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Iodine Supported on 3-Aminopropyl Silica Gel as Efficient Catalyst for Acetylation of Alcohols under Solvent-free Conditions

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3-Aminopropyl silica gel (I_2/APSG) was found to catalyze the acetylation of alcohols and phenols efficiently with acetic anhydride. The reaction is mild and selective with high yields. A wide variety of alcohols and phenols are selectively converted into the corresponding acetates using I_2/APSG under solvent-free conditions at room temperature.

Keywords iodine, 3-aminopropyl silica gel, acetylation, alcohol

Introduction

The acetylation of alcohols is an important reaction in organic chemistry. This transformation is, in fact, routinely used during multistep syntheses of natural and specialty products, in both laboratory and industrial processes.[1]

Acetyl chloride[2] and acetic anhydride[3] are usually employed as acetylating agents in the presence of tributylphosphine[4] or pyridine derivatives.[5] Various catalysts developed for acylation include DMAP,[6] $CoCl_2$,[7] Bu_3P,[4a] Triflates,[8] $TaCl_5$,[9] zeolite,[10] clays,[11] Nafion-H,[12] yttria-zirconia,[13] $LiClO_4$,[14] $Mg(ClO_4)_2$,[15] ionic liquids,[16] $InCl_3$,[17] $ZrCl_4$,[18] $Cu(BF_4)$•xH_2O,[19] $RuCl_3$,[20] P_2O_5/SiO_2,[21] $ZrOCl_2$•$8H_2O$,[22] and alumina.[23] Although a large number of methods for acetylation are available, the practical applicability of most of these methods suffers from limitations such as the use of: (1) expensive, moisture sensitive and toxic catalysts, (2) long reaction time and (3) a lack of generality. In view of the modern demands of organic synthesis,[24] there is still the need to develop an efficient, mild and environmentally benign protocol for the acetylation of alcohols.

In recent years, molecular iodine has drawn considerable attention as an inexpensive, non-toxic, non-metallic and readily available catalyst for various organic transformations under mild and convenient conditions in excellent yields and high selectivity.[25] Very recently, molecular iodine catalyzed acetylation of alcohols was also reported.[26]

We describe herein an efficient and convenient procedure for acetylation of alcohols under solvent-free conditions in the presence of a catalytic amount of iodine supported on 3-aminopropyl silica gel (APSG).

Results and discussion

APSG was prepared from the reaction of activated silica gel with 3-aminopropyltriethoxysilane in toluene at room temperature. The absorption at 2950 and 3649 cm^{-1} in FT-IR spectrum of 3-aminopropylsilica gel was characterized for methylene and amino groups respectively. Supporting of iodine on APSG was carried out with stirring APSG in solution of I_2/THF at room temperature. The amount of iodine supported on APSG was determined iodometrically. The capacity was 0.14 mmol of iodine per gram of silica support. Surprisingly, this supported iodine was very stable and no changes in its capacity could be observed after 120 d.[25l]

The main target of this work was to setup a new acetylation methodology based on the use of iodine supported on the APSG (I_2/APSG) as the catalyst, which could represent an improvement in efficiency and convenience over previously reported procedures. Initially a systematic study was carried out for catalytic evaluation of I_2/APSG for acetylation of 1-octanol (Table 1, Scheme 1). The reaction was very slow in the ab-

Scheme 1

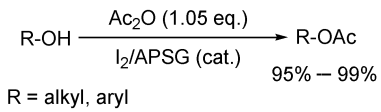

Table 1 Acetylation of 1-octanol under different conditions[a]

Run	Solvent	m(I_2/APSG)/g	Time/h	Yield/%
1	—	Nil	12	N.R.
2	CH_2Cl_2	Nil	12	2
3	CH_2Cl_2	0.1	12	10
4	$CH_3COOC_2H_3$	0.1	12	5
5	$CHCl_3$	0.1	12	15
6	Dioxane	0.1	12	10
7	—	0.1	1	＞99

[a] 1-Octanol: 1 mmol, T＝25 ℃; Ac_2O: 1.05 equiv.

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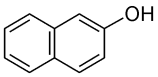
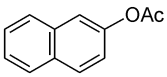
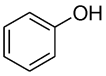
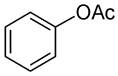
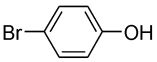
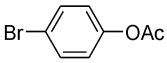
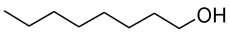
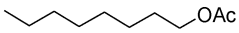
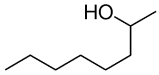
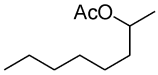
sence of catalyst. Surprisingly, the best rate of acetylation was observed when the reaction was carried out without solvent.

The results of the reactions of a diverse range of alcohols and phenols are summarized in Table 2. Both primary and secondary alcohols reacted very well and *t*-butyl alcohols was also acetylated smoothly without any side reactions. Phenolic compounds and also benzylic alcohols containing electron withdrawing and donating groups reacted with very good efficiency under

Table 2 Acetylation of various alcohols catalysed by I_2/APSG[a]

Entry	Substrate	Time/h	Product[b]	Yield[c]/%
1		40		>99
2		17		>99
3		18		>99
4		1		>99
5		4		>99
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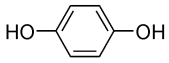
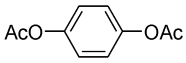
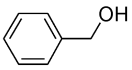
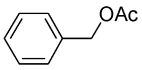
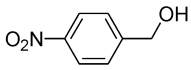
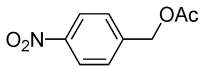
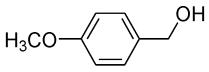
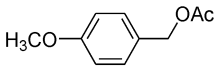
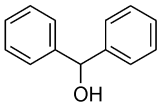
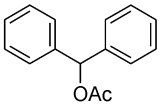
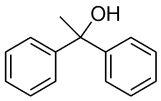
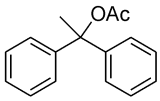
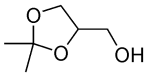
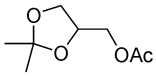
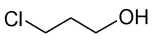
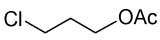
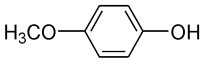
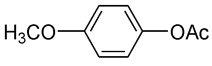
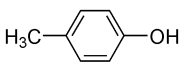
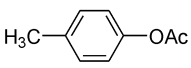
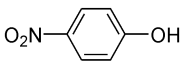
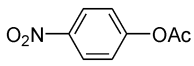
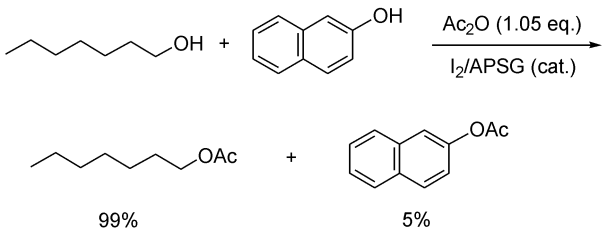
7		10		>99
8[d]		21		>99
9		1.6		>99
10		1.7		98
11		1		98
12		7		99
13		5		3
14		1		95
15		1		97
16		14		98
17		15		97
18		22		98

[a] Reaction conditions: subsrate=1 mol, Ac_2O=1.05 mmol, I_2/APSG=1 g, 25 ℃. [b] Products were characterised by IR, NMR and matched with literature data. [c] Isolated yield. [d] Ac_2O=2 mmol.

this reaction condition.

Selective acetylation of one hydroxyl group in the presence of the other ones is a frequent synthetic problem. The chemo-selectivity of the system was studied by competitive acetylation of the equimolar mixture of hydroxyl compounds (Scheme 2).

Scheme 2

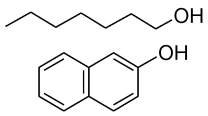
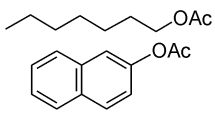
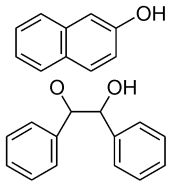
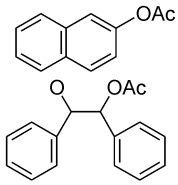
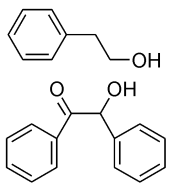
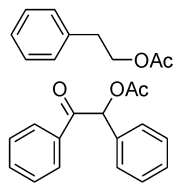
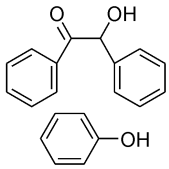
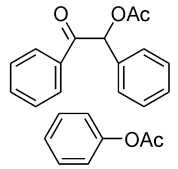
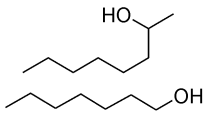
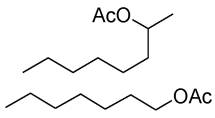
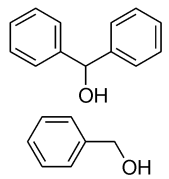
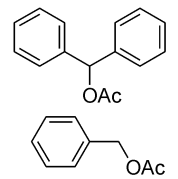


The selectivity of this system is equal to or greater than those of previously reported selective reagents.[5] Table 3 shows a remarkable selective acetylation of compounds under solvent-free conditions by this system.

One of the interesting behaviour of the catalyst (I_2/APSG) lies in the fact that it can be reused many times (>30 times) after simple washing and repeating of iodine supporting step, rendering thus process more economic. Also, another special aspect of this catalyst is its stability and long storing time (>6 month in ordinary condition) without any loss of its iodine capacity and efficiency.

In conclusion, we have demonstrated that iodine supported on 3-aminopropyl silica gel (I_2/APSG) was a useful and highly efficient catalyst for the chemoselec-

Table 3 Chemo-selective acetylation of hydroxyl compounds by I_2/APSG under solvent-free condition[a]

Entry	Substrate	Time/h	Product	Yield[b]/%
1		5		99 5
2		7		10 90
3		1		95 10
4		5		80 20
5		0.7		30 70
6		1		5 99

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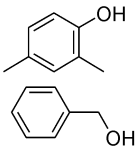
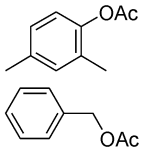
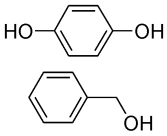
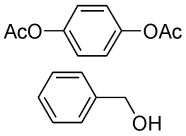
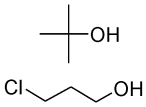
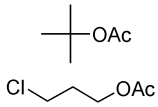
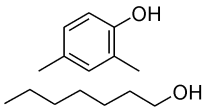
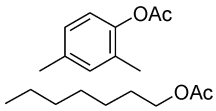
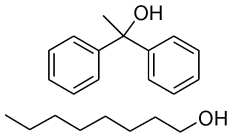
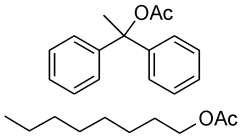
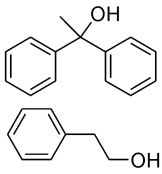
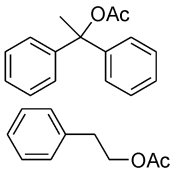
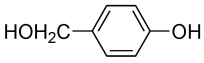
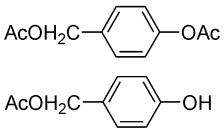
7		1		5 99
8[c]		1		3 99
9		1		37 99
10		1		4 99
11		1		0 99
12		1		0 99
13		1		4 96

[a] Reaction conditions: Subsrate＝1 mol, Ac_2O＝2.5 mmol, I_2/APSG＝1 g, 25 ℃. [b] Determined by GC. [c] Ac_2O＝3 mmol.

tive acetylation of alcohols and phenols in a solvent free condition. Nearly equimolar amount of alcohol and Ac_2O are typically used avoiding waste and providing very simple experimental and workup procedures. Furthermore, this catalyst system has the inherent advantages of a solid catalyst, including operational simplicity, filterability, and reusability.

Typical procedures

Preparation of iodine supported on 3-aminopropyl silica gel (I_2/APSG)

Silica gel (Fluka 100, P.S. 0.015—0.035 nm) was activated by refluxing in concentrated HCl for 4 h, followed by washing with water repeatedly and dried overnight under vacuum at 80 ℃. To this activated silica gel (13.39 g), a toluene solution (70 mL) of 3-aminopropyltriethoxysilane (10.0 g, 0.045 mol) was added and then the mixture stirred for 30 min at 80 ℃. The modified silica was washed successively with toluene, dichloromethane, and ether respectively and then dried overnight under vacuum at 80 ℃.

The prepared 3-aminopropyl silica gel (5 g) was placed in a flask, to which a solution of iodine (4 g) in THF (50 mL) was added and the resulting suspension was stirred magnetically at room temperature for 12 h. The mixture was filtered and washed with THF repeatedly using a Soxhlet apparatus, until the solvent became colourless. The resulting brown precipitate was dried overnight under vacuum at 70 ℃. The 3-aminopropyl silica gel supported iodine was obtained as a yellow solid. The amount of iodine supported on the 3-aminopropyl silica gel was determined iodo-metrically. It was 0.14 mmol of iodine per gram of

the supported catalyst.

General procedure for the acetylation of alcohols using I_2/APSG

To a stirred mixture of alcohol (1 mmol) and 0.1 g of catalyst, Ac_2O (1.05 mmol) was added and stirring continued at room temperature for the appropriate time (TLC). After completion of the reaction, the catalyst was destroyed by adding saturated sodium thiosulfate solution (5 mL). Diethyl ether (10 mL) was added and the organic phase was separated. The organic phase was washed with saturated $NaHCO_3$ solution (5 mL), dried over Na_2SO_4 and concentrated to give the pure product.

Compound 1: 2-Naphthyl acetate (solid, m.p. 67—70 ℃); IR (KBr) *v*: 3068, 1755 (CO), 1627, 1598, 1464, 1440, 1429, 1209, 1046, 768 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ: 2.31 (s, 3H, $COCH_3$), 7.21—7.8 (m, 7H, ArH).

Acknowledgements

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References

1 (a) Greene, T. W.; Wuts, P. G. In *Protective Groups in Organic Synthesis*, 3rd ed., John Wiley & Sons, New York, **1999**, pp. 150—160.
(b) Hofle, G.; Steglish, V.; Vorbrueggen, H. *Angew. Chem., Int. Ed. Engl.* **1978**, *17*, 569.
(c) Otera, J. *Chem. Rev.* **1993**, *93*, 1449.
(d) Franklin, A. S. *J. Chem. Soc., Perkin Trans. 1* **1998**, 2451.
(e) Franklin, A. S. *J. Chem. Soc., Perkin Trans. 1* **1999**, 3537.
2 Horton, D. *Organic Syntheses*, Collect. Vol. V, Wiley, New York, **1973**, p. 1.
3 Dauban, W. G.; Bune, R. A.; Gerdes, J. M.; Henger, K. E.; Cunningham, A. F., Jr.; Ottoboni, T. B. *Tetrahedron Lett.* **1983**, *24*, 5709.
4 (a)Vedejs, E.; Diver, S. T. *J. Am. Chem. Soc.* **1993**, *115*, 3358.
(b) Vedejs, E.; Bennett, N. S.; Conn, L. M.; Diver, S. T.; Gingaves, M.; Lin, S.; Oliver, P. A.; Peterson, M. J. *J. Org. Chem.* **1993**, *58*, 7286.
5 Scriven, E. F. V. *Chem. Soc. Rev.* **1983**, *12*, 366.
6 Steglich, W.; Hofle, G. *Angew. Chem., Int. Ed. Engl.* **1969**, *8*, 981.
7 (a) Iqbal, J.; Srivastava, R. R. *J. Org. Chem.* **1992**, *2001*, 57.
(b) Ahmad, S.; Iqbal, J. *Tetrahedron Lett.* **1986**, *27*, 3791.
8 (a) Ishihara, K.; Kubota, M.; Kurihara, H.; Yamamoto, H. *J. Org. Chem.* **1996**, *61*, 4560.
(b) Ishihara, K.; Kubota, M.; Yamamoto, H. *Synlett* **1996**, 265.
(c) Procopiou, P. A.; Baugh, S. P. D.; Flack, S. S.; Inglis, G. G. A. *J. Org. Chem.* **1998**, *63*, 2342.
(d) Chauhan, K. K.; Frost, C. G.; Love, I.; Waite, D. *Synlett* **1999**, 1743.
(e) Orita, A.; Tanahashi, C.; Kakuda, A.; Otera, J. *J. Org. Chem.* **2001**, *66*, 8926.
(f) Carrigan, M. D.; Freiberg, D. A.; Smith, R. C.; Zerth, H. M.; Mohan, R. S. *Synthesis* **2001**, 2091.
(g) Mohammadpoor-Baltork, I.; Aliyan, H.; Khosropour, A. R. *Tetrahedron* **2001**, *57*, 5851.
(h) Chakraborti, A. K.; Shivani, R. G. *Synlett* **2003**, 1805.
(i) Dalpozzo, R.; De Nino, A.; Maiuolo, L.; Procopio, A.; Nardi, M.; Bartol, G.; Romeo, R. *Tetrahedron Lett.* **2003**, *59*, 5621.
(j) Karimi, B.; Maleki, J. *J. Org. Chem.* **2003**, *68*, 4951.
(k) Chandra, K. L.; Saravanan, P.; Singh, R. K.; Singh, V. K. *Tetrahedron* **2002**, *58*, 1369.
9 Chandrasekhar, S.; Ramachander, T.; Takhi, M. *Tetrahedron Lett.* **1998**, *39*, 3263.
10 Ballini, R.; Bosica, G.; Carloni, S.; Ciaralli, L.; Maggi, R.; Sartori, G. *Tetrahedron Lett.* **1998**, *39*, 6049.
11 Bhaskar, P. M.; Loganathan, D. *Tetrahedron Lett.* **1998**, *39*, 2215.
12 Kumareswaran, R.; Pachamuthu, K.; Vankar, Y. D. *Synlett* **2000**, 1652.
13 Kumar, P.; Pandey, R. K.; Bodas, M. S.; Dongare, M. K. *Synlett* **2001**, 206.
14 Nakae, Y.; Kusaki, I.; Sato, T. *Synlett* **2001**, 1584.
15 Bartoli, G.; Bosco, M.; Dalpozzo, R.; Marcantoni, E.; Massaccesi, M.; Rinaldi, S.; Sambri, L. *Synlett* **2003**, 39.
16 Lee, S. G.; Park, J. H. *J. Mol. Catal. A: Chem.* **2003**, *194*, 49.
17 Chakraborti, A. K.; Gulhane, R. *Tetrahedron Lett.* **2003**, *44*, 3521.
18 Chakraborti, A. K.; Gulhan, R. *Synlett* **2004**, 627.
19 Chakraborti, A. K.; Shivani, R. G. *Synthesis* **2004**, 111.
20 Kanta De, S. *Tetrahedron Lett.* **2004**, *45*, 2919.
21 Eshghi, H.; Shafieyoon, P. *J. Chem. Res.* (*S*) **2004**, 802.
22 Ghosh, R.; Maiti, S.; Chakraborty, A. *Tetrahedron Lett.* **2005**, *46*, 147.
23 Yadav, V. K.; Babu, K. G. *J. Org. Chem.* **2004**, *69*, 577.
24 Anastas, P.; Williamson, T. *Green Chemistry, Frontiers in Benign Chemical Synthesis and Procedures*, Oxford Science Publications, Oxford, **1998**.
25 (a) Kim, K. M.; Ryu, E. K. *Tetrahedron Lett.* **1996**, *37*, 1441.
(b) Karimi, B.; Golshani, B. *J. Org. Chem.* **2000**, *65*, 7228.
(c) Firouzabadi, H.; Iranpoor, N.; Hazarkhani, H. *J. Org. Chem.* **2001**, *66*, 7527.
(d) Deka, N.; Sarma, J. C. *J. Org. Chem.* **2001**, *66*, 1947.
(e) Firouzabadi, H.; Iranpoor, N.; Sobhani, S. *Tetrahedron Lett.* **2002**, *43*, 3653.
(f) Yadav, J. S.; Reddy, B. V. S.; Reddy, M. S.; Prasad, A. R. *Tetrahedron Lett.* **2002**, *43*, 9703.
(g) Bandgar, B. P.; Shaikh, K. A. *Tetrahedron Lett.* **2003**, *44*, 1959.
(h) Das, B.; Banerjee, J.; Ramu, R.; Pal, R.; Ravindranath, N.; Ramesh, C. *Tetrahedron Lett.* **2003**, *44*, 5465.
(i) Miller, R. A.; Hoerrner, R. S. *Org. Lett.* **2003**, *5*, 285.

(j) Sun, J.; Dong, Y.; Wang, X.; Wang, S.; Hu, Y. *J. Org. Chem*. **2004**, *69*, 8932.
(k) Ke, B.; Qin, Y.; He, Q.; Huang, Z.; Wang, F. *Tetrahedron Lett*. **2005**, *46*, 1751.
(l) Tamami, B.; Iranpoor, N.; Mahdavi, H. *Synth. Commun*. **2002**, *32*, 1251.
26 (a) Bosco, J. W. J.; Agrahari, A.; Saikia, A. K. *Tetrahedron Lett*. **2006**, *47*, 4065.
(b) Phukan, P. *Tetrahedron Lett*. **2004**, *45*, 4785.

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