

METHOD FOR MAKING CAPROLACTAM

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BACKGROUND

U.S. Patent 2,357,484, issued to Martin in 1944 discloses that epsilon-aminocapronitrile (ACN) can be converted into epsilon-caprolactam (CL) by contacting water with the ACN in the vapor phase in the presence of a dehydrating catalyst. Martin also described a liquid phase process to produce CL. See U.S. Patent 2,301,964, issued November 17, 1942.

15 In more recent years, technology has been developed to make inexpensive adiponitrile (ADN) by direct hydrocyanation of butadiene. This discovery has led to a renewed interest in the Martin CL process because the inexpensive ADN can be partially hydrogenated to produce an impure product that comprises ACN. This impure product also contains some byproducts of the hydrogenation reaction, notably tetrahydroazepine and its derivatives (both of which being referred to hereinafter as "THA").

25 Some recent patents have expressly taught that the THA and its derivatives must be removed from the impure ACN product before the ACN is converted into CL. See, for example, U.S. Patent 6,169,199, issued January 2, 2001.

30 Contrary to the suggestions in these patents, it has been found that the impure ACN that is recovered from the partial hydrogen of ADN--that contains greater than 500 ppm THA and its derivatives--can be processed in the vapor phase, as taught by Martin, to make CL without first removing the THA and its derivatives, and that the THA and

its derivatives can be removed easily by distillation from the resulting crude CL product.

BRIEF DESCRIPTION OF THE DRAWING

5 The Drawing consists of two figures, figure 1 and figure 2, which are flow diagrams illustrating two alternative embodiments of the process of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

10 As used throughout this application (unless the context suggests otherwise) the term "THA" is used to denote not only THA itself, but both THA and its derivatives. Such THA and its derivatives can be quantitatively measured by gas chromatography.

15 Referring now to figure 1, there is shown in schematic form apparatus 10 for practicing the first embodiment of the current invention. An impure ACN feed material 12 that can contain greater than 500 ppm THA is fed by a pump (not shown) into a heat exchanger 14 which heats the incoming impure ACN to a temperature of about 235 deg C. The heated, impure ACN is mixed with steam 16 in a vaporizer 18. A vapor phase mixture 20 of ACN, THA and water leaves the vaporizer 18 and is fed into at least one super heater 22 that heats the vapor 20 to a temperature of 275 deg C. A superheated vapor 24 exits the super heater and is fed into a CL synthesis reactor 26. The reactor 26 contains a dehydrating catalyst, as taught by Martin, such as activated alumina, titanium dioxide, vanadium oxide, etc. The reactor can be a fixed bed or a fluidized bed reactor.

20 The heat of reaction is removed from the reactor by a heat transfer fluid (not shown) that controls the reaction temperature within a range of 300 to 325 deg C. A suitable

heat transfer fluid is the material sold by DOW Chemical Company under the trademark "Dowtherm-A." The reaction occurring inside reactor 26 produces CL and ammonia.

Conducting the reaction in the vapor phase prevents the
5 formation of CL oligomers. A major portion of the THA present in the superheated vapor 24 passes through the reactor 26 without chemical transformation.

Exiting the reactor 26 is a vaporous product stream 28 that comprises CL, ammonia, water, unreacted ACN and
10 unreacted THA. The product stream 28 is fed into a partial condenser 30 that condenses some of the water, and a major portion of each of the CL, the unreacted ACN and unreacted THA to produce a liquid stream 32. Also exiting the condenser 30 is a vapor stream 34 that comprises some water
15 vapor, ammonia gas and perhaps a minor amount of THA, ACN, and CL. Both the stream 32 and the stream 34 are fed into different stages of an ammonia removal distillation column 36. Stream 32 is fed to the lower part of column 36, while stream 34 is fed to a higher stage than that to which stream
20 32 is fed. Column 36 removes essentially all of the ammonia and water as distillate 38. Distillate 38 is fed into a high pressure ammonia refining column 40 from which anhydrous ammonia product is removed as distillate 42 and water (together with trace amounts of organic materials) is
25 removed as a bottoms 44. The exact pressure is not critical, but will depend on the temperature of available heat removal fluids (not shown). Column 36 produces a bottoms 46 that comprises unreacted ACN, most of the unreacted THA, CL, and some high boilers. Column 36 can
30 contain trays or packing (not shown), and preferably is operated under vacuum and with a bottoms temperature below about 160 deg C to avoid the formation of CL oligomers. The bottoms 46 is fed into a vacuum low boiler removal column

48, again operating with a bottoms temperature below about 160 deg C. Column 48 contains structured packing (not shown). A distillate 50 is removed from column 48. The distillate 50 comprises unreacted ACN, some CL, most of the unreacted THA and some water. A bottoms 52 is removed from column 48. The bottoms comprises CL and high boilers. The bottoms 52 is fed into a vacuum high boiler removal column 54, containing structured packing (not shown) and operating with a bottoms temperature below about 160 deg C. High boilers and a minor portion of the incoming CL are removed as bottoms 56. The majority of the incoming CL is removed as distillate 58. All of the recovered CL is the desired product of the process of the current invention. This CL is suitable for polymerization to make Nylon 6 polymer. If desired, the bottoms 56 can be fed to a wiped film evaporator (not shown) to recover CL that is present in the bottoms 56. This recovered CL can be fed to high boiler removal column 54.

If the present process is operated on a commercial scale, a substantial amount of water will result in stream 44. To increase the economic efficiency of the process, this stream may be appropriately treated, and recycled back to the reactor 26.

Referring now to figure 2, there is shown in schematic form apparatus 100 for practicing a second embodiment of the current invention. An impure ACN feed material 120 that can contain greater than 500 ppm THA is fed by a pump (not shown) into a heat exchanger 140 which heats the incoming impure ACN to a temperature of about 235 deg C. The heated, impure ACN is mixed with steam 160 in a vaporizer 180. A vapor phase mixture 200 of ACN, THA and water leaves the vaporizer 180 and is fed into at least one super heater 220 that heats the vapor 200 to a temperature of 275 deg C. A

superheated vapor 240 exits the super heater and is fed into a CL synthesis reactor 260. The reactor 260 contains a dehydrating catalyst, as taught by Martin, such as activated alumina, titanium dioxide, vanadium oxide, etc. The reactor
5 can be a fixed bed or a fluidized bed reactor.

The heat of reaction is removed from the reactor by a heat transfer fluid (not shown) that controls the reaction temperature within a range of 300 to 325 deg C. A suitable heat transfer fluid is the material sold by DOW Chemical
10 Company under the trademark "Dowtherm-A." The reaction occurring inside reactor 260 produces CL and ammonia. Conducting the reaction in the vapor phase prevents the formation of CL oligomers. A major portion of the THA present in the superheated vapor 240 passes through the
15 reactor 260 without chemical transformation.

Exiting the reactor 260 is a vaporous product stream 280 that comprises CL, ammonia, water, unreacted ACN and unreacted THA. In contrast to the first embodiment, the product stream 280 is fed directly, without condensing, to
20 the lower part of an ammonia removal distillation column 300. This reflects a difference from the teachings of U.S. Patent 6,069,246, issued May 30, 2000, wherein crude CL produced from the vapor phase cyclizing hydrolysis of ACN is cooled, over a period of less than or equal to 1 hour, to a
25 temperature below or equal to 150 deg C, before it is distilled, to limit the formation of oligomers. Since it is well known by those skilled in the art that oligomerization does not readily occur in the vapor phase and is normally confined to the liquid phase, an alternative means of
30 limiting oligomer formation, as practiced in this second embodiment, is to feed the vapor stream 280 leaving the hydrolysis reactor 260 as a vapor to the CL distillation train, at a temperature much higher than 150 deg C, either

directly or after some cooling. This has the added benefit of directly utilizing the heat content of the vapor phase reaction product in the subsequent distillation, without the inefficiencies of indirect heat recovery by heat exchange with other process streams, utility streams, or other heat-exchange fluids. Column 300 removes essentially all of the ammonia and water in an overhead stream 320. Column 300 is equipped with a condenser 340 having sufficient capacity to condense overhead stream 320 to produce a liquid reflux stream 360, a liquid distillate stream 380 and a minor non-condensable vapor vent stream (not shown). Alternatively, vaporous product stream 280 can be passed through a cooler (not shown) to cool the vapor, but not to a temperature below its dew point, as a means of reducing the requirements on condenser 340. The cooling medium for said cooler can be, but is not limited to, circulating cooling water, air, other process streams, or other heat-exchange fluids. Distillate 380 is fed into a high pressure ammonia refining column 400 from which anhydrous ammonia product is removed as distillate 420, and water (together with trace amounts of organic materials) is removed as a bottoms 440. The exact pressure is not critical, but will depend on the temperature of available heat removal fluids (not shown). Column 300 produces a bottoms 460 that comprises unreacted ACN, most of the unreacted THA, CL, and some high boilers. Column 300 can contain trays or packing (not shown), and preferably is operated under vacuum and with a bottoms temperature below about 160 deg C to avoid the formation of CL oligomers. The bottoms 460 is fed into a vacuum low boiler removal column 480, again operating with a bottoms temperature below about 160 deg C. Column 480 contains structured packing (not shown). A distillate 500 is removed from column 480. The distillate 500 comprises unreacted ACN, some CL, most of the

unreacted THA and some water. A bottoms 520 is removed from column 480. The bottoms comprises CL and high boilers. The bottoms 520 is fed into a vacuum high boiler removal column 540, containing structured packing (not shown) and operating
5 with a bottoms temperature below about 160 deg C. High boilers and a minor portion of the incoming CL are removed as bottoms 560. The majority of the incoming CL is removed as distillate 580. All of the recovered CL is the desired product of the process of the current invention. This CL is
10 suitable for polymerization to make Nylon 6 polymer. If desired, the bottoms 560 can be fed to a wiped film evaporator (not shown) to recover CL that is present in the bottoms 560. This recovered CL can be fed to high boiler removal column 540.

15 If the present process is operated on a commercial scale, a substantial amount of water will result in stream 440. To increase the economic efficiency of the process, this stream may be appropriately treated, and recycled back to the reactor 260.

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EXAMPLE

This example illustrates the process of the first embodiment of the present invention.

25 A solution containing approximately 50% by wt. ACN and 50% by wt. water was vaporized, and then reacted over a dehydration (alumina) catalyst at 300 deg C and atmospheric pressure in the vapor phase. The amount of THA present in the ACN used to make the solution was 1800 ppm, as
30 determined by gas chromatographic analysis. The organic product exiting the reactor contained 1.25 % by wt. unreacted ACN, 700 ppm THA, and the balance substantially caprolactam, on an anhydrous basis. Some other trace

impurities were also present, as well as a stoichiometric amount of ammonia reaction product and unconverted water. This data indicates some consumption of THA in the reaction step to form unidentified products. The vapor phase product was then cooled to produce an aqueous caprolactam solution that was saturated with ammonia.

The aqueous caprolactam solution will be flashed at 120 torr (16 kPa) pressure to remove the ammonia and substantially all of the water.

Next, 1.4 liters of molten caprolactam will be transferred to a batch still which will contain 4.5 feet of Sulzer BX[®] mesh packing. The still will be operated at a head pressure of 10 torr (1.3 kPa). The ACN and THA will be distilled overhead at a reflux ratio of 50 to 1. Four successive 50 ml distillation cuts will be taken overhead to remove the THA and ACN. Gas chromatographic analysis of the distillate cuts would be expected to be as follows:

<u>Component</u>	<u>Cut #1</u>	<u>Cut #2</u>	<u>Cut #3</u>	<u>Cut #4</u>
THA (% by wt)	0.758	0.066	0.022	0.014
ACN (% by wt)	45.3	4.46	0.492	0.187

Such data would indicate that both the THA and ACN can be successfully removed from the caprolactam by distillation.

After Cut #4 above is taken, the reflux ratio will be reduced to 1 to 1, and the product caprolactam will be distilled overhead. A total of 850 ml of refined caprolactam product would be expected to be recoverable, and contain no detectable amounts by gas chromatography of THA or ACN. High boilers present in the initial material

charged to the batch still would be expected to remain in the pot residue.

This example illustrates that THA should be readily removed from caprolactam by distillation. This example
5 demonstrates that it should be possible to utilize ACN containing levels of THA greater than 500 ppm for caprolactam synthesis and remove the residual THA from the caprolactam product.

This example, while described as being performable in a
10 batch mode, illustrates that the desired separations can also be carried out in a series of continuous columns, where an improved recovery of caprolactam would be expected.

CLAIMS

WHAT IS CLAIMED IS:

1. A method for making caprolactam from an impure 6-aminocapronitrile (ACN) that comprises both ACN and a
5 minimum of 500 ppm tetrahydroazepine and its derivatives (THA), comprising the steps of:

(1) contacting the impure ACN comprising both ACN and THA with water at elevated temperature in the presence of a dehydration catalyst, both the impure ACN
10 and the water being in the vapor phase, to produce a vapor phase reaction product that comprises caprolactam, ammonia, water, ACN, and THA;

(2) separating the ammonia and a major portion of the water from the vapor phase reaction product to
15 produce a melt comprising caprolactam, ACN and THA;

(3) introducing the melt into a low boiler removal distillation column and removing a major portion of both the THA and ACN as a distillate, and removing caprolactam, high boilers and at most a minor portion of
20 both the THA and ACN as a bottoms; and

(4) introducing the bottoms into a high boiler removal distillation column and removing caprolactam and at most a minor portion of the high boilers as a distillate product and removing a major portion of the
25 high boilers as a bottoms.

2. The method of claim 1 wherein in step (2) the ammonia and the major portion of the water are separated from the vapor phase reaction product by partially
30 condensing the vapor phase reaction product to produce a vapor stream that comprises ammonia and water, and a liquified stream that comprises water, CL, unreacted ACN, and THA, introducing the vapor stream into a predetermined

stage of a distillation column and introducing the liquid stream into a stage of the distillation column lower than the predetermined stage, and withdrawing as a bottoms the melt comprising caprolactam, ACN and THA.