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Crystallisation process for producing highly concentrated hydrogen peroxide



Description

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The invention is directed towards a process for the preparation of very highly concentrated hydrogen peroxide of concentration c_p from aqueous hydrogen peroxide of concentration c_E , c_E being at least 80 wt.% and c_p being greater than c_E , comprising continuous suspension crystallisation with subsequent washing of the hydrogen peroxide that has crystallised out. The process is directed especially towards the preparation of over 98 wt.% hydrogen peroxide from approximately 90 wt.% hydrogen peroxide, as well as at least 99.9 wt.% hydrogen peroxide of very high purity obtainable according to the process.

In the known processes for the preparation of hydrogen peroxide, such as the anthraquinone cyclic process, electrolytic processes and methods of direct synthesis, hydrogen peroxide is obtained in the form of an aqueous solution. In order to convert such solutions into marketable products, the preparation is usually followed by concentration of the solution by distillation. By means of distillation it is possible to obtain aqueous hydrogen peroxide solutions having a content of up to approximately 90 wt.% hydrogen peroxide. Cost and safety considerations stand in the way of further concentration by distillation.

More highly concentrated hydrogen peroxide, that is to say products having an H_2O_2 content in the range of from equal to/greater than 90 wt.% to approximately 98 wt.%, are increasingly gaining importance commercially owing to their high energy content and their high purity. It is known that hydrogen peroxide can be concentrated by repeated recrystallisation. Fundamental aspects regarding the crystallisation of hydrogen peroxide, as well as the solid-liquid phase diagram of the hydrogen peroxide/water system,

are known from the reference book "Hydrogen Peroxide" by Walter C. Schumb et al., Reinhold Publishing Corp. (1955), p. 210-220. According to that book, a prominent property of highly concentrated aqueous hydrogen peroxide is the

5 tendency to extreme supercooling, which makes concentration by crystallisation more difficult. According to Schumb et al. (page 215), crystal formation is not affected in a reproducible manner either by stirring or scraping or by the cooling rate. However, freezing of supercooled highly

10 concentrated hydrogen peroxide is induced by seeding with hydrogen peroxide crystals. The low efficiency of fractional batch crystallisation is regarded as being a disadvantage of concentration by crystallisation (Schumb et al., p. 215), since an increase in concentration of only

15 approximately 2 % and never more than 4 % is achieved per crystallisation stage. That problem is evidently the result of the high boundary solubility, that is to say mixed crystal formation, of water in crystallised hydrogen peroxide, which is also shown in the phase diagram (Schumb,

20 page 211). Because of that boundary solubility, it has hitherto not been possible, according to the experience of the inventors of the present Application, to obtain hydrogen peroxide having a content of at least 99.9 wt.% by fractional crystallisation.

25 DE-PS 10 41 479 teaches a continuous process for the concentration of aqueous hydrogen peroxide solutions, which process also allows very highly concentrated hydrogen peroxide to be obtained. The apparatus for concentration comprises a crystallising vessel and a rectifying column

30 arranged directly beneath it. The hydrogen peroxide starting material is supercooled in the crystallising vessel until there forms a 2-phase system consisting of a solid crystal phase and a liquid mother liquor, which phases differ according to the equilibrium with regard to

35 the hydrogen peroxide concentration. The temperature along the rectifying column is so controlled that it increases

slowly from the upper to the lower end. Owing to the higher density of the crystallised hydrogen peroxide, the crystals sink downwards in the rectifying column, a solid-liquid exchange of material taking place until the respective
5 equilibrium has been reached and the H_2O_2 concentration in the crystals increasing towards the bottom; the H_2O_2 concentration in the mother liquor falls towards the top. Because there is only a slight difference in density between the crystallised hydrogen peroxide and the hydrogen
10 peroxide mother liquor, the process is characterised by a low space-time yield. A further very considerable disadvantage that prevents the prior-known process from being applied on an industrial scale consists in scale-up problems (application of the process on an industrial
15 scale): as the diameter of the rectifying column increases, unforeseeable back-mixing occurs, as a result of which both the function is impaired and the process risk is increased considerably (see Wellinghoff et al. in Chem.-Ing.-Tech. 63 (1991), 881-882).

20 The rectifying column according to DE-PS 10 41 479 is in principle operated as a gravity washing column. In the lowermost portion of the column, some of the crystals melt again and the melt thus acts as the washing medium. In such washing columns, working on the countercurrent principle,
25 solid-liquid separation and further purification of the solid take place in one apparatus, but the scale-up problems remain, even when the suspension crystallisation according to the invention described below is carried out.

Although the above-indicated scale-up problems can be
30 avoided, as has been described in the as yet unpublished patent application DE 100 54 742.7, by means of a layer crystallisation process with a subsequent sweating operation, the advantage of the simple separation of solid and liquid that can be carried out without problems even on
35 a large scale is, however, offset by the disadvantages of

discontinuous, multi-stage operation and the higher energy requirement.

Accordingly, the object of the present invention is to provide a continuous process for the preparation of very highly concentrated hydrogen peroxide from at least 80 wt.% aqueous hydrogen peroxide, which process can be carried out without problems even on an industrial scale. According to a further object of the invention it is to be possible to obtain over 98 wt.%, preferably at least 99.9 wt.%, hydrogen peroxide from approximately 90 wt.% hydrogen peroxide in one step. A further object, in addition to concentrating and hence obtaining substantially anhydrous hydrogen peroxide, is directed towards lowering the content of impurities, such as organic carbon and conventional stabilisers. Conventional impurities are process-dependent secondary constituents, and stabilisers added during/after the preparation of the H_2O_2 starting material to be concentrated. The mentioned objects can be achieved in a simple manner and with an unforeseeably high degree of efficiency by means of the process according to the invention.

Accordingly, the invention provides a process for the continuous preparation of very highly concentrated hydrogen peroxide of concentration c_p from aqueous hydrogen peroxide of concentration c_E , c_E being at least 80 wt.% and c_p being greater than c_E , comprising suspension crystallisation of the aqueous hydrogen peroxide of concentration c_E and after-treatment of the hydrogen peroxide crystals contained in the suspension, which process is characterised in that the after-treatment takes the form of countercurrent washing in a hydraulic or mechanical washing column with a packed crystal bed, and molten hydrogen peroxide of concentration c_p is used as the washing medium. The dependent claims are directed towards preferred embodiments of the process according to the invention.

The process is especially suitable for concentrating aqueous hydrogen peroxide having a concentration c_E in the range from 85 to 95 wt.%, especially from 88 to 92 wt.%, in a single step, preferably to a concentration c_P of over 5 98 wt.%, but especially equal to or greater than 99.9 wt.%. In addition to concentration of the H_2O_2 starting material, the content of impurities is at the same time lowered to surprisingly low values. For example, the TOC content (total organic carbon) of, for example, from 40 to 50 mg/kg 10 in the H_2O_2 starting material can be reduced in one step to a value below approximately 3 mg/l of H_2O_2 product. The content of other secondary constituents and stabilisers, such as phosphate, tin and nitrate, can also be reduced to values below the detection limit of conventional analytical 15 methods, generally to values below 3 mg in each case, especially below 1 mg/kg of H_2O_2 product.

Accordingly, the present invention also provides hydrogen peroxide having a concentration of from 99.9 to 100 wt.% and a content of TOC, nitrate, phosphate, nickel and tin of 20 less than 4 mg/l in each case. The 99.9 to 100 wt.% hydrogen peroxide preferably contains less than 1 mg of Ni and Sn per litre of H_2O_2 and less than 2 mg of phosphate per litre of H_2O_2 .

The substantially anhydrous hydrogen peroxide obtainable 25 according to the invention and having an extraordinarily low content of impurities can be used, for example, as a motor fuel, as an oxidising agent or for electronics purposes, such as the preparation of solutions for the treatment of electronic components. If required, it is also 30 possible to add to the very highly concentrated and very pure H_2O_2 an effective amount of one or more auxiliary substances directed towards the particular application or/and of stabilisers known per se or of a stabiliser combination. Suitable stabilisers are, for example, tin 35 compounds, phosphates, di- and tri-phosphates, phosphonates and radical acceptors. The very high purity of the H_2O_2

product that can be achieved by means of the process according to the invention is, therefore, a way of replacing a stabiliser combination contained in the H_2O_2 starting material by other auxiliary substances/active ingredients in the H_2O_2 product.

The fundamental principle of the process according to the invention comprises the production of a crystal suspension in any desired single- or multi-stage crystalliser, cooling being effected via walls of the apparatus or by evaporation in *vacuo*, subsequent solid-liquid separation, countercurrent washing of the crystals, and melting of the concentrated and purified crystals.

Examples of suitable crystallisers are: stirrer vessel crystalliser, scraper-type crystalliser, cooling plate crystalliser, crystallising screw, drum crystalliser, tube-bundle crystalliser. Suitable devices for the solid-liquid separation are conventional devices, such as filters and centrifuges, it also being possible to thicken the suspension beforehand by means of a hydrocyclone. Separation and washing are preferably carried out in a single apparatus, for example in a hydraulic or mechanical washing column with a packed crystal bed.

A scraper-type cooler or scraper-type crystalliser that is preferably to be used is a container that is cooled via the outside wall or a container containing cooling plates, in which the aqueous hydrogen peroxide to be concentrated is supercooled to such an extent that hydrogen peroxide crystals crystallise on the inside or on the cooling plates and can be removed by a revolving scraper or blade to form individual crystals or flakes. The crystals are held in suspension by suitable measures, such as stirring. According to the invention, hydrogen peroxide of concentration c_E is fed continuously to the crystalliser; the crystal suspension that forms is fed continuously to the hydraulic or mechanical washing column used for the

combined solid-liquid separation and countercurrent washing.

Surprisingly, when a scraper-type crystalliser or other crystallisers based on a comparable principle are used, the starting material must only be cooled marginally below the equilibrium temperature in order to form crystal nuclei. Cooling in the range from greater than 0 to 5 K, especially from 0.5 to 3 K, below the equilibrium temperature is highly suitable. Contrary to the prior art known hitherto (see Schumb, page 219), no appreciable supercooling and no addition of seed crystals are required when a scraper-type crystalliser or crystallisers having an equivalent action are used, as a result of which more efficient concentration and purification are possible. In order to achieve adequate crystal growth following nucleation and hence a suitable suspension density for the solid-liquid separation with subsequent washing, cooling is carried out to the temperature required therefor according to the phase diagram.

According to an especially preferred embodiment, the suspension removed from the crystalliser is fed continuously into an apparatus for solid-liquid separation that at the same time is operated as a washing column. In contrast to the rectifying column described in the prior art for the concentration of hydrogen peroxide, which, for an industrial installation, would have to be in the form of a gravity column/washing column, it is possible by using a hydraulic or mechanical washing column to avoid the disadvantages that occur with a gravity column on scale-up, including incalculable back-mixing. In a hydraulic or mechanical washing column to be used according to the invention, the crystals are conveyed in the axial direction by hydraulic or mechanical forces, so that a tightly packed crystal bed forms.

- In a conventional embodiment of a hydraulic washing column, the suspension is introduced in the upper portion of the column; the liquid phase (mother liquor) is removed from the column via a filter, as a result of which a tightly packed crystal bed forms. The liquid phase flows through the crystal bed in the direction towards the base of the column, and the crystal bed is pressed downwards as a result of the flow resistance. At the base of the column there is a rotating scraping device, which produces a suspension again from the tightly packed crystal bed and the washing melt introduced in the lower portion of the washing column. The suspension is pumped through a heat exchanger and melted. A portion of the melt is used as the washing melt; it is pumped back into the column and washes the crystal bed moving in the opposite direction. On the one hand the washing melt effects washing of the crystals, on the other hand the melt crystallises on the crystals. The enthalpy of crystallisation that is liberated warms the crystal bed in the washing region of the column.
- 20 In a mechanical washing column - reference is made, for example, to EP 0 193 226 B and NL 1007687 A - a dense crystal bed is produced inside the column by means of a plunger that is permeable to the melt. The plunger may be located at the upper or lower end of the column; in the first case, the suspension is fed in in the upper region of the column, in the second case it is fed in in the middle or lower region. The plunger is permeable to the melt so that, on compression, melt emerges from the rear side of the plunger, where it is drawn off. Analogously to a hydraulic washing column, the mechanical washing column also contains a scraping device, for example a rotating scraping member, in order to scrape off crystals from the crystal bed and convert them into a suspension with the washing melt. The washing melt flows in the opposite direction to the crystal bed. Suspension is removed from the side of the washing column opposite the plunger and,

after melting, a portion of the melt is fed back as the washing melt and the other portion is discharged from the circuit as very pure product.

Suitable apparatuses and processes for melt crystallisation using a mechanical or hydraulic washing column, which are used by those skilled in the art for purposes other than the concentration of H_2O_2 , are the so-called Phillips pulsation column, Phillips pressure column, Brennan-Koppers process, Niro-Grenco freeze-concentration and the TNO process. Embodiments for suspension crystallisation with subsequent washing of the crystals in a hydraulic or mechanical washing column are to be found in the book "Melt Crystallization Technology" by G.F. Arkenbout, Technomic Publishing Co. Inc., Lancaster-Basel (1995), p. 265-288, and in the article, relating to Niro freeze-concentration for waste-water pre-concentration, in Chemie Ingenieur Technik (72) (10/2000), 1231-1233.

The Figure shows a process diagram in which the process is described in summary:

From the storage container 1, the starting material to be crystallised, in the liquid state, that is to say at a temperature just above equilibrium, is fed via the inlet 2 into the suspension generator, preferably a scraper-type cooler. By cooling the starting material below the equilibrium temperature, crystal nuclei first form in the suspension generator and, by further cooling, the suspension density increases continuously. The suspension density is generally in the range from 5 to 80 %, preferably from 20 to 50 % and especially from 20 to 30 %. The suspension is fed continuously via the inlet 4 into a mechanical washing column 5 and is there separated, via a moving filtering device, into a liquid phase and a solid phase. The filtrate leaves the washing column and is fed continuously to the mother liquor container 12. In order to increase the yield it is advantageous to feed a portion of

the filtrate back into the suspension generator 3 via the mother liquor return 11. The crystals in the washing column are compressed to form a crystal bed and, depending on the type of washing column, are scraped off at the top or the bottom by means of revolving blades. The product crystals that have been scraped off are pumped round in the form of a suspension in the product circuit 6 by means of the circulating pump 7 and melt owing to the introduction of the enthalpy of fusion by means of a heat exchanger 8. A portion from the circuit 6 is fed back into the washing column as the washing liquid via pipe 10 for countercurrent washing, the other portion is passed into the product container 9.

Although a combination of a scraper-type crystalliser and a mechanical washing column is known for the preparation of organic substances having high purity, it was not foreseeable that such a process would also be highly suitable for the concentration of aqueous hydrogen peroxide that forms mixed crystals even with water, for the purposes of obtaining very highly concentrated and especially pure hydrogen peroxide. In view of the properties of concentrated hydrogen peroxide, which are to be found in the phase diagram of the Schumb document mentioned above, it was not to be expected that concentration in the region of about/over 10 % could be achieved in one step. As mentioned above, it was also not to be expected that not only over 98 wt.%, but also equal to/greater than 99.9 wt.% H_2O_2 , that is to say substantially 100 wt.% H_2O_2 , would be obtainable. Also surprising was the fact that the content of impurities, such as organic carbon, phosphate and heavy metals, falls to values below the detection limit by means of the process according to the invention.

Examples

1. In an apparatus according to the Figure having a scraper-type crystalliser for producing a suspension and a mechanical washing column with a plunger arranged at the bottom and an outlet for the purified melt arranged at the top, aqueous hydrogen peroxide having a concentration $c_E = 89.7$ wt.% was used. The starting material was cooled to approximately 3 K below the equilibrium temperature of -12.2°C . Surprisingly, crystallisation occurred without the addition of seed crystals. By further cooling to -21°C , further crystallisation was effected, the suspension density increasing. The crystal suspension removed from the crystalliser was compressed in the washing column to form a compact crystal bed. The upper side of the crystal bed was scraped away by means of a rotating scraper and formed with the washing melt introduced in that region, that is to say hydrogen peroxide of concentration c_P , a crystal suspension, which was melted in the product circuit and a portion of which was fed back into the crystal bed for the countercurrent washing. Hydrogen peroxide having a concentration of substantially 100 wt.% was obtained. The TOC content was reduced from approximately 40 mg/kg in the starting material to less than 4 mg/l in the product. The Sn, Ni, nitrate and phosphate contents in the H_2O_2 product were also below their respective detection limits, which were < 0.02 mg of Sn/l, < 1 mg of Ni/l and < 2 mg of phosphate/l.
2. Using an aqueous hydrogen peroxide having a content of 87.5 wt.%, supercooling to -16°C for nucleation purposes and further cooling to -26°C in order to achieve an adequate suspension density, and solid/liquid separation and washing in the mechanical washing column also used in Example 1, identical results were achieved.

Patent claims

1. Process for the continuous preparation of very highly concentrated hydrogen peroxide of concentration c_p from aqueous hydrogen peroxide of concentration c_e , c_e being
5 at least 80 wt.% and c_p being greater than c_e , comprising suspension crystallisation of the aqueous hydrogen peroxide of concentration c_e and after-treatment of the hydrogen peroxide crystals contained in the suspension,
10 characterised in that the after-treatment takes the form of countercurrent washing in a hydraulic or mechanical washing column with a packed crystal bed, and molten hydrogen peroxide of concentration c_p is used as the washing medium.
- 15 2. Process according to claim 1, characterised in that aqueous hydrogen peroxide of concentration c_e in the range from 85 to 95 wt.%, especially from 88 to 92 wt.%, is concentrated in one step to a concentration
20 c_p of over 98 wt.%, especially equal to or greater than 99.9 wt.%.
3. Process according to claim 1 or 2, characterised in that the suspension crystallisation is carried out in a
25 single- or multi-stage scraper-type crystalliser.
4. Process according to any one of claims 1 to 3, characterised in that the suspension crystallisation is carried out in a
30 scraper-type crystalliser, the countercurrent washing of the crystals, combined with solid-liquid separation of the suspension, is carried out in a mechanical washing column, and a portion of the mother liquor that leaves the washing column is fed back into the scraper-type crystalliser.

5. Process according to claim 3 or 4,
characterised in that
nucleation in the suspension crystallisation is carried
out at a temperature in the range from greater than 0
to 5 K, especially from 0.5 to 3 K, below the
equilibrium temperature of the H_2O_2 starting material,
and the temperature is then lowered further until a
suspension density in the range from 5 to 80 % is
achieved.
6. Process according to any one of claims 1 to 5,
characterised in that
the suspension crystallisation is carried out to a
suspension density in the range from 20 to 50 %,
especially from 20 to 30 %.
7. Process according to any one of claims 1 to 6,
characterised in that
hydrogen peroxide having a concentration c_p of at least
98 wt.%, preferably at least 99.9 wt.%, that leaves the
washing column in the form of a melt is stabilised with
an effective amount of one or more stabilisers,
especially stabilisers from the group of the tin
compounds, phosphates, di- and tri-phosphates,
phosphonates and radical acceptors.
8. Hydrogen peroxide having a concentration of from 99.9
to 100 wt.% and a content of TOC, nitrate, phosphate,
nickel and tin of in each case less than 4 mg/l,
preferably less than 1 mg of Ni/l, less than 1 mg of
Sn/l and less than 2 mg of phosphate/l.
9. Use of the hydrogen peroxide according to claim 8 as an
oxidising agent for motors or for the treatment of
electronic components.