Afaf Mohamed Abdel Hameed*, Moustafa Sherief Moustafa, Saleh Mohammed Al-Mousawi, Reham R. Awed and Kamal Usef Sadek

An efficient and catalyst-free synthesis of N-arylidene-2-arylimidazo[1,2-a]pyridine-3-ylamine derivatives *via* Strecker reaction under controlled microwave heating

DOI 10.1515/gps-2017-0019
Received January 31, 2017; accepted April 11, 2017; previously published online June 13, 2017

Abstract: An efficient one-pot multicomponent reaction of 2-aminopyridine with aromatic aldehydes and either benzoyl cyanide or cyanamide in pyridine under controlled microwave heating afforded N-aryldene-2-arylimidazo[1,2-a]-pyridine-3-ylamine derivatives. The reaction is catalyst free and is of high atom economy.

Keywords: catalyst free; microwave heating; multicomponent reaction; N-aryldene-2-arylimidazo[1,2-a]-pyridine-3-ylamine; Strecker reaction.

1 Introduction

Imidazo[1,2-a]pyridine derivatives are highly potent heterocyclic scaffolds because of their biological activity and are found in numerous drugs, such as Zolpidem, Alpidem, Zolimidine, Alprinone, Saripidem, and Necopidem [1–9]. Imidazo[1,2-a]pyridines possess a variety of biological activities such as anticancer [10], antiviral [11], antimicrobial [12], antiparkinson [13], antimutagenics [14], antihypoxia [15], and antinflammatory effects [16]. The synthesis of such scaffold has been extensively studied. Among these, the multicomponent reaction of 2-aminopyridine, aldehydes, and alkynes is one of the most common methods for their synthesis utilizing transition metal catalyst such as palladium [17], copper [18], silver [19], and gold [20]. Transition metal salts such as Ag (I), Au (III), and Cu (II) in combination with either *p*-toluenesulfonic acid (PTSA) or copper (I) complex have been utilized to catalyze such three-component reactions [21, 22]. Indium (III) bromide has also been used for the synthesis of imidazo[1,2-a]pyridines [23]. Multicomponent synthesis strategies to prepare a series of imidazo[1,2-a]pyridines have also been reported, however, the most utilized methodology to prepare such scaffold is the Grobke-Blackburn-Bienayme reaction [24–26], and its recent modifications [27–30] that mainly afforded 3-amino-imidazo[1,2-a]pyridines. It is worth to mention that other few protocols for the synthesis of 3-amino substituted products are reported such as nitration of C-3 and subsequent reduction [31]; multicomponent reaction of 2-aminopyridines aromatic aldehydes and imidazoline-2,4,5-trione [32]; as well as Strecker reaction using trimethylsilyl cyanide (TMSCN) or cyanohydrins as the source of cyanide ion utilizing either silica sulfuric acid or (bromo dimethylsulfonium) bromides catalysts [33] with reaction time ranging from 2–3 days to 10–20 h, the use of MCM-41 supported boron trifloride (BF3MCM-41) as a nanosaturated solid acid catalyst with reaction time ranging from 40 to 240 min [34] or Ugi-type multicomponent reaction in water utilizing KF for activation of TMSCN [35]. Although these methods afford good to excellent yields, TMSCN or cyanohydrin is known to be highly toxic and thus an environmental pollutant. Only one recent protocol utilizing polymer-bound scandium triflate as a catalyst under microwave heating has been reported [36]. Though, these protocols are useful, many of these have some demerits such as the use of expensive and excess amount of catalyst, longer reaction times, difficult work-up procedures, and harsh reaction conditions. Extensive efforts have been invested in utilizing green technologies in synthetic organic chemistry. One such technology involves microwave heating with its advantageous features such as operational simplicity, enhanced reaction rates with short reaction times, high yields, and purity of production [37, 38]. In continuation of our interest and others [39–45] in performing

***Corresponding author: Afaf Mohamed Abdel Hameed,** Department of Chemistry, Faculty of Science, El-Minia University, El-Minia 61519, Egypt, e-mail: afafabdelhamid1@yahoo.com
Moustafa Sherief Moustafa and Saleh Mohammed Al-Mousawi: Department of Chemistry, Faculty of Science, Kuwait University, P.O. Box 5969, Safat 13060, Kuwait
Reham R. Awed and Kamal Usef Sadek: Department of Chemistry, Faculty of Science, El-Minia University, El-Minia 61519, Egypt

reactions utilizing microwave heating we have developed an efficient catalyst-free multicomponent reaction for the synthesis of N-arylidene-2-arylimidazo[1,2-a]pyridine derivatives under controlled microwave heating.

2 Materials and methods

2.1 General information

All the reactions were carried out in a Milestone START microwave Labstation (temperature controlled by IR sensor). Melting points are reported uncorrected and were determined with a Sanyo (Gallaenkamp) instrument. Infrared spectra were recorded using KBr pellets and a Jasco FT–IR 6300 instrument and absorption bands are reported in cm^{-1}. ^1H- and ^{13}C-NMR spectra were determined by using a Bruker DPX instrument (Billerica, USA) at 400 and 600 MHz for ^1H-NMR and 100 MHz for ^{13}C-NMR and either $CDCl_3$ or DMSO-d_6 solutions with TMS as internal standards. Chemical shifts are reported in ppm. Mass spectra and accurate mass measurements were made using a GCMS DFS Thermo spectrometer with the EI (70 EV) mode. Starting materials were obtained from Aldrich (Mumbai, India) and used directly.

2.2 General procedure for the synthesis of 3-N-arylidene-2-arylimidazo[1,2-a]pyridines 4a–j

Method A: A solution of 2-aminopyridine **1** (1 mmol), aromatic aldehydes **2a–j** (2 mmol), and either benzoyl cyanide or cyanamide **3a,b** (1 mmol) in pyridine (10 ml) was heated under reflux in a Milestone Microwave Lab station at 120°C for 30 min. On completion of the reaction monitored by thin layer chromatography (TLC), the reaction mixture was concentrated under reduced pressure and cooled at room temperature. The resulting precipitate was filtered, washed with ethyl alcohol, and recrystallized from absolute EtOH to give **4** (Table 1).

Method B: A solution of 2-aminopyridine **1** (1 mmol) and aromatic aldehydes **2a–j** (1 mmol) in pyridine (10 ml) was heated under reflux in a Milestone Microwave Lab station at 120°C for 10 min. The formation of corresponding Schiff's base could be detected by using TLC with 1:1 ethyl acetate-petroleum ether as eluant. To the reaction mixture either benzoyl cyanide or cyanamide **3a,b** (1 mmol) and aromatic aldehyde **2a–j** (1 mmol) were added and microwave irradiation was continued for additional 20 min. After evaporation of the solvent, the reaction mixture was left to cool to room temperature. The solid product so formed was collected by filtration, washed with ethanol, and purified by crystallization from EtOH to give **4**.

Representative spectral and analytical data:

N-(4-chlorobenzyilidene)-[2-(4-chlorophenyl)imidazo[1,2-a]pyridine-3yl]amine (4a) Yellow solid, yield 88%; mp 170°C–172°C (Lit. mp 170°C–172°C) [35]; ^1H NMR (400 MHz, DMSO-d_6): δ (ppm) = 7.04 (t, 1H, J = 6.2 Hz, Ar–H), 7.35–7.39 (m, 1H, Ar–H), 7.45–7.55 (m, 2H, Ar–H), 7.60–7.64 (m, 3H, Ar–H), 7.98–8.01 (m, 4H, Ar–H) 8.70 (t, 1H, J = 6.0 Hz, Ar–H) 8.94 (s, 1H, N = CH). ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) = 114.1, 114.6, 122.2, 126.2, 128.8, 129.2, 130.6, 131.1, 134.2, 134.5, 136.6, 138.8, 145.2, 158.7. MS: m/z (%) 365 (M^+, 100).

N-(2-nitrobenzyilidene)-[2-(2-nitrophenyl)imidazo[1,2-a]pyridine-3yl]amine (4b) Buff solid, yield 83%; mp 218°C–219°C; ^1H NMR (400 MHz, DMSO-d_6): δ (ppm) = 7.09 (t, 1H, J = 7.2 Hz, Ar–H), 7.43 (t, 1H, J = 7.6 Hz, Ar–H), 7.68 (d, 1H, J = 8.8 Hz, Ar–H), 7.77 (t, 1H,

Table 1: List of [1,2-a]pyridine-3-ylamine derivatives synthesized *via* microwave irradiation.

Entry	Aldehyde	X–CN	Time (min)	Yield % Method (A)	Yield % Method (B)	m.p. (°C)
4a	*p*-ClC_6H_4	NH_2CN	30	65	60	170–172
		PhCOCN	30	88	75	
4b	*o*-$NO_2C_6H_4$	NH_2CN	30	60	52	218–219
		PhCOCN	30	83	70	
4c	*m*-$NO_2C_6H_4$	NH_2CN	30	55	50	312–313
		PhCOCN	30	76	65	
4d	*p*-$OMeC_6H_4$	NH_2CN	30	58	50	154–156
		PhCOCN	30	79	64	
4e	3,4-$OMeC_6H_4$	NH_2CN	30	57	51	140–142
		PhCOCN	30	81	72	
4f	*p*-$NO_2C_6H_4$	NH_2CN	30	59	52	290–291
		PhCOCN	30	85	76	
4g	*m*-OHC_6H_4	NH_2CN	30	55	50	132–133
		PhCOCN	30	78	67	
4h	*p*-BrC_6H_4	NH_2CN	30	64	60	184–186
4i	*2-thienyl*	PhCOCN	30	77	68	126–128
4j	*m*-ClC_6H_4	NH_2CN	30	57	50	94–96
		PhCOCN	30	79	66	
		NH_2CN	30	53	50	
		PhCOCN	30	65	61	

J = 7.6 Hz, Ar–H), 7.83 (t, 1H, *J* = 8.0 Hz, Ar–H), 8.20 (d, 1H, *J* = 8.0 Hz, Ar–H), 8.35 (d, 1H, *J* = 8.0 Hz, Ar–H), 8.45 (d, 1H, *J* = 7.6 Hz, Ar–H), 8.53 (d, 1H, *J* = 7.6 Hz, Ar–H), 8.79–9.01 (m, 3H, Ar–H), 9.2 (s, 1H, N = CH). MS: m/z (%) 387 (M^+, 100).

N-(3-nitrobenzylidene)-[2-(3-nitrophenyl)imid azo[1,2-a]pyridine-3yl]amine (4c) Orange crystals, yield 76%, m.p. 312–313°C; ^{1}H NMR (600 MHz, DMSO-d_6): δ (ppm) = 7.12 (t, 1H, *J* = 6.6 Hz, Ar–H), 7.45 (t, 1H, *J* = 7.2 Hz, Ar–H), 7.70 (d, 1H, *J* = 7.8 Hz, Ar–H), 7.79 (t, 1H, *J* = 8.0 Hz, Ar–H), 7.85 (t, 1H, *J* = 8.4 Hz, Ar–H), 8.22 (d, 1H, *J* = 7.8 Hz, Ar–H), 8.37 (d, 1H, *J* = 7.2 Hz, Ar–H), 8.48 (d, 1H, *J* = 7.8 Hz, Ar–H), 8.54 (d, 1H, *J* = 7.8 Hz, Ar–H), 8.82 (s, 1H, Ar–H), 8.85 (d, 1H, *J* = 6.6 Hz, Ar–H), 9.01 (s, 1H, Ar–H), 9.24 (s, 1H, N = CH).

N-(4-Bromobenzyilidene)-[2-(4-Bromophenyl)imidazo[1,2-a] pyridine-3yl]amine (4h) Yellow solid, yield 77%; mp 184°C–186°C (Lit. mp 184–186°C) [35]; ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) = 6.91 (t, 1H, *J* = 7.2 Hz, Ar–H), 7.32 (t, 1H, *J* = 7.2 Hz, Ar–H), 7.52 (d, 2H, *J* = 8.3 Hz, Ar–H), 7.57 (d, 2H, *J* = 8.3 Hz, Ar–H), 7.64 (d, 2H, *J* = 8.3 Hz, Ar–H), 7.76 (t, 4H, *J* = 7.2 Hz, Ar–H), 8.75 (s, 1H, N = CH). MS: m/z (%) 455 (M^+, 80).

3 Results and discussion

With the initial aim of optimizing the experimental reaction conditions we explored the reaction of 2-aminopyridine (**1**), aromatic aldehyde (**2a**), and either benzoyl cyanide (**3a**) or cyanamide (**3b**) under both acidic and basic conditions. The reaction was promoted by microwave heating over 30 min (Scheme 1). When ethanol in the presence of 10 mol% PTSA was used, the process led to a low yield (36%) of the target imidazo[1,2-a]pyridine derivatives **4a**. Pyridine was also examined and found to be very convenient for such a reaction with a higher yield (88%). To determine the role of the reaction medium, other solvents were examined such as water, methanol, or ethanol without any catalyst. In this case **4a** was not formed even after prolonged microwave irradiation. Finally irrespective of the aryl substituent reactions took place in reasonable yields (Table 1).

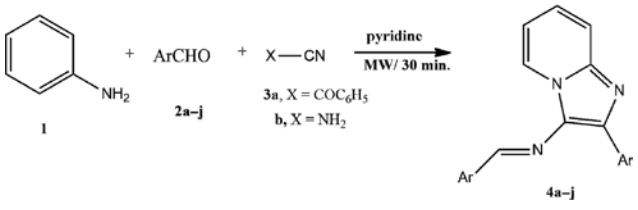
The structure of products could be established based on the analytical and spectral data. Mass spectra of **4a** showed M^+ peak at 365 (100%). ^{1}H NMR showed peaks assigned for aromatic protons and a singlet at δ = 8.94 ppm for CH = N function. ^{13}C NMR was in agreement with the proposed structure.

In order to determine the effect of the reactants molar ratio on the overall yield we started our protocol by mixing the reactants 2-aminopyridine, aromatic aldehydes, and cyanating agent in the ratio 1:1:1 all dissolved in 10 ml pyridine and heated under reflux in a microwave lab station for 30 min. The products were obtained in almost 40% yield as a maximum. However, with a ratio of 1:2:1 of the reactants under the same reaction conditions, the yields increased as shown in Table 1.

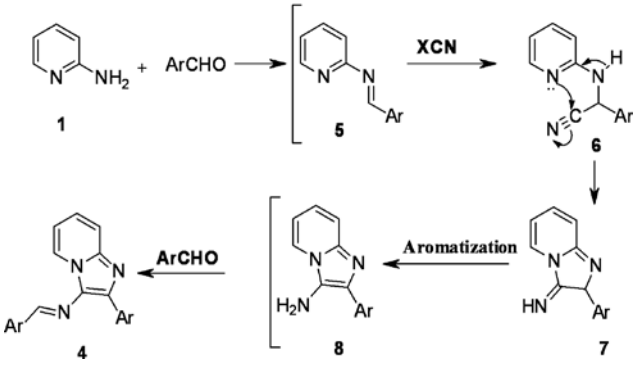
To evaluate the advantages of performing the reaction under microwave heating, a control experiment was conducted under conventional heating. It was observed that lower amounts of the products were obtained after 3–4 h. The use of microwave irradiation provided a more efficient and clear reaction.

A suggested mechanism for the formation of compound **4** displayed in Scheme 2 involves the formation of Schiff's base **5** from the reaction of 2-aminopyridine with aldehydes which undergoes Strecker reaction by the cyanide ion to form the corresponding aminonitrile adduct **6**. Attack of the pyridine nitrogen ion pair to the CN function would result in the formation of the bicyclic imine product **7**. 1,3-Proton shift followed by aromatization led to the formation of the corresponding 3-aminoimidazo[1,2-a]pyridine **8** which react with another molecule of aromatic aldehyde to afford final isolable product.

In support of this mechanism, when 2-aminopyridine and aromatic aldehydes in pyridine were allowed to react first for 10 min followed by addition of cyanide ion source and another molecule of aldehyde and microwave heating continued for additional 20 min, compounds **4a–d** were obtained in lower yields (cf. Table 1)



Scheme 1: Synthesis of imidazo[1,2-a]pyridine derivatives **4a–j**.



Scheme 2: Proposed mechanism for the synthesis of imidazo[1,2-a] pyridine derivatives **4a–j**.

than method A. Although, method B is a one-pot synthesis it includes two steps. Accordingly, method A is much desired because it saves time while increasing chemical yields. This is contrary to the previously reported formation of the corresponding cyanohydrin [33] from the reaction of aldehydes with TMSCN followed by the reaction with 2-aminopyridine.

4 Conclusion

In conclusion, we have reported a catalyst-free, one-pot three component, general high yielding method for the synthesis of N-arylidene-2-arylimidazo[1,2-a]pyridine-3-ylamine derivatives under microwave heating. Only one article, which describes using microwave heating with polymer-bound scandium triflate as a catalyst and trimethylsilyl cyanide as a cyanide ion source, has been reported. Our protocol was developed to avoid the use of both the hazardous reagents and expensive catalysts, with the advantages of the short microwave-assisted reaction time.

Acknowledgments: The authors are grateful to the Kuwait University Research Administration for the financial support of project SC12/13. Analytical facilities provided by GFS projects nos. GS 01/01, GS 01/03, GS 01/05, GS 02/10, and GS 03/08 are greatly appreciated.

References

[1] Tietze LF, Modi A. *Med. Res. Rev.* 2000, 20, 304–322.
[2] Toure BB, Hall DG. *Chem. Rev.* 2009, 109, 4439–4486.
[3] Yu S, Ma S. *Angew. Chem.* 2012, 51, 3074–3112.
[4] Marson CM. *Chem. Soc. Rev.* 2011, 40, 5514–5533.
[5] Hanson SM, Morlock EV, Elaine V, Satyshur KA, Kenneth A, Czajkowski C. *J. Med. Chem.* 2008, 51, 7243–7252.
[6] Moraski GC, Oliver AG, Markley LD, Cho S, Franzblau SG, Miller MJ. *Bioorg. Med. Chem. Lett.* 2014, 24, 3493–3498.
[7] Moraski GC, Markley LD, Hipskind PA, Boshoff H, Cho S, Franzblau SG, Miller MJ. *ACS Med. Chem. Lett.* 2011, 2, 466–470.
[8] Ollinger J, Bailey MA, Moraski GC, Casey A, Florio S, Alling T, Miller MJ, Parish T. *PLoS One* 2013, 8, e60531.
[9] Moraski GC, Markley LD, Cramer J, Hipskind PA, Boshoff H, Bailey MA, Alling T, Ollinger J, Parish T, Miller MJ. *ACS Med. Chem. Lett.* 2013, 4, 675–679.
[10] Li GY, Jung KH, Lee H, Son MK, Seo J, Hong SW, Jeong Y, Hong S, Hong SS. *Cancer Lett.* 2013, 329, 59–67.
[11] Hamdouchi C, Ezquerra J, Vega JA, Vaquero JJ, Alvarez-Builla J, Heinz BA. *Bioorg. Med. Chem. Lett.* 1999, 9, 1391–1394.
[12] Shukla NM, Salunke DB, Yoo E, Mutz CA, Balakrishna R, David SA. *Bioorg. Med. Chem.* 2012, 20, 5850–5860.
[13] McGuiness BF, Cole AW, Dong G, Brescia MR, Shao Y, Henderson I, Rokosz LL, Stauffer TM, Mannava N, Kimble EF, Hicks C, White N, Wines PG, Quadros E. *Bioorg. Med. Chem. Lett.* 2010, 20, 6845–6849.
[14] El-Sayed WM, Hussin WA, Al-Faiyz, YS, Ismail MA. *Eur. J. Med. Chem.* 2013, 715, 212–218.
[15] Frohn M, Viswanadhan V, Pickrell AJ, Golden JE, Muller KM, Bürli RW, Biddlecome G, Yoder SC, Rogers N, Dao JH, Hungate R, Allen JR. *Bioorg. Med. Chem. Lett.* 2008, 18, 5023–5026.
[16] Grädler U, Fuchß T, Ulrich WR, Boer R, Strub A, Hesslinger C, Anézo C, Diederichs K, Zaliani A. *Bioorg. Med. Chem. Lett.* 2011, 21, 4228–4232.
[17] Gao Y, Yin M, Wu W, Huang H, Jiang H. *Adv. Synth. Catal.* 2013, 355, 2263–2273.
[18] Attanasi OA, Bianchi L, Campisi LA, De Crescentini L, Favi G, Mantellini F. *Org. Lett.* 2013, 15, 3646–3649.
[19] Cao H, Liu X, Zhao L, Cen J, Lin J, Zhu Q, Fu M. *Org. Lett.* 2014, 16, 146–149.
[20] Zhan H, Zhao L, Liao J, Li N, Chen Q, Qiu S, Cao H. *Adv. Synth. Catal.* 2015, 357, 46–50.
[21] Dudnik AS, Chernyak N, Huang C, Gevorgyan V. *Angew. Chem. Int. Ed.* 2010, 49, 8729–8732.
[22] Bakherad Mo, Nasr-Isfahani H, Keivanloo A, Sang G. *Tetrahedron Lett.* 2008, 49, 6188.
[23] Reddy BVS, Sivaramakrishna RP, Jayasudhan RY, Yadav JS. *Tetrahedron Lett.* 2011, 52, 5789–5791.
[24] Groebke K, Weber L, Mehlin F. *Synlett* 1998, 661, 661–663.
[25] Bienayme H, Bouzid K. *Angew. Chem. Int. Ed.* 1998, 37, 2234–2237.
[26] Blackburn C, Guan B, Fleming P, Shiosaki K, Tsai S. *Tetrahedron Lett.* 1998, 39, 3635–3638.
[27] Kishore KG, Basavanag UMV, Islas-Jacome A, Gamez-Montano R. *Tetrahedron Lett.* 2015, 56, 155–158.
[28] Sanaeishoar T, Tavakkoli H, Mohave F. *Appl. Catal. A* 2014, 470, 56–62.
[29] Khan AT, Sidick R, Lal M. *Tetrahedron Lett.* 2012, 53, 2211–2217.
[30] Ramesha AB, Raghavendra GM, Nandeesh KN, Rangappa KS, Mantelingu K. *Tetrahedron Lett.* 2013, 54, 95–100.
[31] Roubaud C, Vanelle P, Maldonado J, Crozet MP. *Tetrahedron* 1995, 51, 9643–9656.
[32] Polyakov AI, Eryomina VA, Medvedeva LA, Tihonova NI, Listratova AV, Voskressensky LG. *Tetrahedron Lett.* 2009, 50, 4389–4393.
[33] Abdollahi-Alibeik M, Rezaeipoor-Anari A. *Catal. Sci. Technol.* 2014, 4, 1151–1159.
[34] Guchhait SK, Chaudhary V, Madaan C. *Org. Biomol. Chem.* 2012, 10, 9271–9277.
[35] Venkatesham R, Manjula A, Rao BV. *J. Het. Chem.* 2011, 48, 942–947.
[36] Martinez-Ariza G, Nunez-Rios J, Lee Y, Hulme C. *Tetrahedron Lett.* 2015, 56, 1038–1040.
[37] Carpenter RD, Lam KS, Kurth MJ. *J. Org. Chem.* 2007, 72, 284–287.
[38] Majetich G, Wheless K. In Kingston HM, Haswell SJ, Eds., *Microwave-Enhanced Chemistry*, American Society: Washington DC, 1997, p. 455.
[39] Sadek KU, Shaker RM, Abd-Elrady M, Elnagdi MH. *Tetrahedron Lett.* 2010, 51, 6319–6321.

[40] Sadek KU, Mekheimer RA, Mohamed TM, Moustafa MS, Elnagdi MH. *Beilstein J. Org. Chem.* 2012, 8, 18–24.
[41] Abd-El Latif FM, Barsy MA, Aref AM, Sadek KU. *Green Chem.* 2002, 4, 196–198.
[42] Mekheimer RA, Sadek KU. *J. Het. Chem.* 2009, 46, 149–151.
[43] Sadek KU, Abdel-Hameed AM, Mekhiemer RA, Abd Elmonem M, Elnagdi MH. *Curr. MW Chem*. 2016, 3, 227–230.
[44] Ramírez JR, Caballero R, Guerra J, Ruiz-Carretero A, Ana Sánchez-Migallón A, Hoz A. *Sustain. Chem. Eng.* 2015, 3, 3405–3411.
[45] Brun E, Safer A, Carreaux F, Bourahla K, L'helgoua'ch J, Bazureau J, Villalgordo JM. *Molecules* 2015, 20, 11617–11631.

Bionotes

Afaf Mohamed Abdel Hameed

Afaf Mohamed Abdel-Hameed graduated from the Faculty of Science, Minia University (Egypt) in 1995. She received her PhD degree in organic chemistry from the Faculty of Science, Minia University (2005). She is currently an associate professor of organic chemistry at the Faculty of Science, Minia University. Her current research interests include the design of green and environmental-friendly techniques for the synthesis of bioactive heterocyclic compounds.

Moustafa Sherief Moustafa

Moustafa Sherief Moustafa graduated from the Faculty of Science at Cairo University in 2002. He obtained his Master's degree from Kuwait University in 2012. He received the University of Kuwait Prize for the best Master's thesis in the academic year 2011–2012. He received his PhD degree in organic chemistry in 2014 from South Valley University at Egypt. He is a research associate in the Chemistry Department, University of Kuwait. He published three reviews and 30 research papers until 2016.

Saleh Mohammed Al-Mousawi

Saleh Mohammed Al-Mousawi graduated from the Faculty of Science at Kuwait University in 1975 and obtained his PhD from Bristol University, UK in 1980 on synthetic organic chemistry. Prof. Al-Mousawi worked all the time at Kuwait University. He started as an assistant professor (1980–2005), then worked as an associate professor (2005–2016), and has been professor of organic chemistry since then. He has published 42 papers in the field of organic chemistry till 2016.

Reham R. Awed

Reham R. Ahmed Awed graduated from the Faculty of Science, Minia University, Egypt in 2008. She received her biochemistry diploma in 2009 and her MSc degree in 2014 from the Faculty of Science, Minia University. She works as a chemist in the Environment Monitoring Center, Minia Governorate, Egypt. She is currently a PhD candidate at the Faculty of Science, Minia University.

Kamal Usef Sadek

Kamal Usef Sadek graduated from the Faculty of Science, Assuit University (honor). He was awarded his MSc and PhD degrees from Cairo University, Egypt. He is currently a professor of organic chemistry at the Faculty of Science, Minia University. He was awarded an Alexander von Humboldt fellowship and had several study leaves to Germany. His current field of interest is green and environmental-friendly techniques for the synthesis of biologically relevant heterocycles.