

PROCESS FOR THE PREPARATION OF AMMOXIDATION CATALYSTS

The present invention relates to a new process for the preparation of mixed vanadium, antimony and iron oxides and to the use of these oxides as catalysts for the ammoxidation of alkanes.

Certain mixed oxides of vanadium and of antimony or of vanadium, of antimony and of other metals are known compounds which have been described, among many other mixed oxides, in Patent FR-A-2, 072,334.

A description is given, in Patent US 5,008,427, of a process for the ammoxidation of propane or of butane in the presence of a catalyst which can comprise, in particular, oxides of vanadium, of antimony and of iron or of titanium or of chromium or of gallium or of tin, and optionally of other metals. These catalysts exhibit the essential characteristic of having been calcined at a temperature equal to or greater than 780°C.

A description has likewise been given, in Patent EP-A-0,558,424, of a process for the ammoxidation of alkanes which is catalysed by mixed oxides of vanadium, of antimony, of iron and/or of gallium and/or of indium. These mixed oxides are prepared by mixing aqueous suspensions of compounds of the various metals, heating with stirring and then evaporating the water, drying and calcining.

The present invention relates to a new process for the preparation of a mixed vanadium, antimony and iron oxide corresponding to the general empirical formula (I):



in which:

- a represents a whole or fractional number equal to or greater than 0.1
- b represents a whole or fractional number equal to or greater than 0.5
- x represents a whole or fractional number determined by the oxidation state of the other elements,

characterized in that:

- respective vanadium, antimony and iron compounds are dissolved in at least one saturated alcohol or in water,
- the alcoholic solution or the aqueous solution thus obtained is brought into contact with an aqueous solution containing an ammonium salt, in order to precipitate the mixed oxide,
- the mixed oxide obtained is separated and calcined.

The vanadium, antimony and iron compounds used in the process must be soluble in a saturated alcohol or a mixture of saturated alcohols or in water.

In the present text, a compound is regarded as soluble when its solubility, measured at 25°C, is at least 5 grams per litre of saturated alcohol or of water. These compounds can be introduced together; they
5 can also, first of all, be dissolved separately in an alcohol, the various alcoholic solutions thus obtained then being mixed with each other. They can also, first of all, be dissolved separately in water, the various aqueous solutions thus obtained then being mixed with
10 each other. Generally, but non-limitingly, an alcoholic solution or an aqueous solution is prepared by dissolving the various compounds, without intermediate preparation of solutions of each of the vanadium, antimony and iron compounds.

15 The prevent the decomposition or the precipitation of certain compounds, more particularly of the iron salts, it is preferable to use an acidic aqueous solution having a pH of less than or equal to 2, when the catalysts of the invention are prepared in
20 water.

In this case, the acid used to prepare this acidic aqueous solution can be any strong inorganic or organic acid capable of giving a solution having a pH of less than or equal to 2 and preferably a pH of 0.5
25 to 1.

Mention may be made, as non-limiting examples of such acids, of, in particular, hydrochloric, hydrobromic, sulphuric, nitric and trifluoroacetic

acids.

For convenience, it is preferable to use the acid corresponding to the iron salt used, without this being essential.

5 Use is often made of hydrochloric acid, generally in the form of aqueous solutions having a weight for weight concentration of 10 to 20 %.

 In the present text, the expression aqueous solution used in the context of the process for the
10 preparation of the catalysts also covers, except when otherwise mentioned, the above acidic aqueous solutions.

 Mention may be made, as examples of soluble vanadium compounds, of vanadyl acetylacetonate, vanadyl
15 trichloride, vanadium trifluoride, vanadium tetrafluoride, vanadium pentafluoride, vanadium tribromide, vanadium dichloride, vanadium trichloride, vanadium tetrachloride or vanadium triiodide.

 Mention may be made, as examples of soluble
20 antimony compounds, of antimony pentachloride, antimony trichloride, antimony tribromide, antimony trifluoride, antimony triiodide, antimony trioxide or stibine.

 Mention may be made, as examples of soluble iron compounds, of iron dichloride, iron trichloride,
25 iron dibromide, iron tribromide, iron diiodide, ferrous nitrate, ferrous sulphate, ferric sulphate, ferrous thiosulphate, ferric formate, ferric acetate, ferric acetylacetonate, ferric benzoate, ferric oleate,

ferrous lactate or ferric lactate.

The saturated alcohols used in the process of the invention are more particularly alkanols and cycloalkanols. Use will preferably be made of alkanols and cycloalkanols in which the boiling point is not excessively high, in order to facilitate the operations of separation or of recycling by distillation or evaporation. Thus, alkanols having from 1 to 6 carbon atoms, such as methanol, ethanol, n-propanol, 2-propanol, n-butanol, 2-butanol, tert-butanol, pentanols and hexanols, and cyclohexanol are preferred.

The alcoholic solution or the aqueous solution obtained above is then mixed with an aqueous solution of an ammonium salt, so as to precipitate the mixed oxides. The operation is preferably carried out in an aqueous solution of an ammonium carboxylate (for example, acetate, citrate or tartrate), of ammonium oxalate, of ammonium carbonate or of ammonium hydrogenphosphate, which makes it possible to have a pH of between 5 and 9 and preferably in the region of 7. Thus, ammonium acetate at a concentration of two moles per litre in water has a pH in the region of 7.

In order to maintain the value of the pH of the solution preferably at a value in the region of 7, it may be necessary to progressively neutralize the acidity possibly formed during the precipitation of the mixed oxides (for example, hydrohalic acid formed when an antimony halide and/or an iron halide and/or a

vanadium halide is/are used) or the possible acidity of the aqueous solution used, with the aid of a basic compound. It is preferable, in the process of the invention, to carry out this neutralization by
5 controlled progressive addition of aqueous ammonia.

After precipitation of the mixed oxides of the invention, they are separated from the saturated alcohol/water or water liquid by any technique commonly used for this type of operation, in particular by
10 filtration. The isolated mixed oxides are then dried, at atmospheric pressure or at reduced pressure, at a temperature lying, for example, between 30°C and 200°C, without these values being of critical importance.

The mixed oxides of formula (I) are then
15 calcined at a temperature of 400°C to 800°C. The calcination is preferably carried out at a temperature of 500°C to 750°C.

Preference is given, among the mixed oxides of formula (I) defined above, to those in which:

- 20 - a represents a whole or fractional number equal to or less than 100
- b represents a whole or fractional number equal to or less than 100
- x represents a whole or fractional number
25 determined by the oxidation state of the other elements.

Finally, preference is still more particularly given to the mixed oxides of formula (I)

in which:

- a represents a whole or fractional number from 0.5 to 50
- b represents a whole or fractional number from 1 to 50
- x represents a whole or fractional number determined by the oxidation state of the other elements.

Another subject of the present invention is a process for the ammoxidation of alkanes in the vapour phase in the presence of a solid catalyst containing at least one active phase, characterized in that the said active phase comprises at least one mixed oxide corresponding to the general empirical formula (I) and prepared according to the process defined above.

According to the present invention, alkanes having from 3 to 12 carbon atoms per molecule are reacted in the vapour phase with ammonia and oxygen in the presence of a catalyst whose active phase has just been indicated.

Of course, in the context of the present process, it is possible to use diluent gases which are inert under the reaction conditions, such as helium, nitrogen and argon. Likewise, steam can be added to the gaseous reaction mixture within wide limits. The reactive gas (alkane, ammonia, oxygen) can thus be diluted with an inert diluent and/or with steam. In this grouping, the content of steam can vary within

wide limits, in particular from 0 to 50 % and, preferably, between 3 and 30 %. For a good implementation of the process according to the invention, the content of reactive gas will be at least
5 3 % and preferably at least 20 %.

Within the reactive gas, the respective contents of alkane, ammonia and oxygen can vary within wide limits.

The alkane content in the reactive gas is
10 preferably between 5 and 70 %. The ammonia content is preferably between 3 and 50 % and the oxygen content is preferably between 3 and 45 %.

For a good implementation of the process according to the invention, the composition of the
15 reactive mixture will preferably be chosen outside the explosive region.

Starting from propane, a mixture will be obtained containing essentially propylene and acrylonitrile. Acrylonitrile is an intermediate
20 produced industrially on a large scale, propylene is a starting material traditionally used to produce acrylonitrile and various other intermediate products well known to those skilled in the art.

Starting from isobutane, a mixture will be
25 obtained containing methacrylonitrile and isobutene or n-butenes.

The process according to the invention is more particularly suitable for the ammoxidation of

propane.

If the alkane used can be of technical quality, it will not contain significant amounts of compounds containing ethylenic unsaturation. Thus, the
5 propane involved will generally only contain trace amounts of propylene, for example less than 10 %.

The process according to the invention is carried out in the form of a vapour phase reaction. Consequently, any device suitable for carrying out
10 ammoxidation or oxidation reactions in the vapour phase can be used. The process can be carried out continuously or noncontinuously and it can comprise the use of a stationary bed or of a fluidized bed.

The reaction temperature is generally between
15 300°C and 550°C and, preferably, between 400°C and 500°C.

The total pressure of the reaction mixture can be greater than or equal to atmospheric pressure. It is generally between 1 and 6 bar and, preferably,
20 between 1 and 4 bar.

The gas flow rate is fixed such that the hourly volume rate is between 100 and 36,000 h⁻¹ and, preferably, between 200 and 20,000 h⁻¹.

The hourly volume rate is defined as the
25 total gas volume/volume of the catalyst/hour ratio.

Of course, those skilled in the art will be able to find a compromise between the temperature, the gas flow rate, the precise nature of the catalyst used

and the various other parameters of the reaction taking into account their production objectives.

The catalyst used in the process for the ammoxidation of alkanes can comprise solely one or a number of mixed vanadium, antimony and iron oxides defined above, constituting the active phase of the catalyst, or can additionally comprise an inorganic oxide, such as, for example, alumina, silica, silica/alumina, zirconia, cerite, magnesia, titanium oxide or niobium oxide, on which the said active phase is deposited or with which the active phase is mixed, by using various techniques known to those skilled in the art, such as impregnation or slurry deposition.

The catalytic phase, consisting of the active phase alone or of the active phase deposited on an inorganic oxide or mixed with the said inorganic oxide, can then be used in the bulk form or in the particulate state; it can therefore be used in the powder form or be shaped, for example as balls, pellets, extrudates or crushed particles, according to various known techniques.

For use of the process in a stationary bed, these techniques can be, for example, pelleting or coating on an inert substrate or on a ceramic or metal substrate of monolithic type.

For use of the process in a moving bed or in a fluidized bed, the catalytic phase is generally formed by atomization, drying and calcination.

The catalytic phases can, for example, be shaped by compression, so as to obtain pellets. These pellets can then optionally be crushed into fragments. The precise values of the pressure, diameter and
5 thickness of the pellets and particle size of the fragments can be chosen by those skilled in the art according to the pressure drop acceptable in the reactor.

A variant of the preparation of the catalytic
10 phase can consist in carrying out, in a single stage, the synthesis of the active phase and its deposition on an inorganic oxide or its mixture with the said inorganic oxide.

The catalytic phases can also be deposited on
15 an inert substrate or can coat it. The nature of this substrate is not critical so long as it is chemically inert with respect to the reactants under the chosen reaction conditions. By way of examples of substrates capable of being suitable for the preparation of
20 catalysts which can be used in the context of the process according to the invention, there may be mentioned: silica, alumina, silica/alumina, sintered clay, carborandum, magnesia, magnesium silicate and diatomaceous earth. This substrate is preferably
25 nonporous and can be especially based on refractory oxide in the particulate form, the most commonly employed substrate being clay-based. This substrate can, for example, consist of inert, complete, solid and

rough clay balls with a diameter of between 0.5 and 6 mm. The precise value of the diameter of the balls can be chosen as a function of the acceptable pressure drop in the reactor. This substrate can also be made
5 nonporous by enamelling.

This substrate can also be a ceramic substrate, the said substrate being preferably in the form of an inert and rigid structure of monolithic type comprising channels or ducts. Such supports are well
10 known and have been widely described in the literature. The substrates used which are made of ceramic substance are especially those comprising, as the main substance, cordierite, alumina, mullite, porcelain, and the carbides of boron or silicon.

15 This substrate can also be a metal substrate. Such substrates are well known. Suitable metal substrates are in particular those obtained from iron, nickel and chromium alloys or those obtained from iron, chromium, aluminium and cobalt alloys, such as those
20 known under the trade name Kanthal, or those obtained from iron, chromium, aluminium and yttrium alloys, known under the trade name Fecralloy. The metal can also be carbon steel or simple cast iron.

When a coated catalyst is resorted to, the
25 amount of catalytic phase, which can vary within wide limits, is in practice between 1 and 50 % and, preferably, between 5 and 35 % by weight with respect to the substrate + catalytic phase combination.

Thus, certain catalysts, useful for an implementation of the process in a stationary bed, can be obtained by coating the crushed, intermediate or finished, catalytic phases in a way known per se. This conventional method consists in depositing a layer of intermediate or finished catalytic phase around inert but rough balls. Once the balls are covered with the desired quantity of the catalytic phase, they are dried with hot air between 70 and 150°C for at least 30 minutes and then introduced into an oven in order to be calcined between 300 and 600°C, preferably between 450 and 500°C, for at least 3 hours.

Certain catalysts which are useful for an implementation of the process according to the invention in a moving bed or fluidized bed can be obtained by the technique, known per se, of drying by atomization in a preferably nonreducing atmosphere. By such an operation, followed if appropriate by calcination at a temperature of the order of 400 to 800°C, powders are obtained which are spherical in shape and have a diameter of between 5 and 700 μm . Powders consisting of at least 80 % by weight of particles whose sizes are between 5 and 200 μm are preferred in the context of use in a fluidized bed.

The catalytic phase, alone or thus used in the bulk form or in the particulate state, constitutes the catalyst.

The products of the reaction can be recovered

from the effluent gases by any suitable means. For example, the effluent gases can pass into a condenser containing dilute sulphuric acid in order to neutralize the unreacted ammonia. The gases can then pass through
5 a refrigerated absorbing column to condense the acrylonitrile, acetonitrile and hydrocyanic acid, the uncondensed vapours containing mainly unreacted propane, propylene, light hydrocarbons and, if appropriate, CO₂. The acrylonitrile and hydrocyanic acid
10 can then be separated from the acetonitrile by distillation and the recovered acrylonitrile/hydrocyanic acid mixture can then be distilled in its turn to separate the acrylonitrile from the hydrocyanic acid.

15 The examples below illustrate the present invention.

EXAMPLES OF THE PREPARATION OF MIXED OXIDES

EXAMPLE 1 - Preparation of the mixed oxide (A)
according to the invention, of the
following empirical formula: VSb₅Fe_{2.5}O_x

5 A solution of 7.77 g of FeCl₃·6H₂O, 3.05 g of vanadyl acetylacetonate and 17.22 g of SbCl₅ in 100 ml of an aqueous hydrochloric acid solution having a 15 % weight for weight concentration is prepared.

 The aqueous solution is poured dropwise into
10 500 ml of aqueous solution containing ammonium acetate (2 mol/litre) in order to have an initial pH of the order of 7.0. During the precipitation of the mixed V, Sb and Fe oxides, the pH, which tends to decrease due to the release of hydrochloric acid and the presence of
15 hydrochloric acid in the aqueous solution, is kept constant by addition of a concentrated aqueous ammonia solution (containing 30 % by weight).

 The precipitate thus formed is isolated by filtration, washed with water, dried for 12 h at 140°C
20 and then calcined for 3 h at 700°C.

 The compound of formula VSb₅Fe_{2.5}O_x thus obtained is then compressed under a pressure of 4300 bars. Pellets with a diameter of 3 cm and with a thickness of approximately 0.5 cm are then obtained.
25 These pellets are crushed into fragments with a particle size of between 0.3 and 0.8 cm, constituting the catalyst (A) in accordance with the invention.

EXAMPLES 2 TO 7 - Preparation of different mixed oxides according to the invention.

Different mixed oxides are prepared by following the procedure described in Example 1 but by
 5 using different amounts of vanadyl acetylacetonate (Examples 2 and 5) or of antimony pentachloride and of ferric chloride (Examples 3, 4, 6 and 7).

The mixed oxides according to the invention exhibiting the following formulae are thus obtained:

- | | | |
|----|-----------|---|
| 10 | Example 2 | $\text{VSb}_{10}\text{Fe}_5\text{O}_x$ (reference B) |
| | Example 3 | $\text{VSb}_{12.5}\text{Fe}_5\text{O}_x$ (reference C) |
| | Example 4 | $\text{VSb}_{17.5}\text{Fe}_5\text{O}_x$ (reference D) |
| | Example 5 | $\text{VSb}_{20}\text{Fe}_{10}\text{O}_x$ (reference E) |
| | Example 6 | $\text{VSb}_{25}\text{Fe}_{10}\text{O}_x$ (reference F) |
| 15 | Example 7 | $\text{VSb}_{30}\text{Fe}_{10}\text{O}_x$ (reference G) |

EXAMPLES 8 AND 9 - Preparation of the mixed oxides (H) and (J) according to the invention

A solution of 7.77 g of $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$, 1.52 g of vanadyl acetylacetonate and 21.4 g of SbCl_5 in 100 ml of
 20 absolute ethanol is prepared.

The ethanolic solution is poured dropwise into 500 ml of aqueous solution containing ammonium acetate (2 mol/litre) in order to have an initial pH of the order of 7.0. During the precipitation of the mixed
 25 V, Sb and Fe oxides, the pH, which tends to decrease

due to the release of hydrochloric acid, is kept constant by addition of a concentrated aqueous ammonia solution (containing 30 % by weight).

The precipitate thus formed is isolated by
5 filtration, washed with water, dried for 12 h at 140°C and then calcined for 3 h at 700°C.

The compound of formula $\text{VSb}_{12.5}\text{Fe}_5\text{O}_x$ thus obtained is then compressed under a pressure of 4300 bars. Pellets with a diameter of 3 cm and with a
10 thickness of approximately 0.5 cm are then obtained. These pellets are crushed into fragments with a particle size of between 0.3 and 0.8 cm, constituting the catalyst (H) according to the invention.

A catalyst (J) according to the invention,
15 with the composition $\text{VSb}_{20}\text{Fe}_{10}\text{O}_x$, is prepared according to the procedure used for the catalyst (H) but using different amounts of ferric chloride and of antimony pentachloride.

GENERAL PROCEDURE FOR THE AMMOXIDATION TESTS

20 The catalyst sample is brought beforehand to a temperature of 150°C on a measuring bench while purging with helium for 10 min, and it is then subjected to a gas flow whose composition will be specified for each example and which contains propane,
25 ammonia, oxygen, helium and, if appropriate, steam.

The total pressure of the reaction mixture, of between 1 and 6 bar, will also be specified for each

example.

The total gas flow rate is defined so as to have an hourly volume rate (HVR) of between 100 and 36000 h⁻¹, the precise value of which will be indicated
5 for each example.

Volume of active phase: 25 cm³.

The principle of the ammoxidation test for propane is the following:

- The catalyst is brought to a temperature T₁,
10 for example 310°C, and, after stabilizing for 30 min at the temperature T₁, the composition of the mixture at the reactor outlet is determined by gas phase chromatography.

- The conversion percentages and the
15 selectivities obtained on the catalyst examined at the inlet temperature T₁ are calculated using relationships of the type:

conversion of propane (in mol %) = converted propane/
introduced propane

20 selectivity towards acrylonitrile (in mol %) = propane
converted to acrylonitrile/converted propane.

- The catalyst is then brought from 310 to 550°C by increments of 20°C and the conversion percentages and the selectivities are determined every
25 40 min.

In the ammoxidation examples below, the following conventions are used:

Temp = temperature of the reaction

- ct = contact time
- DC(C₃H₈) = conversion of propane
- S(ACN) = selectivity towards acrylonitrile
- 5 S(ACN+C₃H₆) = selectivity towards acrylonitrile and propylene
- S(Ammox) = selectivity towards acetonitrile, hydrocyanic acid and other ammoxidation by-products
- 10 ACN Prod = acrylonitrile productivity expressed as g of acrylonitrile formed/litre of catalyst x hour.

The remainder to 100 % of the selectivities corresponds to the formation of CO and CO₂ and optionally methane, ethane and ethylene.

EXAMPLES OF THE AMMOXIDATION OF PROPANE

EXAMPLES 10 TO 20

Ammoxidation of propane is carried out, as described above, by using, as catalysts, active phases composed of the mixed oxides prepared according to the invention A, B, C, D, E, F, G, H and J.

The specific conditions used are the following:

- 25 - hourly volume rate = 1800 h⁻¹ or 3600 h⁻¹
or 7200 h⁻¹
- total pressure = 1.3 bar

- composition by volume of the reaction

mixture: C_3H_8 = 25 %

NH_3 = 10 %

O_2 = 20 %

He = 45 %

5

The temperature conditions and the results obtained are collated in Table 1 below.

10

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Examples	Mixed oxide used	Temp (°C)	ct	HVR (h ⁻¹)	DC (C3H8) (in %)	S (ACN) (in %)	S (ACN + C3H6) (in %)	S (Ammon) (in %)	ACN Prod (g/l x h)
Example 10	A	365	2 s	1800	12	17	40	21	20
		385			24	17	33	13	40
		405			27	16	37	14	43
		425			29	18	41	14	52
Example 11	B	390	2 s	1800	10	27	35	31	27
		415			29	26	31	11	75
		430			29	34	39	10	98
		445			29	35	41	8	101
Example 12	C	410	2 s	1800	15	35	39	14	52
		430			16	46	49	11	73
Example 13	C	410	1 s	3600	9	47	51	18	84
		430			12	49	53	13	117
Example 14	C	410	0.5 s	7200	3	53	68	21	63
		430			7	54	62	25	150
		450			11	60	69	17	262
		470			15	53	58	12	316
Example 15	D	410	2 s	1800	5	41	50	23	20
		430			6	43	50	16	26
		450			8	48	55	13	38
		470			11	51	59	8	56
Example 16	E	410	2 s	1800	8	35	42	12	28
		430			10	39	45	10	39
		450			18	44	49	8	79
		470			26	40	44	7	103
Example 17	F	410	2 s	1800	4	42	46	35	17
		430			8	49	52	21	39
		450			12	50	53	14	60
		470			15	47	49	12	70

Table 1

Examples	Mixed oxide used	Temp (°C)	ct	HVR (h ⁻¹)	DC (C ₃ H ₈) (in %)	S (ACN) (in %)	S (ACN + C ₃ H ₆) (in %)	S (Ammon) (in %)	ACN Prod (g/l x h)
Example 18	G	410	2 s	1800	3	56	59	25	17
		430			5	55	57	25	27
		450			8	60	62	18	48
		470			10	60	61	15	60
Example 19	H	410	2 s	1800	6	39	45	30	23
		430			8	47	52	23	37
		450			13	49	54	16	63
		470			15	48	53	12	71
Example 20	J	410	2 s	1800	6	33	40	24	20
		430			9	40	44	20	36
		450			14	49	53	13	68
		470			20	46	49	8	91

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Table 1 (end)

CLAIMS

1. Process for the preparation of a mixed oxide containing vanadium, antimony and iron corresponding to the general empirical formula (I):



in which:

- a represents a whole or fractional number equal to or greater than 0.1
- b represents a whole or fractional number equal to or greater than 0.5
- x represents a whole or fractional number determined by the oxidation state of the other elements,

characterized in that:

- 15 - respective vanadium, antimony and iron compounds are dissolved in at least one saturated alcohol or in water,
- the alcoholic solution or the aqueous solution thus obtained is brought into contact with an aqueous solution containing an ammonium salt, in order
- 20 to precipitate the mixed oxide,
- the mixed oxide obtained is separated and calcined.

2. Process according to claim 1, characterized





in that the soluble vanadium and/or antimony and/or iron compounds are dissolved in an acidic aqueous solution having a pH of less than or equal to 2.

3. Process according to claim 2, characterized
5 in that the acid used to prepare the acidic aqueous solution is any strong inorganic or organic acid capable of giving a solution having a pH of less than or equal to 2 and preferably a pH of 0.5 to 1.

4. Process according to either of claims 2 or 3,
10 characterized in that the acid used to prepare the acidic aqueous solution is chosen from hydrochloric, hydrobromic, sulphuric, nitric and trifluoroacetic acids.

5. Process according to one of claims 1 to 4,
15 characterized in that the soluble vanadium compound is chosen from vanadyl acetylacetonate, vanadyl trichloride, vanadium trifluoride, vanadium tetrafluoride, vanadium pentafluoride, vanadium tribromide, vanadium dichloride, vanadium trichloride,
20 vanadium tetrachloride or vanadium triiodide.

6. Process according to one of claims 1 to 5, characterized in that the soluble antimony compound is chosen from antimony pentachloride, antimony trichloride, antimony tribromide, antimony trifluoride,
25 antimony triiodide, antimony trioxide or stibine.

7. Process according to one of claims 1 to 6, characterized in that the soluble iron compound is chosen from iron dichloride, iron trichloride, iron





dibromide, iron tribromide, iron diiodide, ferrous
nitrate, ferrous sulphate, ferric sulphate, ferrous
thiosulphate, ferric formate, ferric acetate, ferric
acetylacetonate, ferric benzoate, ferric oleate,
5 ferrous lactate or ferric lactate.

8. Process according to one of claims 1 to 7,
characterized in that the saturated alcohols used are
alkanols and cycloalkanols and preferably alkanols
having from 1 to 6 carbon atoms and cyclohexanol.

10 9. Process according to one of claims 1 to 8,
characterized in that the alcoholic solution or the
aqueous solution obtained is then mixed with an aqueous
solution of an ammonium salt, so as to precipitate the
mixed oxides, preferably with an aqueous solution of an
15 ammonium carboxylate, of ammonium oxalate, of ammonium
carbonate or of ammonium hydrogenphosphate, which makes
it possible to have a pH of between 5 and 9 and
preferably in the region of 7.

10. Process according to claim 9, characterized
20 in that the value of the pH of the solution is
maintained at a value in the region of 7, by
progressively neutralizing the acidity formed during
the precipitation of the mixed oxides or which arises
from the aqueous solution used, with the aid of a basic
25 compound, preferably by controlled progressive addition
of aqueous ammonia.

11. Process according to one of claims 1 to 10,
characterized in that, after separation of the mixed





oxides, the latter are calcined at a temperature of 400°C to 800°C, and preferably from 500°C to 750°C.

12. Process according to one of claims 1 to 11, characterized in that it is applied to the preparation
5 of mixed oxides of general formula (I) in which:

- a represents a whole or fractional number equal to or less than 100 and preferably a whole or fractional number from 0.5 to 50
- b represents a whole or fractional number
10 equal to or less than 100 and preferably a whole or fractional number from 1 to 50
- x represents a whole or fractional number determined by the oxidation state of the other elements.

15 13. Process for the ammoxidation of alkanes in the vapour phase in the presence of a solid catalyst containing at least one active phase, characterized in that the said active phase comprises at least one mixed oxide corresponding to the general empirical formula
20 (I) and prepared according to the process of one of claims 1 to 12.

14. Process according to claim 13, characterized in that alkanes having from 3 to 12 carbon atoms per molecule, preferably chosen from propane and isobutane,
25 are reacted in the vapour phase with ammonia and oxygen.

15. Process according to either of claims 13 or 14, characterized in that within the reactive gas,

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composed of alkane, ammonia and oxygen, the alkane content is preferably between 5 and 70 %, the ammonia content is preferably between 3 and 50 % and the oxygen content is preferably between 3 and 45 %.

- 5 16. Process according to one of claims 13 to 15, characterized in that the reaction temperature is between 300°C and 550°C and preferably between 400°C and 500°C.

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