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Solvent-free reduction of aromatic nitro compounds with alumina-supported hydrazine under microwave irradiation

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Abstract—Aromatic nitro compounds are readily reduced to the corresponding amino compounds in good yield with hydrazine hydrate supported on alumina in the presence of $FeCl_3·6H_2O$, Fe(III) oxide hydroxide or Fe(III) oxides. Published by Elsevier Science Ltd.

Supported reagents on mineral oxide surfaces have been widely employed in organic synthesis.[1] Reagents immobilized on porous solid materials have several advantages over the conventional solution phase reactions because of the good dispersion of active sites leading to improved reactivity and milder reaction conditions. The solvent-free use of supported reagents in combination with microwave irradiation provide ideal reaction conditions with special attributes such as reduced reaction time, easier work-up procedure and enhanced selectivity and reactivity.[2] The recyclability of the inorganic solid support is often possible thus rendering the procedure relatively environmentally acceptable.

Aromatic amines are widely used as intermediates for dyes, photographic materials, pharmaceutical and agricultural chemicals and as antioxidants. They are generally prepared by reduction of aromatic nitro compounds using a vast array of reagents in solution phase reactions.[3] Hydrazine hydrate has been extensively used for reduction purposes in the presence of heterogeneous catalysts such as activated zinc–copper,[4] Zn–C,[5] Fe–C,[6] Pd–C,[7a–c] Pt–C,[7a,b] Raney Ni,[7b,8a–c] $FeCl_3·6H_2O$-activated carbon,[9a–d] Fe(III) oxides,[10a–c] Fe(III)–MgO,[11] graphite[12] and clays.[13] The reduction is usually conducted in refluxing alcoholic solvents or dioxane, a process that requires several hours of reaction time.

Herein, we report our results for a solvent-free microwave reduction protocol that leads to a facile preparation of aromatic amines from the corresponding nitro compounds with hydrazine hydrate supported on solid materials such as alumina, silica gel and clays. Some non-traditional solid support materials, such as NaCl, NaBr, NaI, KCl, KBr, KI, Na_2SO_4, K_2SO_4, $CaCO_3$ etc., which couple poorly with microwaves, have also been examined. Since only the supported reactants absorb the microwave energy, a variety of such chemically inactive supports can be utilized for the enhancement of organic reactions.[14]

Two series of experiments were performed to identify and optimize the ideal solid support material and the appropriate catalyst to affect the reduction of aromatic nitro compounds. First, the effect of supports on the reduction of 4-nitroaniline to 1,4-phenylenediamine was examined on various inorganic solid supports. The data presented in Table 1 clearly show the efficiency of alumina-supported hydrazine hydrate in the reduction of 4-nitroaniline in good yield. The traditional solid supports with soft acidic surface were found to be less effective, whereas non-traditional solid supports with soft basic or neutral surface are moderately effective. Some of them (K_2CO_3, NaI, KI) were chemically active and participated in the reaction that led to the generation of several by-products.

In the second series of experiments, the catalytic activity of some well-known catalysts was examined under solvent-free conditions using alumina as the solid support. Interestingly, Fe(III) chloride, Fe(III) oxide

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Keywords: reduction; hydrazine hydrate; nitro compounds; aromatic amines; microwave heating.

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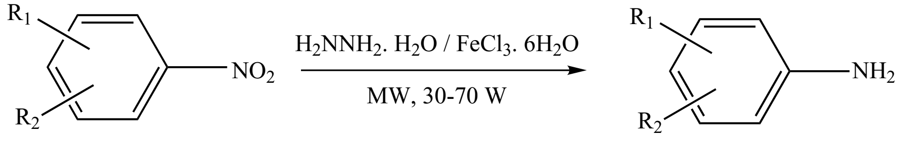
Table 1. Reduction of 4-nitroaniline with hydrazine on various inorganic solid supports in the presence of catalytic $FeCl_3 \cdot 6H_2O$ under microwave irradiation[a]



Supports surfaces	Final temperature (°C)	Conversion (%)	Yield (%)
Alumina	119–125	100	97
Silica gel	124–128	93	65
Florisil	138–142	95	64
K10	150–154	94	33
Talc	165–172	94	73
CaO	149–155	90	75
MgO	154–157	97	76
$CaCO_3$	156–161	94	70
K_2CO_3	142–146	30	20
NaCl	128–134	95	75
NaBr	150–154	95	71
NaI	171–176	80	20
KCl	146–149	96	72
KBr	154–159	96	76
KI	174–180	96	22
Na_2SO_4	168–173	100	55
K_2SO_4	158–164	100	56

[a] Microwave heating was programmed as follows: 3/30, 5/45, 2/75 (min/W).

hydroxide and Fe_3O_4 were found to be the most effective catalysts (Table 2). In contrast to earlier reports, it was found unnecessary to use activated carbon, since alumina ensured the high surface area.

Table 2. Reduction of 4-nitroaniline with various catalysts by alumina-supported hydrazine hydrate under microwave irradiation[a]

Catalyst	Yield (%)	Catalyst	Yield (%)
Without catalyst	0	$NiCl_2$	~5
Fe(III) chloride	97	$CoCl_2$	10
Fe(III) oxide hydroxide	91	$SnCl_2$	0
Fe_3O_4	78	K10 clay	0

[a] Microwave heating was programmed as follows: 3/30, 5/45, 2/75 (min/W).

The following is the general procedure employed for the reduction of nitro compounds. Aromatic nitro compound (10 mmol) was mixed with inorganic solid support or alumina (10 g) and the mixture was added to hydrazine hydrate (30 mmol) and $FeCl_3 \cdot 6H_2O$ (0.5 mmol).[15] The solid homogenized mixture was placed in a modified reaction tube which was connected to a removable cold finger and sample collector to trap excess hydrazine hydrate. The reaction tube was placed in a Maxidigest MX 350 (Prolabo) microwave reactor fitted with a rotational mixing system. After irradiation for a specified period (see Table 3), the contents were cooled to room temperature and the

Table 3. Microwave assisted reduction of aromatic nitro compounds with alumina-supported hydrazine hydrate and catalytic $FeCl_3 \cdot 6H_2O$

R_1	R_2	Microwave irradiation			Yield (%)
		Power (W)	Reaction time (min)	Temp. (°C)	
H	H	30+45	5+2	108	89
4-OCH_3	H	30+45	5+3	108	96
4-CH_3	H	30+45	5+2	108	89
4-Cl	H	30+45	4+2	112	96
4-I	H	30+45	4+4	108	91
3-OH	H	30+45	2+4	103	92
2-OH	H	30+45	6+2	110	81
2-NH_2	H	30+45	6+3	115	92
4-NH_2	H	30+45	3+5	119	97
2-NH_2	5-CH_3	45	6	111	96
2-NH_2	5-CF_3	45	10	116	83

product extracted into ethyl acetate (2×20 mL). The solid inorganic material was filtered and the solvent was removed under reduced pressure to afford the product that was further purified by crystallization.

In conclusion, a facile solvent-free method for reduction of aromatic nitro compounds to aromatic amines is developed. The reagent system described here may be a good alternative to well known methods since the reduction of aromatic nitro compounds proceeds expeditiously and in high yields.

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15. In control experiments with hydrazine hydrate without any support, we explored the reactions with catalytic $FeCl_3$ and obtained very modest yields of amines. Among the disadvantages are the formation of two phases which could not be efficiently mixed. Further, while heating beyond 70–80°C, intensive gas formation and bubbling was observed that rendered the reaction uncontrollable.