

Unique and Convenient Use of Raney Nickel for the Reduction of Aryl Bromides, Benzyl Alcohols, Benzyl Ethers, and Benzylamines in an Acidic Medium

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A simple and convenient method for laboratory-scale reduction using Raney nickel is described. The reaction was achieved by the inclusion of sulfuric acid to a mixture of a substrate and Raney nickel. Using this method, several aryl bromides, benzyl alcohols, benzyl ethers, and benzylamines were cleaved at the carbon–bromine bond or at the benzylic position to afford corresponding hydrogenated products in good yields without the use of compressed hydrogen gas and without requiring any special apparatus.

Raney nickel (Ra/Ni) has been widely used for the catalytic reduction of a variety of organic compounds.¹ Accordingly, we have reported on two unique applications of Ra/Ni for the preparative-scale reduction of organic compounds. In the first application, Ra/Ni was employed as a cathode material for electro-

reduction in which a number of unsaturated organic compounds, such as ketones, aldehydes, Schiff's bases, nitriles, and nitro compounds were readily converted into corresponding hydrogenated products in good yields.² In the second application, several types of ketones, aldehydes, and olefinic compounds were reduced using Ra/Ni in the presence of sulfuric acid to afford corresponding alcohols or alkanes in excellent yields.³ In the case of ketones that have their carbonyl group directly to an aromatic nucleus, reduction using an excess amount of Ra/Ni resulted in corresponding hydrocarbons. Herein, the latter Ra/Ni–sulfuric acid method was applied for the reduction of several aryl bromides, benzyl alcohols, benzyl ethers, and benzylamines. It is well known that organic compounds that bear a benzyl group attached to an oxygen, nitrogen, or halogen tend to cleave at the benzylic position during hydrogenation via catalytic reduction⁴ or during a chemical reaction with sodium and mercury.⁵ Since Ra/Ni is soluble even in a weak acid, such as acetic acid, catalytic reduction using Ra/Ni is typically carried out under neutral or weakly basic conditions. To the best of our knowledge, there have been no reports that describe reductive cleavage utilizing hydrogen that is generated from Ra/Ni, itself, under strong acidic conditions. The results of the reduction of several aryl bromides, benzyl alcohols, benzyl ethers, and benzylamines are given in Table 1. The optimal reaction conditions listed in the table were determined separately for each substrate.

Although the reduction of aryl bromides (Entries 1 and 2) afforded the corresponding aromatic hydrocarbons in good yields, the reduction of octyl bromide failed to proceed under these conditions, even in the presence of excess Ra/Ni (Entry 3). In the cases of 1-phenylethanol and 1-phenylpentanol, the hydroxymethylene group was reduced to a methylene group, even at low temperatures (10 °C; Entries 5 and 6); in contrast, the reduction of benzhydrol required elevated temperatures (50 °C; Entry 7). Although benzyl octyl ether was readily hydrogenated using less than an equimolar amount of Ra/Ni (Entry 9), octyl 1-phenylethyl ether required a large excess of Ra/Ni and MeOH to advance the reaction (Entry 11). Further-

Table 1. Reduction of Aryl Bromides, Benzyl Alcohols, Benzyl Ethers, and Benzylamines

Entry	Substrate ^{a)}	Mol. ratio ^{b)}	Solvent/mL		Temp. °C	Product	Yield ^{c)} %
			H ₂ O	MeOH			
1	1-Bromonaphthalene	1.5	30	30	20	Naphthalene	93
2	4-PhCH ₂ C ₆ H ₄ -Br	2.5	10	70	40	PhCH ₂ Ph	90
3	<i>n</i> -C ₈ H ₁₇ -Br	3.0	5	50	50	<i>n</i> -C ₈ H ₁₈	(9)
4	PhCH(OH)CH ₃	0.6	50	0	10	PhC ₂ H ₅	(51)
5	PhCH(OH)CH ₃	1.2	50	0	10	PhC ₂ H ₅	81
6	PhCH(OH)- <i>n</i> -C ₄ H ₉	1.2	50	0	10	Ph- <i>n</i> -C ₅ H ₁₁	92
7	PhCH(OH)Ph	1.2	50	0	50	PhCH ₂ Ph	89
8	PhCH ₂ -O-Ph	2.0	30	70	40	PhOH	92
9	PhCH ₂ -O- <i>n</i> -C ₈ H ₁₇	0.8	20	50	30	<i>n</i> -C ₈ H ₁₇ OH	94
10	PhCH ₂ -O-CH(CH ₃)- <i>n</i> -C ₆ H ₁₃	1.0	20	50	30	<i>n</i> -C ₆ H ₁₃ CH(CH ₃)OH	93
11	PhCH(CH ₃)-O- <i>n</i> -C ₈ H ₁₇	4.0	5	95	50	<i>n</i> -C ₈ H ₁₇ OH	91
12	PhCH ₂ -NHPH	1.2	30	30	40	PhNH ₂	92
13	PhCH ₂ -N(<i>n</i> -C ₄ H ₉) ₂	1.2	30	30	40	(<i>n</i> -C ₄ H ₉) ₂ NH	85
14	PhCH ₂ -N(CH ₃)Ph	1.2	30	30	40	PhNHCH ₃	84

a) Substrate: 25 mmol. b) Ra/Ni (molar amount)/Substrate (mol). c) Isolated yields based on substrates. Value in parenthesis was determined by GLC analysis.

more, our results show that the amount of Ra/Ni has a significant effect on the yields of the products. For example, in the case of 1-phenylethanol, reducing the molar ratio of Ra/Ni from 1.2 to 0.6 resulted in a decreased yield of ethylbenzene from 81 to 51% (Entries 4 and 5) with unreacted substrate. It is interesting to note that, when dissolved completely by the addition of sulfuric acid, the evolved hydrogen gas from the Ra/Ni was approximately 1.5 times by volume as compared to that from an equal weight of ordinary nickel powder. As a note, in all cases the hydrogenation product of the aromatic moiety was not detected.

Although the details of the reaction mechanism of this reduction remain unclear, it can be suggested that the reaction proceeds by consuming both the adsorbed hydrogen on the Ra/Ni and the hydrogen generated by the reaction between Ra/Ni and sulfuric acid. Presumably, the hydrogen is activated on fresh nickel surfaces that are ceaselessly renewed during the reaction. In the initial stages of the hydrogenation, most of the substrates are adsorbed on the Ra/Ni surfaces. As the reaction proceeds, the substrates gradually react with the hydrogen formed between Ra/Ni and sulfuric acid to produce the corresponding hydrogenated products, along with the dissolution of Ra/Ni into nickel sulfate. In this reductive methodology, it can be said that Ra/Ni plays an important role not only as a catalyst, but also as the hydrogen source.

The advantages of this reduction method are that the reaction can be carried out without use of extraneous hydrogen, and does not require any counter-pressure apparatus, such as an autoclave at reaction temperatures lower than 50 °C. Overall, hydrogenated products were obtained in high yields by relatively simple handling procedures.

Experimental

All of the products were identified by comparing their physical and spectral data with those of authentic samples. Benzyl ethers and benzylamines were prepared according to typical Williamson syntheses⁶ and alkylation of amines,⁷ respectively. Other reagents were obtained from commercial suppliers, and were used without further purifications.

Typical Procedures for the Development of Ra/Ni. To a suspension of Raney nickel alloy (4.3 g; content of Ni, 50% w/w; Wako Pure Chemical Industries, Ltd.) in distilled water (40 mL) in a 200-mL round-bottomed flask was added sodium hydroxide (6.5 g). After allowing to stand for several minutes, the mixture

was cooled to room temperature, and then subsequently warmed in a water bath (70 °C) with occasional shaking for 30 min. The resulting Ra/Ni (approximately 2.15 g, 37 mmol) was washed with water (3 × 50 mL), and was used immediately.

Typical Procedures for the Reduction. In a 100- or 200-mL three-necked round-bottomed flask equipped with a reflux condenser and a dropping funnel, the substrate (25 mmol) was dissolved in the solvents and in the presence of Ra/Ni, as listed in Table 1. To the mixture, sulfuric acid was added dropwise using a dropping funnel over a period of ca. 2 h (60% w/w H₂SO₄ aq 12 mL per each 37 mmol of Ra/Ni). During the course of the reaction, the mixture was magnetically stirred to avoid the formation of any lumps. Ra/Ni was almost completely dissolved upon the addition of sulfuric acid; however, any solid residues were removed by filtration using suction. After saturating the filtrate with sodium chloride, the oily layer was extracted with ether (3 × 50 mL). The combined ether extracts were washed with aqueous sodium hydrogencarbonate (3% w/w, 30 mL) and dried over anhydrous magnesium sulfate. Upon removal of the ether solvent, the resulting residue was further purified by distillation under reduced pressure. In the cases where the product was an amine, the filtrate was alkalinized before extraction by the addition of aqueous sodium hydroxide (25% w/w), followed by an appropriate amount of saturated aqueous sodium chloride to avoid possible complications due to the formation of colloidal nickel hydroxide under basic conditions.

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