

# Mild and convenient one pot synthesis of Schiff bases in the presence of $P_2O_5/Al_2O_3$ as new catalyst under solvent-free conditions

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## Abstract

In this study  $P_2O_5/Al_2O_3$  is found to catalyze the preparation of Schiff bases from the reaction of carbonyl compounds with primary amines efficiently under solvent-free conditions. The advantages of this friendly, environmentally and mild method are such as simplicity of the reaction procedure, the elimination of solvents, simple work-up, high product yields and short reaction times.

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*Keywords:* Catalyst; Schiff base;  $P_2O_5$ ; Solvent-free; Alumina

## 1. Introduction

Organic reactions under solvent-free conditions have gained in popularity in recent years [1]. This is because solvent-free reactions usually need shorter reaction times and simpler reactors and resulting simple and efficient work up procedures. Furthermore, reactions, which performed under solvent-free conditions especially have been important and attracted much attention [2].

The development of cleaner technologies is a major in green chemistry. Among the several aspects of green chemistry, the reduction or replacement of volatile organic solvents from the reaction medium is of at most importance [3]. The solid-state reaction or solvent free reaction has many advantages: reduced pollution, low costs and simplicity in process and handling. These factors are especially important in industry [4]. For the increasing environmental and economical concerns in recent years, it is now essential for chemists to search environmentally reactions as many as possible.

Schiff base ligands, as variety of compounds with imine group, have gained importance because of physiological and pharmacological activities associated with them. They constitute an interesting class of chelating agents capable of coordination metal ions given complex, which serves as models for biological

system [5–7]. A lot of investigations have been made concerning the synthesis of Schiff bases [8–13], but these procedures have some limitations such as low yield, long reaction times, highly environmental pollution regarding to solvent, hardness reaction work up. These are once again topical in connection with a diverse rang of application in organic synthesis, bioorganic and medicinal chemistry. Also these complexes find many important catalytic applications, such as catalysts for epoxidation of olefins [14], alkene cyclopropanation [15], trimethylsilylcyanation of aromatic aldehydes [16], borohydride reduction of methyl phenyl sulfide [17], asymmetric oxidation of methyl phenyl sulfide [18], enantioselective epoxidation of silyl enol [19], ring opening polymerization of lactide [20], application of ion-selective electrodes [21–25], determination of heavy metal ions in environment samples [26], extraction of metal ions [27], etc.

A solvent-free or solid state reaction may be carried out using the reactants alone or incorporating them in clays, zeolites, silica, alumina or other matrices [28]. In recent years,  $\beta$ -zeolite [29], montmorillonite clays [30],  $SiO_2$  and  $Al_2O_3$  were employed as catalysts for this purpose to obtain relatively better results.

Alumina is a particularly interesting metal oxide as it is widely used industrially as filler, adsorbent, drying agent, catalyst support and reagent.  $\gamma$ -Alumina is the transition alumina most commonly utilized to carry out surface organic chemistry [31]. In contrast to clays and zeolites, this material does not contain accessible channels or cavities and shows large surface area and highly porous exteriors available to substrates [32]. Although some of these methods represent a convenient proce-

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ture with good to high product yields, representation of a new, efficient and facile procedure for synthesis of these compounds can be very significant.

In continuation of our research, because of these economical and environmental reasons, here we hope to report a procedure using  $P_2O_5/Al_2O_3$  as a catalyst for the synthesis of Schiff bases from carbonyl compounds and different amines in the absence of a solvent under mild reaction conditions.

## 2. Experimental

### 2.1. Materials

Chemicals were purchased from the Merck and Fluka Chemical Companies in high purity. All of the materials were of commercial reagent grade. The amines and carbonyl compounds were purified by standard procedures.

### 2.2. Apparatus

IR spectra were recorded as KBr pellet on a Perkin-Elmer 781 spectrophotometer and an Impact 400 Nicolet FT-IR spectrophotometer.  $^1H$  NMR and  $^{13}C$  NMR spectra were recorded in  $CDCl_3$  and DMSO solvents on a Bruker DRX-400 spectrometer (400 MHz) using TMS as an internal reference. Melting points obtained with a Yanagimoto micro melting point apparatus are uncorrected. The purity determination of the substrates and reactions monitoring were accomplished by TLC on silica-gel polygram SILG/UV 254 plates.

### 2.3. General procedure

#### 2.3.1. Procedure for preparation of $P_2O_5/Al_2O_3$ catalyst

A mixture of phosphorous pentoxide (1 g) and alumina (6 g) have been placed in a flask and stirred for 2 h at room temperature. The obtained homogeneous mixture, free flowing, white powder substance is sensitive towards moisture and thus should be stored in a desiccator.

#### 2.3.2. General procedure and then a typical reaction for preparation of Schiff bases **3a–3k** and **6a–6e**

In a typical reaction, a mixture of benzaldehyde (0.21 g, 2 mmol), isopropyl amine (0.25 g, 2 mmol) and  $P_2O_5/Al_2O_3$  mixture (0.6 g, 3 mol% of  $P_2O_5$ /benzaldehyde) was ground 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 (15 ml) was added to the reaction mixture, filtered off the solid product and was washed with cold methanol. The crude product was purified by recrystallization from petroleum ether and the pure Schiff base **3a** was obtained as a yellow liquid in 80% yield. The Schiff base products were identified by spectroscopic data.

**Benzylidene isopropylamine (3a)**: yellow liquid (lit) [33];  $^1H$  NMR ( $CDCl_3$ , 400 MHz)/ $\delta$  ppm 1.20 (d, 6H,  $J=7.1$  Hz), 3.40–3.55 (m, 1H), 7.29–7.75 (m, 5H), 8.38 (s, 1H);  $^{13}C$  NMR ( $CDCl_3$ , 100 MHz)/ $\delta$  ppm 24.3, 62.1, 136.7, 158.7.

**Benzylidene cyclohexylamine (3b)**: yellow liquid (lit) [34];  $^1H$  NMR ( $CDCl_3$ , 400 MHz)/ $\delta$  ppm 1.10–1.80 (m, 10H), 3.21 (m, 1H), 7.39–7.67 (m, 5H), 8.38 (s, 1H);  $^{13}C$  NMR ( $CDCl_3$ , 100 MHz)/ $\delta$  ppm 24.8, 25.7, 34.5, 70.1, 136.7, 158.5.

**Benzylidene allylamine (3c)**: yellow liquid (lit) [35];  $^1H$  NMR ( $CDCl_3$ , 400 MHz)/ $\delta$  ppm 4.21 (dd, 2H,  $J_1=2.2$  Hz,  $J_2=6.1$  Hz), 5.08–5.25 (dd, 2H,  $J_1=2.2$  Hz,  $J_2=10.1$  Hz), 5.80–6.12 (m, 1H), 7.31–7.72 (m, 5H), 8.35 (s, 1H);  $^{13}C$  NMR ( $CDCl_3$ , 100 MHz)/ $\delta$  ppm 63.5, 116.1, 135.9, 136.2, 162.1.

**N-phenyl-N-(1-phenylmethylidene) amine (3d)**: white solid; m.p. 65–67 °C; IR (KBr)/ $\nu$  ( $cm^{-1}$ ) 3052 (Ar, C–H), 1623 (s, C=N), 1405, 1560 (Ar, C=C);  $^1H$  NMR ( $CDCl_3$ , 400 MHz)/ $\delta$  ppm 7.2–7.78 (m, 10H), 8.3 (s, 1H).

**N-[1-(3-methyl-phenyl)-methylidene]-N-phenylamine (3e)**: brown oil; IR (KBr)/ $\nu$  ( $cm^{-1}$ ) 3027 (Ar, C–H), 1630 (s, C=N), 1435, 1500 (Ar, C=C), 2900 (C–H);  $^1H$  NMR ( $CDCl_3$ , 400 MHz)/ $\delta$  ppm 2.6 (s, 3H), 7.2–8.2 (m, 9H), 8.65 (s, 1H).

**N-[1-(4-methyl-phenyl)-methylidene]-N-phenylamine (3f)**: brown oil; IR (KBr)/ $\nu$  ( $cm^{-1}$ ) 3027 (Ar, C–H), 1630 (s, C=N), 1435, 1500 (Ar, C=C), 2900 (C–H);  $^1H$  NMR ( $CDCl_3$ , 400 MHz)/ $\delta$  ppm 2.2 (s, 3H), 6.8–7.7 (m, 9H), 8.25 (s, 1H).

**N-[1-(3-chloro-phenyl)-methylidene]-N-phenylamine (3g)**: brown oil; IR (KBr)/ $\nu$  ( $cm^{-1}$ ) 3060 (Ar, C–H), 1623 (s, C=N), 1435, 1560 (Ar, C=C), 1050 (C–Cl);  $^1H$  NMR ( $CDCl_3$ , 400 MHz)/ $\delta$  ppm 6.8–7.8 (m, 9H), 8.3 (s, 1H).

**N-[1-(4-chloro-phenyl)-methylidene]-N-phenylamine (3h)**: white solid; m.p. 53–56 °C; IR (KBr)/ $\nu$  ( $cm^{-1}$ ) 3060 (Ar, C–H), 1618 (s, C=N), 1475, 1567 (Ar, C=C), 1086 (C–Cl);  $^1H$  NMR ( $CDCl_3$ , 400 MHz)/ $\delta$  ppm 7.2–8.4 (m, 9H), 8.6 (s, 1H).

**N-[1-(4-bromo-phenyl)-methylidene]-N-phenylamine (3i)**: pale yellow solid; m.p. 61–63 °C; IR (KBr)/ $\nu$  ( $cm^{-1}$ ) 3056 (Ar, C–H), 1625 (s, C=N), 1445, 1535 (Ar, C=C), 1135 (C–Br);  $^1H$  NMR ( $CDCl_3$ , 400 MHz)/ $\delta$  ppm 7.2–8.4 (m, 9H), 8.6 (s, 1H).

**N-[1-(3-nitro-phenyl)-methylidene]-N-phenylamine (3j)**: yellow solid; m.p. 66–68 °C; IR (KBr)/ $\nu$  ( $cm^{-1}$ ) 3010 (Ar, C–H), 1625 (s, C=N), 1470, 1582 (Ar, C=C), 1320, 1517 (N–O);  $^1H$  NMR (DMSO, 400 MHz)/ $\delta$  ppm 7.3–7.93 (m, 9H), 8.5 (s, 1H).

**N-[1-(4-nitro-phenyl)-methylidene]-N-phenylamine (3k)**: yellow solid; m.p. 138–140 °C; IR (KBr)/ $\nu$  ( $cm^{-1}$ ) 3010 (Ar, C–H), 1625 (s, C=N), 1480, 1593 (Ar, C=C), 1310, 1500 (N–O);  $^1H$  NMR (DMSO, 400 MHz)/ $\delta$  ppm 7.3–7.93 (m, 9H), 8.5 (s, 1H).

**N-[1-(4-methyl-phenyl)-methylidene]-N-phenylamine (6a)**: brown oil; IR (KBr)/ $\nu$  ( $cm^{-1}$ ) 3027 (Ar, C–H), 2900 (C–H), 1630 (s, C=N), 1435, 1500 (Ar, C=C);  $^1H$  NMR ( $CDCl_3$ , 400 MHz)/ $\delta$  ppm 2.2 (s, 3H), 6.8–7.7 (m, 9H), 8.25 (s, 1H).

**N-(4-nitrobenzylidene)-benzylamine (6b)**: m.p. 56–58 °C (lit) [36];  $^1H$  NMR ( $CDCl_3$ , 400 MHz)/ $\delta$  ppm 4.84 (s, 2H), 7.30–8.07 (m, 9H), 8.42 (s, 1H).

**Benzylidene benzylamine-1-methyl (6c)**: yellow solid; m.p. 56–58 °C (lit) [37];  $^1H$  NMR ( $CDCl_3$ , 400 MHz)/ $\delta$  ppm 2.25 (s, 3H), 4.75 (s, 2H), 7.10–7.80 (m, 10H);  $^{13}C$  NMR ( $CDCl_3$ , 100 MHz)/ $\delta$  ppm 15.9, 57.6, 140.6, 141.1, 165.1.

**Benzylidene cyclohexylamine-1-methyl (6d)**: liquid (lit) [38];  $^1H$  NMR ( $CDCl_3$ , 400 MHz)/ $\delta$  ppm 1.10–1.80 (m, 10H), 2.15 (s, 3H), 3.20 (m, 1H), 7.10–8.0 (m, 5H);  $^{13}C$  NMR ( $CDCl_3$ ,

100 MHz)/ $\delta$  ppm 15.2, 24.9, 25.2, 33.6, 59.8, 133.1, 137.1, 141.8, 162.2.

*Benzylidene isopropylamine-1-methyl (6e)*: liquid (lit) [39];  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)/ $\delta$  ppm 1.20 (d, 6H,  $J=7.1$  Hz), 2.18 (s, 3H), 3.20 (m, 1H), 7.1–7.8 (m, 5H);  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)/ $\delta$  ppm 15.3, 23.6, 51.2, 134.5, 142.3, 162.8.

### 2.3.3. General procedure and then a typical reaction for synthesis of double Schiff bases 9a–9g

To a mixture of salicylaldehyde (0.24 g, 2 mmol) and diamine (0.2 g, 1 mmol)  $\text{P}_2\text{O}_5/\text{Al}_2\text{O}_3$  mixture (0.6 g, 3 mol% of  $\text{P}_2\text{O}_5/\text{salicylaldehyde}$ ) was added and was ground thoroughly in a mortar. The resulting mixture was placed in a flask and mechanically stirred for 10 min at room temperature. The progress of the reaction was monitored by TLC. After the completion of the reaction, methanol (20 ml) was added to the reaction mixture, filtered off the solid product and was washed with cold methanol. The crude product was purified by recrystallization from methanol and the pure Schiff base **9a** was yielded in 100% yield as a yellow solid. The obtained products were identified by physical and spectroscopic data.

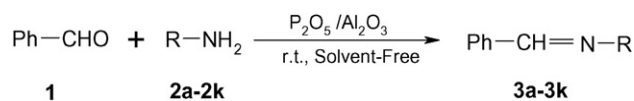
*N,N'*-bis(salicylidene)-4,4'-diaminodiphenylether (**9a**): green-yellow solid; m.p. 206–207 °C; IR (KBr)/ $\nu$  ( $\text{cm}^{-1}$ ) 3425–3450 (OH), 3045 (Ar, C–H), 2920 (C–H), 1620 (s, C=N), 1595, 1568, 1490 (C=C), 1358 (s), 1280 (s, C–O), 1110 (m), 980 (s), 738 (s), 650 (w),  $^1\text{H}$  NMR (DMSO, 400 MHz)/ $\delta$  ppm 6.75 (d, 4H,  $J=8.27$  Hz), 7.01 (t, 2H,  $J=7.74$  Hz), 7.16 (d, 2H,  $J=8.4$  Hz), 7.42 (d, 4H,  $J=6.37$  Hz), 7.52 (d, 2H,  $J=8.42$  Hz), 7.67 (d, 2H,  $J=7.85$  Hz), 8.95 (s, 2H), 13.12 (s, 2H);  $^{13}\text{C}$  NMR (DMSO, 100 MHz)/ $\delta$  ppm 94.46, 112.21, 118.27, 120.32, 123.12, 126.18, 128.42, 134.81, 151.42, 159.32, 187.49.

*N,N'*-bis(5-nitrosalicylidene)-4,4'-diaminodiphenylmethane (**9b**): yellow solid; m.p. 193–195 °C; IR (KBr)/ $\nu$  ( $\text{cm}^{-1}$ ) 3420–3500 (OH), 3006 (Ar, C–H), 2903 (C–H), 1635 (s, C=N), 1475, 1605 (s, C=C), 1335–1535 (s, N=O), 1080 (s, C–O), 940, 730, 670 (m);  $^1\text{H}$  NMR (DMSO, 400 MHz)/ $\delta$  ppm 3.7 (s, 2H), 6.4–7.3 (m, 10H), 8.0 (d, 2H,  $J=8.2$  Hz), 8.4 (d, 2H,  $J=8.5$  Hz), 8.95 (s, 2H), 14.5–15.0 (s, 1H).

*N,N'*-bis(5-nitrosalicylidene)-4,4'-diaminodiphenylether (**9c**): yellow solid; m.p. 233–236 °C; IR (KBr)/ $\nu$  ( $\text{cm}^{-1}$ ) 3420–3500 (br, OH), 3056 (Ar, C–H), 1618 (s, C=N), 1475, 1570 (C=C), 1345, 1570 (s, N=O), 1090 (s, C–O), 740, 940 (m);  $^1\text{H}$  NMR (DMSO, 400 MHz)/ $\delta$  ppm 6.6–7.4 (m, 10H), 8.1 (dd, 2H,  $J_1=2.3$  Hz,  $J_2=6.4$  Hz), 8.5 (d, 2H,  $J=8.2$  Hz), 8.95 (s, 2H), 13.5–14.5 (s, 1H).

*N,N'*-bis(5-nitrosalicylidene)-4,4'-diaminodiphenylsulfone (**9d**): yellow solid; m.p. 281–284 °C; IR (KBr)/ $\nu$  ( $\text{cm}^{-1}$ ) 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 (m);  $^1\text{H}$  NMR (DMSO, 400 MHz)/ $\delta$  ppm 6.9–7.3 (m, 6H), 7.8 (m, 4H), 8.0 (dd, 2H,  $J_1=2.1$  Hz,  $J_2=6.7$  Hz), 8.4 (d, 2H,  $J=8.0$  Hz), 8.8 (s, 2H), 13.5–14.5 (s, 1H);  $^{13}\text{C}$  NMR (DMSO, 100 MHz)/ $\delta$  ppm 115.8, 122.8, 123.1, 128.2, 133.2, 134.1, 135.1, 136.1, 159.0, 168.8, 177.4.

*2,2'*-[4,4'-Diphenyl methane-bis(nitriloethylidyne)]-bisphenol (**9e**): pale yellow solid; m.p. 128–130 °C; IR (KBr)/ $\nu$  ( $\text{cm}^{-1}$ ) 3420–3500 (br, OH), 3060 (Ar, C–H), 2895 (C–H),



Scheme 1.

1608 (s, C=N), 1465, 1565 (Ar, C=C), 1160 (C–O);  $^1\text{H}$  NMR (DMSO, 400 MHz)/ $\delta$  ppm 2.6 (s, 6H), 3.3 (s, 2H), 6–8 (m, 16H), 14.5–15.0 (s, 2OH).

*2,2'*-[4,4'-Diphenylether-bis(nitriloethylidyne)]-bisphenol (**9f**): pale yellow solid; m.p. 210–212 °C; IR (KBr)/ $\nu$  ( $\text{cm}^{-1}$ ) 3300–3500 (br, OH), 3056 (Ar, C–H), 1608 (s, C=N), 1475, 1570 (Ar, C=C), 1250 (C–O);  $^1\text{H}$  NMR (DMSO, 400 MHz)/ $\delta$  ppm 3.7 (s, 6H), 6.0–8.0 (m, 16H), 14.5–15 (s, 2OH).

*2,2'*-[4,4'-Diphenylsulfone-bis(nitriloethylidyne)]-bisphenol (**9g**): white solid; m.p. 165–167 °C; IR (KBr)/ $\nu$  ( $\text{cm}^{-1}$ ) 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);  $^1\text{H}$  NMR (DMSO, 400 MHz)/ $\delta$  ppm 3.6 (s, 6H), 6.1–8.0 (m, 16H), 14.5–15.0 (s, 2OH).

### 3. Results and discussion

Firstly, in this study, 1 mol benzaldehyde was treated with 1 mol aliphatic or aromatic primary amine in the presence of  $\text{P}_2\text{O}_5$  supported on  $\text{Al}_2\text{O}_3$  as a catalyst via grinding at room temperature under solvent-free conditions (Scheme 1).

In this reaction, regarding the  $\text{P}_2\text{O}_5$  catalyst, a 0.03 M amount of benzaldehyde was used. The yields of products were determined by TLC analyses and via isolated amounts of products based on carbonyl compound. The results of the above mentioned reactions are shown in Table 1.

In each case, condensation of substrates 1 and 2 occurred and upon work-up, the corresponding Schiff base was obtained. As can be seen in Table 1, a lot of Schiff bases were synthesized using  $\text{P}_2\text{O}_5/\text{Al}_2\text{O}_3$  as a catalyst in solvent-free media. We were pleased to find that the reaction of benzaldehyde with pri-

Table 1  
The reaction of benzaldehyde with various amines catalyzed by  $\text{P}_2\text{O}_5/\text{Al}_2\text{O}_3$  in room temperature

Entry	Amine substrate (2) (R)	Time (min)	Product (3)	Yield <sup>a</sup> (%)
1	$\text{CH}(\text{CH}_3)_2$	15	<b>a</b>	85
2	$\text{C}_6\text{H}_{11}$	15	<b>b</b>	80
3	Allyl	15	<b>c</b>	90
4	Ph	20	<b>d</b>	80
5	3-Me- $\text{C}_6\text{H}_4$	20	<b>e</b>	85
6	4-Me- $\text{C}_6\text{H}_4$	20	<b>f</b>	90
7	3-Cl- $\text{C}_6\text{H}_4$	25	<b>g</b>	75
8	4-Cl- $\text{C}_6\text{H}_4$	25	<b>h</b>	72
9	4-Br- $\text{C}_6\text{H}_4$	25	<b>i</b>	77
10	3- $\text{NO}_2$ - $\text{C}_6\text{H}_4$	30	<b>j</b>	75
11	4- $\text{NO}_2$ - $\text{C}_6\text{H}_4$	30	<b>k</b>	70
12 <sup>b</sup>	4-Br- $\text{C}_6\text{H}_4$	>200	–	10 <sup>c</sup>
13 <sup>d</sup>	3-Cl- $\text{C}_6\text{H}_4$	>100	<b>g</b>	20

<sup>a</sup> Isolated yield based on benzaldehyde.

<sup>b</sup> In absence of catalyst under solution media.

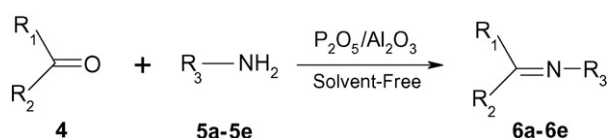
<sup>c</sup> Yield determined by  $^1\text{H}$  NMR.

<sup>d</sup> In the presence of  $\text{Al}_2\text{O}_3$  alone.

Table 2

Preparation of Schiff bases from various carbonyl compounds and primary mono amines in the presence of P<sub>2</sub>O<sub>5</sub>/Al<sub>2</sub>O<sub>3</sub>

Entry	Carbonyl compound (4)		Primary amine (5) (R <sub>3</sub> )	Reaction condition (°C)	Time (min)	Product (6)	Yield <sup>a</sup> (%)
	R <sub>1</sub>	R <sub>2</sub>					
1	Ph	H	4-Me-C <sub>6</sub> H <sub>4</sub>	25	20	<b>a</b>	90
2	4-NO <sub>2</sub> -C <sub>6</sub> H <sub>4</sub>	H	CH <sub>2</sub> Ph	25	40	<b>b</b>	75
3	Ph	CH <sub>3</sub>	CH <sub>2</sub> Ph	100	40	<b>c</b>	70
4	Ph	CH <sub>3</sub>	C <sub>6</sub> H <sub>11</sub>	100	40	<b>d</b>	65
5	Ph	CH <sub>3</sub>	CH(CH <sub>3</sub> ) <sub>2</sub>	100	40	<b>e</b>	70
6	Ph	Ph	4-Br-C <sub>6</sub> H <sub>4</sub>	120	120	–	10
7 <sup>b</sup>	4-NO <sub>2</sub> -C <sub>6</sub> H <sub>4</sub>	H	CH <sub>2</sub> Ph	100	>150	<b>b</b>	40
8	Ph	CH <sub>3</sub>	CH <sub>2</sub> Ph	<sup>c</sup>	<sup>d</sup>	<b>c</b>	10

<sup>a</sup> Isolated yield based on carbonyl compound.<sup>b</sup> Without catalyst in methanol solvent.<sup>c</sup> The reaction was refluxed in methanol solvent.<sup>d</sup> Several days.

Scheme 2.

primary amines were yielded the Schiff base products in good to high yields in a shorter time using P<sub>2</sub>O<sub>5</sub>/Al<sub>2</sub>O<sub>3</sub> as catalyst than some of the other methods which have been occurred in solution medium [8–13]. In comparison, the reaction of benzaldehyde with 4-bromo-aniline in the absence of a catalyst under solution conditions is given in entry 12 (Table 1). As can be considered, the yield of Schiff base product in this reaction was very low and the reaction time was very long. Also, the reaction of benzaldehyde with 3-chloro-aniline in the presence of Al<sub>2</sub>O<sub>3</sub> alone and without P<sub>2</sub>O<sub>5</sub> has been preceded in low product yield and long reaction time (entry 13 in Table 1).

Next, in order to study the development of this method, treatment of various carbonyl compounds with primary mono amines have been occurred in the presence of P<sub>2</sub>O<sub>5</sub>/Al<sub>2</sub>O<sub>3</sub> catalyst at temperatures between 25 and 120 °C (Scheme 2). The obtained results of these reactions are indicated in Table 2.

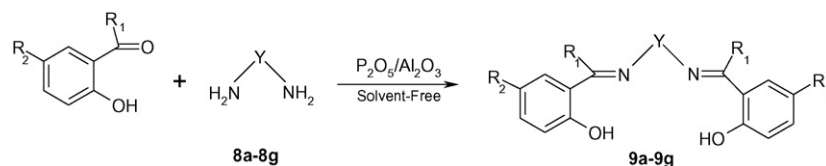
As shown in Table 2, the yields of the reactions with this new method for preparation of various Schiff bases from aldehydes or ketones with primary mono amines are quite fair, and reaction time is very short. In the entry 6, the reaction of benzophenone with *p*-bromo-aniline has been carried out in low yield and long reaction time. This low reactivity may be related to steric hindrance in ketone accompanied to electron with-

drawing of bromine atom on aromatic ring of amine. It is of great importance that the reaction is largely affected by the P<sub>2</sub>O<sub>5</sub>/Al<sub>2</sub>O<sub>3</sub> catalyst. The entries 7 and 8 (Table 2) are respectively shown the reaction of *p*-nitro-benzaldehyde with benzyl amine without catalyst and the reaction of acetophenone with benzyl amine under reflux in methanol solution in which in long reaction times, the corresponding products were obtained in low yields.

Then to ascertain the scope and limitation of the present reaction, several carbonyl compounds with various diamines were examined using catalyst P<sub>2</sub>O<sub>5</sub>/Al<sub>2</sub>O<sub>3</sub> (Scheme 3); the corresponding results are summarized in Table 3.

In order to study the catalytic effect of P<sub>2</sub>O<sub>5</sub>/Al<sub>2</sub>O<sub>3</sub> in this method, a comparison of the reaction of 2-hydroxy acetophenone with diamines **8e**, **8f** and **8g** in the absence of catalyst is given in Table 3 (for example; compare entries 5–7 versus 8–10 respectively). As can be seen, the reaction without a catalyst in methanol solvent under reflux conditions was carried out in very low yields even an extension of the reaction time to several days. The double Schiff bases as products of this new method were yielded in excellent yields and the reaction times were very short.

The structure of products has been assigned by spectroscopic data. In the IR spectra, the characteristic Schiff base C=N stretching frequency is formed in the region between  $\nu = 1600\text{--}1700\text{ cm}^{-1}$  as a signal strong band. The stretching vibration of C–H in the alkyl groups appear at region between  $\nu = 2800\text{--}2900\text{ cm}^{-1}$ . In the <sup>1</sup>H NMR spectra, one protons of CH=N have chemical shifts in  $\delta = 8.25\text{--}8.35\text{ ppm}$ . The signals around  $\delta = 6.5\text{--}8.4$  are assigned by protons of CH=CH of aromatic rings.



Scheme 3.

Table 3

Reaction times and yields of double Schiff bases in the reaction of several carbonyl compounds with diamines catalyzed by P<sub>2</sub>O<sub>5</sub>/Al<sub>2</sub>O<sub>3</sub>

Entry	Carbonyl compounds (7)		Diamine (8) (Y)	Temperature (°C)	Time (min)	Product (9)	Yield <sup>a</sup> (%)
	R <sub>1</sub>	R <sub>2</sub>					
1	H	H	C <sub>6</sub> H <sub>4</sub> -O-C <sub>6</sub> H <sub>4</sub>	25	10	<b>a</b>	100
2	H	NO <sub>2</sub>	C <sub>6</sub> H <sub>4</sub> -CH <sub>2</sub> -C <sub>6</sub> H <sub>4</sub>	25	20	<b>b</b>	95
3	H	NO <sub>2</sub>	C <sub>6</sub> H <sub>4</sub> -O-C <sub>6</sub> H <sub>4</sub>	25	20	<b>c</b>	90
4	H	NO <sub>2</sub>	C <sub>6</sub> H <sub>4</sub> -SO <sub>2</sub> -C <sub>6</sub> H <sub>4</sub>	25	20	<b>d</b>	92
5	CH <sub>3</sub>	H	C <sub>6</sub> H <sub>4</sub> -CH <sub>2</sub> -C <sub>6</sub> H <sub>4</sub>	60	35	<b>e</b>	78
6	CH <sub>3</sub>	H	C <sub>6</sub> H <sub>4</sub> -O-C <sub>6</sub> H <sub>4</sub>	60	35	<b>f</b>	80
7	CH <sub>3</sub>	H	C <sub>6</sub> H <sub>4</sub> -SO <sub>2</sub> -C <sub>6</sub> H <sub>4</sub>	60	35	<b>g</b>	78
8	CH <sub>3</sub>	H	C <sub>6</sub> H <sub>4</sub> -CH <sub>2</sub> -C <sub>6</sub> H <sub>4</sub>	<sup>b</sup>	<sup>c</sup>	<b>e</b>	10
9	CH <sub>3</sub>	H	C <sub>6</sub> H <sub>4</sub> -O-C <sub>6</sub> H <sub>4</sub>	<sup>b</sup>	<sup>c</sup>	<b>f</b>	15
10	CH <sub>3</sub>	H	C <sub>6</sub> H <sub>4</sub> -SO <sub>2</sub> -C <sub>6</sub> H <sub>4</sub>	<sup>b</sup>	<sup>c</sup>	<b>g</b>	12

<sup>a</sup> Isolated yields.<sup>b</sup> Under reflux in methanol media.<sup>c</sup> Several days.

#### 4. Conclusion

In this research, we have described a novel and highly efficient protocol for preparation of Schiff bases catalyzed by P<sub>2</sub>O<sub>5</sub>/Al<sub>2</sub>O<sub>3</sub> under solvent-free conditions. The advantages of this environmentally benign and safe method include a simple reaction set-up not requiring specialized equipment, high product yields, short reaction times and the elimination of solvents.

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#### References

- [1] (a) J.O. Metzger, *Angew. Chem. Int. Ed.* 37 (1998) 2975, and references therein;  
(b) C.-J. Li, T.-H. Chan, *Tetrahedron* 55 (1999) 11149.
- [2] T.P. Loh, J.M. Huang, S.H. Goh, J.J. Vittal, *Org. Lett.* 29 (2000) 1291–1294.
- [3] S.V. Rajinder, V.N. Vasudevan, *Pure Appl. Chem.* 73 (2001) 1309.
- [4] K. Tanka, F. Toda, *Chem. Rev.* 100 (2000) 1025.
- [5] G. Wilkinson, *Comp. Coordin. Chem.* 4–6 (1987), 166–167, 494–495, 634, 639, 687.
- [6] P.H. Hang, J.G. Keck, E.J. Lein, M. Mclai, *J. Med. Chem.* 33 (1990) 608.
- [7] A.E. Tai, E.J. Lein, M. Mclai, T.A. Khwaja, *J. Med. Chem.* 27 (1984) 236.
- [8] N. Aizadeh, S. Ershad, H. Naeimi, H. Sharghi, M. Shamsipur, *Polish J. Chem.* 73 (1999) 915–925.
- [9] D. Sans, A. Perona, R.M. Claramunt, J. Elquero, *Tetrahedron* 61 (2005) 145–154.
- [10] J.M. Fernandez-G, F. Del Rio-Portilla, B. Quiroz-Garcia, R.A. Toscano, R. Salcedo, *J. Mol. Struct.* 561 (2001) 197–207.
- [11] (a) J.A. Sclatani, M.T. Maranto, T.M. Sisk, S.A.V. Arman, *J. Org. Chem.* 61 (1996) 3221;  
(b) R. Ando, T. Yagy, M. Maeda, *Inorg. Chim. Acta* 357 (2004) 2237–2244.
- [12] H. Naeimi, J. Safari, A. Heidarneshad, *Dyes Pigments*, 2006, in press.
- [13] H. Sharghi, H. Naeimi, *Iran J. Chem. Chem. Eng.* 18 (1999) 72.
- [14] K. Ambroziak, R. Pelech, E. Milchert, T. Dziembowska, Z. Rozwadowski, *J. Mol. Catal. A: Chem.* 211 (2004) 9–16.
- [15] H. Suga, T. Fudo, T. Ibata, *Synlett* (1998) 933.
- [16] Z.H. Yang, L.X. Wang, Z.H. Zhou, Q.L. Zhou, C.C. Tang, *Tetrahedron Asymmetry* 12 (2001) 1579–1582.
- [17] G.J. Kim, J.H. Shin, *Catal. Lett.* 63 (1999) 83–89.
- [18] C. Sasaki, K. Nakajima, M. Kojima, *Bull. Chem. Soc. Jpn.* 64 (1991) 1318–1324.
- [19] A. Waldemar, Rainer, R.S. Veit, *J. Am. Chem. Soc.* 120 (1998) 708–714.
- [20] T.M. Ovitt, G.W. Coates, *J. Am. Chem. Soc.* 121 (1999) 4072.
- [21] M. Shamsipur, S. Sadeghi, H. Naeimi, H. Sharghi, *Polish J. Chem.* 74 (2000) 231.
- [22] N. Alizadeh, S. Ershad, H. Naeimi, H. Sharghi, M. Shamsipur, *Fresen. J. Anal. Chem.* 365 (1999) 511.
- [23] M.M. Ardakany, A.A. Ensafi, H. Naeimi, A. Dastanpour, A. Shamelli, *Sens. Actuators B* (2003) 441.
- [24] A.R. Khorrami, H. Naeimi, A.R. Fakhari, *Talanta* 64 (2004) 13.
- [25] M. Shamsipur, M. Yousefi, M. Hosseini, M.R. Ganjali, H. Sharghi, H. Naeimi, *Anal. Chem.* 73 (2001) 2869.
- [26] A.R. Fakhari, A.R. Khorrami, H. Naeimi, *Talanta* 66 (2005) 813–817.
- [27] M. Shamsipur, A.R. Ghiasvand, H. Sharghi, H. Naeimi, *Anal. Chim. Acta* (2000) 271.
- [28] G. Nagendrappa, *Resonance* (2002) 59.
- [29] (a) C. Pereira, B. Gigante, M.J.M. Curto, H. Carreyre, G. Perot, M. Guisnet, *Synthesis* (1995) 1077;  
(b) P. Kumar, V.R. Hegde, T.P. Kumar, *Tetrahedron Lett.* 36 (1995) 601.
- [30] (a) Z.H. Zhang, T.S. Li, C.G. Fu, *J. Chem. Res. (S)* (1997) 174;  
(b) T.S.Z.H. Li, Y. Zhang, J. Gao, *Synth. Commun.* 28 (1998) 4665.
- [31] G.W. Kabalka, R.M. Pagni, *Tetrahedron* 53 (1997) 7999–8065.
- [32] R. Maggi, R. Ballini, G. Sartori, R. Sartorio, *Tetrahedron Lett.* 45 (2004) 2297–2299.
- [33] Skita, *Wulf Ber* 59 (1926) 2691.
- [34] R.G. Pews, *J. Org. Chem.* 32 (1976) 1628.
- [35] L.M. Lung, C.A. Miller, H.D. Troutman, *J. Am. Chem. Soc.* 70 (1984) 900.
- [36] V. Madan, L.B. Clapp, *J. Am. Chem. Soc.* 11 (1969) 6078.
- [37] F. Texier-Boulet, *Synthesis* (1985) 679.
- [38] R. Mayer, H.J. Hartmann, J. Jentsch, *J. Prakt. Chem.* 31 (1966) 312.
- [39] P. Asinger, H.W. Becker, A. Saus, *Monatsh* 97 (1966) 301.