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Facile and Efficient Method for Preparation of Schiff Bases Catalyzed By P_2O_5/SiO_2 under Free Solvent Conditions

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ABSTRACT: *A simple and convenient method for the preparation of Schiff bases is developed. In this method, the Schiff base compounds were prepared from the reaction of carbonyl compounds with primary amines. In this reaction, P_2O_5/SiO_2 have catalyzed the Schiff base formation in dry media under solvent-free conditions. Advantages of this method are use of an inexpensive and efficient catalyst, high yields of products, short reaction times, and simplicity of the reaction and workup.* © 2008 Wiley Periodicals, Inc. Heteroatom Chem 19:43–47, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/hc.20383

INTRODUCTION

The Schiff base ligands and their complexes have significant importance in chemistry, and every year a number of reports are published on the preparation of these compounds and their application in chemical reactions [1].

These ligands represent one of the most widely utilized classes of ligand in metal coordination chemistry [2]. The Schiff base compounds and their complexes are widely applied in enantioselective cyclopropanation of styrenes [3], asymmetric addition of cyanide to aldehydes [4], asymmetric aziridination of olefins [5], enantioselective epoxidation [5,6], regio-selective ring opening of epoxides [7], and as a membrane in ion selective electrode [8–12].

Schiff base compounds containing imine group ($-RC{=}N-$) are usually formed by the condensation of a primary amine and diamine with an active carbonyl compound in a methanol solvent [13]. These methods have not been entirely satisfactory owing to a number of drawbacks such as low yields, long reaction time [14], and tedious workup.

Over the past few years, significant research has been directed toward the development of new technologies for environmentally benign processes (green chemistry) [15], which are both economically and technologically feasible [16,17]. An important area of green chemistry deals with solvent minimization. A solvent-free or solid-state reaction may be carried out by using the reactants alone or incorporating them in clays, zeolites, silica, alumina, or other matrices [18]. In recent years, β-zeolite [19], montmorillonite clays [20], SiO_2, and Al_2O_3 were employed as catalysts for this purpose to obtain relatively better results.

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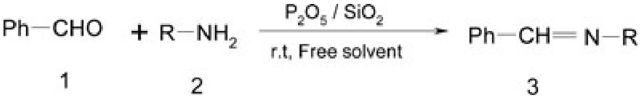


SCHEME 1

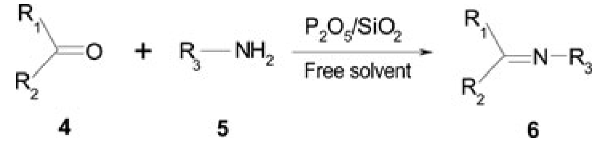
Although some of these methods represent a convenient procedure with good to high product yields, we hope to report a procedure using P_2O_5/SiO_2 as a catalyst for the preparation of Schiff bases in the absence of a solvent under mild conditions.

RESULTS AND DISCUSSION

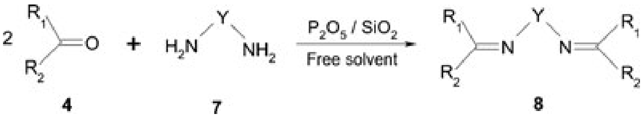
The carbonyl compound was treated with the primary amine in the presence of P_2O_5 supported on SiO_2 as a catalyst without a solvent by grinding. For the first time, in this reaction, 1 mol benzaldehyde was reacted with 1 mol aliphatic or aromatic primary amine in the presence of P_2O_5/SiO_2 at room temperature under solvent-free conditions (Scheme 1).

The results are indicated in Table 1. As shown in Table 1, a series of Schiff bases were synthesized using P_2O_5/SiO_2 as a catalyst in solvent-free media. We were pleased to find that the reaction of different amines with benzaldehyde was obtained as the corresponding Schiff bases in good to excellent yields in a shorter time, using P_2O_5/SiO_2 than some of the previously reported methods [21–27]. In comparison, the reaction of benzaldehyde with 4-nitroaniline in the absence of a catalyst is given at entry 12 in Table 1. As can be seen, the yield of reaction without a catalyst was very low and the reaction time was very long.

Then, to study the development of this method, various carbonyl compounds with diamines and monoamines were treated in the presence of



SCHEME 2



SCHEME 3

P_2O_5/SiO_2 as a catalyst (Scheme 2 and Scheme 3). The results of such studies are in Table 2 and Table 3.

As shown in Table 2, the yields of the reactions with this new method for the preparation of various Schiff bases are quite fair, and the reaction time is very short. At the entry 5, Table 2, the reaction of benzophenone with *p*-bromo-aniline occurred in low yield and long reaction time. This low reactivity may be related to steric hindrance in the carbonyl compound and electron withdrawing of a bromine atom from the aromatic ring of amine. It is of great importance that the reaction is largely affected by the P_2O_5/SiO_2 catalyst.

To study the effect of catalyst in this method, the reaction in the presence of P_2O_5/SiO_2 catalyst with the same one without a catalyst has been compared (e.g., compare entries 4, 5, and 6 vs. 7, 8, and 9, respectively, in Table 3). However, the reaction products were obtained in very low yield in the absence of a catalyst in methanol solvent under reflux condition, even after extending the reaction time to several days.

TABLE 1 The Reaction of Benzaldehyde with Various Amines Catalyzed by P_2O_5/SiO_2 at Room Temperature

Entry	*Amine Substrate* (**2**) *R*	*Time (min)*	*Product* (**3**)	*Yield (%)*[a]
1	C_6H_{11}	20	**a**	85
2	$CH(CH_3)_2$	25	**b**	80
3	Allyl	25	**c**	90
4	Ph	30	**d**	80
5	3-Me-C_6H_4	35	**e**	82
6	4-Me-C_6H_4	30	**f**	85
7	3-Cl-C_6H_4	40	**g**	79
8	4-Cl-C_6H_4	42	**h**	77
9	3-NO_2-C_6H_4	45	**i**	70
10	4-NO_2-C_6H_4	45	**j**	75
11	4-Br-C_6H_4	40	**k**	78
12[b]	4-NO_2-C_6H_4	>180	–	10[c]

[a] Isolated yield based on benzaldehyde.
[b] In absence of catalyst.
[c] Yield obtained by ^{1}H NMR.

TABLE 2 Preparation of Schiff Bases from Various Carbonyl Compounds and Primary Amines

	Carbonyl Compound (**4**)		*Primary Amine* (**5**)				
Entry	R_1	R_2	R_3	*Reaction Condition* (°*C*)	*Time (min)*	*Product* (**6**)	*Yield (%)*[a]
1	4-NO_2-C_6H_4	H	CH_2Ph	RT	45	**a**	75
2	Ph	CH_3	CH_2Ph	100	60	**b**	70
3	Ph	CH_3	C_6H_{11}	100	60	**c**	65
4	Ph	CH_3	$CH(CH_3)_2$	100	60	**d**	70
5	Ph	Ph	4-BrC_6H_4	120	120	**e**	10[b]

[a] Isolated yield based on carbonyl compound.
[b] Yield obtained by ^{1}H NMR.

TABLE 3 Preparation of Schiff Bases from Various Carbonyl Compounds and Diamines

	Carbonyl compound (**4**)		*Diamine* (**7**)				
Entry	R_1	R_2	*Y*	*Reaction Condition* (°*C*)	*Time (min)*	*Product* (**8**)	*Yield (%)*[a]
1	2-OH-4-NO_2-C_6H_3	H	C_6H_4-CH_2-C_6H_4	RT	20	**a**	95
2	2-OH-4-NO_2-C_6H_3	H	C_6H_4-O-C_6H_4	RT	20	**b**	85
3	2-OH-4-NO_2-C_6H_3	H	C_6H_4-SO_2-C_6H_4	RT	20	**c**	92
4	2-OH-C_6H_4	CH_3	C_6H_4-CH_2-C_6H_4	50	50	**d**	78
5	2-OH-C_6H_4	CH_3	C_6H_4-O-C_6H_4	50	50	**e**	75
6	2-OH-C_6H_4	CH_3	C_6H_4-SO_2-C_6H_4	50	50	**f**	78
7	2-OH-C_6H_4	CH_3	C_6H_4-CH_2-C_6H_4	–[b]	–[c]	**g**	–
8	2-OH-C_6H_4	CH_3	C_6H_4-O-C_6H_4	–[b]	–[c]	**h**	–
9	2-OH-C_6H_4	CH_3	C_6H_4-SO_2-C_6H_4	–[b]	–[c]	**i**	–

[a] Isolated yield based on carbonyl compound.
[b] The reaction was refluxed in methanol solvent.
[c] Several days.

The structure of products was assigned by the spectroscopic data. In the IR spectra, the characteristic Schiff base C=N stretching frequency is observed in the region between υ 1600 and 1700 cm^{-1} as a strong signal band. The stretching vibration of C—H in the alkyl groups appears at region between υ 2800 and 2900 cm^{-1}. In the ^{1}H NMR spectra, one proton of CH=N has chemical shifts at $\delta = 8.25$–8.35 ppm. The signals around $\delta = 6.5$–8.4 are assigned by protons of CH=CH of the aromatic rings.

CONCLUSION

Schiff base ligands have been prepared from carbonyl compounds with high yields and short reaction times, catalyzed by P_2O_5/SiO_2 under solvent-free conditions. The other advantages of this methodology are simple reaction procedures, simplicity of workup, and mild reaction condition at room to low temperature.

EXPERIMENTAL

Chemicals were purchased from the Merck Chemical Company Frankfurter Str. 250 64293 Darmstadt, Germany in high purity. IR spectra were recorded as KBr pellets on a Perkin-Elmer 781 spectrophotometer and an Impact 400 Nickolet FTIR spectrophotometer. ^{1}H NMR spectra were recorded in $CDCl_3$ and DMSO with (400 MHz) spectrometer using TMS as an internal reference. Melting points were obtained with a Yanagimoto micromelting point apparatus and are uncorrected. The purity of the substrates and reactions was determined by TLC on silica-gel polygram SILG/UV 254 plates.

General Procedure for Preparation of Schiff Bases

In a typical reaction, a mixture of benzaldehyde (0.29 g, 2 mmol), amine (0.25 g, 2 mmol), and P_2O_5/SiO_2 mixture (0.4 g, 2 mol% of P_2O_5/benzaldehyde) was grounded thoroughly in a mortar. The resulting mixture was placed in a flask and mechanically stirred for 30 min. The progress of the reaction was monitored by TLC. After completion of the reaction, methanol (50 mL) was added to the reaction mixture, filtered off the solid product and washed with cold methanol. The crude product was purified by recrystallization in petroleum ether, and the pure Schiff base was obtained in 80% yield. The Schiff base products were identified and confirmed by the spectroscopic data and physical methods and were consistent with the previously reported data [21–27].

*Benzylidene Cyclohexylamine (**3a**).* Yellow liquid (lit.) [21]; ^{1}H NMR ($CDCl_3$), δ (ppm): 1.10–1.80 (m, 10H), 3.21 (m, 1H), 7.39–7.67 (m, 5H), 8.38 (s, 1H); ^{13}C NMR ($CDCl_3$), δ (ppm): 24.8, 25.7, 34.5, 70.1, 136.7, 158.5.

*Benzylidene Isopropylamine (**3b**).* Yellow liquid (lit.) [22]; ^{1}H NMR ($CDCl_3$), δ (ppm): 1.20 (d, 6H), 3.40–3.55 (m, 1H), 7.29–7.75 (m, 5H), 8.38 (s, 1H); ^{13}C NMR ($CDCl_3$), δ (ppm): 24.3, 62.1, 136.7, 158.7.

*Benzylidene Allylamine (**3c**).* Yellow liquid (lit.) [23]; ^{1}H NMR ($CDCl_3$), δ (ppm): 4.21 (dd, 2H), 5.08–5.25 (dd, 2H), 5.80–6.12 (m, 1H); ^{13}C NMR ($CDCl_3$), δ (ppm): 63.5, 116.1, 135.9, 136.2, 162.1

*Benzylidene Aniline (**3d**).* White solid; mp 65°C–67°C; IR (KBr), υ (cm^{-1}): 3052 (Ar, C—H), 1623 (s, C=N), 1405, 1560 (Ar, C=C); ^{1}H NMR/($CDCl_3$), δ (ppm): 8.3 (s, 1H), 7.2–7.78 (m, 10H)

*N-(3-Methylbenzylidene)aniline (**3e**).* Brown oil; IR (KBr) υ (cm^{-1}) 3027 (Ar, C—H), 1630 (s, C=N), 1435, 1500 (Ar, C=C), 2900 (C—H); ^{1}H NMR/($CDCl_3$), δ (ppm): 8.65 (s, 1H), 2.6 (s, 3H), 7.2–8.2 (m, 9H).

*N-(4-Methylbenzylidene)aniline (**3f**).* Brown oil; IR (KBr) υ (cm^{-1}) 3027 (Ar, C—H), 1630 (s, C=N), 1435, 1500 (Ar, C=C), 2900 (C—H); ^{1}H NMR/($CDCl_3$), δ (ppm) 8.25 (s, 1H), 2.2(s, 3H), 6.8–7.7 (m, 9H).

*N-(3-Chlorobenzylidene)aniline (**3g**).* Brown oil; IR (KBr)/υ (cm^{-1}): 3060 (Ar, C—H), 1623 (s, C=N), 1435, 1560 (Ar, C=C), 1050 (C–Cl); ^{1}H NMR/$CDCl_3$, δ (ppm): 8.3 (s, 1H), 6.8–7.8 (m, 9H).

*N-(4-Chlorobenzylidene)aniline (**3h**).* White solid; mp 53°C–56°C IR(KBr) υ (cm^{-1}): 3060 (Ar, C—H), 1618 (s, C=N), 1475, 1567 (Ar, C=C), 1086 (C–Cl); ^{1}H NMR/($CDCl_3$), δ (ppm): 8.6 (s, 1H), 7.2–8.4 (m, 9H).

*N-(3-Nitrobenzylidene)aniline (**3i**).* Yellow solid; mp 66°C–68°C IR(KBr) υ (cm^{-1}): 3010 (Ar, C—H), 1625 (s, C=N), 1470, 1582 (Ar, C=C), 1320, 1517 (N—O); ^{1}H NMR/(DMSO), δ (ppm): 8.5 (s, 1H), 7.3–7.93 (m, 9H).

*N-(4-Nitrobenzylidene)aniline (**3j**).* Yellow solid; mp 138°C–140°C; IR (KBr) υ (cm^{-1}): 3010 (Ar, C—H), 1625 (s, C=N), 1480, 1593 (Ar, C=C), 1310, 1500 (N—O); ^{1}H NMR/(DMSO), δ (ppm): 8.5 (s, 1H), 7.3–7.93 (m, 9H).

*N-(4-Bromobenzylidene)aniline (**3k**).* Pale yellow solid; mp 61°C–63°C IR (KBr) υ (cm^{-1}): 3056 (Ar, C—H), 1625 (s, C=N), 1445, 1535 (Ar, C=C), 1135 (C—Br); ^{1}H NMR/($CDCl_3$) δ (ppm): 8.6 (s, 1H), 7.2–8.4 (m, 9H).

*N-(4-Nitrobenzylidene)benzylamine (**6a**).* mp 56°C–58°C (lit.) [24]; ^{1}H NMR ($CDCl_3$) δ (ppm): 4.84 (s, 2H), 7.30–8.07 (m, 9H), 8.42 (s, 1H).

*Benzylidene Benzylamine-1-methyl (**6b**).* Yellow solid; mp 56°C–58°C (lit.) [25]; ^{1}H NMR/($CDCl_3$) δ (ppm): 2.25 (s, 3H), 4.75 (s, 2H), 7.10–7.80 (m, 10H); ^{13}C NMR/($CDCl_3$) δ (ppm): 15.9, 57.6, 140.6, 141.1, 165.1.

*Benzylidene Cyclohexylamine-1-methyl (**6c**).* Liquid (lit.) [26]; ^{1}H NMR/($CDCl_3$) δ (ppm): 1.10–1.80 (m, 10H), 2.15 (s, 3H), 3.20 (m, 1H), 7.10–8.0 (m, 5H); ^{13}C NMR/($CDCl_3$) δ (ppm): 15.2, 24.9, 25.2, 33.6, 59.8, 133.1, 137.1, 141.8, 162.2.

*Benzylidene Isopropylamine-1-methyl (**6d**).* Liquid (lit.) [27]; ^{1}H NMR/($CDCl_3$) δ (ppm): 1.20 (d, 6H), 3.20 (m, 1H), 7.1–7.8 (m, 5H); ^{13}C NMR/($CDCl_3$) δ (ppm): 15.3, 23.6, 51.2, 134.5, 142.3, 162.8.

*N,N′-bis(4-Nitrosalicylidene)-4,4′-diaminodiphenylmethane (**8a**).* Yellow solid; mp 193°C–195°C IR/(KBr) υ (cm^{-1}): 3420–3500 (OH), 3006 (Ar, C—H), 2903 (C—H), 1635 (s, C=N), (1605, 1475 C=C), 1335–1535 (s, N=O), 1080 (s, C—O), 940, 730, 670; ^{1}H NMR/(DMSO) δ (ppm): 14.5–15) s, 1H), 8.95 (s, 2H), 8.4 (d, 2H), 8.0 (d, 2H), 6.4–7.3 (m, 10H), 3.7 (s, 2H).

*N,N′-bis(4-nitrosalicylidene)-4,4′-diaminodiphenylether (**8b**).* Yellow solid; mp 233°C–236°C; IR/(KBr) υ (cm^{-1}) 3420–3500 (br, OH), 30569 (Ar, C—H), 1618 (s, C=N), 1475, 1570 (C=C), 1345–1570 (s, N=O), 1090 (s, C—O), 940, 740; ^{1}H NMR/(DMSO), δ ppm 13.5–14.5 (s, 1H), 8.95 (s, 2H), 8.5 (d, 2H), 8.1 (dd, 2H), 6.6–7.4 (m, 10H).

*N,N′-bis(4-Nitrosalicylidene)-4,4′-diaminodiphenylsulphone (**8c**).* Yellow solid; mp 281°C–248°C; IR/(KBr) υ (cm^{-1}): 3420–3500 (br, OH), 3056 (Ar, C—H), 1618 (C=N), 1475, 1570 (Ar, C=C), 1345, 1530 (s, N=O), 1090 (s, C—O) 940, 740; ^{1}H NMR/(DMSO)

δ (ppm): 13.5–14.5 (s, 1H), 8.8 (s, 2H), 8.4 (d, 2H), 8.0 (dd, 2H), 7.8 (m, 4H), 6.9–7.3. (m, 6H). ^{13}C NMR/(DMSO) δ (ppm): 177.4, 168.8, 159, 135.1, 136.1, 133.2, 1341.6, 128.2, 123.1, 122.8, 115.8.

N,N′-bis(1-Salicylethylidene)-4,4′-diaminodiphenylmethane (**8d**). Pale yellow solid; mp 128°C–130°C; IR (KBr) υ (cm^{-1}): 3420–3500 (br, OH), 3060 (Ar, C—H), 2895 (C—H), 1608 (s, C=N), 1465, 1565 (Ar, C=C), 1160 (C—O); ^{1}H NMR/(DMSO) δ (ppm): 14.5–15 (s, 2OH), 6–8 (m, 16H), 3.3 (s, 2H), 2.6 (6H).

N,N′-bis(1-Salicylethylidene)-4,4′-diaminodiphenylether (**8e**). Pale yellow solid; mp 210°C–212°C; IR (KBr) υ (cm^{-1}): 3300–3500 (br, OH), 3056 (Ar, C—H), 1608 (s, C=N), 1475, 1570 (Ar, C=C), 1250 (C—O); ^{1}H NMR (DMSO) δ (ppm): 14.5–15 (s, 2OH), 6–8 (m, 16H), 3.7 (s, 6H).

N,N′-bis(1-Salicylethylidene)-4,4′-diaminodiphenylsulfone (**8f**). White solid; mp 165°C–167°C; IR (KBr) υ (cm^{-1}): 3300–3500 (br, OH), 3056 (Ar, C—H), 2903 (C—H), 1629 (s, C=N), 1450, 1570 (Ar, C=C), 1142, 1265 (s, S=O), 1101 (C—O); ^{1}H NMR/(DMSO) δ (ppm): 14.5–15 (s, 2OH), 6–8 (m, 16H), 3.6 (s, 6H).

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