Journal of Information Systems Engineering and Management
2025, 10(61s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

1,8-Dioxo-Decahydroacridines Synthesis Using a Maghnite-H+ Clay as Acid Eco-Friendly Catalyst

Abdelkader Brahimi[1, 2*], Boumadiene Benlahrech[2], Mokhtar Boualem Lahrech[2] and Amar Djemoui[2].
[1] *Department of Technology, Faculty of Science and Technology, ZIANE Achour University. Djelfa, Algeria.*
[2] *Laboratory of Organic Chemistry and Natural Substance, Faculty of Exact Sciences and informatics, University of Ziane Achour, Djelfa, Algeria.*
** Corresponding Author: abdelkader.brahimi@univ-djalfa.dz*

ARTICLE INFO

Received: 28 Dec 2024
Revised: 18 Feb 2025
Accepted: 26 Feb 2025

ABSTRACT

A simple and efficient approach for the synthesis of 1,8-dioxo-decahydroacridines 4a-f was proposed by multicomponent one-pot condensation of an aromatic aldehyde, 1,3-diketones and ammonium acetate in the presence of Maghnite-H+, an Algerian proton-exchange montmorillonite clay, as a green catalyst. Maghnite-H+ is an efficient, economical, recyclable and environmentally friendly catalyst. Its catalytic effect is considerable for the condensation reaction, with good to excellent yields in a short time.

Keywords: 1,8-dioxo-decahydroacridines, ammonium acetate, aromatic aldehyde, one-pot multicomponent reactions, Maghnite-H+.

1. INTRODUCTION

In organic synthesis, researchers are always interested in the fastest synthetic methods. Indeed, multicomponent reactions (MCRs) offer the possibility of synthesizing new compounds from three reactants in a single step. This type of reaction (MCRs) constitutes a promising strategy in organic synthesis to produce bioactive molecules, because their synthesis is fast and efficient, without isolation of intermediates and in a single step.[1] The Hantzsch synthesis of 1,4-dihydropyridines (1,4-DHP) represents a typical example of a one-pot multicomponent reaction between an aldehyde, two equivalents of α-methylene such as ethyl acetoacetate or 1,3-cyclohexanedione and a nitrogen donor such as ammonium acetate. The first successful example of this reaction was reported in 1881 by Arthur Rudolf Hantzsch.[2]

Acridine derivatives constitute an important class of 1,4-dihydropyridines with a broad spectrum of potential biological and pharmacological activities, including: antibacterial and antimicrobial,[3] anticancer,[4] anti-inflammatory,[5] antiviral, antimalarial, and antiallergic,[6,7] mutagenic,[8] antidiabetic,[9] and antitumor activity in vitro and in vivo against various murine and human tumors.[10] Acridine and its derivatives have also found industrial applications and are used in the production of dyes. Their excellent photophysical properties[11] make them ideal candidates for use as laser dyes.[12] Acridine and its derivatives are used as photosensitizers, [13] and as photoinitiators in polymerization reactions.[14] These molecules can exist in neutral, protonated, or deprotonated forms.[15]

Numerous methods have been described for the synthesis of these compounds, involving condensation between aldehydes, 1,3-diketone, and an amine, catalyzed by various compounds such as 2-hydroxyethylammonium acetate,[16] [CMIM][HSO_4],[17]L-proline,[18] ZnO nanoparticles,[19] CAN,[20] ρ-TsOH,[21]Amberlsyt-15,[22] sodium 1-dodecanesulfonic acid (SDS),[23] 4-toluenesulfonic acid,[24] alginic acid,[25] In$(OTf)_3$,[26] [H-NMP]$^+$[HSO_4]$^-$,[27] TPANPs/PAA,[28] copper-doped ZnO,[29] sulfuric acid on silica,[30] ultrasound,[31] ionic liquids,[32] and microwave irradiation.[33]

Each of these methods has limitations such as low yield, long reaction times, the use of large quantities of volatile organic solvents, and the complexity of some work-up procedures. Therefore, the development of new strategies for the synthesis of acridines, with advantages in terms of the use of less expensive and readily available catalysts or reagents, cleaner reactions, and simple product isolation, is of interest.

In this current work, we describe an environmentally friendly, simple, and highly efficient method for the synthesis of 1,8-dioxodecahydroacridine derivatives by reacting ammonium acetate with aldehydes and 1,3-dicarbonyls in the

Journal of Information Systems Engineering and Management
2025, 10(61s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

presence of Maghnite-H+.
The catalyst used in this study is a green, non-toxic, inexpensive, recyclable, and non-polluting montmorillonite clay called Maghnite-H+.[34]It has recently been used in the synthesis of bis-Schiff bases, [35] and in the synthesis of macromonomers and polymers by cationic polymerization. [36-39] Maghnite-H+ offers a potential new route for the synthesis of 1,8-dioxo-decahydroacridines with good to excellent yields.

2. EXPERIMENTAL MATERIALS

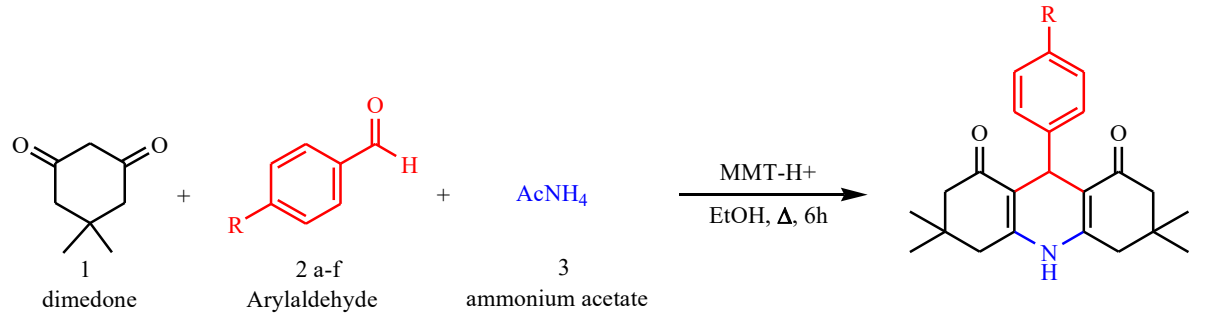
All chemicals were obtained from Biochem and sigma Aldrich and were used withoutfurther purification. Raw-Maghnite, Algerian montmorillonite clay was procured from "BENTAL" (Algerian Society of Bentonite). Thin layer chromatography (TLC) was done on silica gel TLC aluminium plates (E. Merck Kieselgel 60 F-254) and were visualized by exposure to UV-light at 254 nm or iodine vapor for few seconds. Melting point in °C was determined in open capillaries using Electrothermal melting point apparatus Stuart MPS-10. ^{1}H and ^{13}C NMR spectra were acquired on a Bruker AQS-AVANCE spectrometer (400 MHz) at 25°C using DMSO-d_6 as solvent. Chemical shifts (δ) are reported in parts per million (ppm) relative to the internal standard tetramethylsilane (TMS, δ = 0.00 ppm).

2.1. General procedure for the preparation of Maghnite-H+ catalyst (MMT-H+)

The reaction was catalyzed by Maghnite-H+. It was prepared according to the following method: [40, 41] An amount of 20g of raw-Maghnite in powder form was dried for two hours at a temperature of 105°C to remove any traces of water. After drying, the Maghnite was put in an Erlenmeyer containing 500ml distilled water, then 0.23M sulfuric acid solution was added at once to the mixture Maghnite / water and agitated by a mechanical stirrer for about two days at room temperature. After that, the mineral part of the whole mixture was washed by distilled water until it becomes a free from sulfate and finally dried at 105°C for about 2hours.

2.2. General method for synthesis of 1,8-dioxo-decahydroacridines derivatives (4a-e)

To a mixture of dimedone 1 (2 eq), arylaldehyde 2a-f (1 eq), and the ammonium acetate 3 (3 eq) in 10ml ethanol with catalytic amount of montmorillonite-H+ (10%). the reaction mixture was heated under reflux for the 4h. The progress of reaction is monitored by TLC. The crude product is dissolved with hot ethanol and then filtered to remove the solid catalyst. The filtrate is cooled to give the solid product. The resulting product is filtered, washed with ethanol and dried at 60-70°C to afford compound 4a-f (Scheme 1).



1
dimedone

2 a-f
Arylaldehyde

3
ammonium acetate

4a: R=H
4b: R=Cl
4c: R=Br
4d: R=OMe
4e: R=OH
4f: R=NO_2

Scheme 1. One-pot three compounds reaction for synthesis of 1,8-dioxo-decahydroacridines derivatives (4a-f) using Maghnite-H+

9-(phenyl)-3,3,6,6-tetramethyl-3,4,6,7,9,10-hexahydroacridine-1,8-(2H, 5H)-dione (4a): yellow solid, (yield 87%), m.p: 260-262°C; ^{1}H NMR (400 MHz, DMSO-d_6, δ in ppm): 9.35 (s, 1H, NH), 7.41-7.23 (m, 5H), 4.78 (s, 1H), 2.76 -2.45 (m, 4H), 2.11-1.82 (m, 4H), 1.11 (s, 6H), 1.02 (s, 6H);^{13}C NMR (100MHz, DMSO-d_6, δ in ppm) : 193.51, 152.87,150.11, 126.15, 125.82, 123.10, 109.70, 50.34, 36.87, 27.27, 24.29, 20.40.

Journal of Information Systems Engineering and Management
2025, 10(61s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

9-(4-chlorophenyl)-3,3,6,6-tetramethyl-3,4,6,7,9,10-hexahydroacridine-1,8(2H,5H)-dione (4b): yellow solid, (yield 94%), m.p: 297-299°C; ^{1}H NMR (400 MHz, DMSO-d_6, δ in ppm): 9.48 (s, 1H, NH), 7.32 (d, J= 8.2 Hz, 2H), 7.18 (d, J= 8.2 Hz, 2H), 4.58 (s, 1H), 2.59-2.47 (m, 4H), 2.12-2.07 (m, 4H), 1.09 (s, 6H), 0.92 (s, 6H) ;^{13}C NMR (100MHz, DMSO-d_6, δ in ppm) δ: 194.41, 149.50, 149.32, 147.17, 127.87, 127.80, 126.07, 111.94, 50.73, 33.10, 31.28, 29.36, 27.42.

9-(4-bromophenyl)-3,3,6,6-tetramethyl-3,4,6,7,9,10-hexahydroacridine-1,8(2H,5H)-dione (4c): yellow solid, (yield 85%), m.p: 312-314°C; ^{1}H NMR (400 MHz, DMSO-d_6, δ in ppm): 9.52 (s, 1H, NH), 7.34 (d, J= 8.4 Hz, 2H), 7.25 (d, J= 8.4 Hz, 2H), 4.78 (s, 1H), 2.48-2.40 (m, 4H), 2.24-2.18 (m, 4H), 1.09(s, 6H), 0.99 (s, 6H);^{13}C NMR (100MHz, DMSO-d_6, δ in ppm) δ: 194.41, 149.50, 149.32, 148.17, 127.62, 126.51, 125.27, 111.95, 50.77, 33.12, 31.44, 29.46, 27.52.

9-(4-methoxyphenyl)-3,3,6,6-tetramethyl-3,4,6,7,9,10-hexahydroacridine-1,8(2H,5H)-dione (4d): yellow solid, (yield 92%), m.p. 275-277°C; ^{1}H NMR (400 MHz, DMSO-d_6, δ in ppm): 9.32 (s, 1H, NH), 8.22 (d, J= 8.2 Hz,2H), 7.23(d, J= 8.2 Hz,2H), 5.04 (s, 1H), 3.66 (s, 3H), 2.39-2.28 (m,4H), 2.04-1.97 (m, 4H), 1.05 (s, 6H), 0.94 (s, 6H); ^{13}C NMR(100MHz, DMSO-d_6, δ in ppm): 195.12, 157.23, 149.96, 136.32, 128.20, 113.8, 54.9, 50.8, 41.51, 33.24, 33.15, 29.4, 28.69.

9-(4-hydroxyphenyl)-3,3,6,6-tetramethyl-3,4,6,7,9,10-hexahydroacridine-1,8(2H,5H)-dion (4e): yellow solid, (yield 90%), m.p: 284-286°C; ^{1}H NMR (400 MHz, DMSO-d_6, δ in ppm):9.58 (s, 1H, NH), 7.75 (d, J= 8.2 Hz,2H), 6.92 (d, J= 8.2 Hz,2H), 5.62 (s, 1H), 4.82 (s, 1H), 2.60-2.49 (m, 4H), 2.32-2.21 (m, 4H), 1.14 (s, 6H), 0.99 (s, 6H); ^{13}C NMR (100MHz, DMSO-d_6, δ in ppm): 194.98, 160.01, 151.48, 140.21, 132.66, 117.74, 113.04, 52.16, 41.18, 38.51, 35.41, 33.74, 28.70.

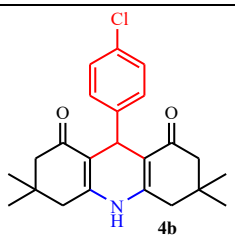
9-(4-nitrophenyl)-3,3,6,6-tetramethyl-3,4,6,7,9,10-hexahydroacridine-1,8(2H,5H)-dione (4f): yellow solid, (yield 77%), m.p. 289-291°C; ^{1}H NMR (400 MHz, DMSO-d_6, δ in ppm):9.76 (s, 1H, NH), 8.17 (d, J= 8.2 Hz,2H), 7.42 (d, J= 8.2 Hz,2H), 4.89(s, 1H), 2.51-2.46 (m,4H), 2.23-2.17 (m, 4H), 1.15 (s, 6H), 1.01 (s, 6H); ^{13}C NMR (100MHz, DMSO-d_6, δ in ppm): 190.21, 181.60, 147.52, 146.12, 127.21, 123.52, 114.10, 111.21, 50.7, 33.65, 32.79, 30.14, 28.54.

3. RESULTS AND DISCUSSION

In this work, a green, non-toxic and recyclable catalyst was used for the synthesis of 1,8-dioxo-decahydroacridines derivatives (4a-f) by one-pot three compounds reaction (scheme 1).

To investigate the catalytic effect on the reaction yield, tests are carried out with different amounts of catalyst for the compound (4b). The results shown (Table 1) show that the use of 10% of catalyst at 79°C. Is the most effective and the yield obtained was 94% for 4 hours in ethanol (scheme 1).

Table 1. Catalytic effect on the one-pot synthesis of 1,8-dioxo-decahydroacridines derivatives (4a-e) catalyst by Maghnite-H+.

Entry	Cat (%)	Time(h)	T(°C)	Yield (%)
 4b	**10**	4	Reflux	**93.96**
	20			86.92
	30			79.32

Cat: Maghnite-H+

In general, 1,8-dioxo-decahydroacridine derivatives (4a-f) were obtained in good to excellent yields when mixtures

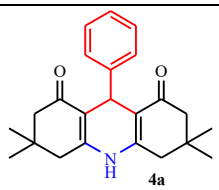
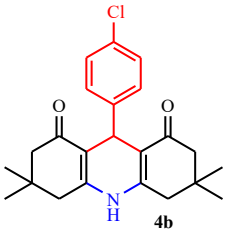
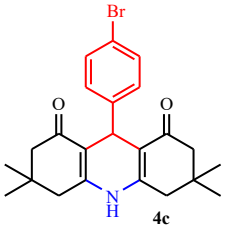
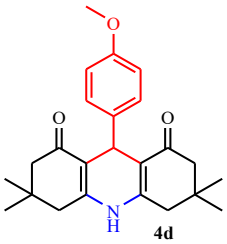
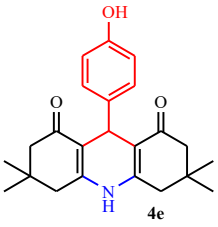
Journal of Information Systems Engineering and Management
2025, 10(61s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

of dimedone 1, arylaldehyde 2a-f and ammonium acetate 3 containing 10% Maghnite-H+ were refluxed in ethanol for 4 hours (Table 2). The desired products precipitated after cooling the reaction mixture, and filtration yielded an analytically pure product. The experimental results (Table 2) obtained by this reaction show excellent yields compared to those in the literature.

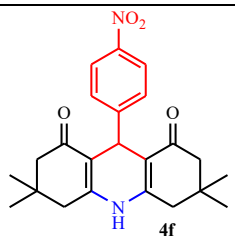
The reaction mechanism for the synthesis of 1,8-dioxo-decahydroacridines derivatives **4a-f** is shown in (Scheme 2). The mechanism we propose for this transformation is based on the in situ formation of enaminone **B** derived from dimedone and ammonium acetate, the adduct of Knoevenagel **A** derived from dimedone and an aromatic aldehyde, followed by cyclization of intermediates **A** and **B**, followed by removal of a water molecule to give the products **4a-f**.

Table 2. One-pot synthesis of 1,8-dioxo-decahydroacridines derivatives (4a-f) catalyst by 10% of Maghnite-H+.

Entry	Product	Yield* (%) Exp **	(Lit.)	M.P. (°C) Exp**	(Lit.)
1	 4a	87	85 [42]	260-262	290-291 [42]
2	 4b	94	95 [42]	297-299	299-302 [42]
3	 4c	85	88 [42]	312-314	313-315 [42]
4	 4d	92	85 [42]	275-277	276-278 [42]
5		90	75 [42]	284-286	303-305 [42]
6	 4e	77	75 [42]	289-291	284-286 [42]

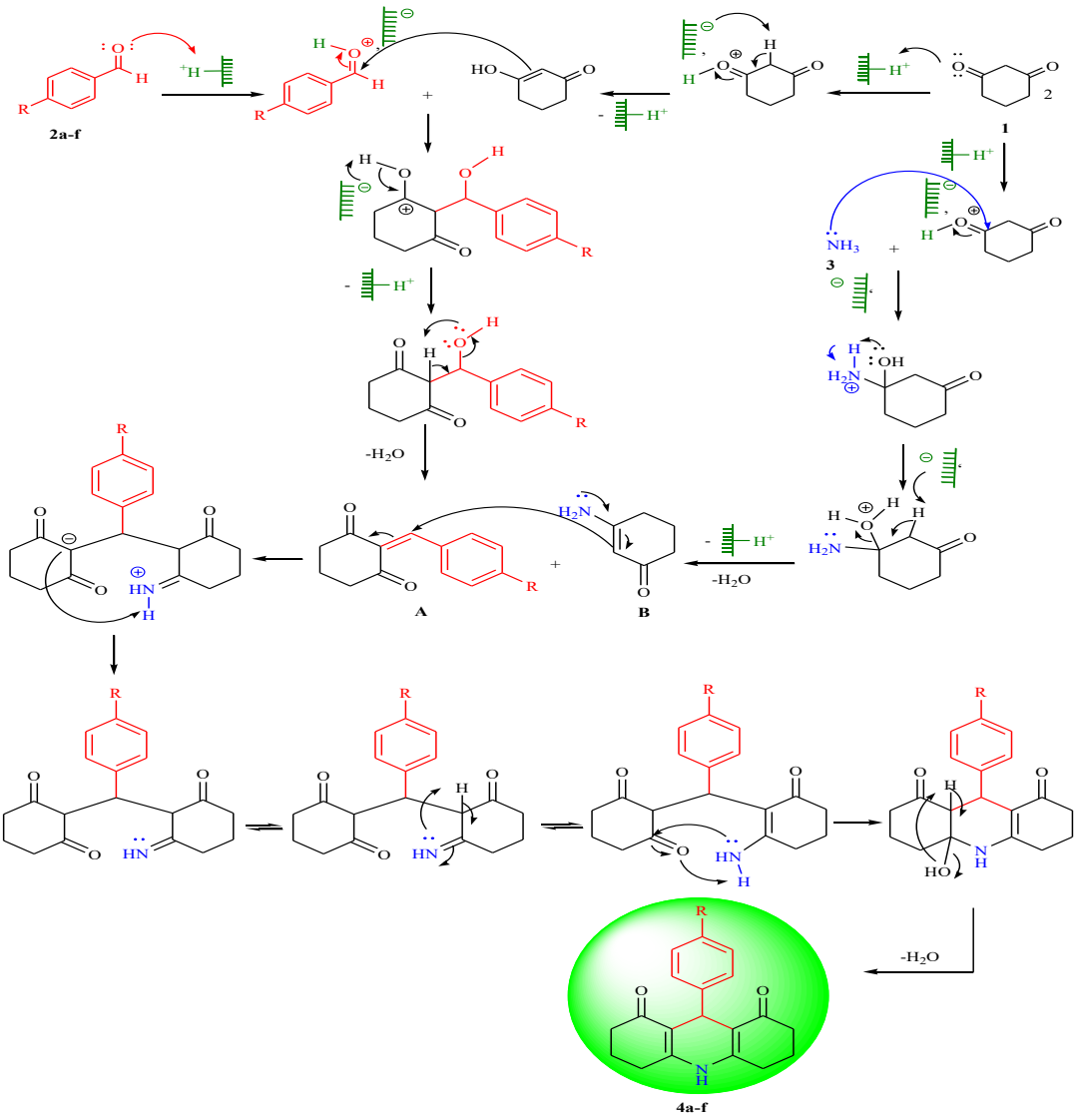
Journal of Information Systems Engineering and Management
2025, 10(61s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

	 4f		

(*) Isolated yield of product using montmorillonite-H+. The structure of products are determined by NMR and all spectral data are in good agreement with those of literature.

(**) Exp.: Experimental value (Lit.: literature value).



Scheme1. Proposed mechanism of the synthesis of 1,8-dioxo-decahydroacridines derivatives using Maghnite-H+

4. CONCLUSION

In conclusion, the one-pot three-component reaction of dimedone 1 with arylaldehyde 2a-f and ammonium acetate 3, in the presence of a catalytic amount of Maghnite-H+ in ethanol as solvent, constitutes an extremely efficient and chemoselective method for the synthesis of 1,8-dioxo-decahydroacridine derivatives. Moreover, Maghnite-H+ is a

non-toxic, inexpensive, and environmentally friendly catalyst. The products were obtained in good to excellent yield without further purification.

REFRENCES

[1] Gaudio, A. C., Korolkovas, A., & Takahata, Y. (1994). Quantitative structure-activity relationships for 1, 4-dihydropyridine calcium channel antagonists (nifedipine analogues): A quantum chemical/classical approach. *Journal of pharmaceutical sciences*, *83*(8), 1110-1115.

[2] Hantzsch, A. (1881). Condensationsprodukte aus Aldehydammoniak und ketonartigen Verbindungen. *Berichte der deutschen chemischen Gesellschaft*, *14*(2), 1637-1638.

[3] Shchekotikhin, Y. M., Nikolaeva, T. G., Shub, G. M., & Kriven'ko, A. P. (2001). Synthesis and antimicrobial activity of substituted 1, 8-dioxodecahydroacridines. *Pharmaceutical Chemistry Journal*, **35**(4), 206-208.

[4] Sondhi, S. M., Singh, J., Rani, R., Gupta, P. P., Agrawal, S. K., & Saxena, A. K. (2010). Synthesis, anti-inflammatory and anticancer activity evaluation of some novel acridine derivatives. *European journal of medicinal chemistry*, **45**(2), 555-563.

[5] Banerjee, A. G., Kothapalli, L. P., Sharma, P. A., Thomas, A. B., Nanda, R. K., Shrivastava, S. K., & Khatanglekar, V. V. (2016). A facile microwave assisted one pot synthesis of novel xanthene derivatives as potential anti-inflammatory and analgesic agents. *Arabian Journal of Chemistry*, **9**, S480-S489.

[6] Girault, S., Grellier, P., Berecibar, A., Maes, L., Mouray, E., Lemiere, P., ... & Sergheraert, C. (2000). Antimalarial, antitrypanosomal, and antileishmanial activities and cytotoxicity of bis (9-amino-6-chloro-2-methoxyacridines): influence of the linker. *Journal of medicinal chemistry*, **43**(14), 2646-2654.

[7] Kelly, J. X., Smilkstein, M. J., Brun, R., Wittlin, S., Cooper, R. A., Lane, K. D., ... & Riscoe, M. K. (2009). Discovery of dual function acridones as a new antimalarial chemotype. *Nature*, **459**(7244), 270-273.

[8] Di Giorgio, C., Benchabane, Y., Boyer, G., Piccerelle, P., & De Méo, M. (2011). Evaluation of the mutagenic/clastogenic potential of 3, 6-di-substituted acridines targeted for anticancer chemotherapy. *Food and chemical toxicology*, **49**(11), 2773-2779.

[9] Toobaei, Z., Yousefi, R., Panahi, F., Shahidpour, S., Nourisefat, M., Doroodmand, M. M., & Khalafi-Nezhad, A. (2015). Synthesis of novel poly-hydroxyl functionalized acridine derivatives as inhibitors of α-glucosidase and α-amylase. *Carbohydrate research*, **411**, 22-32.

[10] Charmantray, F., & Martelli, A. (2001). Interest of acridine derivatives in the anticancer chemotherapy. *Current pharmaceutical design*, **7**(17), 1703-1724.

[11] Karunakaran, V., Ramamurthy, P., Josephrajan, T., & Ramakrishnan, V. T. (2002). Solvent effects and photophysical studies of a new class of acridine (1, 8) dione dyes. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, **58**(7), 1443-1451.

[12] Srividya, N., Ramamurthy, P., & Ramakrishnan, V. T. (1998). Photophysical studies of acridine (1, 8) dione dyes: a new class of laser dyes. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, **54**(2), 245-253.

[13] Fouassier, J. P., Morlet-Savary, F., Lalevée, J., Allonas, X., & Ley, C. (2010). Dyes as photoinitiators or photosensitizers of polymerization reactions. *Materials*, **3**(12), 5130-5142.

[14] Xiao, P., Dumur, F., Tehfe, M. A., Graff, B., Gigmes, D., Fouassier, J. P., & Lalevée, J. (2013). Difunctional acridinediones as photoinitiators of polymerization under UV and visible lights: Structural effects. *Polymer*, **54**(14), 3458-3466.

[15] Venkatachalapathy, B., Ramamurthy, P., & Ramakrishnan, V. T. (1997). Ground and excited states acid-base properties of acridine-1, 8-dione dyes. *Journal of Photochemistry and Photobiology A: Chemistry*, **111**(1-3), 163-169.

[16] Wang, Y., Liu, X., & Du, C. (2017). Dihydroquinolines via the Hantsch Reaction using Hydroxylammonium Carboxylates as Efficient and Recyclable Catalysts under Solvent-free Conditions. *Organic Preparations and Procedures International*, *49*(1), 28-34.

[17] Kour, D., Patil, D. R., Deshmukh, M. B., Gupta, V. K., & Kant, R. (2014). Synthesis and X-Ray Crystal Structure of Two Acridinedione Derivatives. *Journal of Crystallography*, *2014*(1), 914504.

[18] Venkatesan, K., Pujari, S. S., & Srinivasan, K. V. (2008). Proline-catalyzed simple and efficient synthesis of 1, 8-dioxo-decahydroacridines in aqueous ethanol medium. *Synthetic Communications*, *39*(2), 228-241.

[19] Reen, G. K., Ahuja, M., Kumar, A., Patidar, R., & Sharma, P. (2017). ZnO Nanoparticle-catalyzed multicomponent reaction for the synthesis of 1, 4-diaryl dihydropyridines. *Organic Preparations and Procedures International*, *49*(3), 273-286.

[20] Kidwai, M., & Bhatnagar, D. (2010). Ceric ammonium nitrate (CAN) catalyzed synthesis of N-substituted decahydroacridine-1, 8-diones in PEG. *Tetrahedron Letters*, *51*(20), 2700-2703.

[21] Jamalian, A., Miri, R., Firuzi, O., Amini, M., Moosavi-Movahedi, A. A., & Shafieea, A. (2011). Synthesis, cytotoxicity and calcium antagonist activity of novel imidazolyl derivatives of 1, 8-acridinediones. *Journal of the Iranian Chemical Society*, *8*(4), 983-991.

22. Kaya, M., Yıldırır, Y., & Çelik, G. Y. (2011). Synthesis and antimicrobial activities of novel bisacridine-1, 8-dione derivatives. *Medicinal chemistry research*, *20*(3), 293-299.

[22] Shi, D. Q., Shi, J. W., & Yao, H. (2009). Three-component one-pot synthesis of polyhydroacrodine derivatives in aqueous media. *Synthetic Communications®*, *39*(4), 664-675.

[23] Putic, A., Stecher, L., Prinz, H., & Müller, K. (2010). Structure–activity relationship studies of acridones as potential antipsoriatic agents. 1. Synthesis and antiproliferative activity of simple N-unsubstituted 10H-acridin-9-ones against human keratinocyte growth. *European journal of medicinal chemistry*, *45*(8), 3299-3310.

[24] Marjani, A. P., Khalafy, J., & Mahmoodi, S. (2016). A simple one-pot synthesis of new 9-aroyl-3, 4, 6, 7, 9, 10-hexahydro-1, 8 (2H, 5H)-acridinediones. *Arkivoc*, *3*, 262-270.

[25] To, Q. H., Lee, Y. R., & Kim, S. H. (2012). Efficient one-pot synthesis of acridinediones by indium (III) triflate-catalyzed reactions of β-enaminones, aldehydes, and cyclic 1, 3-dicarbonyls. *Bulletin of the Korean Chemical Society*, *33*(4), 1170-1176.

[26] Naeimi, H., & Nazifi, Z. S. (2014). A facile one-pot ultrasound assisted synthesis of 1, 8-dioxo-octahydroxanthene derivatives catalyzed by Brønsted acidic ionic liquid (BAIL) under green conditions. *Journal of Industrial and Engineering Chemistry*, *20*(3), 1043-1049.

[27] Nasr-Esfahani, M., Rafiee, Z., & Kashi, H. (2016). Nanoparticles tungstophosphoric acid supported on polyamic acid: Catalytic synthesis of 1, 8-dioxo-decahydroacridines and bulky bis (1, 8-dioxo-decahydroacridine) s. *Journal of the Iranian Chemical Society*, *13*(8), 1449-1461.

[28] Alinezhad, H., & Mohseni Tavakkoli, S. (2013). Efficient and Convenient Synthesis of 1, 8-Dioxodecahydroacridine Derivatives Using Cu-Doped ZnO Nanocrystalline Powder as a Catalyst under Solvent-Free Conditions. *The Scientific World Journal*, *2013*(1), 575636.

[29] Mansoor, S. S., Aswin, K., Logaiya, K., & Sudhan, S. P. N. (2014). Aqua-mediated synthesis of acridinediones with reusable silica-supported sulfuric acid as an efficient catalyst. *Journal of Taibah University for Science*, *8*(3), 265-275.

[30] Sudha, S., & Pasha, M. A. (2013). A Facile Synthesis of N-H-and N-Substituted Acridine-1, 8-diones under Sonic Condition. *The Scientific World Journal*, *2013*(1), 930787.

[31] Safaei-Ghomi, J., Sadeghzadeh, R., & Shahbazi-Alavi, H. (2016). A pseudo six-component process for the synthesis of tetrahydrodipyrazolo pyridines using an ionic liquid immobilized on a FeNi 3 nanocatalyst. *RSC advances*, *6*(40), 33676-33685.

[32] Montes-Avila, J., Delgado-Vargas, F., Díaz-Camacho, S. P., & Rivero, I. A. (2012). Microwave-assisted synthesis of hydropyridines and study of the DPPH-scavenging activity. *RSC Advances*, *2*(5), 1827-1834.

[33] Masoumeh, M., Farhad, S., Mohadeseh, S., Masoumeh, M. (2018). Efficient Synthesis of Pyrimido[1,2-a] Benzimidazoles and Ethyl Pyrimido[1,2-a] Benzimidazole-3-Carboxylates Using Brönsted Acidic Ionic Liquid Supported on Nanoporous Na^+-Montmorillonite, *Poly. Arom. Comp.* doi: 10.1080/10406638.2018.1454967.

[34] Belbachir, M., Bensaoula, A. (2006). Composi-tion and method for catalysis using bentonites. *U. S. Pat.*, US 7,094,823 B2.

[35] Benlahreche, B., Taleb, Assya., Lahrech, M. B., Hacini, S. (2019). Isatin Aldazines Synthesis using A Proton Exchanged Algerian Montmorillonite Clay as Acid Eco-friendly Catalyst. *Bull. Chem. React. Eng. Cat.*, 14 (3): 551-557

[36] Souli, L., Meghabar, R., Djemoui, A., Lahrech, M. B., Belbachir, M. (2015). Water-soluble poly (HMBC-co-AM) prepared using tetrafunctional methacrylate macromonomer. *J. Chem. Pharm. Res.*, 7(10):108-115.

Journal of Information Systems Engineering and Management
2025, 10(61s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

[37] Ayat, M., Belbachir, M., Rahmouni, A. (2016) Selective Synthesis, Characterization, and Kinetics Studies of poly (*α*-Methyl styrene) induced by Maghnite-Na+ Clay (Algerian MMT). *Bull. Chem. Rea. Eng. Cat.*, 11(3):376-388**,** doi.org/10.9767/bcrec.11.3.578.376-388.

[38] Kherroub, D. E., Belbachir, M., Lamouri, S. (2014). Cationic Ring Opening Polymerization of ε-caprolactam by a Montmorillonite Clay Catalyst. *Bull. Chem. Rea. Eng. Cat.*, 9 (1):74-80

[39] Belbachir M.; Bensaoula A., Composition and method for using Bentonites. US Patent., 6274,527 B1, 2001.

[40] Harrane A.; Meghabar R.; Belbachir M., Kinetics of the ring opening polymerization of e-caprolactone catalysed by proton exchanged montmorillonite clay., React. Funct. Polym. 66, 1696-1702, 2006.

[41] Mohammadipour, M., & Amoozadeh, A. (2017). The synthesis of polyhydroacridines by covalent 5-sulfobenzoic acid-functionalized graphene oxide as a novel, green, efficient, and heterogeneous catalyst. *Monatshefte für Chemie-Chemical Monthly*, *148*(6), 1075-1084.