

Method and Device for Purifying Substances by Means of Crystallization

The present invention relates to a process and a device for the purification of crystallizable compounds by means of optionally fractional crystallization, wherein a molten material or a mixture containing essentially one desired compound and at least one impurity is subjected to at least partial crystallization.

At present, chemical starting materials and intermediates, particularly starting materials used in polymer production, are produced in enormous quantities. In order to meet the increasing demands with respect to quality, impurities in these products must be virtually absent.

In addition to distillation, crystallization has increasingly been used as a method of purification in recent years. The latter method is advantageous in that impurities which cannot be removed by distillation may frequently be removed by means of crystallization.

However, crystallization involves the drawback that impurities possibly present in the molten material will also precipitate during crystallization. It is a well-known fact that the desired product is depleted in the mother liquor or molten material during crystallization, and that impurities accumulate accordingly. Thus, some of the impurities reach and exceed their solubility limit in the course of the purification process. The impurities will precipitate as soon as the solubility limit is reached. These undesirable crystals then undergo sedimentation on the bottom or the walls of a crystallizer. As these crystals adhere to the surfaces, they will remain in the crystallizer when

discharging the non-crystallized molten material. Then, when melting the deposited layer of crystals, where normally two or more fractions are formed, the precipitated impurities still present on the bottom and the walls of the crystallizer will be reabsorbed by the heated molten material. As a consequence, the impurities can never be removed completely and concentrate in the crystallizer.

If the desired compound is purified at least partially in a static crystallizer, the impurities will also be incorporated in the crystallized material because there is no agitation in the molten material.

For example, problems of the above-mentioned type occur in the purification of acrylic acid. Depending on the production process and the efficiency of the subsequent distillation, the prepurified acrylic acid will contain a more or less large proportion of maleic acid and phenothiazine (PTZ) which are by-products in the production of acrylic acid.

According to a purification process suggested in EP-A-0,616,998, acrylic acid is purified using a combination of dynamic and static crystallization, wherein the residue from the dynamic crystallization is purified using static crystallization, and the purified acrylic acid is refeed into the dynamic crystallization. As a result, the molten acrylic acid material which is refeed into the static crystallizer already contains a high percentage of by-products such as maleic acid and phenothiazine (PTZ). When cooling the molten material, maleic acid and phenothiazine (PTZ) are precipitated and part thereof will subsequently be incorporated in the deposited layer of crystals.

Thus, in an industrial purification plant, several hundred kilograms of maleic acid may be formed during one day. Ob-

viously, the solid maleic acid may block pipes and valves. Also, this maleic acid may precipitate as a solid deposit on the crystallizer walls or the bottom thereof. Therefore, it was found necessary to remove these precipitates.

Various solutions have been suggested to separate the precipitated by-products from the molten material. One solution suggests removal of the precipitated impurities by filtration. For this purpose, a static crystallizer 11 is connected with a separator 13 as illustrated in **Figure 1**. Normally, the separator 13 can be a filter, but also, a centrifuging device, a suction filter, or any other device allowing separation of solid and liquid materials. The separator 13 is connected with the crystallizer 11 via pipes 15, 17. The pipe 17 is connected to tubes 19, 21 arranged on opposite sides in the bottom area of crystallizer 11. The tubes 19, 21 have a number of openings 23 preferably oriented at an angle to the crystallizer bottom. A collector channel 25 is provided in the center of the bottom 24 which is designed in a V-shaped cross-section. The collector channel is connected with separator 13 via pipe 15. Pipe 15 is provided with a pump 27 which is used to circulate the molten material.

The removal of impurities precipitating during the crystallization process is effected in such a way that molten material is withdrawn through pipe 15 by means of pump 27 and conveyed through separator 13 wherein the solids are retained. The molten material discharging from separator 13 is then refeed into crystallizer 11 via pipe 17. Preferably, the flow rate of the molten material discharging from the openings 23 is selected in such a way that a laminar flow will form within the area of crystallizer bottom 24. In this way, the circulation of molten material will not interfere with the crystallization process. By continuously withdrawing the bottom layers of the molten material, it is

possible to remove the gradually depositing impurities. Obviously, such a separator can be combined with any type of crystallizer where the product is deposited on cooled surfaces (e.g., falling film or static crystallizers). However, incorporation of precipitating impurities in the crystals cannot be completely avoided when using the separator as described. Also, it was found that not only maleic acid but also other compounds may undergo precipitation.

It is therefore the object of the present invention to provide a process and a device by means of which the problems mentioned above can largely be avoided. In particular, said process and device should allow for efficient purification of products where purification using fractional crystallization is impeded or made impossible due to precipitating impurities, and for further reduction of the percentage of residual impurities. Another object is to provide an improved process and a device for the purification of acrylic acid.

According to the invention, this is done by using a process wherein in case at least one impurity is present, which undergoes precipitation during the purification process as a result of surpassing the solubility limit, the molten material or the mixture to be purified is added with a solvent or a mixture of solvents in such an amount that the respective impurity is retained in solution.

The solvent or the mixture of solvents preferably has a high affinity to at least one of the impurities, i.e., the solvent preferably has a superior dissolving capacity for the impurity compared to the product to be purified. This is advantageous in that only a small amount of solvent has to be added to the molten material in order to prevent precipitation of the impurities. Moreover, only a small amount of product to be purified will dissolve in the solvent in

this case, so that the efficiency of the process is maintained.

Conveniently, the suitable solvent or mixture of solvents is selected according to the well-known solubilities of these substances in the respective solvents. As is well-known, polar compounds have particularly good solubility in polar solvents and apolar substances in apolar solvents, for example. In order to increase the solubility of specific impurities, it is particularly preferred to add a solvent to the molten material, which is already present as an impurity in the employed material.

The inventive advancement of the well-known crystallization processes may be used in the purification of any material during which precipitation of impurities occurs. Fractional crystallization is preferably used as crystallization method. In particular, materials to be purified using fractional crystallization are acrylic acid, methacrylic acid, waste water, methylenediphenylisocyanate (MDI), toluenediisocyanate (TDI), caprolactam, benzoic acid, bisphenol A, nitrochlorobenzene, straight-chain and branched fatty acids, hydrazine, phenols such as para-, meta- and ortho-cresol, 2,6- and 3,5-dimethylphenol, naphthol and o,o-diphenol, chlorinated hydrocarbons such as dichlorobenzene and nitrochlorobenzene, naphthalene, 1-, 2-methylnaphthalene, acenaphthene, fluorene, phenanthrene, adipic dinitrile, hexamethylenediamine, as well as paraffins from C₁₇ on.

In particular, the process according to the invention is suitable in the purification of acrylic acid by removing maleic acid and/or its anhydride and other impurities, if necessary.

The present invention is also directed to a crystallization device and plant which differs from well-known devices in

that the device is provided with a connecting piece for metering a solvent or a mixture of solvents. The solvent preferably is added to a holding tank or a tank for intermediate storage of the fractions obtained. It is also preferred to add the solvent directly to the crystallizer.

With reference to the Figures, the embodiments of the invention will be described below. The illustrations are merely by way of example and thus, do not limit the general idea of the invention.

Figure 1 shows a schematic view of a static crystallizer having a separator.

Figure 2 shows a schematic view of a crystallizer according to the invention.

Figure 3 likewise in schematic view, shows a crystallization plant according to the invention.

Figure 2 shows the crystallizer 70 according to the invention. This crystallizer 70 is a crystallizer according to Figure 1 which, however, has an additional connecting piece 49 which can be used to meter a solvent into the crystallizer. Those skilled in the art will appreciate that this crystallizer could be any crystallizer.

The crystallization plant schematically depicted in **Figure 3** essentially consists of a crystallizer 31 of a well-known type not specified in detail, a measuring tank 33 arranged downstream with respect to crystallizer 31, and a so-called discontinuous tank 35 wherein the employed material is put to intermediate storage. The crystallizer 31, measuring tank 33 and discontinuous tank 35 are connected via pipes 37, 39, 41. Conveying pumps 43, 45 are used to carry the molten material from measuring tank 33 to the discontinuous

tank 35 and from the latter to the crystallizer 31, respectively.

A special feature of this crystallization plant is that the tank 35, in addition to a connecting piece 47 for supplying the employed material, is provided with another connecting piece 49 for supplying a solvent or a mixture of solvents. A metering device not depicted in detail allows metering an amount of solvent which corresponds to the percentage of impurities, so that precipitation of the impurities can be prevented.

Precipitations occurring in spite of the above may be filtered off by means of a filter 51 provided in pipe 39.

Those skilled in the art will appreciate that the metering of solvent can be performed automatically. For example, as soon as crystals of a specific composition accumulate in filter 51, the metering of solvent will be increased.

Two separate pipes 53, 55 connected to pipe 39 permit withdrawal of purified product or remaining residue via shut-off valves 57, 58. Further shut-off valves 59, 61 are provided between crystallizer 31 and measuring tank 33, and between measuring tank 33 and tank 35, respectively.

It will be understood that the plant which is depicted merely schematically in **Figure 2** may actually have multiple tanks and crystallizers. Exemplary plants have been disclosed in EP-A-0,616,998, the subject matter of which is hereby incorporated by reference and thus, is considered as part of the disclosure.

Using the example of acrylic acid purification, the process of the invention will be illustrated in more detail below.

In addition to other impurities, acrylic acid pre-purified by distillation may contain maleic acid, its anhydride, and phenothiazine which precipitate from the molten material at concentrations of more than 4% (maleic acid) and 1.5% (phenothiazine), respectively. The respective amounts of solid precipitating during a crystallization process as a result of surpassing the solubility limit can be inferred from the following Examples (Table 1 and 2).

The first line in Tables 1, 2 and 3 shows the respective composition of the employed material, the second line shows the composition of purified acrylic acid (using static crystallization) which then can be purified further by falling film crystallization, and the third line illustrates the composition of the residue obtained.

As can be seen from Table 2, 17.3 kg of residue (= mother liquor) is obtained, 3.6% (= 0.62 kg) of which is PTZ. However, since the solubility of PTZ is only about 1.5%, 0.4 kg of PTZ is obtained as a solid.

As can be seen from Table 1, the case is similar with maleic acid and its anhydride, the figures in Table 1 referring to maleic acid and its anhydride, given as maleic acid. The solubility of maleic acid in acrylic acid is about 4%. The residue (13.2 kg) contains 20.4% or 2.7 kg of maleic acid, 2.4 kg of which precipitates as a solid as a result of surpassing the solubility limit.

If the employed material, which contains a total of 15% impurities (cf., Table 1 and 2), is added with a solvent having good dissolving capacity for maleic acid and its anhydride, it is possible to retain all of the maleic acid in solution, i.e., precipitations do no longer occur.

Since maleic acid and its anhydride are known to have high solubility in water, it is possible to prevent precipitation of maleic acid by adding water to the molten acrylic acid, although the former will accumulate in the mother liquor during the crystallization process. In the Example as illustrated (Table 3), addition of 6.8 kg of water is required to keep the maleic acid dissolved in the residue. The addition of water is advantageous in that water is already present as an impurity in raw acrylic acid, i.e., no further impurity is introduced when adding water.

Because phenothiazine dissolves in water only in small amounts (dissimilar polarities), addition of water does not have a substantial impact on the solubility of phenothiazine, i.e., where an amount of more than 1.5% phenothiazine is simultaneously present in the mother liquor, precipitation of phenothiazine will continue to occur.

According to an advantageous first embodiment of the process of the invention, the suggestion is made to add a mixture of water and a low molecular weight alcohol (methanol, ethanol, n- or i-propanol) in order to retain both maleic acid and phenothiazine in solution. In principle, any other mixture of solvents can be used that achieves an increase of the solubility limits for both substances which tend to precipitate.

Because the addition of solvent requires further cooling of the molten material, a more unfavorable energy balance of the process results. Therefore, efforts are made to keep the addition of solvent as low as possible.

Alternatively, a combined process is suggested, namely, to remove the phenothiazine which, compared to maleic acid, is obtained in substantially smaller amounts, and retain maleic acid and its anhydride in solution by addition of

water. As a result of combining these two methods, it is possible to achieve optimum performance of the process with respect to the energy balance.

Reference numerals

11	Static crystallizer
13	Separator
15, 17	Pipes
19, 21	Tubes
23	Tube openings
25	Collector channel
31	Crystallizer
33	Measuring tank
35	Discontinuous tank
37, 39, 41	Pipes
43, 45	Conveying pumps
47	Tank connecting piece for employed material
49	Tank connecting piece for solvent
51	Filter
53, 55	Pipes
57, 58	Shut-off valves for pipes 53, 55
59, 61	Shut-off valves
70	Crystallizer according to the invention

Table 1: Accumulation of maleic acid in the residue during acrylic acid purification (with no solvent added)

Amount [kg]	Weight	Maleic ac. [%]	Acrylic ac. [%]	Other impurities [%]
Employed material	100	4.0	85.0	11.0
Purified fraction	86.8	1.5	88.4	10.1
Residue	13.2	20.4	62.7	16.8

Table 2: Accumulation of phenothiazine in the residue during acrylic acid purification (with no solvent added)

Amount [kg]	Weight	Phenothiazine [%]	Acrylic ac. [%]	Other impurities [%]
Employed material	100	1.4	85.0	13.6
Purified fraction	82.7	0.9	89.6	9.4
Residue	17.3	3.6	62.8	33.6

Table 3: Accumulation of dissolved maleic acid in the residue during acrylic acid purification (with addition of solvent)

Amount [kg]	Weight	Maleic ac. [%]	Acrylic ac. [%]	Other impurities [%]	Solvent [%]
Employed material	106.8	3.7	79.6	10.3	6.4
Purified fraction	87.6	1.3	86.8	9.8	2.1
Residue	19.2	15.1	46.5	12.5	25.9

Claims:



1. A process for the purification of crystallizable compounds by means of optionally fractional crystallization, wherein a molten material or a mixture containing essentially the desired compound and at least one impurity is subjected to at least partial crystallization, and the molten material or the mixture is added with such an amount of a solvent or a mixture of solvents that at least one impurity having a tendency to precipitate is retained in solution, characterized in that in case two or more impurities having a tendency to precipitate are present, at least the quantitatively more significant impurity is retained in solution by adding a suitable solvent or a mixture of solvents, and that the residual impurities still precipitating despite addition of said solvent or mixture of solvents are removed from the molten material by means of a separator (51).
2. The process according to claim 1, characterized in that the solvent has a superior dissolving capacity for at least one of the impurities having a tendency to precipitate, compared to the product to be purified.
3. The process according to claim 1 or 2, characterized in that in case two or more impurities having a tendency to precipitate are present, a solvent or a mixture of solvents is added which is suitable in retaining multiple impurities in solution.
4. The process according to claims 1 to 3, characterized in that the crystallized product formed, which contains



the desired compound in a purified form, is melted and the molten material is collected, optionally in fractions, the fractions obtained being subjected to further crystallization/melt cycles, if necessary.

5. A process for the purification of contaminated acrylic acid using crystallization, characterized in that a molten material or a mixture containing acrylic acid and impurities is added with a water/alcohol mixture.
6. The process according to claim 5, characterized in that maleic acid, its anhydride and/or phenothiazine and optionally other impurities are separated from the acrylic acid.
7. The process according to claims 5 to 6, characterized in that other precipitating impurities are removed by at least one separator (51).
8. The process according to claim 7, characterized in that the separator is a filter, a suction filter or a centrifuge.
9. A crystallizer (70), characterized in that it includes a connecting piece (49) for metering a solvent or a mixture of solvents.
10. The crystallizer according to claim 9, characterized in that the connecting piece is in connection with a metering device for a solvent or a mixture of solvents.
11. A crystallization plant having at least one crystallizer (31) and at least one tank (35) for receiving a compound to be purified or a mixture of substances to be purified, pipes (37, 39, 41) and a connecting piece for supplying and discharging the compound to/from the



crystallizer (31) and to/from the tank (35), as well as conveying pumps (43, 45) connected with pipes (37, 39, 41) to convey the compound through said pipes (37, 39, 41), characterized in that it includes a connecting piece (49) for metering a solvent or a mixture of solvents.

12. The crystallization plant according to claim 11, characterized in that the connecting piece (49) is arranged on tank (35).
13. The crystallization plant according to claim 11 or 12, characterized in that it includes a separator (51) connected with the crystallizer in order to remove precipitations from the molten material.
14. The crystallization plant according to claim 13, characterized in that the separator is a filter, a suction filter and/or a centrifuge.