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IMPROVEMENT OF NICKEL CATALYST FOR ENANTIOFACE-DIFFERENTIATING (ASYMMETRIC) HYDROGENATION OF METHYL ACETOACETATE

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Among the factors affecting the optical yield of hydrogenation of methyl acetoacetate to optically active methyl 3-hydroxybutyrate with tartaric acid-modified nickel catalysts, the presence of aluminium or related metal compound on the catalysts was found to be the unfavorable one. The use of reduced nickel oxide instead of Raney nickel resulted in a good optical yield (maximum optical yield, 85%).

Many features of enantioface-differentiating hydrogenation of methyl acetoacetate (MAA) to optically active methyl 3-hydroxybutyrate (MHB) over Raney nickel modified with optically active substance (MRNi) have been made clear by a series of studies$^{1)}$. As for preparative conditions of Raney nickel, a high leaching temperature and heavy water-washing are preferable. The Raney nickel modified at 100°C with a 1% tartaric acid solution adjusted to pH 5 with sodium hydroxide showed a fairly good enantioface-differentiating ability. The optical yield was 46% on an average$^{2)}$. On the other hand, when the modifying solution was adjusted to pH 5 with sodium aluminate, the resulting tartaric acid-MRNi showed poor enantioface-differentiating ability

Gross and Rys reported that the optical yield was the lowest with the Raney nickel containing larger amount of aluminium (W-6 type) and the highest with the one containing lower amount of aluminium (W-1 type)$^{3)}$.

Orito and coworkers have recently developed an excellent catalyst, Ni-Pd/support, for the enantioface-differentiating hydrogenation of MAA. A higher optical yield was reported with a tartaric acid modified Ni-Pd/kieselguhr than with a tartaric acid modified Ni-Pd/alumina$^{4)}$.

All facts mentioned above suggested that aluminium derivatives on the catalyst may decrease the enantioface-differentiating ability of the modified catalyst.

Since the complete elimination of aluminium from Raney nickel is practically impossible, we turned to use aluminium-free catalysts. The use of either Urushibara Ni (A type) or activated nickel powder prepared from Ni-Mg or Ni-Si alloy resulted in a low optical yield. On the other hand, the use of activated nickel powder prepared by either thermal decomposition of nickel formate or hydrogenolysis of nickel oxide resulted in a considerably high optical yield.

The poor results by the use of the catalyst activated by the wet process showed that the exclusion of aluminium or related metal compounds from the catalyst surface is an essential factor for for obtaining a high enantioface-differentiating catalyst.

As for the activated nickel prepared by dry process, the best result was obtained by the use of reduced nickel oxide.

Further improved optical yields were obtained with modified reduced nickel oxide by using a solvent and an additive as shown by Orito and coworkers$^{4)}$. Thus the use of THF or methyl propionate with a small amount of acetic acid resulted in a high optical yield with good reproducibility. The results are summarized in Table 1.

Table 1 Enantioface-differentiating hydrogenation of MAA with tartaric acid-modified nickel catalysts

Source of activated Ni	Modifying conditions		Reaction conditions					Optical[a] yield
	pH	Temp. (°C)	Amount of modified Ni(g)	MAA (ml)	Solvent /(ml)	Additive /(ml)	Temp. (°C)	(%)
Raney alloy	5.0	100	0.6	17.5	neat	-	60	46
Raney alloy	5.0[b]	100	0.6	17.5	neat	-	60	31
Ni-Mg alloy[c]	5.0	100	0.6	17.5	neat	-	60	6
Ni-Si alloy[d]	5.0	100	0.6	17.5	neat	-	60	46
Urushibara Ni-A	4.1	85	1.0	11.5	THF/23	AcOH/0.2	100	4
$Ni(HCO_2)_2\cdot 2H_2O$	5.0	100	0.6	17.5	neat	-	100	57
NiO[e]	5.0	100	0.6	11.5	THF/23	AcOH/0.2	120	83
NiO[e]	5.0	100	0.6	17.5	neat	-	100	61
NiO[e]	4.1	85	0.8	11.5	THF/23	AcOH/0.2	100	79-85
NiO[f]	4.1	85	0.8	11.5	$EtCO_2Me$ /23	AcOH/0.2	120	85
NiO[f]	4.1	85	0.8	11.5	THF/23	AcOH/0.2	120	82

a) Optical yield was calculated based on the value of $[\alpha]_D^{16}$=22.05 for optically pure MHB.

b) The pH of modifying solution was adjusted with $NaAlO_2$ instead of NaOH.

c) The alloy was leached with a 3% tartaric acid solution.

d) The alloy was leached with a 5% NaOH solution.

e) NiO was supplied by Wako Pure Chemical Industries, Ltd.

f) NiO was supplied by Mitsuwa Pure Chemicals, Ltd.

The typical experimental conditions are as follows. One gram of greenish NiO (Mitsuwa Pure Chemicals, Ltd.) was reduced for 1 hr at 350°C under 8 l/hr of hydrogen stream. The resulting grayish powder (0.8g) was soaked for 1 hr at 85°C in 100ml of 1% tartaric acid solution adjusted to pH 4.1 with N sodium hydroxide. After removal of the solution by decantation, the modified catalyst was washed successively with a 10ml portion of water, two 50ml portions of methanol, and a 25ml portion of methyl propionate. MAA (11.5ml) in 23ml of methyl propionate and 0.2ml of acetic acid was hydrogenated with 0.8g of the modified catalyst under 110kg/cm^2 of initial hydrogen pressure at 120°C for overnight. After removal of the catalyst, fractional distillation gave 6.3g of MHB, bp 68-70°C/20 mmHg, $[\alpha]_D$-18.76 (neat).

The use of simple metal catalyst may cut down various preparative variables and facilitate the understanding of reaction mechanism. Further investigations are now in progress.

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