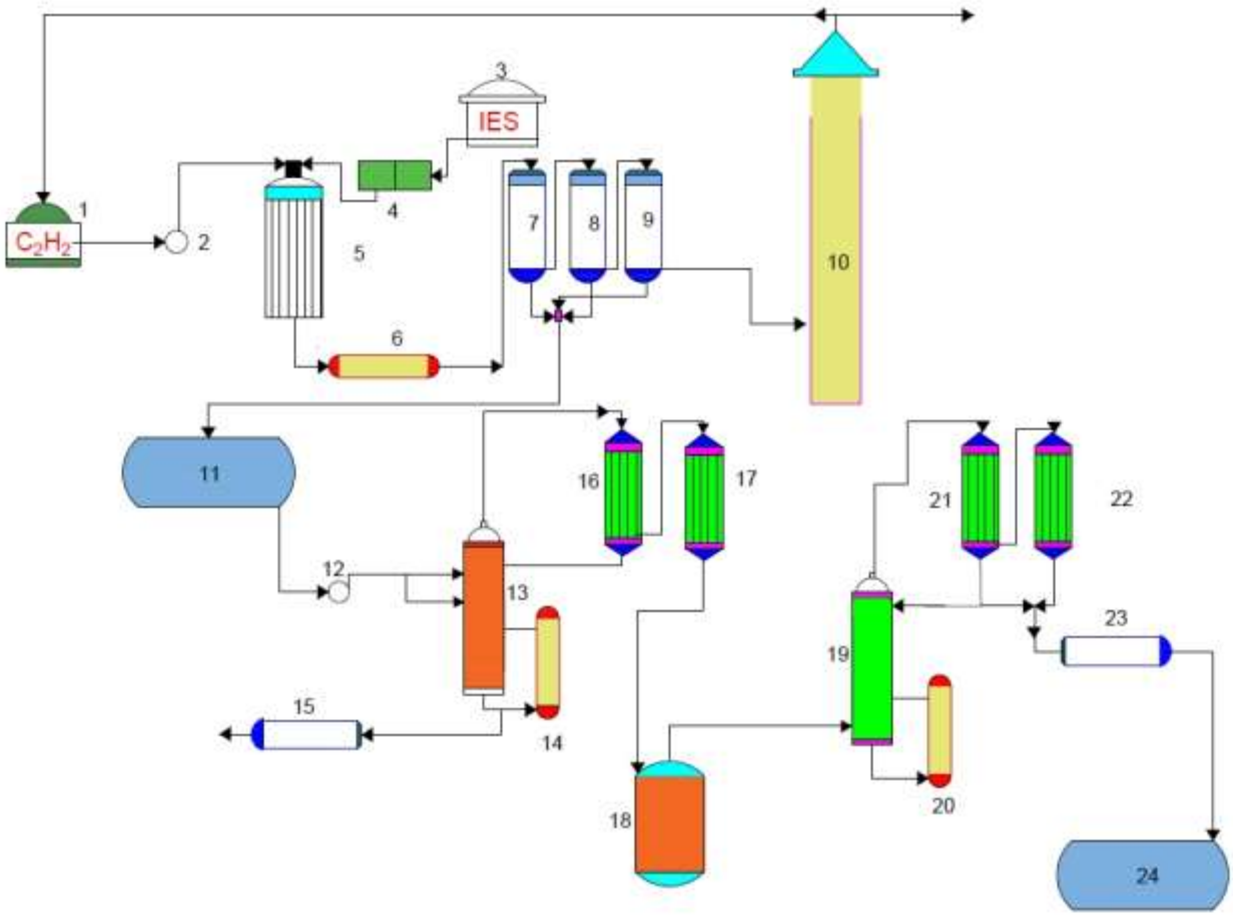

Figure 1. Technological scheme of obtaining acetone from acetylene and water
1-acetylene; 2, 12th pump; 3-water; 4-evaporator; 5th reactor; 6, 14 and 20-heater; 7, 8 and 9- coolers; 10-gas processing tower; 11th collector;13, 19-rectification column; Alkali 18; 15 and 23-small cooler;16, 17, 21 and 22 deflegator; collector 24

Catalyst regeneration. In the process of acetylene hydration, carbon and tar products accumulate on the surface of the catalyst, which leads to a decrease in its activity. After 72 hours of contact, the catalyst is regenerated using a mixture of steam and air heated to a temperature of 500-550 °C. Before supplying air to the hydrator, the system is vaporized and purged with nitrogen, blowing off acetylene, as well as combustible organic products formed during the hydration reaction and deposited on the surface of the catalyst. Catalyst regeneration takes 20-24 hours.

Rectification of an aqueous acetone solution. Aqueous acetone (3-7% acetone, 0.1% croton aldehyde, 0.01% acetic aldehyde) containing aqueous acetone collected in tank (11) with a temperature of 50-70°C is fed from the upper part of the rectification column (12) through a pump (13). In the lower part of the rectification column (14), the temperature is heated up to 130°C using steam. The temperature in the upper part of the column is 115-120°C. The fusel water (15) from the lower part of the column is cooled to 40-45°C through the cooler and goes to BXO. The main function of this rectification column is to separate acetone from aqueous acetone.
Acetone (16) in a par form from the top of the column is cooled with circulating water through the dephlegmator and fed as phlegm (saturation) from the top of the column. Gases that have not turned into liquid are cooled by cooled water in the next (17) dephlegmator. In dephlegmators (16-17), a part of cooled acetone is given as phlegm to saturate the column, and the rest is passed through 40% NaOH solution in dephlegmator (18).

Acetone vapors (19) at 45-50°C purified from acetaldehyde are sent to the lower part of the rectification column. This is heated to a temperature of 80-82°C using a heater in the lower part of the rectification column (20). The temperature at the top of the column is 55-58°C. Acetone vapors in the upper part of the column are cooled and condensed in reflux condensers through a dephlegmator installed in series (21-22). Part of the technical acetone is returned to the top of the column as phlegm. The remaining part (23) is cooled in a cooler and (24) is pressed with nitrogen into the collector. According to this technology, it is possible to obtain high purity acetone, not less than 99.5%.

CONCLUSION
Thermally stable, high activity, selectivity and productivity nanocatalysts were created for the $ZnO:Fe_2O_3:Cr_2O_3:MnO_2:V_2O_5/HSZ$ reactions of catalytic hydration of acetylene from local raw materials based on "wet" and suspension technology. The kinetic laws of the catalytic hydration reactions of acetylene were studied and the mechanisms of their progress were proposed, and the additive kinetic equations representing the progress of the reactions

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