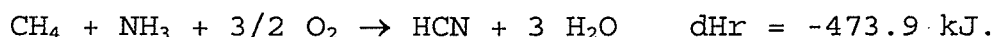


Reactor for preparing hydrogen cyanide by the Andrussow process

The present invention relates to a reactor for
5 preparing hydrogen cyanide (HCN) by the Andrussow
process and to a process for preparing HCN which is
performed using the inventive reactor.

The synthesis of hydrogen cyanide (HCN) by the
10 Andrussow process is described in Ullmann's
Encyclopedia of Industrial Chemistry, Volume 8, VCH
Verlagsgesellschaft, Weinheim 1987, page 161-162. The
reactant gas mixture, which generally comprises methane
or a methane-containing natural gas stream, ammonia and
15 oxygen, is passed through catalyst meshes in a reactor
and converted at temperatures of approx. 1000°C. The
oxygen needed is typically used in the form of air. the
catalyst meshes consist generally of platinum or
platinum alloys. The composition of the reactant gas
20 mixture corresponds roughly to the stoichiometry of the
exothermic net reaction equation



The reaction gas flowing out comprises the HCN product,
25 unconverted NH_3 and CH_4 , and the essential by-products
 CO , H_2 , H_2O , CO_2 and a large proportion of N_2 .

The reaction gas is cooled rapidly in a waste heat
boiler to approx. 150-200°C and subsequently passes
30 through a scrubbing column in which the unconverted NH_3
is scrubbed out with dilute sulphuric acid and portions
of the steam are condensed out. Also known is the
absorption of NH_3 with sodium hydrogenphosphate
solution and subsequent recycling of the ammonia. In a
35 downstream absorption column, HCN is absorbed in cold
water and is prepared in a downstream rectification
with a purity of greater than 99.5% by mass. The HCN-
containing water obtained in the bottom of the column

- 2 -

is cooled and recycled to the HCN absorption column.

A broad spectrum of possible embodiments of the Andrussow process is described in DE 549 055.

Accordingly, reactors are also known for preparing HCN

5 by the Andrussow process, one example of such a reactor being detailed in EP 1 001 843 B1. These reactors generally comprise an inlet for the reactants, an outlet for the products and a catalyst, which may be configured, for example, in the form of a plurality of
10 platinum meshes arranged in succession. Immediately above the catalyst mesh, a gas-permeable protective layer may be provided, which serves as a heat shield and as a flashback guard.

15 The processes performed with known reactors already afford good yields with an acceptable energy demand. Owing to the significance of the product, however, there is a permanent effort to improve the performance and the effectiveness of the reactors.

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In view of the prior art, it is thus an object of the present invention to provide a reactor which enables a particularly simple and inexpensive preparation of HCN.

At the same time, the yield, the production output (kg
25 of HCN/h) and the catalyst lifetime in particular should be increased. In addition, it was consequently an object of the present invention to provide a reactor which enables production of HCN with high HCN concentration in the reaction gas and hence
30 particularly low energy demand in the HCN isolation.

These objects and further objects which are not stated explicitly but which are immediately derivable or discernable from the connections discussed herein by
35 way of introduction are achieved by a reactor having all features of Claim 1. Appropriate modifications to the inventive reactor are protected in subclaims. With regard to the process for preparing HCN, Claim 25

- 3 -

offers a solution to the underlying object.

The present invention accordingly provides a reactor for preparing hydrogen cyanide by the Andrussov process, comprising a reactor vessel, at least one gas inlet which opens into a gas inlet region, an outlet for the reaction products and a catalyst, wherein at least one mixing element and at least one gas-permeable intermediate layer are provided within the reactor vessel between the gas inlet region and the catalyst, the mixing element being arranged between the gas inlet region and the gas-permeable intermediate layer.

As a result of these measures, it is surprisingly possible to provide a reactor which enables a particularly simple and inexpensive preparation of HCN. In addition, the yield and the production output (kg of HCN/h) can be increased by the use of an inventive reactor. Furthermore, HCN can be produced at a particularly low energy demand with an inventive reactor. Moreover, the lifetime of the catalysts can be prolonged by virtue of the construction features of the reactor.

The inventive reactor comprises a reactor vessel into which at least one gas inlet opens. The reactor vessel encloses at least one mixing element, at least one gas-permeable intermediate layer and at least one catalyst. The products are discharged from the reactor vessel through at least one outlet. The shape of the reactor vessel is uncritical per se, such that it may have a rectangular or round cross section. The reactor preferably has a cylindrical shape. The volume of the reactor vessel depends on the intended production output, and the reactor vessel may assume any of the customary volumes. Appropriately, the volume of the reactor vessel may, for example, be in the range of 0.01 m^3 to 50 m^3 . The ratio of height to diameter (H/D) of the reactor vessel may preferably be in the range of

0.4 to 1.8, more preferably 0.6 to 1.4. Appropriately, the reactor vessel, viewed in flow direction of the gas, from the gas-permeable intermediate layer, may have an inner lining of a heat-resistant material. For example, a layer of a ceramic fibre material, for example an Si-containing ceramic fibre material which is obtainable under the trade name Nefalit®, may be provided, which protects the reactor vessel from reaction of heat.

10

The different reactant gases may be combined upstream of or in the reactor vessel. Accordingly, one, two or more gas inlets may open into the reactor vessel. Within the reactor vessel, the gases are conducted first into a gas inlet region whose volume is uncritical per se.

Between the gas inlet region and the catalyst, according to the present invention, at least one mixing element is provided. According to the embodiment, the gas inlet region may also form part of the mixing element. The mixing element serves to mix the reactant gases supplied, and all known embodiments of gas mixers may be used.

25

On the basis of a simple and low-maintenance construction, the mixing element may preferably be designed in the form of plate-shaped internals which more preferably comprise a plurality of plate layers. In a preferred aspect of the invention, the mixing element may have three, four, five or more plate layers. These plate layers are preferably arranged essentially in parallel, the angle of the individual plate layers relative to one another being preferably in the range of -10° to $+10^{\circ}$, more preferably -5° to $+5^{\circ}$. The plate separation may, for example, be 0.5 cm to 200 cm, preferably 1 cm to 100 cm and most preferably 5 cm to 50 cm. In this case, it is possible,

for example, to use perforated plates, in which case the orifices are offset so as to achieve mixing of the gases. Particular preference is given to using impervious plates. In this embodiment, the gas stream
5 can be passed through orifices which are provided at right angles to the plate plane in the plates or between the plates. The particular orifices of the different layers may, based on the particular layer, be provided in an alternating manner in the middle of the
10 reactor vessel, for example in the form of an orifice within the plate, or at the edge of the reactor vessel, i.e. between the particular plate and the wall of the reactor vessel. This construction may preferably be designed as a ring-disc arrangement (disc-donut
15 design), in which case the layers are not connected directly to the reactor vessel, whereas the rings can conclude with the reactor vessel. These arrangements may preferably comprise 2 to 6 discs.

20 In embodiments which achieve mixing of the gas stream using impervious plates, the number of orifices in the particular layer compared to the embodiments with perforated plates is relatively low. Layers configured in the embodiment with impervious plates preferably
25 have at most 10, preferably at most 5, orifices per m^2 .

Embodiments which work using perforated plates have more orifices per m^2 . For example, the perforated plates may comprise at least 11, preferably at least 15
30 and most preferably at least 20 orifices per m^2 .

The mixing element preferably comprises impervious plates which have an area which corresponds to at least 40%, more preferably at least 60% and most preferably
35 at least 80% of the cross-sectional reactor area, and more preferably at least 25%, preferably at least 50% and more preferably at least 75% of the plate layers present in the mixing element have such an area. The

cross-sectional reactor area arises from the area of the reactor vessel which is measured parallel to the particular plate layer in each case.

- 5 The constructions detailed above can preferably result in the formation of a turbulent flow, such that excellent mixing of the gases is achieved.

10 The reactor vessel and the mixing element may be produced from any materials which withstand the conditions which exist. Suitable materials are especially metals, for example steel. In addition, these components of the reactor may be coated with materials which prevent degradation of the reactant
15 gases, especially of NH_3 , under the conditions selected. These materials are detailed, inter alia, in US 5,431,984.

20 According to the invention, a reactor, viewed in the direction of gas flow, downstream of the mixing element, has a gas-permeable intermediate layer. The gas-permeable intermediate layer is preferably configured especially such that it offers flashback protection. In addition, this layer can achieve
25 filtering of the reactant gases, which removes small particles in particular. In addition, the gas-permeable intermediate layer may result in the formation of a pressure difference which leads to particularly uniform flow of the reactant gases towards the catalyst. In
30 this context, the pressure drop may be within a wide range, the inventive advantages being achieved at a relatively high pressure drop, i.e. in the case of formation of a high flow resistance through the gas-permeable intermediate layer in a particularly high
35 degree. On the other hand, in the case of a high flow resistance, a relatively large amount of energy is required to form the intended flow rate of the reactant gases. The person skilled in the art will therefore

optimally adjust the pressure difference and the flow resistance caused by the gas-permeable intermediate layer under the given boundary conditions. In this context, a low gas permeability of the intermediate layer leads to a high pressure difference. The gas-permeable intermediate layer may preferably generate a pressure drop which is in the range of 1 to 100 mbar, more preferably 5 to 30 mbar, measured with a U-tube manometer at a flow rate of the reactant gas mixture of 1.5 m/s.

In a preferred aspect, the distance between the gas-permeable intermediate layer and a catalyst configured areally in the reactor may be at least 30 mm, preferably at least 60 mm. More preferably, this distance may be in the range of 40 mm to 1000 mm, most preferably in the range of 60 mm to 100 mm. The gas-permeable intermediate layer is preferably essentially parallel to the area of the catalyst configured areally in the reactor. In this case, the gas-permeable intermediate layer and the catalyst configured areally in the reactor preferably form an angle in the range of -10° to $+10^{\circ}$, more preferably -5° to $+5^{\circ}$.

The gas-permeable intermediate layer may be configured, for example, in the form of a nonwoven fabric, woven fabric or foam, and this layer may comprise one or more sheets. The intermediate layer may be formed from any material which withstands the conditions which exist. These include especially metals, for example steel, and inorganic materials such as ceramics or mineral glasses. In a preferred embodiment, the gas-permeable intermediate layer comprises at least one metal mesh arranged in the direction of the catalyst and at least one sheet of glass wool, for example quartz wool, which is provided in the direction of the gas inlet region. The metal mesh arranged in the intermediate layer may preferably have a nominal mesh width in the range of

1 μm to 200 μm , more preferably in the range of 5 μm to 100 μm . The nominal mesh width can be determined, for example, with the known gas bubble test (bubble point test) to ISO standard 4003. The metal mesh may, for example, be configured as a woven fabric or braid, which are formed from metal wire. These include, for example, Dutch weave or twill weave. The thickness of the sheet of glass wool may preferably be in the range of 0.5 cm to 10 cm, more preferably in the range of 1 cm to 5 cm. In this case, the metal meshes and the sheets of glass wool may be enclosed by two perforated metal sheets which have, for example, a hole diameter in the range of 1 mm to 100 mm, more preferably 5 mm to 40 mm.

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Once the reactant gases have passed through the gas-permeable intermediate layer, they flow towards a catalyst. The catalysts usable to prepare HCN by the Andrussov process are common knowledge and are detailed, for example, in Ullmann's Encyclopedia of Industrial Chemistry, Volume 8, VCH Verlagsgesellschaft, Weinheim 1987.

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In general, the catalysts comprise at least one noble metal, especially a metal of the platinum group. The platinum group includes especially platinum, palladium, iridium, osmium and rhodium, particular preference being given to the use of platinum. These metals may be used individually or as a mixture. For instance, it is possible especially to use alloys which comprise platinum and rhodium.

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The catalyst may preferably be configured areally in the reactor, the area more preferably being arranged such that this area is flowed through essentially at right angles by the gas. This flow angle is preferably in the range of 70° to 110° and more preferably in the range of 80° to 100°. The catalyst configured areally

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- 9 -

may preferably be arranged essentially parallel to the plate-shaped internals which serve to mix the gases. The angle formed by these planes may preferably be in the range of -10° to $+10^{\circ}$. These values are based on the plate layer which has the smallest distance from the catalyst layer.

The catalyst configured areally in the reactor may, for example, be provided in the form of meshes, for example wire braids, wire fabrics or grids, perforated metal foils or metal foams. Preference is given especially to using meshes which comprise platinum. It is possible here to use one, two, three, four or more meshes. Preferred embodiments of known catalyst arrangements are described, inter alia, in EP-A-0 680 767, EP-A-1 358 010, WO 02/062466 and WO 01/80988.

The catalyst is generally arranged on a support. This support may, for example, be manufactured from metal or from a ceramic material, preference being given to ceramic materials. These supports are detailed, other, in EP-A-0 680 787, EP-A-1 358 010, EP-A-1 307 401, WO 02/062466 and WO 01/80988.

For example, the catalyst can rest on a support which has been produced from ceramic. The ceramic support may preferably have a multilayer structure, in which case the support comprises an upper ceramic support which is provided in the direction of the catalyst, and a lower ceramic support. The upper ceramic support may, for example, have flow channels with a smaller diameter than the lower ceramic support which is provided in the direction of the outlet of the reaction products. The diameter of the flow channels of the upper ceramic support may, for example, be in the range of 2 mm to 20 mm, preferably 4 mm to 12 mm, whereas the diameter of the flow channels of the lower ceramic support may be in the range of 10 mm to 30 mm, preferably 12 mm to

24 mm. The diameter of the flow channels is a mean value which can be determined by measuring (slide rule) a statistically sufficiently large number of channels and subsequently calculating the mean. The support made
5 of ceramic may especially be produced from Al_2O_3 ceramics or aluminium silicate ceramics having an Al_2O_3 content greater than 85%. In a particularly appropriate embodiment of the reactor, a metal mesh may be provided between the catalyst and the support made of ceramic,
10 in which case this metal mesh is produced from a material which withstands temperature conditions which exist. This metal mesh may more preferably be produced from steel or a steel alloy, for example from Mat. 1.4767 or Kanthal.

15 In a further embodiment of the inventive reactor, the catalyst may rest on a support which comprises at least one metallic support mesh which is mounted on a support grid made of metal. The support may preferably comprise
20 one, two, three, four or more metallic support meshes. In this case, the support mesh may, for example, have a mesh width in the range of 1 mm to 50 mm. The support mesh and the support grid may preferably be produced from steel or a steel alloy, for example from Mat.
25 1.4767 or Kanthal or Inconel 600, Mat. 2.4816, and these materials must be stable under the temperature conditions which exist in each case.

The support grid may be secured on the bottom of the
30 reactor vessel, in which case the support grid may be configured such that the areal catalyst has a distance from the bottom of the reactor vessel provided with orifices in the range from 50 mm to 300 mm.

35 Appropriately, a layer of a ceramic material may be applied directly on the catalyst. This layer may be present in the form of one or more ceramic fabrics or of a ceramic foam.

The reactor vessel may have a bottom with one or more orifices through which the reaction products can be conducted out of the reactor vessel. In this case, the
5 bottom of the reactor vessel may also be formed by the outlet of the reaction products. In a preferred embodiment of the inventive reactor, the outlet of the reaction products may comprise tube bundles which are configured in the form of heat exchangers. In this
10 case, the tube bundles may be protected from the action of the heat with ceramic elements (ferrules) close to the reactor vessel.

The inventive reactor may comprise further components,
15 especially a component for starting the catalytic reaction. These include especially hydrogen flares, ignition electrodes or the devices detailed in EP-B-1 001 843.

20 Figure 1 details a preferred embodiment of an inventive reactor. The reactor (1) comprises a reactor vessel (2), a gas inlet (3) which opens into a gas inlet region (4), and an outlet of the reaction products (5). Between the gas inlet region (4) and the catalyst (6),
25 a mixing element (7) and a gas-permeable intermediate layer (8) are provided. In this specific embodiment, the mixing element (7) is configured in a disc-donut design, alternating rings or discs being provided. The rings have orifices in the middle of the reactor and
30 may be in contact with the reactor vessel. The discs are envisaged as impervious plates, orifices being formed by an intermediate space between disc and reactor vessel.

35 The gas-permeable intermediate layer (8) comprises a metal mesh (9) which preferably has a mesh width in the range of 1 μm to 200 μm , more preferably 5 μm to 100 μm , and a sheet of glass wool (10) which may have,

- 12 -

for example, a thickness in the range of 0.5 cm to 10 cm, preferably 1 cm to 5 cm. Perforated metal sheets (11) may be used to secure these elements, and the perforated sheets may have a hole diameter in the range of 1 mm to 100 mm, more preferably 5 mm to 40 mm.

In the present embodiment, the reactor vessel (2), viewed in flow direction of the gas, has an inner lining (12) composed of a heat-resistant material from the intermediate layer (8).

Once the gas has passed through the intermediate layer (8), the gas is contacted with the catalyst (6) which is configured in the form of a surface. The modification shown in Figure 1 has a layer of a ceramic material (13) which has been placed directly on the catalyst (6) to secure it. In the embodiment shown, the catalyst (6) rests on a support (14) which is manufactured from ceramic in the present case. Appropriately, the ceramic support may have a two-layer structure, in which case the support (14) composed of ceramic comprises an upper ceramic support (15) and a lower ceramic support (16).

Subsequently, the reaction products are passed out of the reactor vessel through the outlet (5). The present embodiment comprises especially the tube bundles (20) which are configured in the form of heat exchangers, the tube bundles (20) preferably being protected from the action of heat by ceramic elements, for example inserted sleeves (21), close to the reactor vessel.

Hereinafter, with reference to Figure 2, a second embodiment of the reactor (1) is described, which is essentially similar to the first embodiment, such that merely the differences will be addressed, the same reference symbols being used for the same parts and the above description applying correspondingly.

- 13 -

Like the first embodiment too, the reactor shown in Fig. 2 has a reactor vessel (2), a gas inlet (3) which opens into a gas inlet region (4), an outlet of the reaction products (5), a catalyst (6), a mixing element (7) and a gas-permeable intermediate layer (8).

In contrast to the above embodiment, the modification shown in Fig. 2 comprises a metal mesh (17) which has been provided between the catalyst (6) and the support (14) made from ceramic. As a result, it is surprisingly possible to enhance the effectiveness of the reactor.

Hereinafter, with reference to Figure 3, a third embodiment of the reactor (1) is described, which corresponds essentially to the first embodiment, such that merely the differences will be addressed below, the same reference symbols being used for the same parts and the above description applying correspondingly.

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Like the first embodiment too, the reactor shown in Fig. 3 also has a reactor vessel (2), a gas inlet (3) which opens into a gas inlet region (4), an outlet of the reaction products (5), a catalyst (6), a mixing element (7) and a gas-permeable intermediate layer (8).

In contrast to the embodiment shown in Fig. 1, the modification depicted in Fig. 3 comprises a support (14) which has been produced from metal. The support (14) made from metal comprises especially a metallic support mesh (18) supported by a support grid (19) made from metal. The support mesh (18) may have a mesh width in the range of 1 mm to 50 mm.

The support grid (19) rests with its feet on the ceramic elements (21) which protect the tube bundle (20) from the action of heat, or on the bottom of the tube bundles (20) which serve as heat exchangers. The

- 14 -

distance between catalyst mesh (6) and the bottom of the tube bundle (20) may, for example, be 50 mm to 300 mm.

- 5 The reactor may be used especially for the preparation of hydrogen cyanide (HCN) by the Andrussov process. These processes are known per se and are described in detail in the prior art cited above.
- 10 To prepare HCN, preference is given to using a methane-containing gas. Typically, any gas having a sufficiently high content of methane can be used. The content of methane is preferably at least 80% by volume, more preferably at least 88% by volume. As well
- 15 as methane, it is possible to use natural gas in the reactant gas. Natural gas is understood here to mean a gas which contains at least 82% by volume of methane.

In addition, to prepare HCN according to the Andrussov process, an oxygenous gas is used, for which oxygen or

20 a nitrogen-oxygen mixture can be used. In this case, the proportion by volume of oxygen in relation to the total volume of nitrogen and oxygen ($O_2/(O_2 + N_2)$) is in the range of 0.2 to 1.0 (vol./vol.). For example, air

25 may be used as the oxygenous gas.

In a preferred aspect of the present invention, the proportion by volume of oxygen in relation to the total volume of nitrogen and oxygen ($O_2/(O_2 + N_2)$) is in the

30 range of 0.25 to 1.0 (vol./vol.). In a particular aspect, this proportion may preferably be in the range of greater than 0.4 to 1.0. In a further feature of the present invention, the proportion by volume of oxygen in relation to the total volume of nitrogen and oxygen

35 ($O_2/(O_2 + N_2)$) may be in the range of 0.25 to 0.4.

The molar ratio of methane to ammonia (CH_4/NH_3) in the reactant gas mixture may preferably be range of 0.95 to

- 15 -

1.05 mol/mol, more preferably in the range of 0.98 to 1.02.

The reaction temperature is preferably between 950°C and 1200°C, preferably between 1000°C and 1150°C. The reaction temperature can be adjusted via the proportion of the different gases in the reactant gas stream, for example via the ratio of O_2/NH_3 . In this case, the composition of the reactant gas mixture is adjusted such that the reactant gas is outside the concentration range of ignitable mixtures. The temperature of the catalyst mesh is measured by means of a thermoelement or by means of a radiation pyrometer. The measurement point used for the radiation pyrometer is an open site on the glowing catalyst. For measurement with a thermoelement, the measurement point, viewed in flow direction of the gases, may be beyond the catalyst mesh at a distance of approx. 0-10 cm.

The molar ratio of oxygen to ammonia (O_2/NH_3) is preferably in the range of 0.7 to 1.25 (mol/mol).

The reactant mixture may preferably be preheated to a maximum of 150°C, more preferably a maximum of 120°C.

The flow rate with which the reactant gas is passed to the catalyst may be within a wide range. In a preferred modification of the process according to the invention, the reactant gas is passed to the catalyst at a rate in the range of 0.5 to 5 m/s, more preferably 0.8 to 2.5 m/s. The flow rate specified is based on the cross section of the reactor vessel and takes into account the operating conditions (pressure, temperature) of the reactant gas mixture which is passed to the catalyst. Since the cross section of the reactor can vary, these data are based on the average cross section of the reactor between the mixing element and the gas-permeable intermediate layer.

The present invention will be illustrated in detail hereinafter with reference to examples, without any intention that this should impose a restriction.

5 Examples

The results of the examples described below were found in an experimental apparatus consisting of a dosage unit with thermal mass flow controllers for the reactant gases used (methane, ammonia, air), an
10 electrical heater for preheating the reactant gases to 100°C and a reactor vessel with an internal diameter of 100 mm. In the reactor vessel, various internals were tested.

15 Example 1:

The gas is supplied to the reactor vessel from the top. The feed orifice has a diameter of 25 mm. Below the feed region is a mixing element consisting of an alternating arrangement of discs and rings which are
20 installed parallel to one another at a distance of 10 mm. The centrally fixed discs have a diameter of 93 mm. The free gap at the edge region is thus 3.5 mm. The rings fill the entire internal diameter (100 mm) and have a circular orifice in the middle with a
25 diameter of 40 mm. In flow direction, the elements are arranged

disc-ring-disc-ring-disc.

30 The mixing element is concluded by an edge deflector (guide plate) in the form of a 10 mm-wide ring.

Approx. 10 mm below the ring is installed a gas-permeable layer. This construction consists of two perforated metal sheets (external diameter 100 mm, hole
35 diameter: 5 mm) between which a metal Dutch-woven fabric having a nominal mesh width of 80 µm and, above it, an approx. 6 mm-thick sheet of mineral wool are positioned.

- 17 -

At a distance of 30 mm below the gas-permeable layer, the catalyst consisting of 6 sheets of a Pt/Rh10 catalyst mesh (1024 meshes/cm, wire thickness 0.076 mm) is installed. The catalyst meshes are supported by a
5 metallic support grid of mesh width 10 mm and wire thickness 2 mm, and are embedded in Nefalit sealant (Si-ceramic fibre mixture) in the edge region. The support grid rests on a ceramic support with flow channels of diameter 6 mm. Below the ceramic support,
10 the reaction gas enters a tube bundle heat exchanger in which the reaction gas is cooled to approx. 200°C.

Example 2:

As Example 1, except that the Pt mesh catalyst rests
15 directly on the ceramic support without a metallic support grid.

Example 3:

As Example 1, except with a mixing element in which, in
20 flow direction, the elements are arranged disc-ring-disc.

Example 4:

As Example 3, but with a mixing element consisting of
25 2 perforated metal sheets with a diameter of 100 mm and with holes of diameter 5 mm. The two perforated discs are arranged parallel to one another at a distance of 20 mm.

30 Comparative Example 1:

As Example 4, but without mixing element. The gas mixture flowing in meets the gas-permeable layer directly.

35 Comparative Example 2:

As Comparative Example 1, but without a gas-permeable layer. The gas mixture flowing in meets the catalyst meshes described directly.

Downstream of the reactor vessel, the reaction gas was cooled to approx. 200°C in a tube bundle reactor and supplied to a downstream HCN scrubber for neutralization of the HCN formed with NaOH solution.

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The reaction gas was analysed online in a GC. To assess the amount of HCN formed, the discharged NaCN solution was additionally weighed, and the CN content in the effluent of the HCN scrubber was determined by argento-

10

metric titration

All experiments were performed with a constant reactant gas volume of approx. 25 m³ [norm condition]/h and equal reactant gas compositions, and the air volume flow was approx. 18.2 m³ [norm condition]/h, the NH₃ volume flow approx. 3.35 m³ [norm condition]/h and the methane volume flow approx. 3.27 m³ [norm condition]/h. The reactant gas temperature in all experiments was 100°C. Table 1 shows the results obtained.

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Table 1

	HCN yield [kg/h]	HCN yield based on NH ₃ [%]	HCN yield based on methane [%]	HCN conc. in reaction gas [% by vol.]
Example 1	2.76	67.8	69.9	7.81
Example 2	2.67	65.8	67.6	7.63
Example 3	2.58	64.67	65.46	7.40
Example 4	2.61	64.25	65.42	7.15
Comparative Example 1	2.37	58.69	59.95	6.43
Comparative Example 2	2.11	52.41	53.86	5.77

The inventive embodiments of the reactor (Examples 1-4) show significantly better results with regard to the reactor performance and the yield. The higher HCN concentration in the reaction gas additionally enables an energetically more advantageous isolation of the HCN in the workup process.

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Claims

1. Reactor (1) for preparing hydrogen cyanide by the
5 Andrussow process, comprising a reactor vessel (2), at
least one gas inlet (3) which opens into a gas inlet
region (4), an outlet for the reaction products (5) and
a catalyst (6), characterized in that at least one
mixing element (7) and at least one gas-permeable
10 intermediate layer (8) are provided within the reactor
vessel (2) between the gas inlet region (4) and the
catalyst (6), the mixing element (7) being arranged
between the gas inlet region (4) and the gas-permeable
intermediate layer (8).
- 15 2. Reactor according to Claim 1, characterized in
that the mixing element (7) comprises plates.
3. Reactor according to Claim 2, characterized in
20 that the mixing element (7) comprises impervious plates
which have an area which corresponds to at least 40% of
the cross-sectional reactor area.
4. Reactor according to Claim 2 or 3, characterized
25 in that the plates are arranged in a layered manner,
the mixing element (7) comprising at least 3 plate
layers.
5. Reactor according to Claim 4, characterized in
30 that the plate distance is 1 cm to 100 cm.
6. Reactor according to at least one of the preceding
claims, characterized in that the catalyst (6) is
configured areally in the reactor, the area being
35 arranged such that the area is flowed through by the
gas at an angle in the range of 70 to 110°.
7. Reactor according to Claim 6, characterized in that

- 20 -

the catalyst (6) comprises at least one mesh which comprises platinum.

8. Reactor according to at least one of Claims 2 to 7, characterized in that the catalyst (6) configured areally in the reactor and the plates which are present in the mixing element (7) form an angle which is in the range of -10° to $+10^{\circ}$.

9. Reactor according to at least one of the preceding claims, characterized in that the gas-permeable intermediate layer (8) and the catalyst (6) configured areally in the reactor form an angle which is in the range of -10° to $+10^{\circ}$.

10. Reactor according to at least one of the preceding claims, characterized in that the gas-permeable intermediate layer (8) generates a pressure drop which is in the range of 5 to 100 mbar, measured by means of a U-tube manometer at a flow rate of the reactant gas mixture of 1.5 m/s.

11. Reactor according to at least one of the preceding claims, characterized in that the gas-permeable intermediate layer (8) comprises at least one metal mesh (9) arranged in the direction of the catalyst (6) and a layer of glass wool (10) which is arranged in the direction of the gas inlet region (4).

12. Reactor according to Claim 11, characterized in that the metal mesh (9) arranged in the intermediate layer has a nominal mesh width in the range of $1\text{ }\mu\text{m}$ to $200\text{ }\mu\text{m}$.

13. Reactor according to Claim 12, characterized in that the metal mesh (9) has a nominal mesh width in the range of $5\text{ }\mu\text{m}$ to $100\text{ }\mu\text{m}$.

14. Reactor according to at least one of Claims 11 to 13, characterized in that the metal mesh (9) and the layer of glass wool (10) are enclosed by two perforated sheets (11).

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15. Reactor according to at least one of the preceding claims, characterized in that the distance between the gas-permeable intermediate layer (8) and the catalyst (6) configured areally in the reactor is at least

10 30 mm.

16. Reactor according to at least one of the preceding claims, characterized in that the reactor vessel (2), viewed in flow direction of the gas from the intermediate layer (8) has an inner lining (12) of a heat-resistant material.

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17. Reactor according to at least one of the preceding claims, characterized in that a layer of a ceramic material (13) has been applied directly to the catalyst (6).

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18. Reactor according to at least one of the preceding claims, characterized in that the catalyst (6) rests on a support (14) which has been produced from ceramic.

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19. Reactor according to Claim 18, characterized in that the support (14) composed of ceramic has an upper ceramic support (15) and a lower ceramic support (16).

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20. Reactor according to at least one of Claims 18 and 19, characterized in that a metal mesh (17) is provided between the catalyst (6) and the support (14) composed of ceramic.

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21. Reactor according to at least one of Claims 1 to 17, characterized in that the catalyst (6) rests on a support (14) which comprises at least one metallic

- 22 -

support mesh (18) which has been applied on a support grid (19) composed of metal.

22. Reactor according to Claim 21, characterized in
5 that the support mesh (15) has a mesh width in the range of 1 mm to 50 mm.

23. Reactor according to at least one of the preceding claims, characterized in that the outlet of the
10 reaction products (5) comprises tube bundles (20) which are configured in the form of heat exchangers.

24. Reactor according to Claim 23, characterized in
15 that the tube bundles (20) are protected from the action of heat with ceramic elements (21) close to the reactor jacket.

25. Process for preparing HCN by the Andrussov process, characterized in that a reactor according to
20 Claims 1 to 24 is used.

26. Process according to Claim 25, characterized in
that the temperature of the gas in the region of the mixing element is at most 150°C.

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