

# Nano Nickel-Cobalt Ferrite Catalysed One-Pot Multi-Component Synthesis of Xanthenediones and Acridinediones

Srividhya Maripi\*, Raghu Babu Korupolu, Suri Babu Madasu

Department of Engineering Chemistry, A. U. College of Engineering (A), Andhra University, Visakhapatnam, India

Email: \*vidyasri.chem@gmail.com

**How to cite this paper:** Maripi, S., Korupolu, R.B. and Madasu, S.B. (2017) Nano Nickel-Cobalt Ferrite Catalysed One-Pot Multi-Component Synthesis of Xanthenediones and Acridinediones. *Green and Sustainable Chemistry*, 7, 70-84.  
<https://doi.org/10.4236/gsc.2017.71006>

**Received:** December 29, 2016

**Accepted:** February 25, 2017

**Published:** February 28, 2017

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## Abstract

1,8-Dioxo-octahydroxanthenes (4a-4f) and 1,8-dioxohexahydroacridines (5a-5c) were synthesized by novel, simple and eco-friendly method with higher yields in the presence of magnetically separable nano nickel-cobalt ferrite catalyst ( $\text{Ni}_{0.5}\text{Co}_{0.5}\text{Fe}_2\text{O}_4$ ). The former, 1,8-dioxo-octahydroxanthenes have been synthesized from dimedone and different aromatic aldehydes, while the latter from this mixture are along with ammonium acetate. The main advantage of this method is that the nano catalyst can be reused up to five reaction cycles without losing the catalytic activity.

## Keywords

1,8-Dioxo-Octahydroxanthenes, 1,8-Dioxohexahydroacridines, Nano Nickel Cobalt Ferrite Catalyst and Recyclable Catalyst

## 1. Introduction

One-pot, multi-component reactions (MCRs) are having momentous meaning due to formulation of mono product with elevated yields by the blending of two or more components in a one step process [1] [2]. The advantages of MCR's are atom economy, less time-consuming, easy purification process and avoiding protection-deprotection steps. Therefore, the design and development of efficient and green MCRs focused on a target molecule are one of the most significant challenges in organic synthesis in both medicine and industry.

Xanthenediones and acridinediones are having a significant role in the biological chemistry and organic synthesis [3]. 1,8-Dioxo-octahydroxanthenes are an important group of oxygen heterocycle family. 1,8-Dioxo-octahydroxanthenes

are having phenyl substituted pyran ring which is fused on either side with two cyclohexanone rings. From past several years, biological and pharmaceutical industries are showing more interest towards synthesis of xanthenediones. Derivatives of xanthenediones will act as antiviral [4], antibacterial [5] and anti-inflammatory [6]. Xanthenediones are also utilised as antagonists for paralyzing action of zoxazolamine [7] and in photodynamic therapy [8]. Xanthenediones are the same structural units constituting various natural products [9] and used as versatile synthons, because of inherent reactivity of their pyran ring [10]. 1,8-Dioxohexahydroacridines are an important class of nitrogen heterocycle in which a phenyl substituted pyran ring is fused on either side with two cyclohexanone rings. 1,8-Acridinediones have 1,4-dihydropyridine (1, 4 DHP) parent nucleus, which is used for the treatment of cardiovascular diseases, such as, angina pectoris. These are also used as bronchodilator, anti-atherosclerotic, anti-tumor, gero-protective, hepatoprotective and antidiabetic agents [11].

For synthesis of xanthenes many methods are available; they are categorised based on starting compounds which include synthesis by cyclisation of polycyclic aryl triflate esters [12], intra-molecular trapping benzynes by phenols [13] and reaction of aryloxy magnesium halides with triethyl orthoformate [14] as well as cyclo-condensation of 2-hydroxyl aromatic aldehyde with 2-tetralone [15]. Condensation of aromatic aldehydes with 5,5-dimethyl-1,3-cyclohexanedione (dimedone) or 1,3-cyclohexanedione is one of the commonly utilized methods. There are different kinds of catalysts which have been reported for 1,8-dioxooctahydroxanthenes synthesis. Some of the catalysts were specified in this section. They are  $\text{SiCl}_4$  [16],  $\text{SmCl}_3$  [17],  $\text{InCl}_3/\text{P}_2\text{O}_5$  [18], triethyl benzyl ammonium chloride (TEBA) [19], trichloro isocyanuric acid [20], p-dodecyl benzenesulfonic acid [21], diammonium hydrogen phosphate [22], tetramethylguanidine trifluoroacetate [23],  $\text{SbCl}_3/\text{SiO}_2$  [24], trimethyl silyl chloride [25],  $\text{ZnO}$ -Acetyl chloride [26],  $\text{ZrOCl}_2 \cdot 8\text{H}_2\text{O}$  [27], Amberlyst-15 [28], montmorillonite K-10 [29] and cellulose sulfonic acid [30]. Aromatic aldehydes will condensate with 1,3-cyclohexanedione or 5,5-dimethyl-1,3-cyclohexanedione (dimedone) with ammonium acetate which is a most commonly used method for the synthesis of 1,8-dioxo-hexahydroacridines. Several catalysts have been reported for the synthesis of 1,8-dioxohexahydroacridines such as HY-Zeolite [31], Silica supported sulphuric acid [32], Bronsted acidic ionic liquid ( $[\text{CMIM}][\text{CF}_3\text{COO}]$ ) [33], methanesulfonic acid [34] and Poly(4-Vinylpyridinium) Hydrogen Sulfate [35].

The methods which are specified above are having its own advantages and merits, however many of these methods are unsatisfactory as they involve the use of halogenated solvents, unsatisfactory yields, harmful catalysts, catalyst loadings up to 30 mol%, prolonged reaction time and tedious experimental procedures. Development of clean and highly yielding and environmentally benign approaches is still desirable and much in demand. Therefore, it is necessary to develop the alternate methods for the synthesis of 1,8-dioxo-octahydroxanthenes and 1,8-dioxohexahydroacridines. The synthesis mechanism should involve simple in process, efficient, eco friendly with high yields with novel catalysts.

In recent years, magnetic nano particles have emerged as a useful group of heterogeneous catalysts. Separation of magnetic nano particles is simple and an attractive alternative to filtration as it prevents catalytic loss and enhances reusability. The use of low cost and readily available species as catalyst plays a significant role for economic feasibility of the chemical process. The greener generation of nanoparticles and their eco-friendly applications in catalysis via magnetically recoverable and recyclable nano-catalysts for a variety of oxidation, reduction, and condensation reactions [36] [37] [38] [39], has made an incredible impact on the development of sustainable pathways. Magnetically recyclable nano catalysts and their use in benign media is an ideal merge for the development of sustainable methodologies in organic synthesis.

Therefore, in order to accomplish the novel, high yielding and eco-friendly synthetic process, minimizing the by-products, with minimum number of separate reaction steps, improving the yields, our research work was extended by the application of nano catalysts in MCRs, in this we report a clean and environmentally friendly approach to the synthesis of 1,8-dioxo-octahydroxanthenes and 1,8-dioxohexahydroacridines via multi-component reaction in the presence of nickel-cobalt ferrite nanoparticles.

Nickel cobalt ferrite nano particles are magnetically separable and having effective activity. Nickel cobalt ferrite nano particles are having advantages of multi cycling, easy work-up and clean reaction profiles apart from the lack of necessity ligands and in minimizing the organic waste generation when compared to the conventional catalytic systems. In this, we report xanthenediones and acridinediones synthesis by using magnetically separable nano nickel cobalt ferrite as heterogeneous catalyst. The synthesised derivatives were characterised by IR, <sup>1</sup>H NMR and Mass spectral data.

## 2. Materials and Methods

### 2.1. Experimental

Sigma Aldrich has been selected as vendor for sourcing the chemicals. All chemicals were purchased, which is having the purity not less than 99.9%. Analytical Thin Layer Chromatography (TLC) was carried out by using silica gel 60 F254 pre-coated plates. Visualization was accomplished with UV lamp. All the products were characterized by their IR, <sup>1</sup>H NMR and Mass spectra. <sup>1</sup>H NMR was recorded on 300 MHz in CDCl<sub>3</sub>/DMSO, and the chemical shifts were reported in parts per million (ppm,  $\delta$ ) downfield from the Tetramethyl silane (TMS).

### 2.2. Preparation of the Nickel-Cobalt Ferrite Nano Catalyst

Nickel-Cobalt Ferrites with formula Ni<sub>x</sub>Co<sub>1-x</sub>Fe<sub>2</sub>O<sub>4</sub> (x = 1, 0.75, 0.5, 0.25 and 0). In this Ni<sub>0.5</sub>Co<sub>0.5</sub>Fe<sub>2</sub>O<sub>4</sub> (x = 0.5) has been chosen for the study and was synthesised by a chemical sol-gel co-precipitation method. In order to prepare Ni<sub>0.5</sub>Co<sub>0.5</sub>Fe<sub>2</sub>O<sub>4</sub> nanoparticles, 0.05 moles of nickel nitrate, 0.05 moles of cobalt nitrate and 2 moles of iron nitrate are dissolved separately in a little amount of deionised water and then citric acid solution was prepared stoichiometric pro-

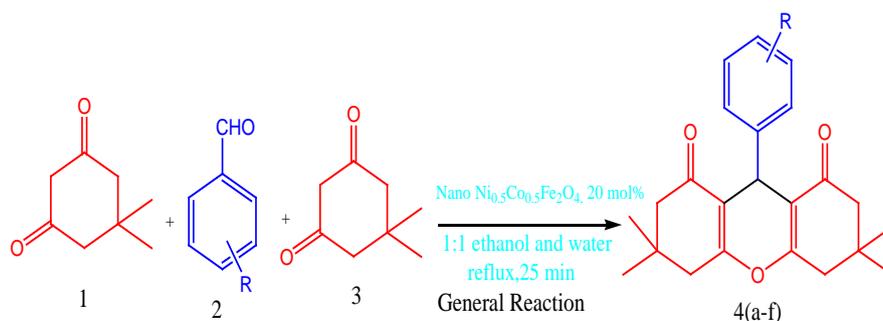
portions. These two solutions were added in a 1:1 molar ratio and  $P^H$  adjusted to 7 by the addition of ammonia and ethylene glycol is added. The aqueous mixture was heated to 60°C, it was converted to gel and then temperature increased to 200°C finally to get powder. That powder was calcined to 600°C and then characterised with XRD and SEM.

### 2.3. General Experimental Procedure for Synthesis of 1,8-Dioxo-Octahydroxanthenes

Aromatic aldehyde (5 mmol) and dimedone (10 mmol) and nano nickel cobalt ferrite ( $Ni_{0.5}Co_{0.5}Fe_2O_4$ , 20 mol%) catalyst was taken in a round bottomed flask and the contents are dissolved in 5 mL of ethanol and 5 mL of water. Then the reaction mixture was stirred for 25 min at reflux temperature (Scheme 1). The completion of the reaction was monitored by TLC (n-hexane: ethyl acetate 4:1). After completion of the reaction the catalyst was separated by using an external strong Neodymium 35 magnet. Then 10 mL of ethanol was added to the reaction mixture and removal of solvent by rota vapor. After, the dried product was recrystallized from hot ethanol for several times to get the corresponding pure product dioxo-octahydroxanthenes in excellent yields. The purity of products was confirmed by IR,  $^1H$  NMR and Mass spectras.

### 2.4. General Experimental Procedure for Synthesis of 1,8-Dioxohexahydroacridines

Aromatic aldehyde (5 mmol), dimedone (10 mmol), ammonium acetate (5 mmol) and 20 mol% nano nickel cobalt ferrite ( $Ni_{0.5}Co_{0.5}Fe_2O_4$ ) were taken in a 100 mL round bottomed flask and the contents are dissolved in 5 mL of ethanol and 5 mL of water. Then the reaction mixture was stirred for 40 min at reflux temperature (Scheme 2). After completion of the reaction the catalyst was separated by using an external strong Neodymium 35 magnet. Then 10 mL of ethanol was added to the reaction mixture and removal of solvent by rot a vapor. After, the dried product was recrystallized from hot ethanol for several times to get the corresponding pure product dioxohexahydroacridines in excellent yields. The purity of products was confirmed by IR,  $^1H$  NMR and Mass spectras.



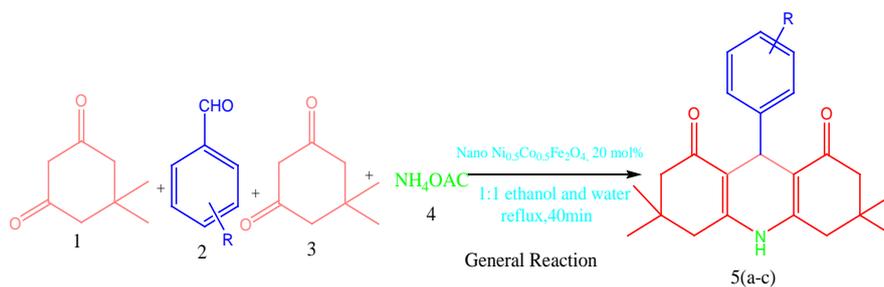
**Scheme 1.** A generalized scheme for synthesis of 1,8-dioxo-octahydroxanthene in presence of nano nickel cobalt ferrite catalyst by cyclocondensation of dimedone and aromatic aldehyde in water and ethanol solvent medium. (R = a) H, b) 4-OCH<sub>3</sub>, c) 4-Cl, d) 4-NO<sub>2</sub>, e) 2-NO<sub>2</sub>, f) 4-(2-pyridyl)).

### 3. Results and Discussions

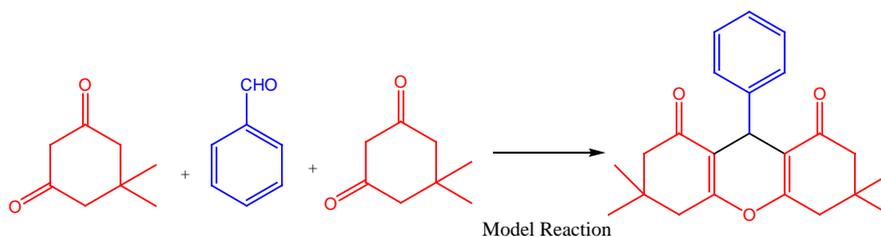
#### 3.1. Chemistry

Initially a model reaction is conducted by using different solvents and different mol% of catalyst for synthesis of 1,8-dioxo-octahydroxanthenes (**Scheme 3**) and 1,8-dioxohexahydroacridines (**Scheme 4**) to investigate the feasibility of the reaction.

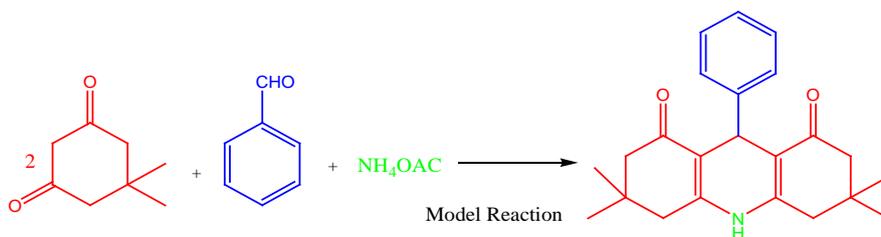
First synthesis of 1,8-dioxo-octahydroxanthenes (**Scheme 3**), in this dimedone and benzaldehyde were taken in different solvents ( $\text{CH}_2\text{Cl}_2$ ,  $\text{CCl}_4$ ,  $\text{CH}_3\text{CN}$ , and  $\text{H}_2\text{O}$ , ethanol and ethanol + water) in the presence of nickel cobalt ferrite ( $\text{Ni}_{0.5}\text{Co}_{0.5}\text{Fe}_2\text{O}_4$ ) NPs and results were captured in **Table 1**. It was clearly observed that low yield of products were obtained with  $\text{CH}_2\text{Cl}_2$ ,  $\text{CCl}_4$ , and  $\text{CH}_3\text{CN}$  (35%, 55% and 40%, **Table 1**, entry 1 - 3) respectively even after 7 hrs stirring. From **Table 1**, it is evident that low product yields (60% and 65%, entries 4 and 5) were obtained with water and ethanol independently. In a combination of 1:1



**Scheme 2.** A generalized reaction for synthesis of 1,8-dioxohexahydroacridines in presence of nano nickel cobalt ferrite catalyst by cyclocondensation of dimedone, aromatic aldehyde and ammonium acetate in ethanol and water solvent medium. (R = a) H, b) 4-Cl, c) 2- $\text{NO}_2$ ).



**Scheme 3.** A model reaction for synthesis of 1,8-dioxo-octahydroxanthene in presence of nano nickel cobalt ferrite catalyst by cyclocondensation of dimedone and benzaldehyde.



**Scheme 4.** A model reaction for synthesis of 1,8-dioxohexahydroacridines in presence of nano nickel cobalt ferrite catalyst by cyclocondensation of dimedone, benzaldehyde and ammonium acetate.

H<sub>2</sub>O and EtOH, good yields of dioxo-octahydroxanthene derivatives were obtained with in 25 min (95 %, **Table 1**, entry 6).

Upon identifying the suitable solvent, next stage is to study the catalyst role on the reaction rate and product yield. To identify the appropriate catalyst, a series of parallel reactions were carried out with the catalytic amounts of different catalysts and the results are summarized in the **Table 2**. When the reaction with SiCl<sub>4</sub>, SmCl<sub>3</sub>, Amberlyst-15, ZnO-acetyl chloride and p-dodecyl benzenesulfonic acid gave capable results with better yields (**Table 2**, entries 1, 2, 6, 7 and 8), and the best result was obtained with nickel cobalt ferrite (Ni<sub>0.5</sub>Co<sub>0.5</sub>Fe<sub>2</sub>O<sub>4</sub>) nano particles in the H<sub>2</sub>O-EtOH solvent system (**Table 2**, entry 10), and the reaction was completed within 25 min.

After finding the suitable solvent and catalyst the model reaction is performed with different mol% of Ni<sub>0.5</sub>Co<sub>0.5</sub>Fe<sub>2</sub>O<sub>4</sub> catalyst and observed that 20 mol% suitable to obtained maximum yield at neat condition (**Table 3**, entry 4). No change was observed on further enhancing the catalyst mol%.

With the optimised reaction conditions in hand, the reaction was performed with different benzaldehydes (**Scheme 1**) with 20 mol% Ni<sub>0.5</sub>Co<sub>0.5</sub>Fe<sub>2</sub>O<sub>4</sub> NPs to explore the scope and generality of the present protocol and the results of these observations are summarized in **Table 4**. From the results, the aromatic aldehydes containing both electron releasing and withdrawing groups give products

**Table 1.** Optimisation of synthesis of 1,8-dioxo-octahydroxanthenes in presence of nickel cobalt ferrite at different solvent medium.

Entry	Solvent	Temperature (°C)	Time	Yield (%)
1	CH <sub>2</sub> Cl <sub>2</sub>	35 - 40	7 hrs	35
2	CCL <sub>4</sub>	60 - 65	7 hrs	55
3	CH <sub>3</sub> CN	80 - 85	7 hrs	40
4	H <sub>2</sub> O	95 - 100	3 hrs	60
5	Ethanol	75 - 78	2.5 hrs	65
6	Ethanol + H <sub>2</sub> O	100 <sup>0</sup>	25 min	95

**Table 2.** Screening of various catalysts with Ni<sub>0.5</sub>Co<sub>0.5</sub>Fe<sub>2</sub>O<sub>4</sub> NPs in the synthesis.

Entry	Catalyst	Conditions	Time (hrs)	Yield (% w/w)	Reference
1	SiCl <sub>4</sub>	CH <sub>2</sub> Cl <sub>2</sub> /60°C - 70°C	3	92	16
2	SmCl <sub>3</sub>	Solvent free/120°C	8	98	17
3	Cellulose sulfonic acid	Solvent free/110°C	6	95	30
4	Trimethyl silyl chloride	CH <sub>3</sub> CN/reflux	8 - 10	72 - 84	25
5	ZrOCl <sub>2</sub> ·8H <sub>2</sub> O	Solvent free/120°C	0.66	95	27
6	Amberlyst-15	CH <sub>3</sub> CN/reflux	5	90 - 96	28
7	ZnO-acetyl chloride		16	96	26
8	p-dodecyl benzenesulfonic acid	Solvent free/80°C	10 - 60 min	80 - 93	21
9	Trichloro isocyanuric acid	Ethanol/reflux	0.5	95	20
10	Ni <sub>0.5</sub> Co <sub>0.5</sub> Fe <sub>2</sub> O <sub>4</sub> NPs'	Ethanol-water/110°C	25 min	95	Present work

**Table 3.** Effect of  $\text{Ni}_{0.5}\text{Co}_{0.5}\text{Fe}_2\text{O}_4$  catalyst concentration on synthesis of 1,8-dioxooctahydroxanthenes.

Entry	Catalyst (mol %)	Time	Yield (%)
1	5	120 min	65
2	10	90 min	78
3	15	60 min	85
4	20	25 min	95
5	25	25 min	95
6	30	25 min	95

**Table 4.**  $\text{Ni}_{0.5}\text{Co}_{0.5}\text{Fe}_2\text{O}_4$  catalysed synthesis of 1,8-dioxo-octahydroxanthenes derivatives.

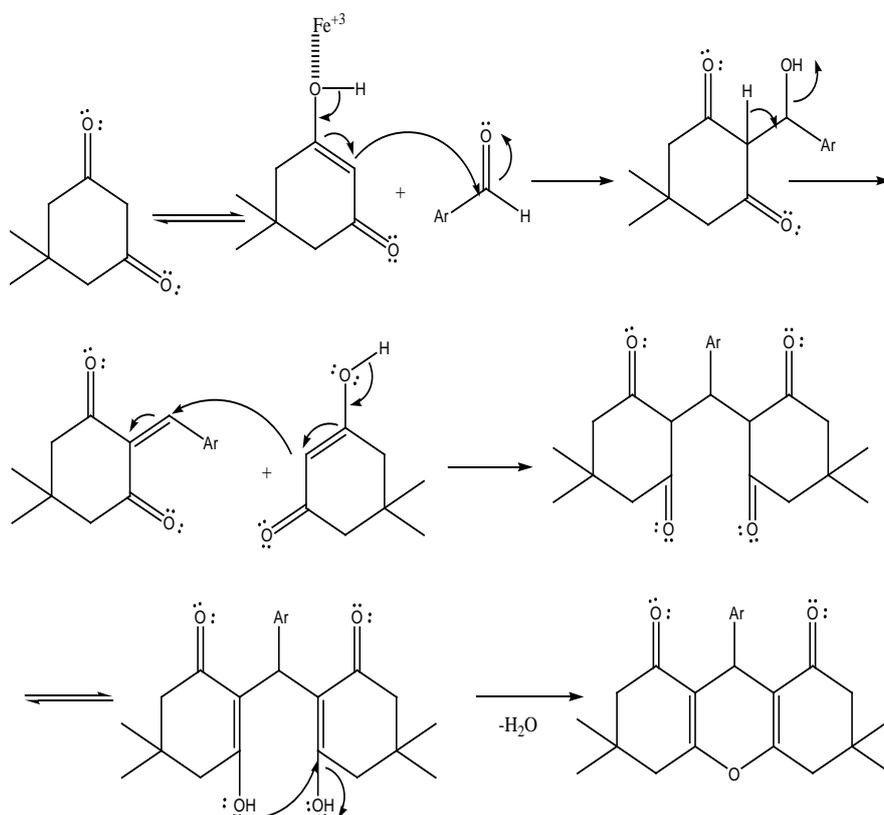
Entry	Product	R	Time (min)	Yield (% w/w)
1	4a	H	25	93%
2	4b	4-OCH <sub>3</sub>	25	90%
3	4c	4-Chloro	25	92%
4	4d	4-NO <sub>2</sub>	25	96%
5	4e	2-NO <sub>2</sub>	25	95%
6	4f	4-(2-pyridyl)	25	94%

with good yields, while electron withdrawing groups give products slightly better than releasing groups. The structures of synthesized 1,8-dioxo-octahydroxanthenes derivatives were confirmed by IR, <sup>1</sup>H NMR and Mass spectral analysis.

The plausible mechanism for the formation of 1,8-dioxo-octahydroxanthenes by using Nickel cobalt ferrite NPs is shown in **Figure 1**.

On the other hand a model reaction is conducted for synthesis of 1,8-dioxo-hexahydroacridines (**Scheme 4**), in this dimedone benzaldehyde and ammonium acetate were taken in different solvents (n-hexane, 1,4-dioxane, diethyl ether, H<sub>2</sub>O, ethanol and ethanol + water) in the presence of  $\text{Ni}_{0.5}\text{Co}_{0.5}\text{Fe}_2\text{O}_4$  NPs and results are summarized in **Table 5**. It was clearly observed that low yield of product was obtained with n-hexane, 1,4-dioxane and diethyl ether (35%, 40% and 55%, **Table 5**, entry 1 - 3) respectively even after 10 hrs stirring. From **Table 5**, it is evident that low product yields (65% and 70%, **Table 5**, entries 4 and 5) were obtained with water and ethanol independently. In a combination of 1:1 H<sub>2</sub>O and EtOH, good yields of dioxohexahydroacridine derivatives were obtained with in 40 min (96 %, **Table 5**, entry 6).

From the **Table 5**, 1:1 mixture of H<sub>2</sub>O and EtOH is a suitable solvent and then we have to find out the suitable catalyst. In order to find a suitable catalyst, a series of parallel reactions were carried out with the catalytic amounts of different catalysts and the results are summarized in the **Table 6**. When the reactions are with silica supported sulphuric acid, methanesulfonic acid and  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  gave capable results with better yields (**Table 6**, entries 2, 4 and 5), and the best result was obtained with  $\text{Ni}_{0.5}\text{Co}_{0.5}\text{Fe}_2\text{O}_4$  NPs in the H<sub>2</sub>O-EtOH solvent system (**Table 6**, entry 6), and the reaction was completed within 40 min with 96% yield.



**Figure 1.** Plausible mechanism for the formation of 1,8-dioxo-octahydroxanthenes.

**Table 5.** Optimisation of synthesis of 1,8-dioxohexahydroacridines in presence of nickel cobalt ferrite at different solvent medium.

Entry	Solvent	Temperature (°C)	Time	Yield (%)
1	n-hexane	68 - 70	10 hrs	35
2	1,4-dioxane	98 - 102	10 hrs	40
3	Diethyl ether	34 - 36	10 hrs	55
4	H <sub>2</sub> O	95 - 100	4 hrs	65
5	Ethanol	75 - 78	3 hrs	70
6	Ethanol + H <sub>2</sub> O	94 - 96	40 min	96

**Table 6.** Screening of various catalysts with nickel cobalt ferrite in the synthesis.

Entry	Catalyst	Conditions	Time (hrs)	Yield (% w/w)	Reference
1	HY-Zeolite	Ethanol/reflux	2.5 - 3.5	90	31
2	Silica supported sulphuric acid	H <sub>2</sub> O/70°C	1.5	95	32
3	Bronsted acidic ionic liquid	Ethanol/80°C	1 - 1.5	85	33
4	Methanesulfonic acid	Solvent free/120°C	1	92	34
5	CuSO <sub>4</sub> ·5H <sub>2</sub> O	EtOH-H <sub>2</sub> O/80°C	1.5	94	-
6	Ni <sub>0.5</sub> Co <sub>0.5</sub> Fe <sub>2</sub> O <sub>4</sub> NPs	EtOH-H <sub>2</sub> O/100°C	40 min	96	Present work

After finding the suitable solvent and catalyst the model reaction is performed with different mol% of Ni<sub>0.5</sub>Co<sub>0.5</sub>Fe<sub>2</sub>O<sub>4</sub> catalyst and observed that 20 mol% suitable

ble to obtained maximum yield at neat condition (Table 7, entry 4). No change was observed on further enhancing the catalyst mol%.

Based on above results, this method extend to synthesis of different substituted 1,8-dioxohexahydroacridines with different aromatic aldehydes (Scheme 2), dimedone and ammonium acetate in presence of  $\text{Ni}_{0.5}\text{Co}_{0.5}\text{Fe}_2\text{O}_4$  (20 mol%) catalyst in  $\text{H}_2\text{O}$ -EtOH solvent system as shown in the Table 8.

The plausible mechanism for the formation of 1,8-dioxohexahydroacridines by using nickel cobalt ferrite NPs is shown in Figure 2.

### 3.2. Reusability of the Catalyst

The reusability of nickel cobalt ferrite NPs is one of the most important advantages of this protocol that makes it useful for practical commercial applications. We have examined the recyclability of nickel cobalt ferrite NPs catalyst for the model reaction. Interestingly, the recovered catalyst could be reused for up to five cycles which is evident from Table 9. The catalyst was separated by using a magnet after completion of the reaction, washed with water followed by chloroform, dried in oven and reused for the next cycle.

### 3.3. Spectral Data

#### 3.3.1. Spectral Data of 1,8-Dioxo-Octahydroxanthenes

##### 1) 3,3,6,6-tetramethyl-9-(phenyl)-1,8-dioxo-octahydroxanthene

White solid,  $^1\text{H}$ NMR (300 MHz,  $\text{CDCl}_3$ )  $\delta$  = 0.96 (s, 6H), 1.08 (s, 6H), 2.02 (d,  $J$  = 16.2 Hz, 2H), 2.28 (d,  $J$  = 16.1 Hz, 2H), 2.51 (d,  $J$  = 17.3 Hz, 2H), 2.56 (d,  $J$  = 17.5 Hz, 2H), 5.12 (s, 1H), 7.05 - 7.28 (m, 5H); FTIR (KBr,  $\text{cm}^{-1}$ ): 3311, 2982, 1794, 1724, 1700, 1654, 1520, 1361, 1199; ESI-MS ( $m/z$ ): 351 ( $M^+ + 1$ ).

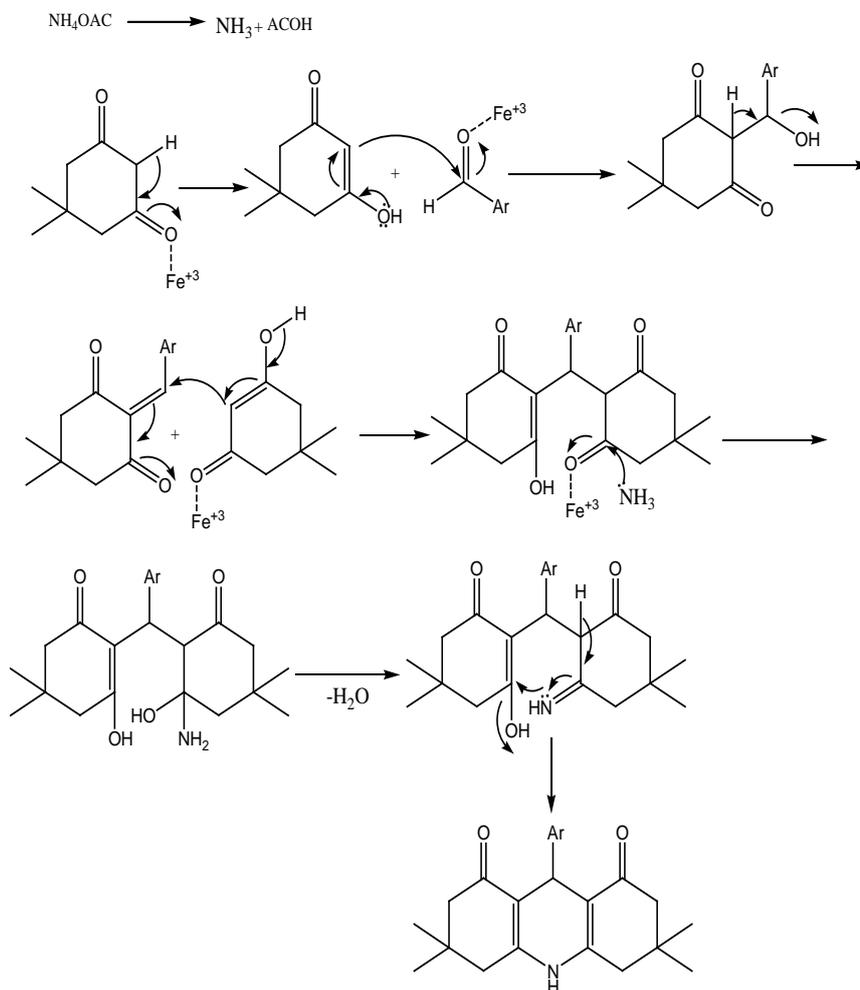
##### 2) 3,3,6,6-tetramethyl-9-(4-methoxy-phenyl)-1,8-dioxo-octahydroxanthenes

**Table 7.** Effect of  $\text{Ni}_{0.5}\text{Co}_{0.5}\text{Fe}_2\text{O}_4$  catalyst concentration on synthesis of 1,8-dioxooctahydroxanthenes.

Entry	Catalyst (mol%)	Time	Yield (%)
1	5	180 min	65
2	10	120 min	73
3	15	90 min	85
4	20	40 min	96
5	25	40 min	96
6	30	40 min	96

**Table 8.**  $\text{Ni}_{0.5}\text{Co}_{0.5}\text{Fe}_2\text{O}_4$  catalysed synthesis of 1,8-dioxohexahydroacridines.

Entry	Product	R	Time (min)	Yield (% w/w)
1	5a	H	40 min	92%
2	5b	4-Chloro	40 min	95%
3	5c	2-Nitro	40 min	94%



**Figure 2.** Plausible mechanism for the formation of 1,8-dioxohexahydroacridines.

**Table 9.** Productivity with re-cycle catalyst.

Entry	Catalyst re-use	Yield (% w/w)
1	1 <sup>st</sup> cycle	94
2	2 <sup>nd</sup> cycle	92
3	3 <sup>rd</sup> cycle	90
4	4 <sup>th</sup> cycle	89
5	5 <sup>th</sup> cycle	87

White solid,  $^1\text{H NMR}$  (300 MHz,  $\text{CDCl}_3$ )  $\delta$  = 0.98 (s, 6H), 1.10 (s, 6H), 2.04 (d,  $J$  = 16.1 Hz, 2H), 2.26 (d,  $J$  = 16.2 Hz, 2H), 2.50 (d,  $J$  = 17.4 Hz, 2H), 2.54 (d,  $J$  = 17.3 Hz, 2H), 3.82 (s, 3H), 5.46 (s, 1H), 6.84 (d, 2H), 7.02 (d, 2H); FTIR (KBr,  $\text{cm}^{-1}$ ): 3030, 2970, 2873, 1679, 1650, 1511, 1460, 1372, 1261, 1193, 1165, 1138, 1030, 841; ESI-MS ( $m/z$ ): 381 ( $\text{M}^+ + 1$ ).

**3) 3,3,6,6-tetramethyl-9-(4-chloro-phenyl)-1,8-dioxo-octahydroxanthenes**

White solid,  $^1\text{H NMR}$  (300 MHz,  $\text{CDCl}_3$ )  $\delta$  = 0.92 (s, 6H), 1.08 (s, 6H), 2.09 (d,  $J$  = 16.1 Hz, 2H), 2.24 (d,  $J$  = 16.1 Hz, 2H), 2.51 (d, 2H), 2.53 (d,  $J$  = 17.6 Hz, 2H), 4.52 (s, 1H), 7.16 (d,  $J$  = 8.3 Hz, 2H), 7.24 (d,  $J$  = 8.2 Hz, 2H); FTIR (KBr,  $\text{cm}^{-1}$ ): 3020, 2985, 2952, 1680, 1660, 1480, 1361, 1200, 1198, 1160, 1090, 1000,

850; ESI-MS ( $m/z$ ): 385.5 ( $M^+ + 1$ )

**4) 3,3,6,6-tetramethyl-9-(4-nitro-phenyl)-1,8-dioxo-octahydroxanthenes**

Yellow solid,  $^1\text{H NMR}$  (300 MHz,  $\text{CDCl}_3$ )  $\delta$  = 0.94 (s, 6H), 1.04 (s, 6H), 2.06 (d,  $J$  = 16.2 Hz, 2H), 2.26 (d,  $J$  = 16.1 Hz, 2H), 2.52 (d, 2H), 2.54 (d,  $J$  = 17.6 Hz, 2H), 4.54 (s, 1H), 7.16 (d,  $J$  = 8.3 Hz, 2H), 7.26 (d,  $J$  = 8.2 Hz, 2H); FTIR (KBr,  $\text{cm}^{-1}$ ): 3030, 2980, 2956, 1685, 1661, 1515, 1465, 1361, 1344, 1292, 1201, 1160, 1090, 850; ESI-MS ( $m/z$ ): 396 ( $M^+ + 1$ ).

**5) 3,3,6,6-tetramethyl-9-(2-nitro-phenyl)-1,8-dioxo-octahydroxanthenes**

Yellow solid,  $^1\text{H NMR}$  (300 MHz,  $\text{CDCl}_3$ )  $\delta$  = 0.92 (s, 6H), 1.08 (s, 6H), 2.02 (d,  $J$  = 16.1 Hz, 2H), 2.24 (d,  $J$  = 16.2 Hz, 2H), 2.46 (d,  $J$  = 17.4 Hz, 2H), 2.52 (d,  $J$  = 17.1 Hz, 2H), 5.46 (s, 1H), 7.04 - 7.28 (m, 4H); FTIR (KBr,  $\text{cm}^{-1}$ ): 3020, 2972, 2870, 1680, 1650, 1512, 1466, 1372, 1260, 1190, 1100, 1030, 841, 574; ESI-MS ( $m/z$ ): 396 ( $M^+ + 1$ ).

**6) 3,3,6,6-tetramethyl-9-(4-(2-pyridyl)-phenyl)-1,8-dioxo-octahydroxanthenes**

White solid,  $^1\text{H NMR}$  (300 MHz,  $\text{CDCl}_3$ )  $\delta$  = 0.96 (s, 6H), 1.12 (s, 6H), 2.18 (d,  $J$  = 16.7 Hz, 2H), 2.23 (d,  $J$  = 17 Hz, 2H), 2.52 (d,  $J$  = 17.8 Hz, 2H), 2.52 (d,  $J$  = 17.5 Hz, 2H), 5.42 (s, 1H), 7.04 - 7.28 (m, 4H), 7.12-7.38 (m, 4H); FTIR (KBr,  $\text{cm}^{-1}$ ): 3030, 2962, 2930, 2872, 1680, 1654, 1610, 1419, 1374, 1299, 1248, 1198, 1160, 1090, 868, 841; ESI-MS ( $m/z$ ): 428 ( $M^+ + 1$ ).

### 3.3.2. Spectral Data of 1,8-Dioxohexahydroacridines

**1) 3,3,6,6-tetramethyl-9-phenyl-3,4,6,7,9,10 hexahydroacridine-1,8-dione**

White solid,  $^1\text{HNMR}$  (300 MHz,  $\text{CDCl}_3$ )  $\delta$  = 9.28 (s, 1H), 4.8 (s, 1H), 0.92 (s, 6H), 1.02 (s, 6H), 1.94 (d,  $J$  = 21.5 Hz, 2H), 2.12 (d,  $J$  = 21.5 Hz, 2H), 2.32 (d,  $J$  = 22.8 Hz, 2H), 2.4 (d, 21.5 Hz, 2H), 7.05 - 7.28 (m, 5H); FTIR (KBr,  $\text{cm}^{-1}$ ): 3433, 3279, 3205, 3063, 2955, 2932, 1630, 1605, 1481, 1365, 1210, 1142; ESI-MS ( $m/z$ ): 350 ( $M^+ + 1$ ).

**2) 3,3,6,6-tetramethyl-9-(4-chlorophenyl)-3,4,6,7,9,10 hexahydroacridine-1,8-dione**

Yellow solid,  $^1\text{H NMR}$  (300 MHz,  $\text{CDCl}_3$ )  $\delta$  = 9.16 (s, 1H), 5.02 (s, 1H), 1.02 (s, 6H), 1.10 (s, 6H), 2.02 (d,  $J$  = 16.1 Hz, 2H), 2.23 (d,  $J$  = 16.3 Hz, 2H), 2.42 (d,  $J$  = 17.3 Hz, 2H), 2.52 (d,  $J$  = 17.1 Hz, 2H), 7.24 (d,  $J$  = 8 Hz, 2H), 7.26 (d,  $J$  = 5.7 Hz, 2H); FTIR (KBr,  $\text{cm}^{-1}$ ): 3430, 3275, 3170, 3030, 2955, 1650 1609 1485, 1398, 1360 850; ESI-MS ( $m/z$ ): 384 ( $M^+ + 1$ ).

**3) 3,3,6,6-tetramethyl-9-(2-nitrophenyl)-3,4,6,7,9,10 hexahydroacridine-1,8-dione**

White solid,  $^1\text{H NMR}$  (300 MHz,  $\text{CDCl}_3$ )  $\delta$  = 8.98 (s, 1H), 5.0 (s, 1H), 0.98 (s, 6H), 1.12 (s, 6H), 2.04 (d,  $J$  = 25.1 Hz, 2H), 2.26 (d,  $J$  = 22.6 Hz, 2H), 2.50 (d,  $J$  = 21.4 Hz, 2H), 2.54 (d,  $J$  = 22.3 Hz, 2H), 7.06 - 7.28 (m, 4H); FTIR (KBr,  $\text{cm}^{-1}$ ): 3440, 3274, 3170, 3030, 2970, 2873, 1685, 1650, 1512, 1460, 1375, 1250, 1190, 1100, 1030, 841; ESI-MS ( $m/z$ ): 380 ( $M^+ + 1$ ).

## 4. Conclusion

Based on the above conclusion it was concluded that, we have described a novel,

efficient, multi-component one-pot green synthetic method using nano nickel cobalt ferrite catalyst and ethanol and water as a solvent. The novel and synthetic utility of this method is established in the efficient synthesis of 1,8-dioxooctahydroxanthenes and 1,8-dioxohexahydroacridines derivatives. The advantages of this method include its simplicity of operation, cleaner reaction, and being good to excellent yields. Further, the purification of the product is simple involving filtration. The catalyst is easily separated by using external magnet and is reusable up to five cycles.

### Acknowledgements

The corresponding author is grateful to CSIR, New Delhi for supporting through fellowship (JRF & SRF) & Department of Engineering chemistry, AUCE (A), Andhra University, and Visakhapatnam for providing general lab facilities. The corresponding author is also grateful to Prof. K. Raghu Babu for his valuable & constant support.

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