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(57) Abrégé/Abstract:

The invention relates to a novel process for the preparation of iminostilbene by high-temperature dehydrogenation of iminodibenzyl on an iron oxide/potassium salt contact catalyst in the vapour phase, wherein there is used an iron oxide/potassium salt contact catalyst comprising from 35 to 90 % by weight of an iron compound, calculated as Fe_2O_3, and from 7 to 35 % by weight of a potassium compound, calculated as K_2O, in addition to from 0.0 to 3.5 % by weight of a chromium compound, calculated as Cr_2O_3, and optionally customary promotors.

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ABSTRACT

High-temperature dehydrogenation process for the preparation of iminostilbene

The invention relates to a novel process for the preparation of iminostilbene by high-temperature dehydrogenation of iminodibenzyl on an iron oxide/potassium salt contact catalyst in the vapour phase, wherein there is used an iron oxide/potassium salt contact catalyst comprising from 35 to 90 % by weight of an iron compound, calculated as Fe_2O_3, and from 7 to 35 % by weight of a potassium compound, calculated as K_2O, in addition to from 0.0 to 3.5 % by weight of a chromium compound, calculated as Cr_2O_3, and optionally customary promotors.

High-temperature dehydrogenation process for the preparation of iminostilbene

The invention relates to a novel process for the preparation of iminostilbene by high-temperature dehydrogenation of iminodibenzyl on an iron oxide/potassium salt contact catalyst in the vapour phase.

Iminostilbene, 5H-dibenz[b,f]azepine, is an important intermediate for the preparation of 5-carbamoyl-dibenz[b,f]azepine which under the generic name carbamazepine has gained great importance as an anti-convulsive active ingredient in medicaments. A number of processes are known for the conversion of iminostilbene into carbamazepine, which processes are based on the direct or stepwise introduction of the carbamoyl group in the 5-position of the azepine ring.

Numerous processes are available for the preparation of iminostilbene, amongst which high-temperature dehydrogenation of iminodibenzyl in the vapour phase on iron oxide contacts has achieved particular importance. According to the variant of that process having the greatest technical importance at present, the variant according to CH-442 319, there is used a contact catalyst comprising "in addition to iron(III) oxide, which is best used in amounts of from 30 to 70 %, preferably also additions of, for example, from 1.5 to 3 % by weight Cr_2O_3, from 10 to 15 % by weight CaO and the remainder K_2CO_3" and the operation is carried out "at temperatures of from 300° to 500°C, preferably from 400° to 450°C". As expressly pointed out, and supported by numerical data for reaction temperatures of from 550° and 600°C, in CH-442 319, temperatures higher than 500°C result "to an unacceptable extent or even predominantly" in undesired acridine secondary products.

Furthermore, the known process has the serious disadvantage expressly mentioned in CH-442 319 that the activity of the catalyst gradually declines, so that according to CH-442 319, Example 2, it would have to be regenerated after only about 30 minutes' use. This can be attributed to the fact that a not inconsiderable proportion of the iminodibenzyl used becomes resinated and is precipitated in the form of tar- or carbon-like deposits which have to be removed periodically by burning out the catalyst. The yields given in

CH-442 319 therefore cannot be obtained in practice, as shown especially by Example 21 in comparison with Comparison Examples 1 and 2. The resination of considerable proportions of the iminodibenzyl used not only reduces the yield of iminostilbene but also involves ecological and industrial safety risks resulting from the oxidative secondary reactions which are difficult to control. In particular, it is necessary to interrupt the process periodically, which renders continuous operation impossible.

The problem underlying the invention is, therefore, to provide an improved process for the preparation of iminostilbene by catalytic high-temperature dehydrogenation of iminodibenzyl in the vapour phase that avoids the above-described disadvantages and other shortcomings of the known process. The solution to this problem proposed according to the invention is based on the surprising finding that the periodic regeneration of the catalyst is unnecessary when there is used an iron oxide/potassium salt contact catalyst comprising from 35 to 90 % by weight of an iron compound, calculated as Fe_2O_3, and from 7 to 35 % by weight of a potassium compound, calculated as K_2O, in addition to from 0.0 to 3.5 % by weight of a chromium compound, calculated as Cr_2O_3, and optionally customary promotors.

It is also surprising that the catalyst used according to the invention in the high-temperature dehydrogenation of a heterocyclic compound of such a high molecular weight as iminodibenzyl works autoregeneratively and exhibits excellent activity and selectivity.

It is especially surprising that, as will be seen from Examples 12 to 15, contrary to the prejudice arising from CH-442 319, according to the invention it is precisely at a reaction temperature of 550°C and above that the best conversion and the highest yield of iminostilbene are achieved.

As will be seen from Example 2, the contact catalyst used according to the invention advantageously achieves a service life of more than 1100 hours without significant amounts of iminodibenzyl being lost as a result of undesired oxidative secondary reactions. As a consequence, the invention opens up the possibility of continuous operation.

The process according to the invention for the preparation of iminostilbene by high-temperature dehydrogenation of iminodibenzyl on an iron oxide/potassium salt contact catalyst in the vapour phase is accordingly carried out by using an iron oxide/potassium salt contact catalyst comprising from 35 to 90 % by weight, for example from 44 to 85 % by weight, of an iron compound, calculated as Fe_2O_3, and from 7 to 35 % by weight, for example from 9 to 31 % by weight, of a potassium compound, calculated as K_2O, in addition to from 0.0 to 3.5 % by weight of a chromium compound, calculated as Cr_2O_3, and optionally customary promotors.

Suitable promotors are, for example, magnesium, calcium, cerium, molybdenum, cobalt, vanadium and tungsten compounds, for example in the form of oxides of the said metals, especially tungsten, cerium, vanadium and cobalt oxides.

Although promotors of the mentioned or similar type can increase the performance of the catalyst, they are not absolutely necessary, as will be seen from Examples 17 to 20. In general the quantitative ratios of the components are not critical provided that the proportions of iron and potassium remain within the scope of the definition given above.

The contact catalyst used according to the invention is preferably, but not necessarily, brought into contact with iminodibenzyl vapours in an adiabatic fixed bed reactor. It is also possible, however, to use tube bundle, fluid bed and fluidised bed reactors, as well as other types of reactor in accordance with the prior art. The morphology of the catalyst used according to the invention should offer as little resistance as possible to the vapours flowing through the catalyst bed. It is preferable to use geometric, for example cylindrical, moulded bodies about 1 to 6 mm, especially 1 to 4 mm, in length and about 0.5 to 5 mm, especially 1 to 3 mm, in diameter, and also granules having an average particle size of about from 0.5 to 5 mm, especially about from 1 to 3 mm.

It is advantageous to carry out the operation in a temperature range above 500°C, preferably at from about 550° to about 600°C, and to dilute the iminodibenzyl vapours with an inert carrier gas, such as with nitrogen or especially an approximately 50- to 200-fold, for example approximately 120- to 140-fold, molar amount of water vapour. It is advantageous to operate at normal pressure or at slightly reduced pressure, for example at about from 0.2 to 1.1 bar, especially about from 0.95 to 1.05 bar, (absolute) and to allow the reaction gases to cool to room temperature, the resulting iminostilbene and unreacted iminodibenzyl being obtained in a solid form suspended in the condensed transport water. The iminostilbene component can then be separated from the condensate and the unreacted iminodibenzyl can be isolated and recycled. The procedure to be used is known and can be found, for example, in CH-442 319.

The following Examples serve to illustrate the invention; temperatures are given in degrees Celsius and pressures in bar absolute.

Example 1: The dehydrogenation of iminodibenzyl (IDB) to iminostilbene (IS) in the gaseous phase is carried out in a quartz glass tube reactor 31 mm in diameter and 1 m in length. 30 g of a catalyst having the following properties

Composition:	1.1	% by weight	chromium oxide, calculated as Cr_2O_3
	22	% by weight	potassium compound, calculated as K_2O
	remainder		iron oxide

particle size: 1-2 mm

are introduced between two filler layers (corundum; particle size: 1-2 mm) in the centre of the reaction tube. The upper filler layer acts as a vaporisation zone for the iminodibenzyl. 27.7 g/h of water are vaporised in a separate oven and passed into the reactor from above. 6 g/h of iminodibenzyl at 120°C in molten form are metered directly into the vaporisation zone, mixed with the pre-heated vapour and vaporised. By electrically heating the reactor, the vapour mixture is heated to the reaction temperature of 550°C. After the reaction in the approximately 35 mm high catalyst layer, the product vapours are cooled to room temperature in a vessel, so that the mixture of iminodibenzyl and iminostilbene is obtained in the form of powder in condensed water. The condensates taken at different times during the experiment are homogenised with dioxane and analysed by capillary gas chromatography (without water). During the 860-hour duration of the experiment, the following product composition (without water) is obtained:

time [h]	IDB % by wt.	IS % by wt.	sec. comp. % by wt.	conversion %	selectivity %
2	25.0	51.4	20.9	75	72
25	28.9	49.6	21.5	71	70
92	27.4	48.4	24.2	73	67
554	30.9	47.5	21.6	68	69
630	26.7	49.9	21.6	73	69
860	29.9	47.2	22.9	70	67

In addition to iminodibenzyl (IDB) and iminostilbene (IS), mainly 9-methylacridine and acridine are detected as secondary compounds. The experiment is carried out continuously for about 100 hours each time with interruptions at weekends. After an interruption the catalyst is scavenged for one hour with water vapour at the reaction temperature and then cooled to room temperature under nitrogen. When the experiment is started up again, that procedure is followed in reverse order.

Example 1 demonstrates the long service life and the continuous operation of the catalyst.

Example 2: 80 g of a catalyst having the following composition is introduced into a quartz glass tube reactor according to Example 1:

Composition:	12.3 % by weight of potassium oxide, calculated as K_2O
	1.9 % by weight of chromium oxide, calculated as Cr_2O_3
	1.6 % by weight of tungsten oxide, calculated as WO_3
	2.4 % by weight of cerium oxide, calculated as Ce_2O_3
	1.5 % by weight of vanadium oxide, calculated as V_2O_5
	0.3 % by weight of cobalt oxide, calculated as Co_2O_3
remainder	iron oxide
particle size:	1-2 mm

A stream of 40 g/h of iminodibenzyl and 480 g/h of water vapour at 590° is passed over the catalyst for 1145 hours with the interruptions at weekends described in Example 1.

The product, which is separated from water by filtration, has the following composition (as a function of the reaction time):

Zeit [h]	IDB Gew-%	IS Gew-%	Nebenverb. Gew-%	Umsatz %	Selektivität %
39	13.5	76.2	10.3	87	88
148	13.5	74.7	11.8	87	87
250	12.6	76.9	10.5	86	88
367	13.1	76.8	10.1	87	88
460	13.7	76.1	10.2	87	88
550	14.6	75.3	10.1	86	88
685	12.7	76.2	11.1	87	87
914	11.6	77.4	11.0	89	88
1028	13.0	75.8	11.2	87	87
1145	14.6	74.4	11.0	86	87

Example 2 demonstrates the good selectivity, the long service life of more than 1100 hours and the continuous operation of a catalyst comprising tungsten oxide, cerium oxide, vanadium oxide and cobalt oxide as promotors.

Examples 3 to 6: Using the same experimental procedure and the same conditions as in Example 1, the amount of water in relation to the metered amount of IDB is varied within a wide range:

Example	water [g/h]	IDB % by wt.	IS % by wt.	sec. comp. % by wt.	conversion %	selectivity %
3	11.7	38.6	32.0	29.4	61	52
4	27.7	26.7	49.9	23.4	73	68
5	55.4	20.6	60.2	19.2	79	76
6	110.8	1.7	60.1	38.2	98	61

Examples 3 to 6 demonstrate the large amount of influence exerted by the ratio of water to IDB on the conversion and on the selectivity of the reaction.

Examples 7 to 11: Using the same experimental procedure and 30 g of the same catalyst as in Example 1, the dehydrogenation is carried out at 570°C. The metered amounts of IDB and water are altered in such a manner that the ratio of water to IDB remains constant.

Example	water [g/h]	IDB [g/h]	IDB % by wt.	IS % by wt.	sec. comp. % by wt.	conversion %	selectivity %
7	276.9	30	34.0	55.4	10.6	66	84
8	138.5	15	16.4	67.3	16.3	84	81
9	92.3	10	9.6	70.9	19.5	90	78
10	55.4	6	8.1	64.7	27.2	92	70
11	27.7	3	5.5	57.5	37.0	95	61

Examples 7 to 11 demonstrate the influence exerted by the contact time (contact time factor = 1-10 h per hour) on the conversion or the selectivity of the reaction,

$$\left(\text{contact time factor} = \frac{g_{(\text{catalyst})} \times h}{g_{(\text{iminodibenzyl})}}\right)$$

with a constant ratio of water to iminodibenzyl (IDB).

Examples 12 to 15: Using the same experimental procedure and 30 g of the same catalyst and the same metered amounts of water and IDB as in Example 1, the dehydrogenation reaction is carried out at various temperatures. The Table below shows the product composition.

Example	temperature [°C]	IDB % by wt.	IS % by wt.	sec. comp. % by wt.	conversion %	selectivity %
12	510	55.1	32.7	12.2	45	73
13	530	39.5	43.4	17.1	61	72
14	550	26.7	49.9	23.4	73	68
15	570	25.5	45.0	29.5	75	60

Examples 12 to 15 demonstrate the strong influence exerted by the temperature on the rate of reaction and the selectivity of the reaction.

Example 16: 30 g of a catalyst having the following properties are introduced into the reactor of Example 1:

Composition:		
	9.0	% by weight of a potassium compound, calculated as K_2O
	0.04	% by weight of chromium oxide, calculated as Cr_2O_3
	2.7	% by weight of a calcium compound, calculated as CaO
	4.8	% by weight of cerium oxide, calculated as Ce_2O_3
	2.5	% by weight of magnesium oxide, calculated as MgO
	2.0	% by weight of molybdenum oxide, calculated as MoO_3
	remainder iron oxide	

particle size: 1.5 mm

At 0.4 bar (absolute) and 570°C, a vaporous stream of 6.0 g/h of IDB and 55.4 g/h of water is passed over the catalyst. The product comprises 2.9 % by weight IDB, 74.0 % by weight IS and 23.1 % by weight secondary compounds (mainly acridine and 9-methylacridine) without taking account of the water. The same experiment at normal pressure results in a product composition of 6.2 % by weight IDB, 66.9 % by weight IS and 26.9 % by weight secondary compounds.

Example 16 demonstrates the influence exerted by reduced pressure (vacuum) on the conversion and the selectivity of the reaction.

Examples 17 to 20: In the following Examples the influence of the composition of the catalyst on the conversion and on the selectivity of the reaction under the same test conditions is demonstrated. In the test apparatus of Example 1, 30 g of each of the catalysts given below are tested (particle size 1-2 mm). At 550°C, 15 g/h of IDB and 180 g/h of water in vapour form are passed over the catalysts.

Example	IDB % by wt.	IS % by wt.	sec. comp. % by wt.	conversion %	selectivity %
17	28.2	59.0	12.8	72	82
18	18.0	67.7	14.3	82	83
19	20.9	63.2	15.9	79	80
20	27.2	60.0	12.8	73	82

The composition of the catalysts used in Examples 17 to 20 is given in the following Table:

Beispiel	Fe_2O_3 [Gew.-%]	K_2O [Gew.-%]	Cr_2O_3 [Gew.-%]	CaO [Gew.-%]	Ce_2O_3 [Gew.-%]	MgO [Gew.-%]	MoO_3 [Gew.-%]
17	61	22	1.1	---	---	---	---
18	85	9	1.9	---	---	---	---
19	77	9	0.04	2.7	4.8	2.5	2.0
20	44	31	2.5	---	0.5	---	0.1

Examples 17 to 20 demonstrate that the reaction can be carried out using various catalysts of very different composition.

Example 21: Using the experimental procedure of Example 1, 30 g of a catalyst having the following properties are introduced:

Composition: 1.3 % by weight of chromium oxide, calculated as Cr_2O_3
13.1 % by weight of a potassium compound, calculated as K_2O
remainder iron oxide

particle size: 1-2 mm

At 550°C and 1 bar absolute, a vaporous stream of 6 g/h of iminodibenzyl and 72 g/h of water is passed over the catalyst. By filtering and drying the condensed products it is possible to recover a mass of 99 %, based on the amount of substance used (iminodibenzyl). The loss in mass of 1 % is attributable to the removal of hydrogen and methane from the reactants. The isolated product has the following composition: 76.2 % by weight iminostilbene, 3.8 % by weight iminodibenzyl and 20 % by weight secondary compounds. The total yield of iminostilbene, taking account of the losses in mass, is therefore 75.4 %.

That Example demonstrates the high yields that can be attained and the low losses in mass when the reaction is carried out continuously.

Comparison Example 1: (Comparison with the cyclic process)

Using the experimental procedure of Example 1, 50 g of the catalyst described in Example 1 of CH-442 319 are introduced. In accordance with the data given in the abovementioned Patent, the reaction is carried out at 430°C, 1 bar absolute and with cyclic operation. The cycle times are as follows: 5 minutes pre-scavenging with water vapour, 18 minutes reaction, 5 minutes post-scavenging with water vapour and 30 minutes regeneration (oxidation of the catalyst with air). The metered amounts are: prescavenging with water vapour: 38.3 g/h, reaction: 8.3 g/h of IDB and 38.3 g/h of water vapour, postscavenging: 38.3 g/h of water vapour, and regeneration: 100 ml/minute of air and 38.3 g/h of water vapour. The product collected during 20 cycles is filtered off and dried. The amount of substance recovered was 88 % by weight of the amount of IDB used. Since a portion of the product remains on the catalyst after the reaction phase, that adsorbed portion is oxidised with air during the regeneration phase to form unusable products. The product composition is on average: 65 % by weight iminostilbene, 28 % by weight iminodibenzyl and 7 % by weight secondary compounds. The total yield, taking account of the losses in mass, is accordingly 57 %.

That Comparison Example demonstrates the significantly poorer yield obtained using the cyclic process in comparison with the continuous process.

Comparison Example 2: (Comparison with the cyclic process)
Using the same experimental procedure, the same cycle times, the same catalyst and the same conditions as in Comparison Example 1, 5 g/h of IDB and 23.3 g/h of water vapour are passed over the catalyst. After filtering and drying the reaction mass it is possible to isolate a further 78 % of the amount of substance used. The product composition is on average: 72 % by weight iminostilbene, 16 % by weight iminodibenzyl and 12 % by weight secondary compounds. The total yield, taking account of the losses in mass, is accordingly 56 %.

That Comparison Example shows that although it is possible to increase the conversion by reducing the ratio of the metered amount of IDB to the amount of catalyst, the total yield is not increased, owing to the greater losses in mass occurring on regeneration of the catalyst.

CLAIMS:

1. A process for the preparation of iminostilbene by high-temperature dehydrogenation of iminodibenzyl on an iron oxide/potassium salt contact catalyst in the vapour phase, wherein there is used an iron oxide/potassium salt contact catalyst comprising from 35 to 90 % by weight of an iron compound, calculated as Fe_2O_3, and from 7 to 35 % by weight of a potassium compound, calculated as K_2O, in addition to from 0.0 to 3.5 % by weight of a chromium compound, calculated as Cr_2O_3.

2. A process according to claim 1, wherein the iron oxide/potassium salt contact catalyst comprises from 44 to 85 % by weight of an iron compound, calculated as Fe_2O_3.

3. A process according to claim 1 or 2, wherein the iron oxide/potassium salt contact catalyst comprises from 9 to 31 % by weight of a potassium compound, calculated as K_2O.

4. A process according to any one of claims 1 to 3, wherein the iron oxide/potassium salt contact catalyst comprises from 0.02 to 2.5 % by weight of a chromium compound, calculated as Cr_2O_3.

5. The process according to any one of claims 1 to 4, wherein the catalyst further comprises one or more promoters, wherein the one or more promoters comprise a maximum of 3.0 % by weight, based on the contact catalyst, of a calcium compound, calculated as CaO.

6. A process according to claim 5, wherein the one or more promoters are selected from magnesium, calcium, cerium, molybdenum, cobalt, vanadium and tungsten compounds.

7. A process according to claim 5, wherein the one or more promoters comprise a tungsten oxide, cerium oxide, vanadium oxide and cobalt oxide.

8. A process according to claim 5, wherein the promotors comprise a magnesium oxide, cerium oxide and molybdenum oxide.

9. A process according to claim 6, wherein the one or more promoters comprise from 0.02 to 2.0 % by weight of the tungsten compound, calculated as WO_3.

10. A process according to claim 6, wherein the one or more promoters comprise from 1.0 to 3.0 % by weight of the calcium compound, calculated as CaO.

11. A process according to claim 6, wherein the one or more promoters comprise from 0.5 to 5.0 % by weight of the cerium compound, calculated as Ce_2O_3.

12. A process according to claim 6, wherein the one or more promoters comprise from 0.02 to 2.5 % by weight of the vanadium compound, calculated as V_2O_5.

13. A process according to claim 6, wherein the one or more promoters comprise from 2.0 to 3.0 % by weight of the magnesium compound, calculated as MgO.

14. A process according to claim 6, wherein the one or more promoters comprise from 0.05 to 2.5 % by weight of the molybdenum compound, calculated as MoO_3.

15. A process according to claim 6, wherein the one or more promoters comprise from 0.02 to 1.0 % by weight of the cobalt compound, calculated as Co_2O_3.

16. A process according to any one of claims 1 to 15, wherein the contact catalyst is brought into contact with

iminodibenzyl vapours in any one of an adiabatic fixed bed reactor, a tube bundle reactor, a fluid bed reactor and a fluidised bed reactor.

17. A process according to any one of claims 1 to 16, wherein the contact catalyst is in the form of geometric moulded bodies approximately 1 to 6 mm in length and approximately 0.5 to 5 mm in diameter or in the form of granules having an average particle size of about from 0.5 to 5 mm.

18. A process according to any one of claims 1 to 17, wherein the dehydrogenation is carried out in a temperature range above 500°C.

19. A process according to any one of claims 1 to 17, wherein the dehydrogenation is carried out at from approximately 550° to approximately 600°C.

20. A process according to any one of claims 1 to 19, wherein the iminodibenzyl vapours are diluted with an inert carrier gas.

21. A process according to any one of claims 1 to 19, wherein the iminodibenzyl vapours are diluted with an approximately 50- to 200-fold, molar amount of water vapour.

22. A process according to any one of claims 1 to 19, wherein the iminodibenzyl vapours are diluted with an approximately 120- to 140-fold molar amount of water vapour.

23. A process according to any one of claims 1 to 22, wherein the dehydrogenation is carried out at approximately from 0.2 to 1.1 bar (absolute).

24. A process according to any one of claims 1 to 22, wherein the dehydrogenation is carried out at approximately from 0.95 to 1.05 bar (absolute).

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