



The study of spiro one-pot reaction of hydrofuran obtained from 1,3 cyclohexane dione with cyanogen bromide and various aldehydes in the presence of sodium methoxide or autoxide

Sara Mostaghim

MSc , Department of Chemistry , Payam Noor University , Roudsar Branch , PO Box 19395-3697 , Iran

Email : saramostaghim67@gmail.com

Abstract

The one-pot reaction of 1,3-Cyclohexanedione with cyanogen bromide and different aldehydes in the presence of sodium autoxide and in methanol solvent lead to selective production of *xanthene* derivatives with high efficiencies. In this research, the formation mechanism of this derivatives is described and the structure of all derivatives obtained with using techniques IR, H-NMR and C-NMR is investigated.

Keywords: Hydrofuran; Cyclohexane; Cyanogen bromide; Aldehydes.



1- Introduction

Carboxyl compounds are cyclic molecules in which ring is formed only from carbon atoms. While heterocyclic compounds are cyclic compounds in which one or more heteroatoms (that is atom other than carbon) are substituted. More than one half of well-known organic compounds at least have one heterocyclic component. Heterocyclic compounds are extensively used and among the variety of pharmaceutical and herbal compounds contributes a significant component. They are used as optical brighteners, anti-oxidation, anti-corrosion, additives, and many other factors [1]. Among other applications of heterocycles, can be mentioned the herbicides, fungicides, insecticides, paints, organic conductors, and pharmaceutical products [2]. Heterocycles chemistry is the unlimited source of ion compounds. The unlimited compounds of carbon, hydrogen and heteroatom can be designed such that new heterocycles are produced with physical, chemical and biological properties [3]. One reason for the widespread use of heterocyclic compounds is that their structure can be changed for achieving other desirable structures. Many heterocycles can be placed in a similar structural group, there is major difference in the group, such differenced include difference in acidic and basic properties, difference in the ability to attack by electrophiles or nucleophiles, and difference in polarity. The structural difference include the replacement of one heteroatom with another heteroatom in one ring and different positions of the same heteroatom within ring. For example, how to use heterocycles is to investigate preparation process of an anti-fungus [4]. Since natural materials are present in small quantities in nature and it is difficult to separate them in large quantities from natural resources, and organic chemists have solved this problem with their synthesis measures. Many heterocyclic compounds are synthesized in the laboratory. The synthetic heterocycles have a wide range of applications including the preparation of herbicides, insecticides, fungicides and plant growth regulators, paints and in many diseases such as cancers (fig. 1) [1.2].

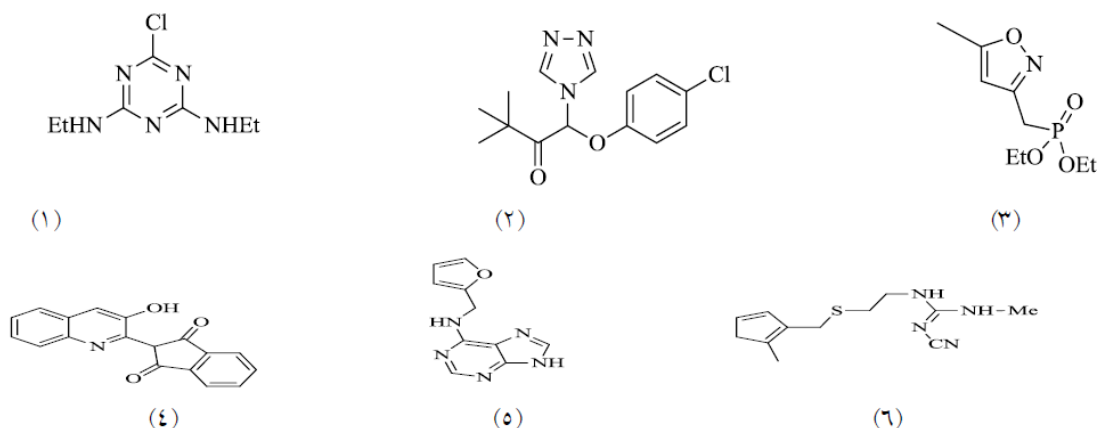


Figure1: Synthetic heterocycles.

Due to the extent performance heterocycle compounds and the specific importance of these compounds in chemistry, always and especially in recent decades, numerous efforts are made to provide and design procedures for synthesis of these compounds. Heterocycles are classified in two aromatic and nonaromatic categories. The heterocycle chemistry indebted to three discoveries:

- 1- Isolation of several furans derivatives from plant materials (1780)
- 2- Discovery of pyrrole from dry distillation of bone and horn by Rongli (1834)
- 3- Isolation of picoline from coal tar by Anderson Scottish chemist (1846)

The study of heterocycle chemistry is indebted to ongoing effort of many chemists, physicists and biologists.

The chemical behavior of many heterocyclic compounds can be explained based on to cyclic systems:

- Compounds that are obtained from substituting one or more CH groups of cyclopentadienyl carbanion with heteroatoms such as O, S, Se, Te, N, or P .
- Aromatic heterocyclic compounds which are obtained from substituting one or more CH groups in benzene.

Heterocyclic compounds are different in many chemical properties such as the strength of acid / base, affinity to attack electrophile or nucleophile and polarity. The important structural difference is in replacement of heteroatom with another one or replacement of heteroatom position in the ring. The important structural properties of heterocyclic compounds is that factor groups can be appeared as substituent or part of ring system itself. For example, the basic nitrogen can both placed as substituent and part of aromatic ring. Heterocyclic compounds have a key role in biologic processes. For example, the main food components such as thiamine (vitamin B1), Niacin, riboflavin (vitamin B2), pyroxole



(vitamin B6), Nicotinamide (vitamin B3) and Ascorbic acid (vitamin C) are heterocyclic compounds. The importance and chemical applications of hetrocylces has led to many theories and synthesis in this area [1,2,5].

2. Literature review

2-1- Cyclohexanedione

1,3- Cyclohexanedione (28) is a beta dicarbonyl compound that is as a white solid. Its molecular formula is $C_6H_8O_2$ and molecular mass is 13.122. This compound has melting point $102.8-105\text{ }^{\circ}\text{C}$ and boiling point $235.06\text{ }^{\circ}\text{C}$ and its density is 1.01 g/cm^3 . 1,3- Cyclohexanedione is solved well in water, chloroform, hot benzene, carbon disulfide and organic solvents such methnaol and ethanol. It is stable compound but it may be sensitive to light. It also unstable against oxidants [8,9]. The structure of 1,3- Cyclohexanedione is shown in figure 2.

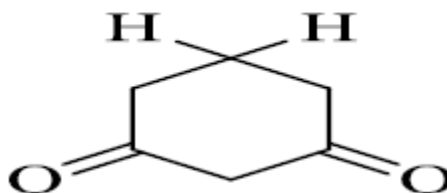


Figure 2.

1,3- Cyclohexanedione due to having exchangeable acidic hydrogen include a tautomeric form. Many factors such as the nature of solvent and medium acidity can affect the equilibrium. Different procedures to investigate the effect of these factors are reported that among them can be mentioned to instrumental procedures H-NMR and dynamic NMR and infrared [1,11]. Among other factors that can stabilize the enolic form can be mentioned to the formation of conjugated bond $C=C$ with $C=O$ and the formation of intermolecular hydrogen bond [12].

2-2- Cyanogen bromide

Cyanogen bromide [29] is an chemical compound with molecular formula $CNBr$. The IUPAC name of this compound is cyanic bromide. Other names that are available for this compound include: Cyanobromide, bromo cyanide, cyanogen mono bromide, bromocyanogen and other

names that are less used. Although its molecular formula is written as CNBr but in fact carbon atom is linked with simple bond to brome and with triple bond to nitrogen atom. The compound is linear and is highly polar. The structure of cyanogen bromide is shown in figure 3. This crystalline solid is white with sharp smell. Its molecular weight is 105.93 gr/mol and its density is obtained in different phases such that in solid phase it is equal to 2.015 [13]. The melting point is 52 °C and boiling point is 61.4 °C. This compound in UV spectroscopy has absorption spectra in the region 184-254 nm [14]. Its vapor pressure in 20 °C is equal to 92 mmHg [15]. The compound is easily solved in water, alcohol, ether and other polar solvents. In chromatography the suitable solvents for work with this compound are: 2-methoxyethanol DMSO, and N methylpyrrolidine [16]. Since the cyanogen bromide is very toxic, it should be careful when working with it, and all safety precautions must be observed. All experiments and activities involved with cyanogen bromide must be carried out under hood. This compound is very active and its maintenance is very difficult. Due to low melting point and boiling point, it must be maintained in the refrigerator and low temperature. Cyanogen bromide is usually prepared from oxidation of cyanide sodium by brome. This reaction is promoted by the intermediate formation of cyanogen (31) (figure 4) [17].

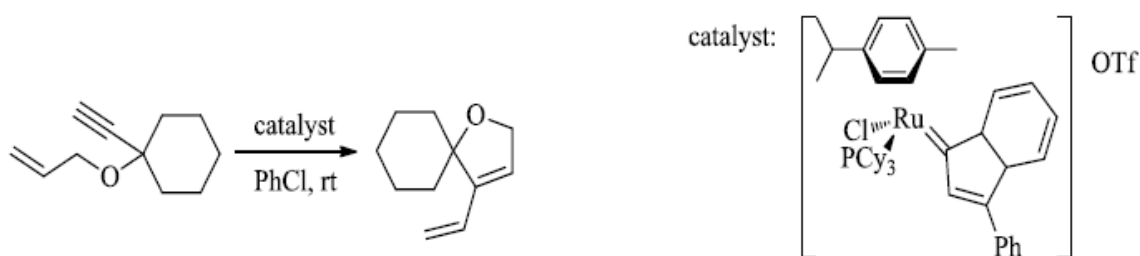


Figure 3.

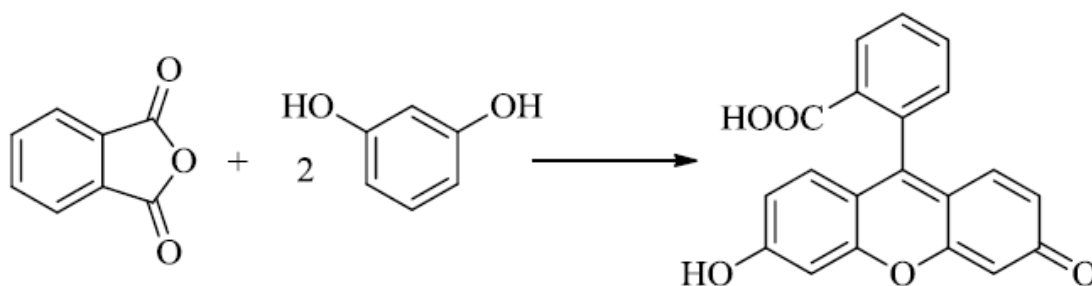


figure 4.

3-Discussion

3-1-Reaction of 1,3-Cyclohexanedione (28) with cyanogen bromide and different aldehydes in the presence of sodium autoxide and in methanol solvent



Because of the biological and pharmaceutical importance of derivatives of 1,3-Cyclohexanedione that has dihydrofuran format, we are determined to synthesize new derivatives from these compounds. The schematic diagram of reaction 1,3-Cyclohexanedione with cyanogen bromide and different aldehydes in the presence of sodium autoxide and in methanol solvent is shown in figure 5.

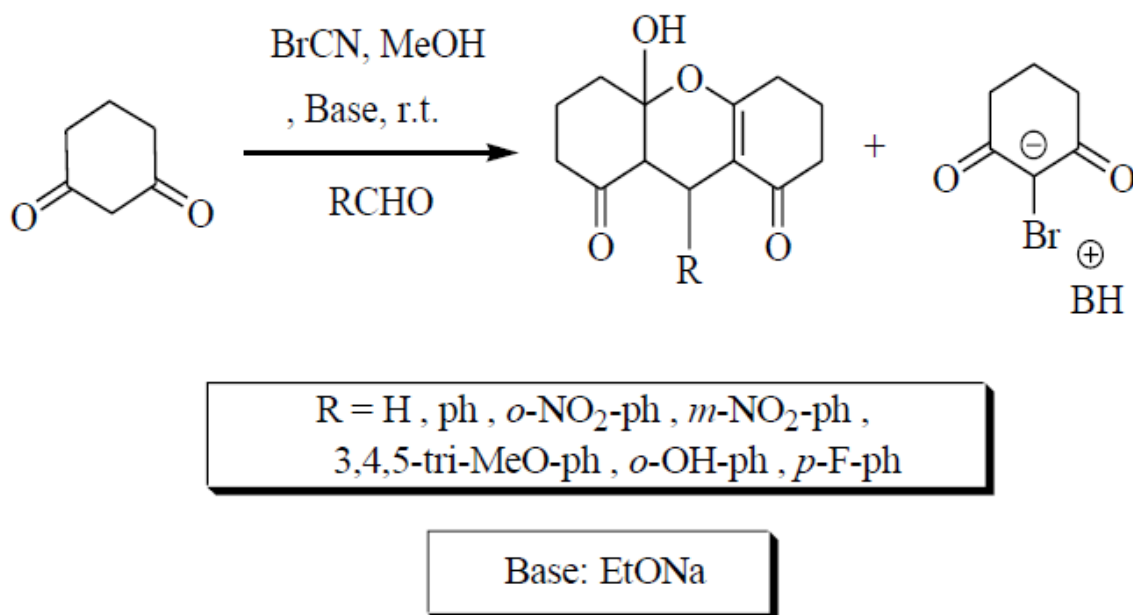


Figure 5.

3-2- Reaction 1-3 -Cyclohexanedione with cyanogen bromide and 3- nitrobenzaldehyde in the presence of sodium autoxide and in methanol solvent

From reaction 1-3 -Cyclohexanedione with cyanogen bromide and 3- nitrobenzaldehyde in the presence of sodium autoxide and in methanol solvent, the compound 104a and 105 is obtained. The IUPAC name of compound 104a, is 10a-hydroxy-9-(3-niro-phenyl)-3,4,5,6,7,8a, 9-10a-octahydro-1H-xanthene-1,8 (2H)-dione1.

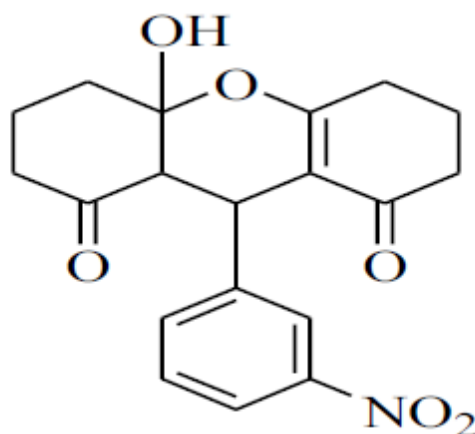


Figure6: Compound (104a).

In the IR spectrum of this compound, the available wide peak in the region cm^{-1} 3400 , 3160 is related to tensile vibration free O-H and with hydrogen bond, which this proves the presence of two equilibrium keto and enol forms in the compound. The two available peaks in the region 2952 and 2873 are related to tensile vibration of aliphatic C-H. The strong peak in the region cm^{-1} 1724 is related to tensile vibration of carbonyl groups. The two strong bands with identical intensity in the cm^{-1} 1525 and 1383 is related to symmetric and asymmetric tensile vibration of nitro group. In the spectrum $^1\text{H-NMR}$, this compound is a multiple peak equal to three protons in $\delta = 7.05 - 8.02 \text{ ppm}$ related to hydrogens of aromatic ring, double peak equal to one proton in $\delta = 7.05 \text{ ppm}$ related to proton of aromatic ring. The single peak in the $\delta = 4.44 \text{ ppm}$ is equal to one hydrogen, double peak equal to one hydrogen in $\delta = 4 \text{ ppm}$, the wide single peak in $\delta = 3.35 \text{ ppm}$ is equal to one hydrogen, single peak in $\delta = 3.28 \text{ ppm}$ is equal to one hydrogen and double peak equal to one proton in $\delta = 3.16 \text{ ppm}$ are observed, also the multiple peak equal to 12 protons in $\delta = 1.55 - 2.51 \text{ ppm}$ is related to methylene hydrogens. It should be noted that due to the presence of one chiral center in compound, 12 protons are related to diastereotopic methylenes and that's why in the spectrum $^1\text{H-NMR}$, the peaks of aliphatic region are observed in the multiple form. In the spectrum $^{13}\text{C-NMR}$, the compound 104a is totally 36 peaks are observed that indicate the existence of 36 types of carbon in this compound and this is due to the presence of three forms of keto-enol in this compound and that's why it can not be predicted the exact position of atoms.

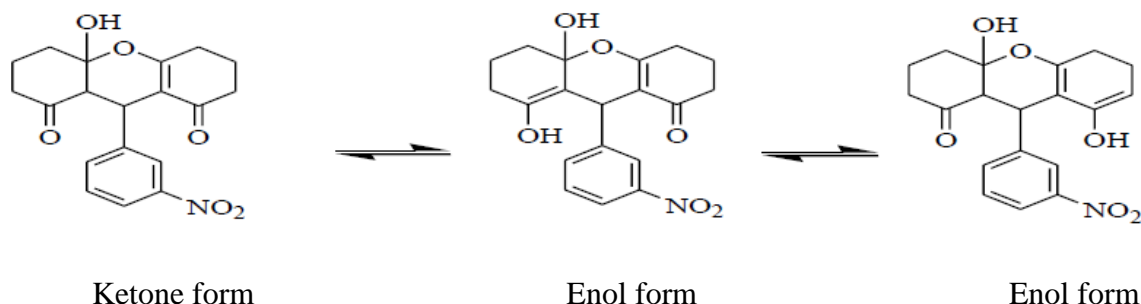


Figure 7: equilibrium mixture of compound 104a

The available peaks in the regions $\delta = 168.5 - 205.4$ are related to carbonyl groups in two ketol and enol forms. Furthermore, 16 peaks available in the $\delta = 100.1 - 147.4$ ppm are related to aromatic ring carbons, and double bond carbon- carbon in two ketol and enol forms, and 14 peaks available in the $\delta = 19.7 - 58.8$ ppm are related to aliphatic carbons in two ketol and enol forms.

3-3- Reaction 1-3 -Cyclohexanedione (28) with cyanogen bromide and 3,4,5 trimethoxybenzene in the presence of sodium autoxide and in methanol solvent

From reaction 1-3 -Cyclohexanedione with cyanogen bromide and 3,4,5 trimethoxybenzene in the presence of sodium autoxide and in methanol solvent, the compound 104b and 105 is obtained. The IUPAC name of compound 104b, is 10a-hydroxy-9-(3,4,5- trimethoxyphenyl) - 3,4,5,6,7,8a, 9-10a-octahydro-1H-xanthene-1,8 (2H)-dione21.

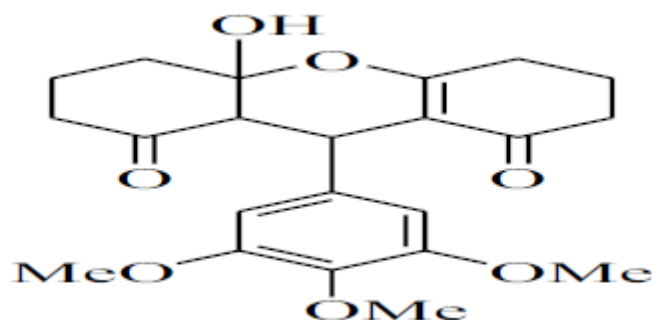


Figure 8: compound 104b



In the IR spectrum of this compound, the available wide peak in the region cm^{-1} 3324 is related to tensile vibration O-H, which this proves the presence of two equilibrium keto and enol forms in the compound. The two available peaks in the region 2946 cm^{-1} and 2838 are related to tensile vibration of aliphatic C-H. The sharp peak in the region 1718 cm^{-1} is related to tensile vibration of carbonyl groups. The strong band in the 1122 cm^{-1} is related tensile vibration of C-O. In the spectrum $^1\text{H-NMR}$, a three single peak, equal to one hydrogen are appeared in the $\delta = 6.86 \text{ ppm}$ and $\delta = 6.858 \text{ ppm}$ and $\delta = 6.851 \text{ ppm}$. One single peak equal to hydrogens in the $\delta = 6.42 \text{ ppm}$ related to hydrogens of aromatic ring, one single peak equal to one hydrogen $\delta = 6.36 \text{ ppm}$ and one single peak related to six protons in $\delta = 3.7 \text{ ppm}$ related hydrogens of OMe in the general tautomeric form, one single peak in the $\delta = 3.68 \text{ ppm}$ equal to three hydrogens related OMe in the general tautomeric form, one single peak equal to one hydrogen in $\delta = 3.67 \text{ ppm}$ related to OMe in the less tautomeric form, one single peak equal to one hydrogen in $\delta = 3.6 \text{ ppm}$ related to OMe in less tautomeric form, one wide single peak equal to four hydrogens in $\delta = 3.36 \text{ ppm}$ and one multiple peak equal to twelve protons in $\delta = 1.88 - 2.47 \text{ ppm}$ related to hydrogens of aliphatic region. In the spectrum $^{13}\text{C-NMR}$, this compound totally 43 peak are observed that indicate 43 types of carbon in the compound.

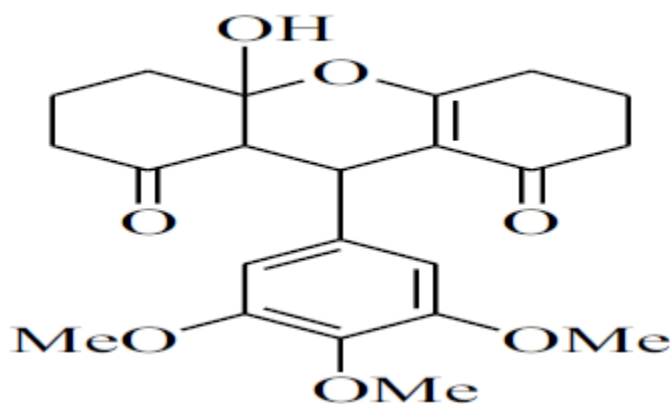


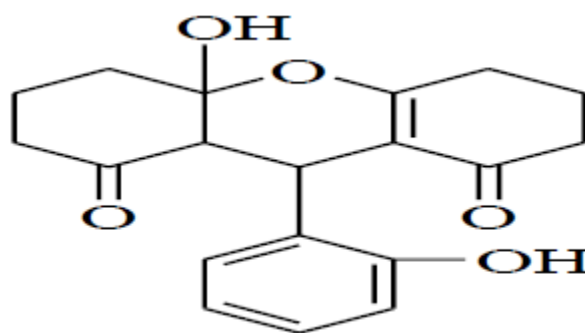
Figure 9: compound (104b).

Two available peaks in the $\delta = 206.2 \text{ ppm}$ and $\delta = 205 \text{ ppm}$ are related to carbons of carbonyl group, peaks in the $\delta = 195.8 \text{ ppm}$ and $\delta = 169 \text{ ppm}$ and 11 peaks in the $\delta = 100 - 151.9 \text{ ppm}$ related to carbons of aromatic ring, and carbon of double bond C=C in keto-enol forms. Peak in the $\delta = 59.8 \text{ ppm}$ is related to carbons equal to OMe, linked to 3,5th from aromatic ring, and peak in the $\delta = 55.6 \text{ ppm}$ is related to OMe linked to 4th carbon of aromatic ring and 22 peaks in the $\delta = 19.8 - 40.4 \text{ ppm}$ are related to aliphatic carbons.



3-4- Reaction 1-3 -Cyclohexanedione (28) with cyanogen bromide and 2-hydroxybenzaldehyde in the presence of sodium autoxide and in methanol solvent

From reaction 1-3 -Cyclohexanedione with cyanogen bromide and 2- hydroxybenzaldehyde in the presence of sodium autoxide and in methanol solvent, the compound 104c and 105 is obtained. The IUPAC name of compound 104c, is 10a-hydroxy-9-(2-hydroxyphenyl) - 3,4,5,7,8a, 9-10a-octahydro-1H-xanthene-1,8 (2H)-dione³¹.



In the spectrum IR of this compound, the very wide peak in the 3446-2538 cm⁻¹ that is interrupted with C-H absorptions, indicate the tensile vibration of O-H, and this is due to the intermolecular or intramolecular strong hydrogen bond and increasement of acidic properties of compound 104c. The peak in the 2951 cm⁻¹ is related to tensile vibration aliphatic C-H. The strong peak in the 1642 cm⁻¹ is related to tensile vibration of carbonyl groups. In the ¹H-NMR it is very likely that, one single peak equal to one proton in the $\delta = 10.77$ ppm, H, one single peak equal to one proton in the $\delta = 7.19$ ppm and one multiple peak equal to one hydrogen in the $\delta = 7.07 - 7.11$ ppm and one multiple peak equal two hydrogens in the $\delta = 6.93 - 6.92$ ppm related to hydrogens of aromatic ring. One single peak equal to one hydrogen in the $\delta = 4.57$ ppm, also double peak equal to one hydrogen in the $\delta = 2.96$ ppm, multiple peak equal to three hydrogens in the $\delta = 2.44 - 2.57$ ppm, multiple peak equal to proton in the $\delta = 2.3 - 2.4$ ppm, multiple peak equal to four protons in the $\delta = 1.88 - 2.11$ ppm and multiple peak equal to two protons in the $\delta = 1.65 - 1.82$ ppm that are appeared in the aliphatic region are related to methylene hydrogens. It should be noted that the aliphatic hydrogens due to diastrotopic are appeared in multiple peaks. In the spectrum ¹³C-NMR, the compound (104c) totally 19 peaks are observed that indicate the existence of 19 types of carbons in this compound and indicate the presence of one tautomeric form.

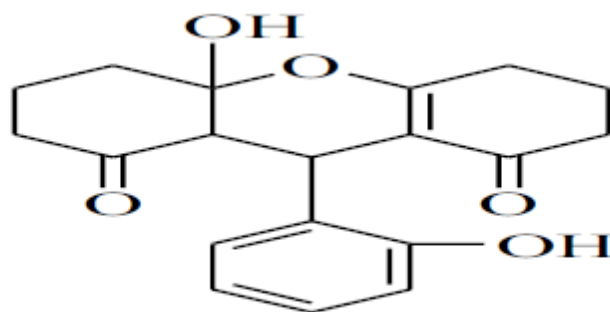


Figure 11: compound (104c)

It is very likely that two peaks in the $\delta = 197.1$ and 201.5 ppm are related to carbonyl carbons, the peak in the region $\delta = 172.8$ ppm and peak in the $\delta = 171.1$ ppm are related to double bond carbons. The peaks in the $\delta = 112.3 - 150.9$ ppm are related to aromatic ring carbons. The peaks in the $\delta = 77.2 - 19.7$ ppm are related to aliphatic carbons.

3-5- Reaction 1-3 -Cyclohexanedione (28) with cyanogen bromide and 2-nitrobenzaldehyde in the presence of sodium autoxide and in methanol solvent

From reaction 1-3 -Cyclohexanedione with cyanogen bromide and 2-nitrobenzaldehyde in the presence of sodium autoxide and in methanol solvent, the compound 104d and 105 is obtained. The IUPAC name of compound 104d, is 10a-hydroxy-9-(2-nitrophenyl) - 3,4,5, 6,7,8a, 9-10a-octahydro-1H-xanthene-1,8 (2H)-dione.

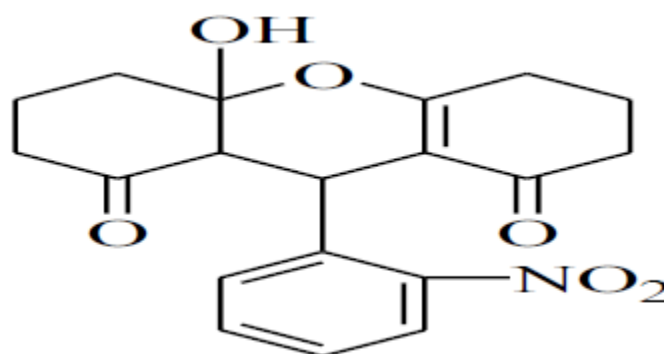


Figure 12: compound 104d.



In the IR spectrum of this compound, two strong peaks in the 3038 cm⁻¹ are related to tensile vibration O-H, two peaks in the 2878 and 2962 cm⁻¹ are related to aliphatic C-H and strong bond in the 1713 cm⁻¹ is related to tensile vibration of carbonyl group. Two strong peaks in the 1343 and 1524 cm⁻¹ are related to symmetric and asymmetric tensile vibration of nitro group. In the ¹H-NMR spectrum of this compound, double peak in the $\delta = 7.87$ ppm is equal to one proton and multiple peak in the $\delta = 7.10 - 7.45$ ppm is equal to three protons related to hydrogens of aromatic ring, three single peak in the $\delta = 4.73$ ppm is equal to one proton related to H and the peaks observed in the $\delta = 1.15 - 2.48$ ppm are equal to 12 protons related to hydrogens of diastrotropic methylene. In the spectrum ¹³C-NMR the compound 104d totally 31 peaks are observed that indicate the existence of more than one tautomeric form in this compound.

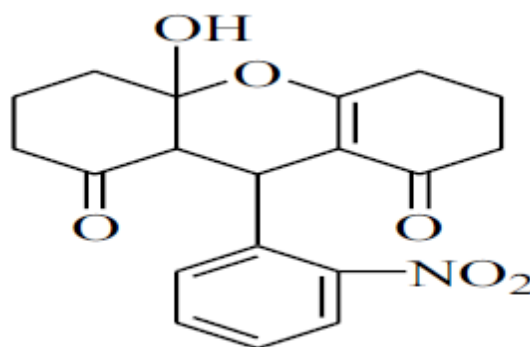


Figure 13: compound 104d.

It is very likely that two peaks in the $\delta = 205.2$ and 205.8 ppm are related to carbonyl carbons, peak in the $\delta = 196.4$ ppm and peak in the $\delta = 170.6$ ppm are related to double carbon bonds. Peaks in the $\delta = 150.6$ and 100.3 ppm are related to aromatic ring carbons, and peaks in the $\delta = 20.4 - 37.3$ ppm are related to aliphatic carbons.

3-6- Reaction 1-3 -Cyclohexanedione (28) with cyanogen bromide and benzaldehyde in the presence of sodium autoxide and in methanol solvent

From reaction 1-3 -Cyclohexanedione with cyanogen bromide and benzaldehyde in the presence of sodium autoxide and in methanol solvent, two compounds 104e and 105 are obtained. The IUPAC name of compound 104e, is 10a-hydroxy-9-phenyl - 3,4,5, 6,7,8a, 9-10a-octahydro-1H-xanthene-1 and (2H)-dione541.

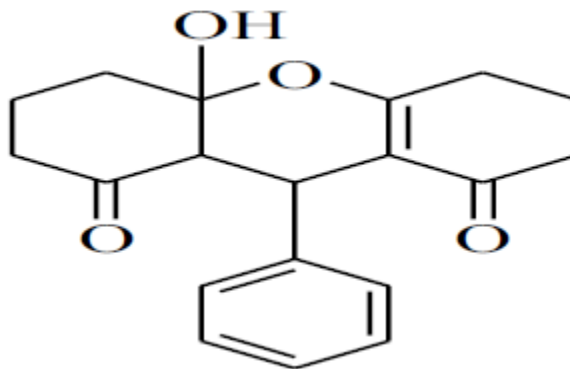


Figure 14: compound 104e

In the spectrum IR of this compound, the appeared peak in the 3303 cm⁻¹ is related to tensile vibration O-H. the peak in the 3053 and 3024 cm⁻¹ is related to tensile vibration of aromatic C-H and two peaks in the 2918 and 2958 cm⁻¹ are related to tensile vibration of aliphatic C-H. the peak appeared in the 1721 cm⁻¹ is related to tensile vibration of carbonyl group and the two appeared spectrum in the 1493 and 1600 cm⁻¹ are related to tensile vibration of C=C. in the ¹H-NMR spectrum of this compound, it is likely that one wise single peak in the $\delta = 12.02$ ppm and one single peak in the $\delta = 12.29$ ppm are related to exchangeable protons of OH tautomeric forms, this peak indicate that likely, more than two tautomeric forms exist in the compound, because two different peaks are observed for OH factor in enol forms. Multiple peak in the $\delta = 7.03 - 7.21$ ppm is related to hydrogens of aromatic ring and single peak equal to one proton in the $\delta = 5.4$ ppm is related to Ha. The peaks observed in the $\delta = 2 - 2.6$ ppm are equal to three protons and peaks in the $\delta = 1.93 - 1.99$ ppm is equal to seven protons related to methylene hydrogens. The multiple peaks in the $\delta = 1.1 - 1.5$ ppm are equal to two protons related to diastrotopic protons on methylenes. In the spectrum ¹³C-NMR of compound 104e, totally 17 peaks are observed that indicate the existence of 17 types of carbon in the compound. It should be noted that in the spectrum ¹³C-NMR of this compound, the peaks related to general tautomeric form are observed.

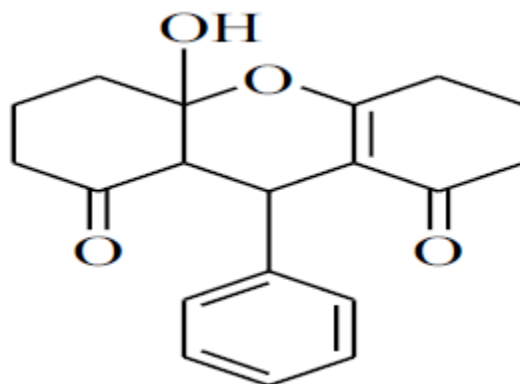


Figure 15: compound 104e

Two peaks in the $\delta = 219.4$ and 205.2 ppm are related to carbonyl carbons, peak in the $\delta = 192.1$ ppm and $\delta = 190.9$ ppm is related to C=C double bond. Peaks in the $\delta = 116.4 - 137.8$ ppm are related to carbons of aromatic ring and peaks in the $\delta = 20.1 - 5.59$ ppm are related to aliphatic carbons.

3-7- Reaction 1-3 -Cyclohexanedione (28) with cyanogen bromide and 4-fluorobenzaldehyde in the presence of sodium autoxide and in methanol solvent

From reaction 1-3 -Cyclohexanedione with cyanogen bromide and 4-fluorobenzaldehyde in the presence of sodium autoxide and in methanol solvent, two compounds 104e and 105 are obtained. The IUPAC name of compound 104f, is 9-(4-fluorophenyl)-10a-hydroxy - 3,4,5,6,7,8a, 9-10a-octahydro-1H-xanthene-1,8 (2H)-dione16.

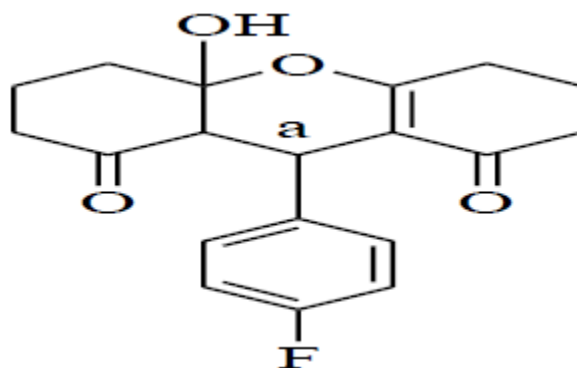


Figure 16: compound 104f

In the IR spectrum of this compound, the appeared peak in the 3315 cm^{-1} is related to tensile vibration O-H of enolic tautomer form in this compound. The peak in the region 3050 cm^{-1} is related to tensile vibration of aromatic C-H and two peaks in the regions 2962 and 2850



cm-I are related to tensile vibration of aliphatic C-H. The peak appeared in the 1721 cm-I is related to tensile vibration of carbonyl group. In the spectrum ¹H-NMR of this compound, it is likely that multiple peak equal to one proton in the $\delta = 7.18$ ppm is related to aromatic ring hydrogen and the multiple peak equal to three protons in the $\delta = 6.86 - 7.03$ ppm is related to protons of aromatic ring, the single peak equal to one proton in the $\delta = 4.40$ ppm is related to Ha, multiple peak equal to one proton in the $\delta = 3.86$ ppm and wide peak equal to four protons in the $\delta = 3.67$ ppm and multiple peak equal to one proton in the $\delta = 2.96$ ppm and multiple peak equal to ten protons in the $\delta = 1.6 - 2.41$ ppm are related to hydrogens of diastrotopic methylene. In the spectrum ¹³C-NMR of compound 104f, totally 25 peaks are observed. The cause of observation of multiple peaks in the aromatic region, is the coupling of fluorine atom with carbon atoms in the phenyl ring and another cause can be related to the existence of ketol-enol tautomeric forms.

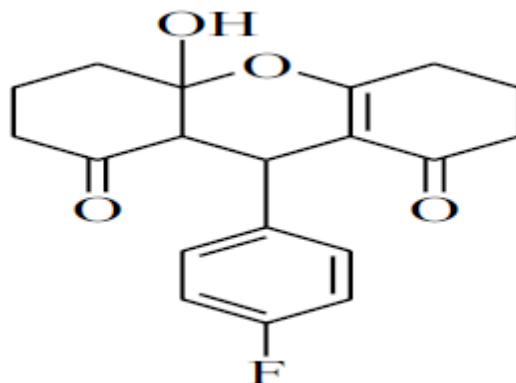


Figure 17: compound 104f

The peak in the $\delta = 205.4$ ppm related to carbonyl carbons, the peak in the $\delta = 196$ ppm and peak in the $\delta = 170$ ppm are related to double carbon bond. The peaks in the $\delta = 100.5 - 168.1$ ppm are related to aromatic ring, and peaks in the $\delta = 20.1 - 60.1$ ppm are related to aliphatic carbons in enol-ketol tautomeric forms.

3-8- Reaction 1-3 -Cyclohexanedione (28) with cyanogen bromide and formaldehyde in the presence of sodium autoxide and in methanol solvent

Due to the good results of aromatic aldehydes reaction, we are determined to carry out reaction with aliphatic aldehydes. From reaction 1-3 -Cyclohexanedione with cyanogen bromide and formaldehyde in the presence of sodium autoxide and in methanol solvent, two compounds 104j and 105 are obtained. The IUPAC name of compound 104j, is 10a-hydroxy - 3,4,5, 6,7,8a, 9-10a-octahydro-1H-xanthene-1,8 (2H)-dione71.

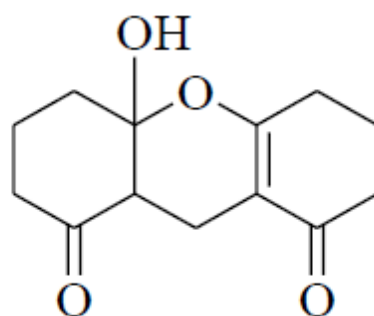


Figure 18: compound 104j.

In the IR spectrum of this compound, the appeared peak in 3315 cm⁻¹ is related to tensile vibration O-H of enol tautomeric form. Two peaks in the 2962 and 2850 cm⁻¹ are related to tensile vibration of aliphatic C-H. The peak appeared in the 1721 cm⁻¹ is related to tensile vibration of carbonyl group. In the ¹H-NMR of this compound, it is likely that wide peak equal to two protons in the $\delta = 11.8$ ppm are related to hydrogen OH of ketol-enol form, and wide peak equal to four protons in the $\delta = 3.5$ ppm are related to methylene protons which overlaps with water. Multiple peak equal to two protons in the $\delta = 2.5$ ppm that overlaps with peak DMSO is related to protons of hidrofuran ring and multiple peak equal to four protons in the $\delta = 1.85$ ppm and multiple peak equal to eight protons which overlaps with water are related to methylene protons in two ketol-enol forms. In the ¹³C- NMR spectrum of compound 104j, 11 peaks are observed that indicate the existence of 11 types of carbon in the compound.

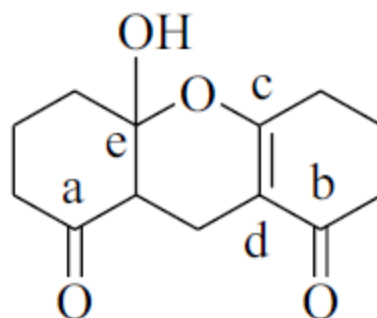


Figure 19: compound 104j

The peak in the $\delta = 204.9$ ppm is related to carbons a, peak in the $\delta = 191.5$ ppm is related to carbon b, and peak in the $\delta = 178$ ppm is related to carbon c. The peak in the $\delta =$



96 ppm is related to carbon d, and peak in the region $\delta = 90.5$ ppm is related to carbon e. The peaks in the region $\delta = 16.4 - 37.2$ ppm are related to methylene carbons.

3-9- Reaction 1-3 -Cyclohexanedione (28) with cyanogen bromide and Phthalaldehyde in the presence of sodium autoxide and in methanol solvent

Due to the good results of one factor aromatic aldehydes reaction, we are determined to carry out reaction with two factors phthalaldehyde and terephthalaldehyde aldehydes. From reaction 1-3 -Cyclohexanedione with cyanogen bromide and phthalaldehyde in the presence of sodium autoxide and in methanol solvent, compound 104h is obtained. The IUPAC name of compound 104h, is 5,10a-dihydroxy - 7,8,9a,10a,11,12,13,13a,14b, -decahydrobenzo [5,6]oxepino[2,3,4-kl]- xanthene-14-(5H) - One18

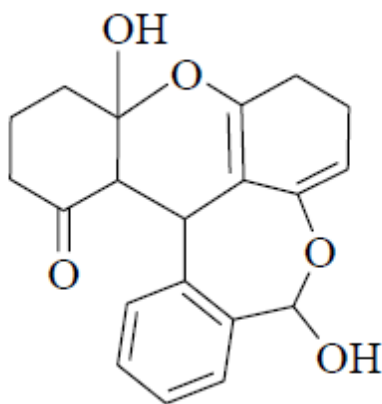


Figure 20: compound 104h

In the IR spectrum of this compound, the appeared peak in the 3274-cm-I is related to tensile vibration O-H. The peak in the 3020 cm-I is related to tensile vibration of aromatic C-H and two peaks in the 2948 and 2900 cm-I are related to tensile vibration of aliphatic C-H. The peak appeared in the 1721 cm-I is related to tensile vibration of carbonyl group. In the 1H-NMR spectrum of this compound, multiple peak equal to four protons in the $\delta = 7.04 - 7.18$ ppm is related to hydrogens of aromatic ring and single peak equal to one hydrogen in the $\delta = 6.62$ ppm is related to Hm. Single peak equal to one hydrogen in the $\delta = 5.52$ ppm is related to Ht and multiple peak equal to two hydrogens in the $\delta = 5.21 - 5.26$ ppm, multiple peak equal to one proton in the $\delta = 4.8$ ppm is related to Hc. Multiple peaks in the $\delta = 1.585$ ppm, $\delta = 2.01 - 2.5$ ppm and $\delta = 2.72 - 2.81$ ppm are related to 12 protons of diastrotopic methylenes. In the



spectrum ^{13}C -NMR, compound 104h, 21 peaks are observed that indicate the existence of 21 types of carbons in this compound.

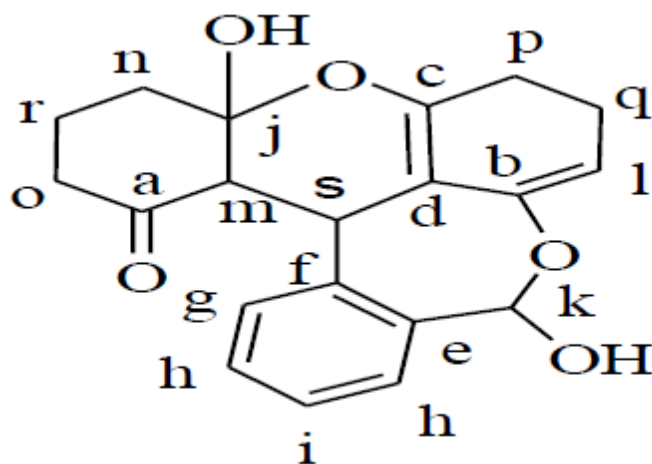


Figure 21: compound 104h

The peaks in the $\delta = 197.5, 197.6, 205.5$ and 205.7 ppm are related to carbons a,b,c,d. The peak in the region $\delta = 123.4 - 144.6$ ppm is related to carbon (e to j). As the molecular structure shows, the compound BrCN has to role in the formation of this compound. The formation mechanism of this compound is shown in the diagram 3-7. The peak in the $\delta = 112.5$ ppm is related to carbon k. The peak in the $\delta = 101.2$ ppm is related to carbon I and peak in the $\delta = 77.2$ ppm is related to carbon m. The peak in the $\delta = 19.7 - 65.3$ ppm is related to carbon (n to s).

3-10- Reaction 1-3 -Cyclohexanedione (28) with cyanogen bromide and terephthalaldehyde in the presence of sodium autoxide and in methanol solvent

From reaction 1-3 -Cyclohexanedione with cyanogen bromide and tereformaldehyde in the presence of sodium autoxide and in methanol solvent, two compounds 104i and 105 are obtained. The IUPAC name of compound 104i, is 9,9'-(1,4-Phenylene)bis(10a-hydroxy-3,4,5,6,7,8a,9,10a-octahydro-1H-xanthene-1,8(2H)-dione).

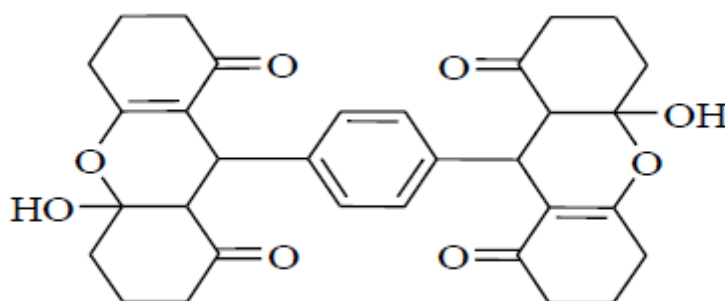


Figure 22: compound 104i

In the IR spectrum of this compound, the appeared peak in the 3500 cm⁻¹, is related to OH groups. The peak in the 3095 cm⁻¹ is related to tensile vibration of aromatic C-H. two peaks in the 2950 and 2874 cm⁻¹ are related to tensile vibration of aliphatic C-H and the peak in the 1719 cm⁻¹ is related to tensile vibration of carbonyl group. In the spectrum 1H-NMR of this compound, it seems that there is one more compound because in the $\delta = 9.89$ ppm and $\delta = 9.91$ ppm, two peaks for OH factor groups are observed that are different in value. As can be observed the aromatic region, it is seen at least three or four double types (which are different in integrals), that indicate at least two or three compounds. The complexity of spectrum 1H-NMR, in the aliphatic region of this compound conforms this point. In the spectrum 13C-NMR of this compound, it is also observed at least 6 carbonyl peaks and the large number of peaks in the carbonyl region also conforms the existence of several compounds with polarity close to each other. Effort to completely prove the structure of this compound still continues, and currently the structure of 104j is proposed for it.

4- Crystallographic structure of compound 104d

The X-ray diffraction patterns of crystalline solids allows to completely identification of molecular structure. In the procedure, on only the molecular arrangement is determined, but also geometric status of molecule such as bonds length, bond angles and two-dimensional is specified. The x-ray diffraction, is the most accurate procedure to determine the structure of molecule and its arrangement but there are limitations for this procedure. The crystallography data are given in table (1). From x-ray of this compound the following results are obtained :

- 1- The compound 104d is as xanthene.
- 2- This structure is dimeric form.
- 3- As can be seen from diagram ORTEP, the cyclohexane ring and cyclohexanone are fused together and have twisted chair form .
- 4- As can be seen from diagram ORTEP, this molecule has hydrogen bond between H one monomer with OH monomer in unit cell. The hydrogen bond length formed between two monomers A and B is equal (O6-H6.....O4) 2.037 and 2.(table2).



- 5- Hydroxyl group in each of monomers has molecular hydrogen bond H one monomer with OH monomer in cell unit of its neighbor and vice versa.
- 6- Accumulation diagram of crystalline compound 104d indicate that in the unit cell there are 2 molecules.
- 7- The percent of each monomers in dimmer 104d are identical.
- 8- There are three chiral centers in each of monomers, which configurations are as follows: (S) C13 and (S) C8 and (R) C7 in monomer A and (R) C38 and (S) C26 and (R) C33 in monomer B, that conclude two monomers A and B are enantiomer to each other.
- 9- dimer form 104d has C₁ symmetry.
- 10 – x-ray data shows that unit cell form is triclinic.

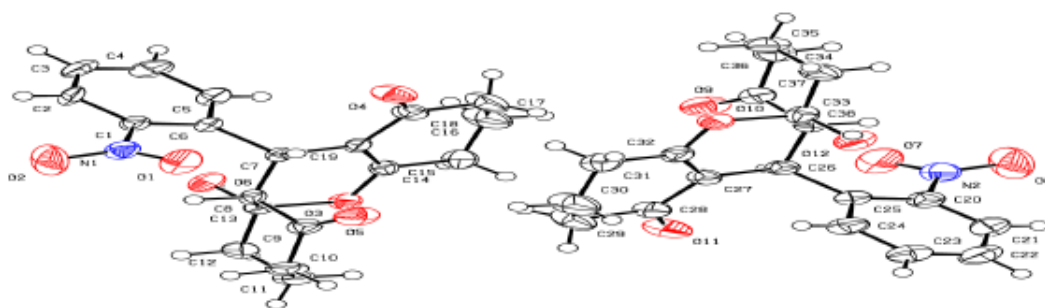


Figure 23: diagram ORTEP of crystalline structure from compound 104d.

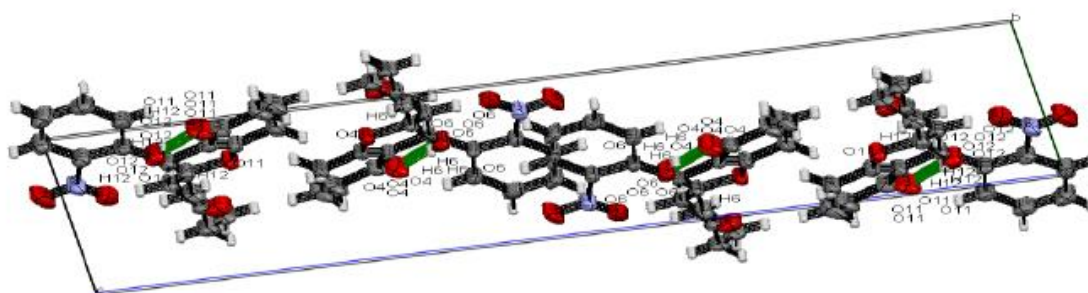


Figure 23: accumulation diagram crystalline compound 104e

Table1: crystallographic data of compound 104d



Crystal data

C ₁₈ H ₁₇ NO ₆	Z = 2
Mr = 686.65	F(000) = 720
Triclinic, P1	D _x = 1.364 Mg m ⁻³
Hall symbol: -P 1	Mo K α radiation, λ = 0.71073 Å
a = 7.124 (5) Å	Cell parameters from 0 reflections
b = 8.170 (5) Å	θ = 0–0°



$c = 29.433 (5) \text{ \AA}$	$\mu = 0.10 \text{ mm}^{-1}$
$\alpha = 90.086 (5)^\circ$	$T = 293 \text{ K}$
$\beta = 90.690 (5)^\circ$	Prism, colourless
$\gamma = 102.490 (5)^\circ$	$0.3 \times 0.2 \times 0.1 \text{ mm}$
$V = 1672.4 (16) \text{ \AA}^3$	

Data collection

Graphite monochromator	$\theta_{\max} = 28.3^\circ$, $\theta_{\min} = 1.4^\circ$
47130 measured reflections	$h = -9 \rightarrow 9$
8157 independent reflections	$k = -10 \rightarrow 10$
3828 reflections with $I > 2\sigma(I)$	$l = -39 \rightarrow 39$
$R_{\text{int}} = 0.045$	

Refinement

Refinement on F2	Primary atom site location: structure-invariant direct methods
Least-squares matrix: full	Secondary atom site location: difference Fourier map
$R[F2 > 2\sigma(F2)] = 0.093$	Hydrogen site location: inferred from neighbouring sites
$wR(F2) = 0.273$	H atoms treated by a mixture of independent and constrained refinement
$S = 1.12$	$w = 1/[\sigma^2(F_o^2) + (0.0786P)^2 + 3.5148P]$ where $P = (F_o^2 + 2F_c^2)/3$
8157 reflections	$(\Delta/\sigma)_{\max} = 0.025$
471 parameters	$\Delta\rho_{\max} = 0.85 \text{ e \AA}^{-3}$
0 restraints	$\Delta\rho_{\min} = -0.53 \text{ e \AA}^{-3}$



Table 2: hydrogen bond lengths and their angles in compound 104e.

D-H·····A	d(D-H)	l(H·····A)	l(D·····A)	<(DHA)	Directionality
O6-H6·····O4	0.82	2.037	2.847	169.84	Weak
O12-H12·····O11	0.82	2.065	2.854	161.47	Weak

5- Conclusions

The physical properties and reactions efficiencies corresponding to current research are presented in table 3.

Table 3: efficiency and melting point of obtained compounds in the research

Number	compound	melting point	efficiency %
۱	(۱۰۴a)	۱۸۲-۱۸۴	۵۰
۲	(۱۰۴b)	۲۱۲-۲۱۴	۷۵
۳	(۱۰۴c)	۱۷۵-۱۷۸	۶۰
۴	(۱۰۴d)	۲۱۰-۲۱۲	۷۵
۵	(۱۰۴e)	۹۳-۹۵	۷۵
۶	(۱۰۴f)	۲۱۲-۲۱۴	۶۰
۷	(۱۰۴j)	۲۳۶-۲۳۷	۷۰
۸	(۱۰۴h)	۲۲۶-۲۲۸	۴۰
۹	(۱۰۴i)	۲۰۷-۲۰۹	۵۰



References

1. Gilchrist, T. L. Heterocyclic Chemistry; Longman, 1997.
2. D. T. Davies, A.H.C., Oxford Chemistry Primers, 1991.
3. T. A. Balaban, C.D.O., R. A. Katritzky, Chem. Rev. 2002, 104, 7222.
4. Clough, J.M.G.C.R.A.C.B., 1991, 444.
5. Joule, J.A. and K. Mills, Heterocyclic Chemistry. 2013: Wiley.
6. A. R. Porcari, R.V.D., L. S. Kucera, J. C. Drach, B. L. Townsend, Journal Medicinal Chemistry 1998, 41, 1252.
7. A. Orjales, L.A.-C., P. Lopez-Tudanca, I. Tapia, R. Mosquera, L. Labeaga, Journal Medicinal Chemistry 1999, 415, 34, 18.
8. Fuchs, K. and L.A. Paquette, The Journal of Organic Chemistry, 1994, 59, 528.
9. Rajamannar, T., N. Palani, and K.K. Balasubramanian, Synthetic Communications, 1993. 23, 22, 3095.
10. A. Martinez-Richa, G.M.-D., P. Joseph-Nathan, Appl. Spec. 1991, 10, 1401.
11. C. L. Angell, R.L.W., Aust. J. Chem. 1991, 4, 794.
12. G. Cook, P.M.F., J. Chem. Edu. 2002, 14, 11.
13. R. C. McClure, E.o.O.H.a.S., Third Edition, Geneva, International labor office Switzerland, 1913, 371. ISBN 97-7-103791-4. .
14. R. B. Mooney, H.G.R., Nature. 2006, 171, 721.
15. R. C. Weast, C.H.o.C.a.P., ed 44th Ed, Boca Raton, Florida: CRC Press, 1911.
16. A. H. Nishikawa, P.B., Anal Biochem. 2009, 44, 741.
17. W. W. Hartman, E.E.D., Org. Synth. 1921, 7, 110; 1916, 11, 30.
18. J. Adamson, B.J.C., J. C. Grassam, J. C. Jeffery, S. J. Cloes, M. B. Hursthouse, J. Chem. Soc., Perkin Trans. 1999, 1, 7413. .
19. Y. S. Rao. Chemical Reviews 1976, 625.
20. S. Ma, Z.Z., X. Jiang, Org. Lett., 2007, 9, 531.
21. S. Xue, L.H., Y.-K. Liu, K.-Z. Han, Q.-X. Guo, Synthesis, 2006, 666-674.
22. F. Boeda, H.C., M. Jordaan, W. H. Meyer, S. P. Nolan, J. Org. Chem., 2008, 73, 259-263.
23. S. Kim, P.H.L., J. Org. Chem., 2012, 77, 215-220.
24. Sannigrahi, M.T., 55, 9007.
25. Wang, G.W., & Gao, J. Organic letters 2009, 11, 2385.
26. Celli, A.M., Donati, D., Scotton, M. Tetrahedron 1989, 45, 7929.
27. Yao, C., Wang, Y., Li, T., Yu, C., Li, L., Wang, C. Tetrahedron 2013, 69, 10593.
28. Savitha, G., Sudhakar ,R., Perumal, P. T. Tetrahedron Letters 2008 49, 7260.
29. Niveditha, S.K., Savitha, G., Muralidharan, D., Perumal, P. T. Tetrahedron letters 2007 48, 2943.
30. Teimouri, M.B., Akbari-Moghaddam, P., Motaghinezhad, M. Tetrahedron 2013 69, 6804.
31. R. Castarlenas, C.V., C. Fischmeister, P. H. Dixneuf, J. Am. Chem. Soc., 2006, 128, 4079-4089.
32. Hideo, T.J.T.K.J., 1981.
33. Chibale, K.V., M.; Schalkwyk, D. V.; Smith, P.J.; Saravanamuthu, A; Fatrlamb, A. H. Tetrahedron 2003, 59, 2289. .
34. Lambert, R.W.M., J. A.; Menett, J. H.; Parkes K E B . PCT Int. Appl. WO 9706178 1997.
35. Knight, C.G.S., T. Biochem. J 1989, 128, 683. .
- 19
36. Menchen, S.M.B.S.C.L., J. Y. L.; Zhen, W.; Khan. S. H.; Taing, M. U. S. Patent 6, 583, 168, 2003.
37. Banerjee, A.M., A. k. Stain technol. 1981, 168, 83.
38. Hatakeyma, S.O., N.; Numata, H.; J. Chem. Soc Chem Commun. 1988, 1202.



39. Hilderbrand, S.A.W., R. Tetrahedron Lett. 2007, 48, 4383.
40. Mchedlov-Petrosyan, N.O. "Differentiation of the strength of organic acids in true and organized solutions" Kharkov, 2004.
41. Mchedlov-Petrosyan, N.O., Vodolazkaya, N. A., Kornienko, A. A., Karyakina, E. L., & Reichardt, C. Langmuir, 2005, 21, 7090.
42. Carvell, M.R., I. D.; Small, P. W. Polymer. 1998, 39, 393 .
43. Gao. H.; Wang, C.Y., W.; Fu, Sh. J Macromol. Sci. , Pure Appl. Chem. 2004. 41. 357.
44. Mchedlov-Petrosyan. N. O.; Salamanova N. V.; Vodolazkaya, N.A.G., Yu. A.; Borodenko, V. I. J. Phys. Org. Chem. 2006, 19,365.
45. Lankard. J. R.; Sorokin P. P. U. S. Pat. 3, 470, 1970.
46. Sun, W.C., ; Gree, K. R.; Klaubert, D. H.; Haugland, R. P. J. Org. Chem. 1997, 62, 6469.
47. Guillen, E., ; Casanueva F.; Anta, J. A.; Vega-Poot,; Oskam, G.; Alcantara, R.; Fernandez-Lorenzo, C.; Martin-Calleja, J. J. Photochem. Photobiol. A. 2008, 200, 364.
48. McCullagh, J.V.D., Kelly A. J. Chem. Educ. 2007, 84, 1799.
49. Kimura. M. Journal of Yasuda Women's University. 2010, 267.
50. Bazgir, A.N.T., Z.; Mirzaei, P. Tetrahedron Lett. 2008, 49, 5165.
51. Yang, I.M.Y., Z. K.; Wu, L. Q. Chin. Chem. Lett. 2012, 23, 265.
52. Yoshida, H.W., M.; Fukushima,H.; Ohshita, J.; Kunai, A. Org. Lett. 2004, 6, 4049.
53. Jha, A.B., J. Tetrahedron Lett. 2004, 45, 8999.
54. Khosropour. A. R.; Khodaei, M.M.M., H. Synlett 2005, 955 .
55. Seyyedhamzeh, M.M., P.; Bazgar, A. Dyes Pigments 2008, 76, 836.
56. Rajitha, B.S.K., B.; Thirupathi Reddy, Y.; Tetrahedron Lett. 2005, 46, 8691.
57. Mahdavinia, G.H., Rostamizadeh, S., Amani, A. M.; Emdadi, Z. Ultrason. Sonochem., in press.
58. Bigddi, M.A.H., M. M.; Mahdavinia, G. H. J. Mol. Catal. A: Chem. 2007, 275, 25.
59. Bigdeli, M.A.H., M. M.; Hossein Mahdavinia, G. Catal. Commun. 2007, 8, 1595.
60. Pasha, M.A.J., V. P. Bioorg. Med. Chem. Lett. 2007. 17, 621.
61. Su, W.Y.D.J., C.; Zhang, B. Tetrahedron Lett. 2008, 49, 3391.
62. Dabiri, M.B., M.; Shakouri Nikchah, M. • Arzroomchilar, E. Bioorg. Med. Chem. Lett. 2008, 18, 436.
63. Mashraqui, S.H.P., M. B.; Mistry, H. D.; Ghadigaonkar,S.; Meetsma, A. Chem. Lett. 2004, 33, 1058.
64. Das, B.L., K.; Krishnaiah, M.; Srinivas, Y. Synlett 2007, 3107.
65. Li, J.T., W.; Lu, L.; Weike, S. Tetrahedron Lett. 2008, 49, 7117.
66. Gao, S.T., C. H.; Yao, C. F. Synlett 2009, 949.
67. Das, B.T., P.; Ravinder Reddy, K.; Ravikanth, B. Catal. Commun. 2007, 8, 535.
68. Li, J.J.T., X. Y.; Zhang, Z. H. Phosphorus Sulfur. 2008, 183, 1672.
69. John, A.Y., P.; J.P.; Palaniappan, S. J. Mol. Catal.A: Chem. 2006. 248, 121.
70. Srihari, P.M., S. S.; Reddy J. S. S.; Yadav, J. S. Chin. Chem. Lett. 2008, 19, 771.
71. Kantevari, S.B., R.; N agarapu, L. J Mol. Catal. A: Chem. 2007, 69, 53.
- 20
72. Lu, H.Y.L., J. J.; Zhang, Z. H. Appl. Organometal. Chem. 2009, 23, 165.
73. Bazgir, A., Z.N. Tisseh, and P. Mirzaei, Tetrahedron Letters, 2008. 49(35): p. 5165.
74. M. Jalilzadeh, N. Noroozi pesyan, F. Rezaee, S. Rastgar, Y. Hosseini, E. Şahin, Mol. Divers. 2011, 15, 721-731.
75. M. Jalilzadeh and N. Noroozi Pesyan, Bull. Korean. Chem. Soc. 2011, 32, 9.