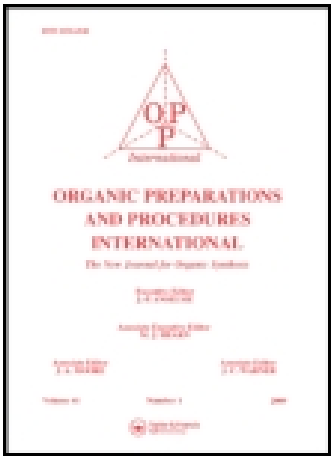


Organic Preparations and Procedures International: The New Journal for Organic Synthesis

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/uopp20

Friedlander Synthesis of Quinolines Promoted By Polymer-bound Sulfonic Acid

Behrooz Maleki[a], Esmail Rezaei Seresht[a] & Zahra Ebrahimi[a]

[a] Department of Chemistry, Hakim Sabzevari University, Sabzevar, Khorasan, Iran

Published online: 18 Mar 2015.

Organic Preparations and Procedures International, 47:149–160, 2015

ISSN: 0030-4948 print / 1945-5453 online
DOI: 10.1080/00304948.2015.1005986

Friedlander Synthesis of Quinolines Promoted By Polymer-bound Sulfonic Acid

Behrooz Maleki, Esmail Rezaei Seresht, and Zahra Ebrahimi

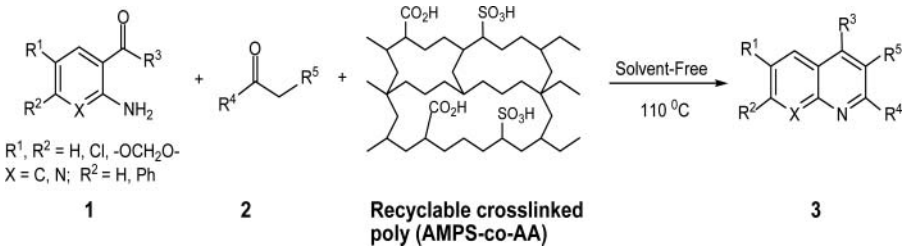
Department of Chemistry, Hakim Sabzevari University, Sabzevar, Khorasan, Iran

Quinolines and their derivatives are very important biologically and occur widely in natural products. Members of this family have displayed interesting physiological activities and found major applications in medicinal chemistry, as anti-malarial,[1–2] anti-bacterial,[3–4] anti-inflammatory,[5–6] anti-hypertensive,[7–8] anti-platelet, and tyrosine kinase inhibiting agents.[9–13] They are also useful for the preparation of nano- and meso-structures having enhanced electronic and photonic properties.[14–15] Moreover, quinolines are also employed in the fields of bioorganic,[16] bioorganometallic processes[17] and industrial organic chemistriy.[18] Therefore, the exploration of efficient synthetic methods to construct the quinoline framework has continually drawn great attention for many decades.

Among these methods, the Friedlander annulations is one of the simplest and most direct approaches for the synthesis of quinolines. It involves the acid-, base-catalyzed or thermal condensation between *o*-aminoarylketones and aldehydes with another carbonyl compound possessing a reactive α-methylene group followed by cyclodehydration.[19–23] It has been shown that acid catalysis is more effective than base catalysts for the Friedlander annulation. In recent years, Bronsted and Lewis acids such as ionic liquids,[24–26] sulfamic acid,[27] hydrochloric acid,[28] zirconium tetrakisdodecyl sulfate [$Zr(DS)_4$],[29] silica sulfuric acid,[30–31] silica supported phosphomolybdic acid [$PMA.SiO_2$],[32] nanocrystalline aluminium oxide,[33] dodecylphosphonic acid (DPA),[34] poly(*N*-bromoethylbenzene-1,3-disulfonamide) [PBBS] or *N,N,N′,N′*-tetrabromobenzene-1,3-disulfonamide [TBBDA],[35] zinc triflate,[36] nano-flake ZnO,[37] $Cs_xH_{3-x}PW_{12}O_{40}$ heteropoly salts,[38] $Yb(OTf)_3$,[39] nanosized MCM-41 supported ionic liquid [$(BSPY)HSO_4$/MCM-41],[40] *o*-benzendisulfonimide[41] and nanocrystalline sulfated zirconia[42] have been utilized. However, many of these methods suffer from harsh reaction conditions, long reaction times, low yields, expensive reagents, tedious work-up procedures. The main disadvantage of nearly all existing methods is that the catalysts cannot be recovered and reused. For these reasons, the use of solid and heterogeneous catalysts has received considerable attention in organic synthesis. This extensive application of heterogeneous catalysts can make the process more efficient from both the environmental and economic points of view when the catalyst can be easily recycled.[43–45]

There are no previous report describing the use of ***Poly(AMPS-co-AA)*** in organic transformations.[46–48] and it has been shown to possess several advantages such as low toxicity and cost, ease of handling and high catalytic activity as a potential green catalyst.

Received April 14, 2014; in final form November 6, 2014.
Address correspondence to Behrooz Maleki, Department of Chemistry, Hakim Sabzevari University, Sabzevar, Khorasan, Iran. E-mail: malekibehrooz@gmail.com



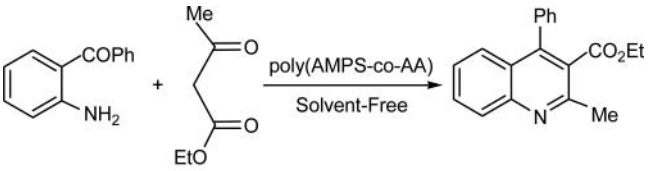
Scheme 1

We now disclose a novel, green, facile and convenient method for the preparation of quinoline from *o*-aminoaryl ketones or aldehydes and various ketones catalyzed by poly (AMPS-co-AA) under solvent-free conditions at 110°C (*Scheme 1*).

In order to determine the optimum conditions, the effect of temperature on the rate of the reaction was studied first for the preparation of **3a** from the two-component condensation of ethyl acetoacetate with *o*-aminobenzophenone under solvent-free conditions (*Table 1, Entries 1–4*). At 110°C, the reaction proceeded smoothly with near complete conversion to product. Further increase in temperature to 120 and 130°C did not accelerate rate or improve the yield. The study to determine optimal amount of Poly (AMPS-co-AA), was carried out by varying the amount of the catalyst (*Entries* 5, 6). The maximum yield was obtained with 0.06 g. Further increases in amount of Poly (AMPS-co-AA) did not have any significant effect on the yield. In absence of the catalyst, no products could be detected even after 1h.

We next established the generality of these conditions using different types of α-methylene carbonyl compounds with *o*-aminoaryl ketones to produce the corresponding quinolines under solvent-free conditions (*Table 2*).

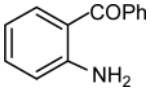
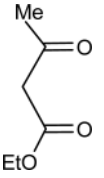
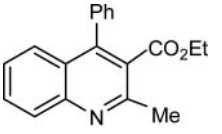
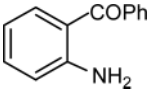
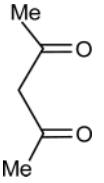
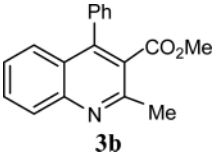
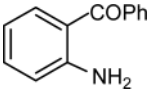
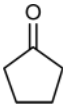
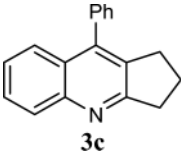
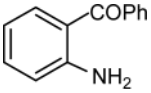
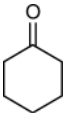
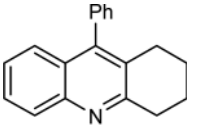
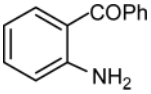
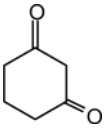
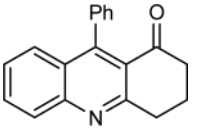
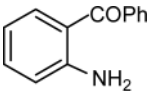
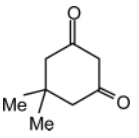
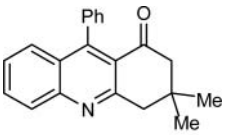
Table 1
Screening of the Reaction Conditions for the Synthesis of **3a**



Entry	Poly (AMPS-co-AA) (g)	Temp. (°C)	Times (min)	Yield (%)
1	0.06	100	15	68
2	0.06	110	10	84
3	0.06	120	10	68
4	0.06	130	10	50
5	0.08	110	10	80
6	0.03	110	20	72
7	—	110	60	—[a]

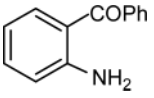
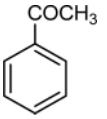
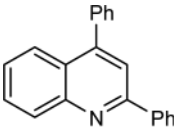
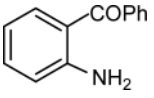
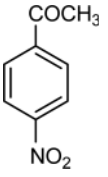
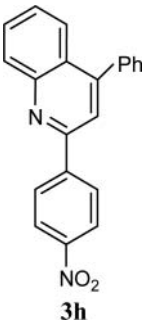
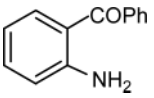
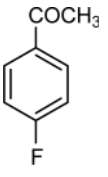
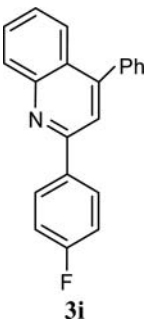
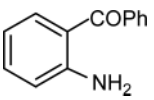
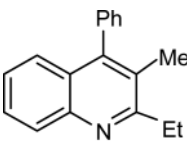
[a] No reaction.

Table 2
The Heterogeneous Synthesis of Quinolines using Poly(AMPS-co-AA)

o-Aminoaryl ketones or aldehydes	**α**-Methylene ketones	Quinoline	Yield (%)	Time (min)	mp (°C) Found	mp (°C) Lit.
		 **3a**	84	10	100–101	100–101[40]
		 **3b**	80	10	108–110	108–109[40]
		 **3c**	80	10	134–135	133–135[37]
		 **3d**	90	60	140–142	138–141[37]
		 **3e**	95	10	156–158	159[26]
		 **3f**	90	10	190–192	189–191[37]

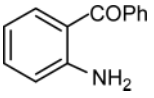
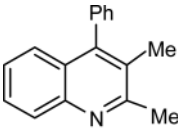
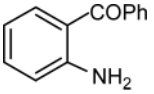
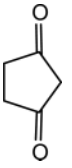
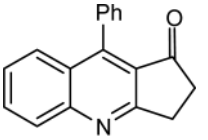
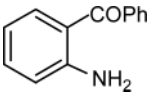
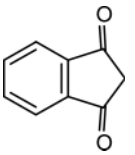
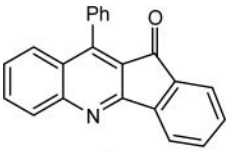
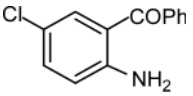
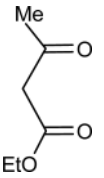
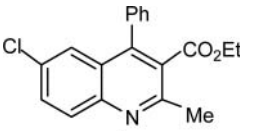
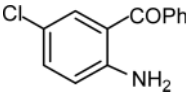
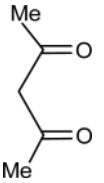
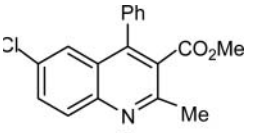
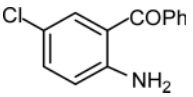
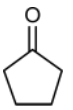
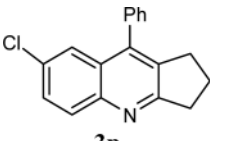
(*Continued on next page*)

Table 2
The Heterogeneous Synthesis of Quinolines using Poly(AMPS-co-AA) *(Continued)*

o-Aminoaryl ketones or aldehydes	**α**-Methylene ketones	Quinoline	Yield (%)	Time (min)	mp (°C) Found	mp (°C) Lit.
		 **3g**	97	70	107–109	107–109[31]
		 **3h**	86	60	160–161	—
		 **3i**	86	70	93–94	—
	Et_2CO	 **3j**	84	20	96–97	95–96[38]

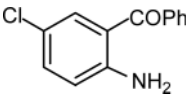
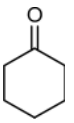
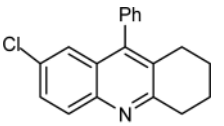
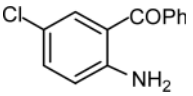
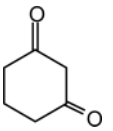
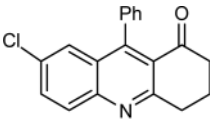
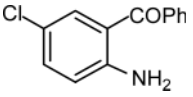
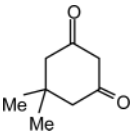
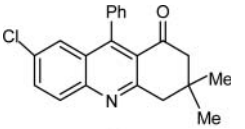
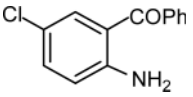
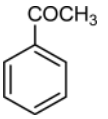
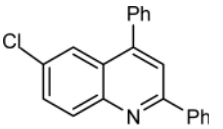
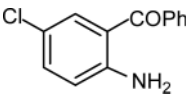
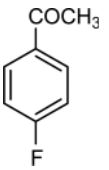
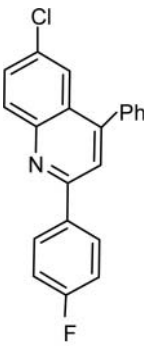
(*Continued on next page*)

Table 2
The Heterogeneous Synthesis of Quinolines using Poly(AMPS-co-AA) *(Continued)*

o-Aminoaryl ketones or aldehydes	**α**-Methylene ketones	Quinoline	Yield (%)	Time (min)	mp (°C) Found	mp (°C) Lit.
	EtMeCO	 **3k**	80	20	145–146	144[38]
		 **3l**	76	60	176–177	174–175[34]
		 **3m**	89	30	174–176	172[38]
		 **3n**	86	10	102–104	102–104[40]
		 **3o**	70	20	154–155	154[40]
		 **3p**	89	15	97–98	97–98[40]

(*Continued on next page*)

Table 2
The Heterogeneous Synthesis of Quinolines using Poly(AMPS-co-AA) *(Continued)*

o-Aminoaryl ketones or aldehydes	**α**-Methylene ketones	Quinoline	Yield (%)	Time (min)	mp (°C) Found	mp (°C) Lit.
		 **3q**	70	25	161–162	162–163[40]
		 **3r**	90	10	185–186	185[29]
		 **3s**	95	15	208–209	209–211[30]
		 **3t**	65	45	126–127	128–130[31]
		 **3u**	94	50	137–139	—

(*Continued on next page*)

Table 2
The Heterogeneous Synthesis of Quinolines using Poly(AMPS-co-AA) *(Continued)*

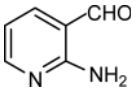
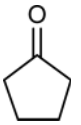
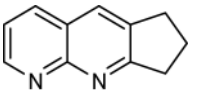
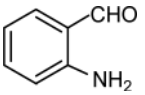
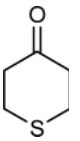
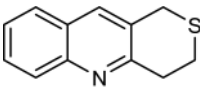
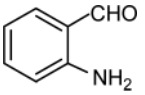
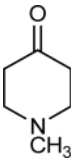
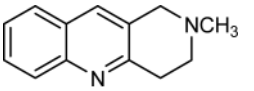
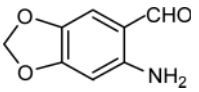
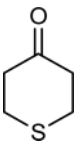
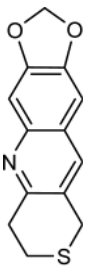
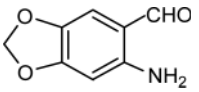
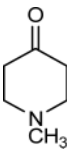
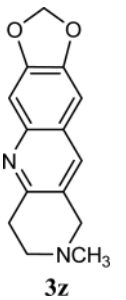
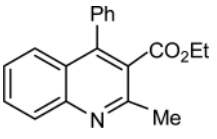
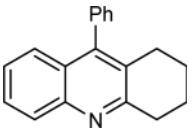
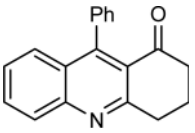
o-Aminoaryl ketones or aldehydes	**α**-Methylene ketones	Quinoline	Yield (%)	Time (min)	mp (°C) Found	mp (°C) Lit.
		 **3v**	82	40	93–95	91–93[39]
		 **3w**	86	40	98–99	96–99[20]
		 **3x**	88	40	78–79	76–77[20]
		 **3y**	92	40	206–207	203–205[20]
		 **3z**	90	40	191–192	190–192[20]

Table 3
Comparison of Methods for the Synthesis of Quinolines.

Entry	Quinolines **3**	Conditions	Time (min)	Yield (%)
3a		$Zr(DS)_4$/EtOH:H_2O(1:2)/Reflux[29]	180	72
		Silica sulfuric acid/100°C/ Solvent-Free[30]	55	87
		PMA.SiO_2/EtOH/Reflux[32]	60	94
		Nanocrystalline Al_2O_3/$CHCl_3$/Reflux[33]	180	98
		DPA/90°C/Solvent-Free[34]	30	90
		Zinc triflate /MWI/Solvent-Free[36]	4/5	90
		Nano-flake ZnO /100°C/Solvent-Free[37]	210	85
		(BSPY)HSO_4/MCM-41/100°C/Solvent-Free[40]	70	93
		o-Benzendisulfonimide/80°C/Solvent-Free[41]	180	93
		Nano-crystalline SZ/EtOH/Reflux[42]	110	84
		This work	10	84
3d		PMA.SiO_2/EtOH/Reflux[32]	70	80
		Nanocrystalline Al_2O_3/$CHCl_3$/Reflux[33]	180	98
		PBBS/100°C/Solvent-Free[35]	390	84
		Nano-flake ZnO /100°C/Solvent-Free[37]	240	63
		(BSPY)HSO_4/MCM-41/100°C/Solvent-Free[40]	90	87
		Nano-crystalline SZ/EtOH/Reflux[42]	110	78
		This work	60	90
3e		SO_3H-functionalized ionic liquid/70°C/ H_2O[26]	300	90
		Sulfamic acid/60°C/Solvent-Free[27]	75	92
		$Zr(DS)_4$/EtOH:H_2O(1:2)/Reflux[29]	360	90
		Nanocrystalline Al_2O_3/$CHCl_3$/Reflux[33]	180	98
		$Cs_xH_{3-x}PW_{12}O_{40}$/100°C/Solvent-Free[38]	30	82
		(BSPY)HSO_4/MCM-41/100°C/Solvent-Free[40]	40	87
		This work	10	95

The insolubility of the Poly (AMPS-co-AA) catalyst in ethanol provided an easy method for its separation from the product. After the addition of 96% ethanol to the thick reaction mixture, the insoluble catalyst was filtered off (suction), dried at 110°C and was re-used three times without substantial decrease in yields (84–75%) of **3a.** The products were isolated by simple evaporation of the filtrate and purified by crystallization from ethanol. It is important to note that acid-sensitive functional groups in the substrates (*Table 2*, **3v–3z**) remain unaffected. Unlike previous procedures, our method does not require the use of either hazardous acids or harsh reaction conditions; it has several advantages such as higher yields, shorter reaction times, and simple experimental and work-up procedures. In addition, polymer-like condensation products resulting from the self-condensation of *o*-aminoaryl ketones and aldehydes were not found.[14–17]

In order to demonstrate the efficiency of our method, we compared our results with some selected catalyst that have been reported in the recent literature. *Table 3* indicates that it is more efficient as a green, heterogeneous catalyst in terms of reaction times and yields.

Experimental Section

IR spectra were recorded as KBr pellets on a Shimadzu 435-U-04 spectrophotometer. ^{1}H and ^{13}C NMR spectra were obtained using Bruker DRX-300 Avance spectrometer in DMSO-d_6 or $CDCl_3$ using TMS as an internal reference. Melting points were determined in open capillary tubes in a Stuart BI Branstead Electrothermal Cat No: IA9200 apparatus and are uncorrected.

Preparation of Catalyst

Cross-linked *N,N*-methylene *bis*-acrylamide (MBA, 2 g) was added to a mixture of 2-acrylamido-2-methylpropanesulfonic acid (AMPS, 10 g) and acrylic acid (AA, 10 ml) in 100 ml distilled water. The mixture was vigorously stirred (magnetic stirrer) at room temperature for 10 min. Then, the solution was added to a three-neck flask equipped with a mechanical stirrer (Heidolph RZR 2021, three blade propeller type). The flask was immersed in a thermo-stated water bath at 70°C and an inert gas (nitrogen) was gently bubbled into the solution to remove any oxygen. After 15 min, an ammonium persulfate solution (APS, 0.2 g in 2 ml H_2O) was added to the mixture, and the mixture was stirred (200 rpm) for 20 min. Methanol (40 mL) was added and the mixture was stirred gently for 72 hrs in order to remove any unreacted monomer. After decantation of the methanol, the product was broken up into small pieces (mortar and pestle), dried in an oven at 110°C for five hours and then powdered (mortar and pestle). The powdered polymer was stored protected from moisture, heat and light.[46–48]

General Procedure for the Synthesis of Quinolines

To mixture of α-methylene carbonyl compounds (1.2 mmol) and *o*-aminoaryl ketones or aldehydes (1 mmol) was added cross-linked poly(AMPS-co-AA) (0.06 g) [for solid substrates 0.1 ml of ethanol was added] and the mixture was heated on an oil bath at 110°C for the time show in *Table 2*. Upon completion of the reaction as indicated by TLC (hexane:ethyl acetate, 8:2), the appropriate amounts of hot EtOH (96%, 5 ml) was added and the mixture stirred for 10 min. After separation of the catalyst by filtration, the filtrate was concentrated in vacuum to remove the ethanol. The residue was washed with cold water and crystallized from hot ethanol (3 ml) to afford the pure products characterized by comparison between their mp, IR and NMR data with those of authentic samples.

Analytical Data for New Compounds

2-(4-Nitrophenyl)-4-phenylquinoline (3h), IR: 3052, 1600, 1580; ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.57–7.64 (m, 5H), 7.83–7.91 (m, 2H), 8.18–8.22 (m, 2H), 9.36–9.39 (d, 2H), 9.61–9.64 (d, 2H); ^{13}C NMR (75 MHz, DMSO-d_6): δ 119.30, 123.97, 125.38, 125.50, 120,76, 128.52, 128.78, 129.68, 130.00, 130.33, 132.29, 144.45, 148.09, 149.18, 153.47.

Anal. Calcd. for $C_{21}H_{14}N_2O_2$: C, 77.29; H, 4.33; N, 8.58. Found: C, 77.31; H, 4.32; N, 8.61.

2-(4-Fluorophenyl)-4-phenylquinoline (3i), IR: 3085, 1600, 1560; ^{1}H NMR (400 MHz, $CDCl_3$): 7.48–7.55 (m, 7H), 7.74–7.78 (m, 2H), 7.89–7.91 (d, 1H), 8.14–8.16 (d, 2H), 8.21–8.23 (d, 1H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 118.92, 125.70, 125.84,

126.56, 128.52, 128.65, 129.02, 129.71, 130.09, 135.58, 138.04, 138.27, 148.78, 149.44, 155.54.

Anal. Calcd. for $C_{21}H_{14}FN$: C, 84.26; H, 4.72; N, 4.68 Found: C, 84.29; H, 4.70; N, 4.65.

6-Chloro-2-(4-fluorophenyl)-4-phenylquinoline (3u), IR: 3085, 1600, 1560; ^{1}H-NMR (300 MHz, DMSO-d_6): δ 7.33–7.39 (t, 2H), 7.55–7.63 (m, 5H), 7.75 (s, 1H), 7.79–7.83 (d, 1H), 8.10 (s, 1H), 8.14–8.17 (d, 1H), 8.37–8.42 (t, 2H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 120.03, 124.50, 126.51, 127.56, 128.73, 128.84, 128.92, 129.44, 129.62, 130.46, 131.77, 132.17, 137.77, 139.22, 147.25, 148.25, 157.07.

Anal. Calcd. for $C_{21}H_{13}ClFN$: C, 75.56; H, 3.92; N, 4.28. Found: C, 75.56; H, 3.90; N 4.32.

Acknowledgment

The authors are thankful to the Research Council of Hakim Sabzevari University for financial support.

References

1. P. M. S. Chauhan and S. K. Srivastava, *Curr. Med. Chem.*, **8**, 1535 (2001).
2. F. S. Yates, *In Comprehensive Heterocyclic Chemistry*, A. J. Boulton, A. McKillop, Eds, Pergamon Press: New York. **2**, 209 (1984).
3. K. Mogilaiah, D. S. Chowdaryand and B. Rao, *Indian J. Chem. Sect. B* **40**, 43 (2001).
4. Y. L. Chen, K. G. Fang, J. Y. Sheu, S. L. Hsu and C. C. Tzeng, *J. Med. Chem.*, **44**, 2374 (2001).
5. G. Roma, M. D. Braccio, G. Grossi, F. Mattioli and M. Ghia, *Eur. J. Med. Chem.*, **35**, 1021 (2000).
6. B. Kalluraya and S. Sreenizasa, *Farmaco*, **53**, 399 (1998).
7. Y. Morizawa, T. Okazoc, S. Z. Wang, J. Sasaki, H. Ebisu and M. Nishikawa, *J. Fluorine Chem.*, **109**, 83 (2001).
8. P. L. Ferrarini, C. Mori, M. Badawneh, V. Calderone, R. Greco, C. Manera, A. Martinelli, P. Nieri and G. Saccomanni, *Eur. J. Chem.*, **35**, 815 (2000).
9. R. D. Larsen, E. G. Corley, A. O. King, J. D. Carrol, P. T. Davis, R. Verhoeven, P. J. Reider, M. Labelle. J. Y. Gauthier, Y. B. Xiang and R. J. Zamboni, *J. Org. Chem.*, **61**, 3398 (1996).
10. Y. L. Chen, K. C. Fang, J. Y. Sheu, S. L. Hsu and C. H. Tzeng, *J. Med. Chem.*, **44**, 2374 (2001).
11. D. Doube, M. Bloun, C. Brideau, C. Chan, S. Desmarais, D. Eithier, J. P. Fagueyret, R. W. Friesen, M. Girad, Y. Girad, Y. J. Guay, P. Tagari and R. N. Young, *Bioorg. Med. Chem. Lett.*, **8**, 1255 (1998).
12. T. C. Ko, M. J. Hour, J. C. Lien, C. M. Teng, K. H. Lee, S. C. Kuo and L. J. Huang, *Bioorg. Med. Chem. Lett.*, **11**, 279 (2001).
13. P. L. Ferrarini, C. Mori, M. Badawneh, C. Manera, A. Martinelli, M. Miceli, F. Ramagnoli and G. Saccomanni, *J. Heterocyclic Chem.*, **34**, 1501 (1997).
14. A. K. Agarwal and S. A. Jenekhe, *Macromolecules*, **24**, 6806 (1991).

15. X. Zhang, A. S. Shetty and S. A. Jenekhe, *Macromolecules*, **32**, 7422 (1999).

16. X. Zhang, A. S. Shetty and S. A. Jenekhe, *Macromolecules*, **33**, 2069 (2000).

17. S. A. Jenekhe, L. Lu and M. M. Alam, *Macromolecules*, **34**, 7315 (2001).

18. K. Nakatani, S. Saito and I. Sando, *Bioorg. Med. Chem.*, **9**, 2381 (2001).

19. J. M. Contelles, E. P. Mayoral, A. Samadi, M. C. Carreiras and E. Soriano, *Chem. Rev.* **109**, 2652 (2009).

20. Yang, K. Jiang, J. Li and F. Xu, *Tetrahedron*, **63**, 7654 (2007).

21. V. R. Ramhari, P. S. Deepak, R. P. Sandeep and N. J. Madhukar, *Org. Prep. Proced. Int.*, **43**, 457 (2011).

22. M. R. Akula, M. W. Wolowyk and E. E. Knaus, *Org. Prep. Proced. Int.*, **23**, 386 (1991).

23. F. Al-Omran, A. A. El-Khair and M. H. Elnagdi, *Org. Prep. Proced. Int.*, **30**, 211 (1998).

24. E. Kermani-Tavakolinejad, H. Khabazzadeh and T. Jazinizadeh, *J. Heterocyclic Chem.*, **48**, 1192 (2011).

25. S. S. Palimkar, S. A. Siddiqui, T. Daniel, R. J. Lahoti and K. V. Srinivasan, *J. Org. Chem.*, **68**, 9371 (2003).

26. J. Akbari, A. Heydari, H. R. Kalhor and S. Azizian Kohan, *J. Comb. Chem.*, **12**, 137 (2010).

27. J. S. Yadav, P. P. Rao, D. Sreenu, R. S. Rao, V. N. Kumar, K. Nagaiah and A. R. Prasad, *Tetrahedron Lett.*, **46**, 7249 (2005).

28. G. C. Muscia, M. Bollini, J. P. Carnevale, A. M. Bruno and S. E. Asis, *Tettahedron Lett.*, **47**, 8811 (2006).

29. M. A. Zolfigol, P. Salehi, A. Ghaderi, M. Shiri and Z. Tanbakouchian, *J. Mol. Catal. A: Chem.*, **259**, 253 (2006).

30. A. Shaabani, E. Soleimani and Z. Badri, *Monatsh. Chem.*, **137**, 181 (2006).

31. M. A. Zolfigol, P. Salehi, M. Shiri, T. Faal Rastegar and A. Ghaderi, *J. Iran. Chem. Soc.*, **5**, 490 (2008); *Chem. Abstr.,* **148**, 214931c (2009).

32. B. Das, M. Krishnaiah, K. Laxminarayana and D. Nandankumar, *Chem. Pharm. Bull.*, **56**, 1049 (2008).

33. S. Sadjadi, S. Shiri, R. Hekmatshoar and Y. S. Beheshtiha, *Monatsh. Chem.*, **140**, 1343 (2009).

34. S. Ghassamipour and A. R. Sardarian, *Tetrahedron Lett.*, **50**, 514 (2009).

35. R. Ghorbani-Vaghei and S. Akbari-Dadamahaleh, *Tetrahedron Lett.*, **50**, 1055 (2009).

36. K. C. Lekhok, D. Bhuyan, D. Prajapati and R. C. Boruah, *Mol. Divers.*, **14**, 841 (2010).

37. M. Hosseini-Sarvari, *J. Iran. Chem. Soc.*, **8**, S119 (2011).

38. M. A. Pasha, V. P. Jayashankara and K. A. Mahammed, *Indian J. Chem.*, **47B**, 1160 (2008).

39. S. Genovese, F. Epifano, M. C. Marcotullio, C. Pelucchini and M. Curini, *Tetrahedron Lett.*, **52**, 3447 (2011).

40. M. Abdollahi-Alibeik and M. Pouriayevali, *Catal. Commun.*, **22**, 13 (2012).

41. M. Barbero, S. Bazzi, S. Cadamuro and S. Dughera, *Tetrahedron lett.*, **51**, 2342 (2010).

42. A. Teimouri and A. Najafi Chermahini, *Arab. J. Chem.*, Doi: 10.1016/j.arabjc.2011.05.018 (2011).

43. A. Zare, A. Hasaninejad, M. Shekouhy and M. R. Moosavi Zare, *Org. Prep. Proced. Int.*, **40**, 457 (2008)

44. R. Ghorbani-Vaghei and S. M. Malekehpoor, *Org. Prep. Proced. Int.*, **42**, 494 (2010).

45. A. Zare, *Org. Prep. Proced. Int.*, **44**, 82 (2012).

46. A. Mohammadi, H. Keshvari, R. Sandaroos, B. Maleki, H. Rouhi, H. Moradi and Z. Sepehr, *Appl. Catal. A: Gen.*, **429**-**430**, 73 (2012)

47. B. Maleki, S. S. Barzegar, Z. Sepehr, M. Kermanian and R. Tayebee, *J. Iran. Chem. Soc.*, **9**, 757 (2012).

48. B. Maleki, R. Tayebee, Z. Sepehr and M. Kermanian, *Acta Chim. Slov.*, **59**, 814 (2012).