

4. Conclusions

In conclusion, we have developed a simple and highly efficient protocol for the synthesis of bis-thiazolidinones by one-pot pseudo-five-component condensation of araldehydes, ethylenediamine and thioglycolic acid with nano-NiZr₄(PO₄)₆ as a retrievable and robust heterogeneous catalyst under microwave irradiation in toluene. High yields, short reaction times, atom economy, reusability of the catalyst, low catalyst loading and using of microwave as clean method are some of the remarkable advantages of the present protocol.

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References

- [1] J. Senkiv, N. Finiuk, D. Kaminsky, D. Havrylyuk, M. Wojtyra, I. Kril, A. Gzella, R. Stoika, R. Lesyk, *Eur. J. Med. Chem.* 117 (2016) 33-46.
- [2] H.M.A. Ashour, I.M. El-Ashmawy, A.E. Bayad, *Monatsh. Chem.* 147 (2016) 605-618.
- [3] R. Nechak, S.A. Bouzroua, Y. Benmalek, L. Salhi, S.P. Martini, V. Morizur, E. Dunach, B.N. Kolli, *Synth. Commun.* 45 (2015) 262-672.
- [4] D.D. Subhedar, M.H. Shaikh, M.A. Arkile, A. Yeware, D. Sarkar, B.B. Shingate, *Bioorg. Med. Chem. Lett.* 26 (2016) 1704-1708.
- [5] M.V. Diurno O. Mazzoni, G. Correale, I.G. Monterrey, A. Calignano, G.L. Rana, A. Bolognese, *Il Farmaco* 54 (1999) 579-583.
- [6] R.K. Rawal, Y.S. Prabhakar, S.B. Katti, E. De Clercq, *Bioorg. Med. Chem. Lett.* 13 (2005) 6771-6776.
- [7] R.K. Rawal, R. Tripathi, S.B. Katti, C. Pannecouque, E. De Clercq, *Bioorg. Med. Chem.* 15 (2007) 1725-1731.
- [8] D. Kumar, M. Sonawane, B. Pujala, V.K. Jain, A.K. Chakraborti, *Green Chem.* 15 (2013) 2872-2884.
- [9] S.P. Shrivastava, N. Seelam, R. Rai, *J. Chem.* 9 (2012) 825-831.
- [10] A. Mobinikhaledi, A.K. Amiri, *Lett. Org. Chem.* 10 (2013) 764-769.
- [11] R.M. Abdel-Rahman, T.E. Ali, *Monatsh. Chem.* 144 (2013) 1243-1252.
- [12] J. Safaei-Ghomi, P. Babaei, H. Shahbazi-Alavi, S.G. Pyne, A.C. Willis, *J. Iran. Chem. Soc.* 13 (2016) 1439-1448.
- [13] M.B. Gawande, S.N. Shelke, R. Zboril, R.S. Varma, *Acc. Chem. Res.* 47 (2014) 1338-1348.
- [14] F.A. Bassyouni, S.M. Abu-Bakr, M.A. Rehim, *Res. Chem. Intermed.* 38 (2012) 283-322.
- [15] J. Safaei-Ghomi, H. Shahbazi-Alavi, P. Babaei, H. Basharnavaz, S.G. Pyne, A.C. Willis, *Chem. Heterocycl. Compd.* 52 (2016) 288-293.
- [16] M.B. Gawande, P.S. Branco, R.S. Varma, *Chem. Soc. Rev.* 42 (2013) 3371-3393.
- [17] A. Dastan, A. Kulkarni, B. Torok, *Green Chem.* 14 (2012) 17-37.
- [18] A. Sharma, P. Appukkuttan, E.V. Eycken, *Chem. Commun.* 48 (2012) 1623-1637.
- [19] J. Safaei-Ghomi, E. Afkhami, H. Shahbazi-Alavi, A. Ziarati, *Iran. J. Catal.* 5 (2015) 321-326.
- [20] N. Gorodylova, V. Kosinová, Z. Dohnalová, P. Sulcová, *Dyes Pigm.* 98 (2013) 393-404.
- [21] J. Safaei-Ghomi, M. Asgari-Kheirabadi, H. Shahbazi-Alavi, A. Ziarati, *Iran. J. Catal.* 6 (2016) 319-324.
- [22] I.G. Trubach, A.I. Beskrovnyi, A.I. Orlova, V.A. Orlova, V.S. Kurazhkovskaya, *Crystallogr. Rep.* 49 (2004) 895-898.
- [23] A.R. Zaripov, V.A. Orlova, V.I. Petkov, O.M. Slyunchev, D.D. Galuzin, S.I. Rovnyi, *Russ. J. Inorg. Chem.* 54 (2009) 45-51.
- [24] T. Previtiera, M. Basile, M.G. Vigorita, G. Fenech, F. Occhiuto, C. Circosta, R.C. de Pasquale, *Eur. J. Med. Chem.* 22 (1987) 67-74.
- [25] V.V. Kouznetsov, D.F. Amado, A. Bahsas, J. Amaro-Luis, *J. Heterocycl. Chem.* 43 (2006) 447-452.