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(57) **Abrégé/Abstract:**

An improved process is provided for the hydrogenation of nitrile rubber wherein the molecular weight increase during the hydrogenation process is minimized and controlled, the improvement being that the hydrogenation is undertaken in the presence in the solution of an NH₂-containing compound selected from ammonia and a C₁ to C₂₀ primary amine.



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AMINE MODIFIED HYDROGENATION OF NITRILE RUBBERAbstract of the Disclosure

30 An improved process is provided for the hydrogenation of nitrile rubber wherein the molecular weight increase during the hydrogenation process is minimized and controlled, the improvement being that the hydrogenation is undertaken in the presence in the solution of an NH_2 -containing compound selected from ammonia and a C_1 to C_{20} primary amine.

FIELD OF THE INVENTION

The present invention relates to an improved process for the production of hydrogenated nitrile rubber.

BACKGROUND OF THE INVENTION

It is well known that the carbon-carbon double bonds in polymers may be hydrogenated by treatment of the polymer with hydrogen in the presence of a number of catalysts. It is also well known that the carbon-carbon
10 double bonds in a nitrile rubber, the nitrile rubber being a polymer comprising a C_4-C_6 conjugated diolefin and a C_3-C_5 unsaturated nitrile, can be selectively hydrogenated, without significant hydrogenation of the $C\equiv N$ bonds, by treatment of the polymer with hydrogen in the presence of selected catalysts - for example, British Patent 1,558,491; U.S. Patents 3,700,637; 4,384,081; 4,464,515 and 4,503,196. The use of ruthenium catalysts for the hydrogenation of nitrile rubbers is described in U.S. Patents 4,631,315;
20 4,816,525 and 4,812,528.

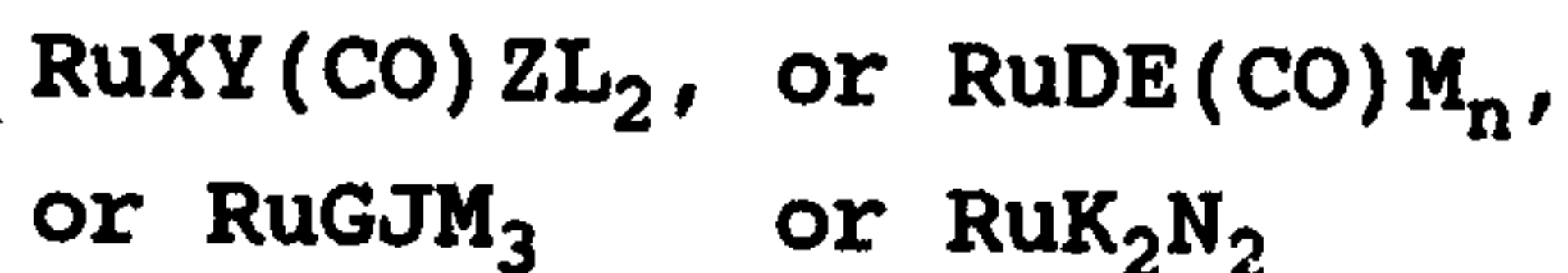
In the hydrogenation of nitrile rubbers, it has been found that the molecular weight of the polymer, as indicated by the measured intrinsic viscosity or the Mooney viscosity, increases--this molecular weight increase is believed to be due to a low level of interaction occurring between two or more polymer molecules. The increase in molecular weight varies with the nature of the catalyst, the solvent used in the hydrogenation process and the reaction conditions used
30 for the hydrogenation. The molecular weight increase is particularly noticeable when certain of the ruthenium catalysts are used and, in fact, under certain conditions the interaction between polymer molecules can

be such that the hydrogenated polymer contains gelled (crosslinked) or insoluble polymer. Although a slight increase in molecular weight can be tolerated, if the molecular weight of the hydrogenated polymer is too high this causes it to be of low acceptability by the manufacturer of the products, such as hoses, gaskets, etc., because it is difficult to handle such high molecular weight polymers on conventional equipment.

Accordingly, the present invention is directed to
 10 an improved process wherein the molecular weight increase in the hydrogenation process is minimized and controlled.

SUMMARY OF THE INVENTION

The present invention provides an improved process for the production of hydrogenated nitrile rubber wherein a nitrile rubber which is a polymer comprising a conjugated C₄-C₆ diolefin and a C₃-C₅ unsaturated nitrile is hydrogenated while in solution in the presence of a divalent ruthenium catalyst selected from
 20 compounds of the general formula



wherein X is selected from a halogen atom or a carboxylate group, Y is selected from a halogen atom, a hydrogen atom, a phenyl group, a carboxylate group or a phenylvinyl group, Z is selected from CO, pyridine, benzonitrile or no ligand and L is selected from the phosphine ligands of the general formula PR₃

in which R is selected from alicyclic or alkyl groups, n
 30 is 2 or 3 and when n is 3 D is a halogen atom and E is a hydrogen atom and when n is 2 D is selected from a halogen atom or a carboxylate group, E is selected from a halogen atom, a hydrogen atom, a phenyl group or a

carboxylate group, and M is selected from the phosphine ligands of the formula PA_3 in which A is a phenyl group or a C_1 to C_4 alkyl group or mixtures thereof, G is selected from a halogen atom or a hydrogen atom, J is selected from a halogen atom or a carboxylate group, K is a carboxylate group and N is triphenylphosphine, the improvement being that the hydrogenation is undertaken in the presence of an NH_2 -containing compound selected from ammonia and a C_1 to C_{20} primary amine in the
 10 solution.

DETAILED DESCRIPTION

The nitrile rubber which is hydrogenated in the process of this invention is a polymer comprising a conjugated C_4 - C_6 diolefin and a C_3 - C_5 unsaturated nitrile. The conjugated C_4 - C_6 diolefin is selected from butadiene, isoprene, piperylene and 2,3-dimethyl butadiene, with butadiene and isoprene being preferred and butadiene being most preferred. The conjugated
 20 diolefin forms from about 50 to about 85 per cent by weight of the polymer. The C_3 - C_5 unsaturated nitrile is selected from acrylonitrile, methacrylonitrile and ethacrylonitrile, with acrylonitrile being most preferred and forms from about 15 to about 50 per cent by weight of the polymer. The polymer may also contain a small amount, that is from about 1 to about 10 per cent by weight of the polymer, of an unsaturated carboxylic acid selected from fumaric acid, maleic acid, acrylic acid and methacrylic acid and the conjugated
 30 diolefin forms from about 40 to about 84 per cent by weight of the polymer. The nitrile rubber has a molecular weight, as expressed by the Mooney viscosity (ML 1+4 at 100°C) of from about 25 to about 70. A preferred nitrile rubber is a butadiene-acrylonitrile

polymer having an acrylonitrile content of from about 25 to about 45 per cent by weight and having a Mooney viscosity (ML 1+4 at 100°C) of from about 25 to about 60.

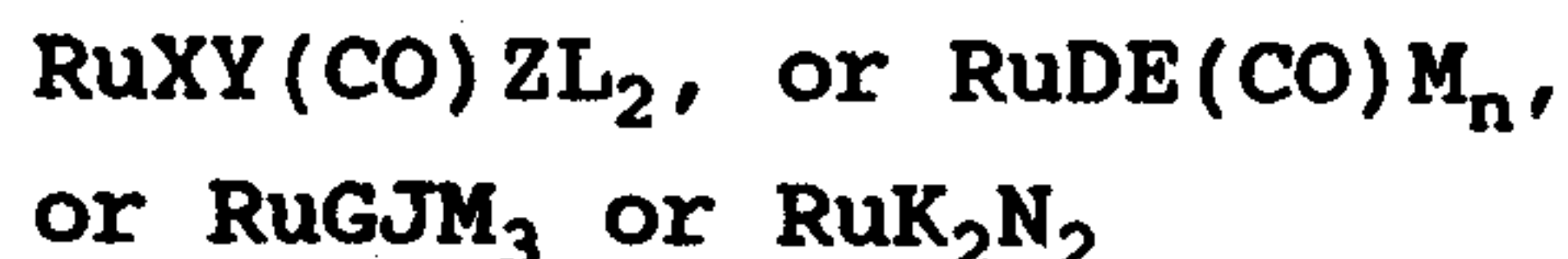
Suitable solvents for the hydrogenation process include the aryl compounds such as benzene, toluene, xylene, monochlorobenzene and dichlorobenzene, with monochlorobenzene being most preferred, aliphatic ethers such as tetrahydrofuran and dioxane, and aliphatic
10 ketones such as methyl ethyl ketone, or mixtures of solvents such as monochlorobenzene and methyl ethyl ketone.

Hydrogen is provided as essentially pure dry gas at a pressure of from about 25 kg/cm² (355 psi) to about 100 kg/cm² (1420 psi).

The hydrogenation reaction is undertaken in a suitable reaction vessel equipped with a temperature regulating means and an agitator. The polymer solution is added to the reaction vessel, any necessary degassing
20 is undertaken, and either the catalyst, pure or in solution, is added followed by pressurizing with hydrogen or the vessel is pressurized with hydrogen and the catalyst, pure or in solution, is added. The reactor is heated to the desired temperature at a suitable point following the addition of the polymer solution. Temperatures for the hydrogenation are from about 80° to about 200°C, preferably from about 100°C to about 155°C. Hydrogen may be added to the reactor during the hydrogenation and the reaction is complete
30 within about 2 to about 24 hours, although when the preferred catalysts are used the reaction time is from about 2 to about 8 hours. The degree of hydrogenation may be controlled by control of one or more of the

reaction time, temperature or hydrogen pressure, preferably reaction time. On completion of the reaction, the reaction vessel is vented and the polymer recovered by contact with hot water/steam or an alcohol followed by drying.

The divalent ruthenium catalyst used in the process is selected from compounds of the general formula



- 10 wherein X is selected from a halogen atom or a carboxylate group, preferably is a halogen atom and most preferably is chlorine; Y is selected from a halogen atom, a hydrogen atom, a phenyl group, a carboxylate group or a phenylvinyl group, preferably is a chlorine atom or a hydrogen atom and most preferably is a hydrogen atom; Z is selected from CO, pyridine, benzonitrile or no ligand; L is selected from phosphine ligands of the general formula PR_3 wherein R is selected from alicyclic or alkyl groups. A preferred alicyclic
- 20 group is cyclohexyl. The alkyl group is preferably selected from isopropyl, tertiary butyl and secondary butyl. Preferably R is cyclohexyl. n is 2 or 3 and when n is 3 D is a halogen atom and E is a hydrogen atom and when n is 2 D is selected from a halogen atom or a carboxylate group; E is selected from a halogen atom, a hydrogen atom, a phenyl group or a carboxylate group, preferably a halogen atom or a hydrogen atom; M is selected from the phosphine ligands of formula PA_3 in which A is a phenyl group or a C_1 to C_4 alkyl group or
- 30 mixtures thereof; G is selected from a halogen atom or a hydrogen atom; J is selected from a halogen atom or a carboxylate group; K is a carboxylate group and N is triphenylphosphine.

Specific examples of suitable divalent ruthenium catalysts include carbonylchlorohydrido bis (tricyclohexylphosphine) ruthenium (II), carbonylchlorohydrido bis (trisopropylphosphine) ruthenium (II), carbonylchloro benzoato bis(triphenylphosphine) ruthenium (II), carbonylchlorohydrido tris (triphenylphosphine) ruthenium (II), and dichloro tris (triphenylphosphine) ruthenium (II).

10 The concentration of the ruthenium catalyst in the solution is not critical and usually is within the range of from about 0.015 to about 2 per cent by weight of the nitrile rubber. For economic reasons it is desirable to minimize the concentration of the ruthenium catalyst and accordingly it is preferably used within the range of from about 0.015 to about 0.15 per cent by weight of the nitrile rubber.

20 The improved process of this invention requires the presence, during the hydrogenation, of an NH_2 -containing compound selected from ammonia and a C_1 to C_{20} primary amine. The NH_2 -containing compound is present in the solution during the hydrogenation process--that is to say, it can be added to the reactants at any convenient stage before the hydrogenation reaction is initiated. When the NH_2 -containing compound is ammonia it is used as the essentially dry, essentially pure material, either gaseous or liquid although gaseous is preferred for control purposes. Suitable primary amines are selected from the primary amines of the formula

30 R-NH_2 where R is selected from C_1 to C_{20} alkyl groups which may be linear or branched, C_6 to C_{12} alicyclic groups, C_6 to C_9 aryl groups, C_7 to C_{10} aralkyl groups and fused ring groups such as adamantane. Examples of

suitable amines include compounds where R is methyl, ethyl, n-butyl, sec-butyl, tert-butyl, amyl, iso-amyl, octyl, dodecyl, tetradecyl, octadecyl and mixtures thereof, cyclohexyl and cyclooctyl, phenyl and tolyl, and benzyl and methyl substituted benzyl. Preferred primary amines include the C₄ to C₂₀ alkyl primary amines and cyclohexylamine present at a concentration of from about 0.4 to about 1 parts by weight per 100 parts by weight of nitrile rubber.

10 The concentration in the reactor of the ammonia is from about 0.1 to about 0.3, preferably from about 0.15 to about 0.25 parts by weight per 100 parts by weight of nitrile rubber and of the primary amine is from about 0.2 to about 3, preferably from about 0.4 to about 1, parts by weight per 100 parts by weight of nitrile rubber. The presence of the NH₂-containing compound during the hydrogenation process leads to the production of a hydrogenated nitrile rubber which has an acceptably small increase in the molecular weight compared to that
20 of the original nitrile rubber. The molecular weight may be measured as the Mooney viscosity determined at 125°C (ML 1+4 at 125°C) or as the intrinsic viscosity determined at 35°C in monochlorobenzene. In the absence of the NH₂-containing compound or in the presence of a secondary or tertiary amine the hydrogenation process yields a polymer having a significantly increased molecular weight compared to the molecular weight of the original nitrile rubber.

30 The following examples illustrate the scope of the invention and are not intended to limit the same.

EXAMPLES

Example 1

A 300 ml glass lined stainless steel autoclave

equipped with temperature control means, an agitator and solution and hydrogen gas addition points was used. A butadiene-acrylonitrile nitrile rubber having a bound acrylonitrile content of about 38 weight per cent and a Mooney viscosity (ML 1+4 at 125°C) of about 29 was used at a concentration of about 9.3 weight per cent in chlorobenzene. The catalyst used was carbonylchlorohydrido bis (tricyclohexylphosphine) ruthenium (II) at a concentration in the reactor of about 0.05 weight per cent based on the nitrile rubber. Hydrogen was added to the reactor to a total pressure of about 56.3 kg/cm² (800 psi). The amine of the type and in the quantity shown in Table I was added to the reactor. The reaction temperature was about 145°C. The reaction time was between 4 and 8 hours. The results in Table I clearly show that primary amines do not significantly interfere with the hydrogenation reaction and that the hydrogenated nitrile rubber has not significantly increased in molecular weight, as shown by the intrinsic viscosity, compared to when no amine or when secondary or tertiary amines are used. An intrinsic viscosity of about 1.5 approximately corresponds to a Mooney viscosity (ML 1+4 at 125°C) of about 55 and an intrinsic viscosity of about 1.9 approximately corresponds to a Mooney viscosity of about 100.

TABLE I

Exp't. No.	Amine Type	Amine Conc.	Reaction Time	% Hydrog.	Intrinsic Viscosity
1	-	-	4	99+	1.93
2	A	0.39	5	99+	1.66
30 3	A	0.78	6	99+	1.56
4	A	1.17	7	99+	1.51
5	B	0.6	6	99+	1.56
6	C	0.7	8	98	1.48
7	D	0.77	6	99+	1.78
8	E	0.73	4	99+	1.93

Notes: Amine Type

A = octylamine, B = hexylamine, C = n-butylamine,
D = di-butylamine, E = triethylamine

Amine Conc.

Concentration of amine, weight per cent based on nitrile rubber.

% Hydrog.

10 Per cent hydrogenation of C=C bonds in nitrile rubber, determined by infra-red spectroscopy and ^1H NMR spectroscopy.

Intrinsic Viscosity

Measured at 35°C in chlorobenzene using the Ubbelohde method; shown as dL/g.

Example 2

20 The equipment and procedure was the same as that used in Example 1. In this example the amines used were (Amine Type F) cyclohexylamine and (Amine Type G) morpholine and the results are shown in Table II.

TABLE II

Exp't. No.	Amine Type	Amine Conc.	Reaction Time	% Hydrog.	Intrinsic Viscosity
10	-	-	4	99+	1.93
11	F	0.85	6	99+	1.50
12	F	0.6	6	99+	1.58
13	G	0.6	4	99+	2.03

The results show that the molecular weight of the polymer is not significantly increased in the presence of the primary amine during the hydrogenation reaction.

30 Example 3

A two gallon reactor was used. The nitrile rubber was the same as that used in Example 1 and was used as a 9.3 per cent solution in chlorobenzene. The same catalyst as in Example 1 was used at a

concentration of about 0.07 weight per cent based on nitrile rubber. Hydrogen was added to a pressure of about 84.5 kg/cm² (1200 psi). The amine used was dodecylamine. The reaction temperature was 145°C. The results are shown in Table III with the molecular weight being shown as the Mooney viscosity (ML 1+4 at 125°C) for polymer samples recovered by contact with steam/hot water and subsequently dried.

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TABLE III

Exp't. No.	Amine Conc.	Reaction Time	% Hydrog.	Mooney Viscosity
20	0.78	5	99.5+	49.5
21	1	4.5	99.5+	50
22	1.5	5	99.5+	50
23	2	5	99.3	48.5
24	0.4	4	99.5+	71
25	0.1	6	99.5+	93
26	0	4	99.5+	100

Example 4

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Using the procedure and nitrile rubber described in Example 1 except that the nitrile rubber concentration was 3 weight per cent, additional catalyst systems were studied. The primary amine used was cyclohexylamine at a concentration of 3 weight per cent based on the nitrile rubber in Experiments 31, 32 and 33, Experiment 30 being a control with no added amine. The solvent was monochlorobenzene, the reaction temperature was 140°C and the hydrogen pressure was 42.2 kg/cm² for Experiments 30, 31 and 32 and 56.3 kg/cm² for Experiment 33. The catalysts used were for Experiments

30

30 and 31 carbonylchloro benzoato bis(triphenylphosphine) ruthenium II, for Experiment 32 carbonylchlorohydrido tris(triphenylphosphine) ruthenium II and for Experiment 33 dichloro tris(triphenyl-

phosphine) ruthenium II. The results are shown in Table IV.

TABLE IV

Exp't. No.	Catalyst Conc.	Reaction Time	% Hydrog.	Intrinsic Viscosity
30	0.5	0.25	nd	nd
31	0.5	10	96.5	1.79
32	0.6	20	89.5	nd
33	0.5	22	92	nd

10 In Experiment 30, the product was a gelled mass. For Experiments 32 and 33, the intrinsic viscosities were not determined but are believed to be of a similar order to that for Experiment 31.

Example 5

Using the procedure described in Example 1, additional amines were tested. The materials and conditions used were as described and the results are shown in Table V.

TABLE V

20	Exp't. No.	Amine Type	Amine Conc.	Reaction Time	% Hydrog.	Intrinsic Viscosity
	40	H	0.35	5	99+	1.62
	41	H	0.7	7	97.2	1.46
	42	I	0.7	6	99+	1.59
	43	J	0.75	6	99+	1.58
	44	K	0.37	3.5	99+	1.73
	45	K	0.75	5	99+	1.52

Amine Type - H = aniline, I - benzylamine,
J = isoamylamine, K = tert-butylamine

Example 6

30 Using the procedure and conditions described in Example 3, further amines were tested with the results shown in Table VI.

TABLE VI

Exp't. No.	Amine Type	Amine Conc.	Reaction Time	% Hydrog.	Mooney Viscosity
50	L	0.78	8.5	99.3	64
51	M	0.78	2	99.5+	66

Amine Type - L = stearyl amine product, commercially available as Kemamine P-900D, believed to contain about 5% C₁₆ amine, about 93% stearylamine and about 2% C₂₀ amine.

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M = hydrogenated tallow amine, commercially available as Kemamine P-970D, believed to contain about 5% C₁₄ amine, 30% C₁₆ amine, about 65% stearylamine.

Example 7

Using the materials and procedure described in Example 1, ammonia was used as the NH₂-containing compound. After the reactor and contents had been purged with hydrogen, ammonia was added to a concentration of 0.19 weight per cent based on the nitrile rubber. The results are shown in Table VII from which it is clear that ammonia does not significantly interfere with the hydrogenation reaction and that the hydrogenated nitrile rubber has not significantly increased in molecular weight.

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TABLE VII

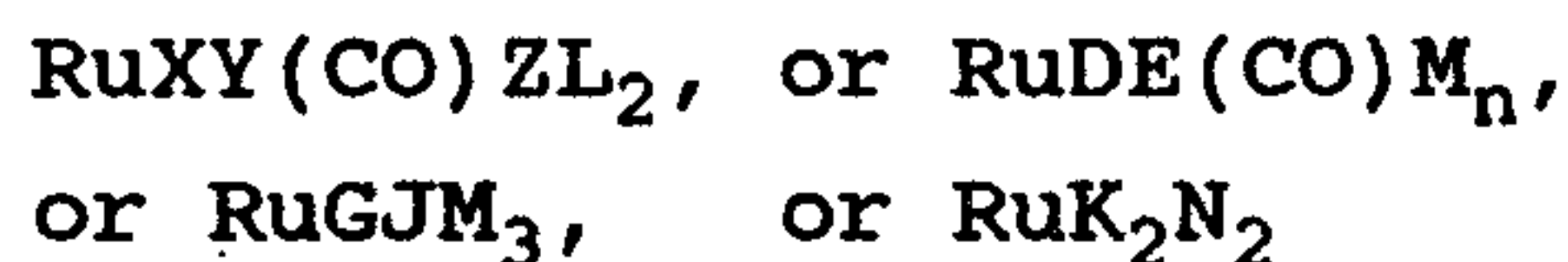
Exp't No.	Reaction Time	% Hydrog.	Intrinsic Viscosity
60	6.5	99.1	1.58
61	7	99.2	1.53

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*Trademark

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An improved process for the production of hydrogenated nitrile rubber wherein a nitrile rubber which is a polymer comprising a conjugated C₄-C₆ diolefin and a C₃-C₅ unsaturated nitrile is hydrogenated while in solution in the presence of a divalent ruthenium catalyst selected from compounds of the
 10 general formula



- wherein X is selected from a halogen atom or a carboxylate group, Y is selected from a halogen atom, a hydrogen atom, a phenyl group, a carboxylate group or a phenylvinyl group, Z is selected from CO, pyridine, benzonitrile or no ligand and L is selected from the phosphine ligands of the general formula PR₃ in which R is selected from alicyclic or alkyl groups, n is
 20 selected from 2 or 3 and when n is 3 D is a halogen atom and E is a hydrogen atom and when n is 2 D is selected from a halogen atom or a carboxylate group, E is selected from a halogen atom, a hydrogen atom, a phenyl group or a carboxylate group and M is selected from the phosphine ligands of the formula PA₃ in which A is a phenyl group or a C₁ to C₄ alkyl group or mixtures thereof, G is selected from a halogen atom or a hydrogen atom, J is selected from a halogen atom or a carboxylate group, K is a carboxylate group and N is
 30 triphenylphosphine, the improvement being that the hydrogenation is undertaken in the presence of an NH₂-containing compound selected from ammonia and a C₁ to C₂₀ primary amine.

2. The process of Claim 1 wherein the NH₂-containing

compound is a primary amine selected from the C₁ to C₂₀ alkyl primary amines.

3. The process of Claim 1 wherein the NH₂-containing compound is a primary amine selected from the C₆ to C₁₂ alicyclic primary amines.

4. The process of Claim 1 wherein the NH₂-containing compound is a primary amine selected from the C₆ to C₉ aryl primary amines.

10 5. The process of Claim 1 wherein the NH₂-containing compounding is a primary amine selected from the C₇ to C₁₀ aralkyl primary amines.

6. The process of Claim 1 wherein the NH₂-containing compound is ammonia.

7. The process of Claim 1 wherein the NH₂-containing compound is a primary amine present at a concentration of from about 0.2 to about 3 parts by weight per 100 parts by weight of the nitrile rubber.

20 8. The process of Claim 1 wherein the NH₂-containing compound is ammonia present at a concentration of from about 0.1 to about 0.3 parts by weight per 100 parts by weight of the nitrile rubber.

9. The process of Claim 2 wherein the primary amine is a C₄ to C₁₂ alkyl primary amine present at a concentration of from about 0.4 to about 1 parts by weight per 100 parts by weight of the nitrile rubber.

10. The process of Claim 3 wherein the primary amine is cyclohexylamine present at a concentration of from about 0.4 to about 1 parts by weight per 100 parts by weight of the nitrile rubber.

30 11. The process of Claim 1 wherein the nitrile rubber is in solution in a solvent selected from benzene, toluene, xylene, chlorobenzene and dichlorobenzene and the hydrogen pressure is from about 25 to about 100 kg/cm².

12. The process of Claim 1 wherein the divalent ruthenium catalyst is selected from carbonylchlorohydrido tris (triphenylphosphine) ruthenium II and dichloro tris (triphenylphosphine) ruthenium II.
13. The process of Claim 1 wherein the divalent ruthenium catalyst is selected from carbonylchlorohydrido bis (tricyclohexylphosphine) ruthenium II and carbonylchlorohydrido bis (tri-
10 isopropylphosphine) ruthenium II.
14. The process of Claim 12 wherein the NH_2 -containing compound is an amine selected from a C_4 to C_{12} alkyl primary amine and cyclohexylamine and is present at a concentration of from about 0.4 to about 1 parts by weight per 100 parts by weight of nitrile rubber.
15. The process of Claim 13 wherein the NH_2 -containing compound is an amine selected from a C_4 to C_{12} alkyl primary amine and cyclohexylamine and is present at a concentration of from about 0.4 to about 1 parts by
20 weight per 100 parts by weight of nitrile rubber.
16. The process of Claim 12 wherein the NH_2 -containing compound is ammonia and is present at a concentration of from about 0.15 to about 0.25 parts by weight per 100 parts by weight of nitrile rubber.
17. The process of Claim 13 wherein the NH_2 -containing compound is ammonia and is present at a concentration of from about 0.15 to about 0.25 parts by weight per 100 parts by weight of nitrile rubber.
18. The process of Claim 1 wherein the nitrile rubber
30 is a polymer containing from about 50 to about 85 weight per cent of butadiene or isoprene and from about 15 to about 50 weight per cent of acrylonitrile.
19. The process of Claim 1 wherein the nitrile rubber is a polymer containing from about 40 to about 84 weight

per cent of butadiene, from about 15 to about 50 weight per cent of acrylonitrile and from about 1 to about 10 weight per cent of an unsaturated carboxylic acid selected from fumaric acid, maleic acid, acrylic acid and methacrylic acid.

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