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4-hydroxy Coumarin: a possible γ-radiation dosimeter

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ABSTRACT

The synthesized 4-hydroxy Coumarin was investigated for the purpose of developing a new chemical γ-radiation dosimeter. The compound was exposed to ^{60}Co γ-radiation source at room temperature. The compound dosimeter exhibited good sensitivity to γ-radiation of dose less than 30 Gy and a fairly good linearity of response in dose range 0-25Gy. The present compound may be used as sensitive, and as well as cost-effective dosimeter in 0-25Gy γ-radiation environment.

Introduction

Ionization results in the production of negatively charged free electrons and positively charged ionized atoms. Ionizing radiation can be classified into two categories: photons [X-radiation and gamma (γ) radiation and particles (alpha and beta particles and neutrons)]. In last decades, intensive research has been carried out on the need of improved devices for detection of invisible ionizing γ and neutron radiations. A visual reason could be their increased application and proliferation of radioactive materials in civil and military sectors. γ rays and neutrons are extremely penetrating. The efficient way of their detection is due to indirect interaction with the detector material and produce light flash called scintillation [1]. The best way to detect γ radiations are by using Organic scintillators[2]. Organic scintillator materials comprise of crystals of organic molecules such as stilbene and anthracene, liquid scintillators and plastic scintillators [1-2].

Recently, highly sensitive fluorescent dosimeters with coumarin derivatives have been reported[3]. Coumarins are among important group of naturally occurring compounds largely distributed in the plants and has been produced artificially for so many decades for different applications [4]. Associate members of this compound show a verity of applications, such as pharmaceuticals, cosmetics, agrochemicals, fragrances, additives to food, optical brightening agents, dispersed fluorescent, tunable dye lasers, biological activities like anthelmintic, hypnotic, insecticidal and anticoagulant properties[5]. Also among synthetic coumarins, the hydroxycoumarins (HCs), are well-known natural products and are used as sun screens [5], laser dyes [5], pesticides, etc [5]

Coumarin and its derivatives can be prepared by different methods, the list include Reformatsky reaction[6], Knovenegal reaction [7], Perkin reaction [8], Wittig reaction [9], and Pechmann reaction. Among these reactions, the Pechmann reaction is the mostly used method for the preparation of substituted coumarins. This reactions starts from a very simple material and gives high yields of different substituted coumarins.

In the present study, 4-hydroxy coumarin was prepared in laboratory and its possible application as radiation dosimetry were also tried.

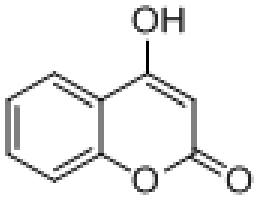

Fig.(1). Molecular structure of 4-hydroxy coumarin

Experimental

The 4-hydroxy coumarin molecule were synthesizes by the method describe in reference [10]. Fig.(1) shows the molecular structure of understudy compound. After formation of this synthesized product, certain amount of this product was dissolved in ethanol. Then this mixture was irradiated with ^{60}Co γ-radiation source, the facility available at Interuniversity Accelerator Centre (IUAC) New Delhi, India in dose range 15-30Gy (in steps of 5Gy). Ultraviolet–visible (Uv-Vis) spectroscopy of unirradiated and irradiated mixture was recorded on Shimadzu UV-1601 spectrometer. All the experiments were done at room temperature under. It is also mentioned here that the study is done on 4-hydroxy Coumarin+ ethanol solution and not compound alone.

Results And Discussion

The UV-VIS spectra of 4-hydroxy Coumarin after γ irradiation is shown in Fig.(2). An absorption band at around 300nm is clearly seen for this compound. After irradiation, a decrease in absorbance coefficient up to certain dose is also seen. In addition, a slight shift in this band edge is also observed. It can also be noted that after or before irradiation, no other absorbance due to electronic transitions in this region is seen.

From structural data, one can notice that coumarin is a molecule made up of a benzene ring I joined together with a lactone ring II. In them the lactone ring accommodates a double bond such a way that it projects the conjugated π-system across

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the molecule. For most of coumarins and their derivatives, an electron-donating substituent is attached at some particular position of ring (most commonly an amine or methyl group). In these molecules, intramolecular charge transfer (ICT) can occurs when they are excited by an appropriate light [11]. The ICT process can be helped by any electron-donating group at some position and/or an electron accepting group at another suitable position via resonance and inductive effects. The induced "push-pull" effect on the electronic charge perturbs the aromatic state of ring and sets it into a resonance state.

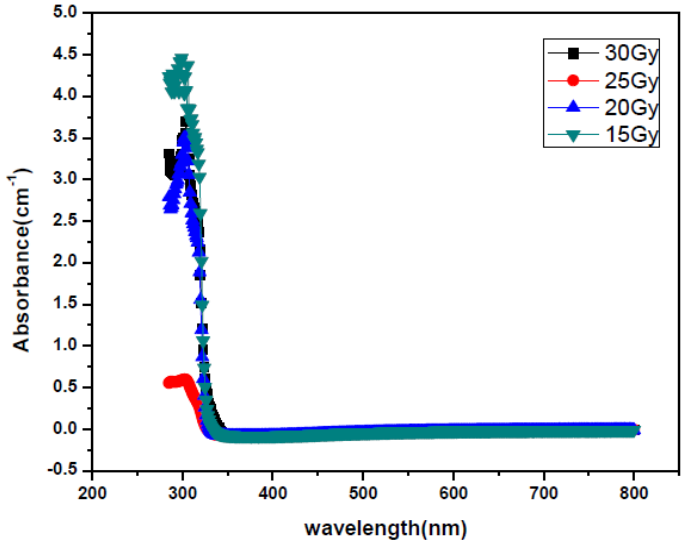

Fig.(2). Uv-Vis absorption spectra of 4-hydroxy coumarin after exposing to various doses

Due to the restoring nature of this resonance state, a variation in bond length of carbon bonds in the ring is taken place. Such bond variations will impact existing sp^2 hybridizations of carbon atoms of the aromatic ring and as result of this affect the band structure of the compound [11]. This type of variation in molecular structures has been reported for a few 7-hydroxycoumarins [12]. Recently this resonance theory and the "push-pull" effect was used to explain the bond-length patterns in coumarins, their optoelectronic properties, with specific reference to their absorption wavelengths and molar extinction coefficients[13].

Recently, the absorption characteristics of similar coumarin compounds and its derivatives were explained theoretically [14]. The main observed absorption are considered due to transition from *HOMO* to *LUMO* with different proportions (like, LUMO + %). The observed low absorbance/ high transmittance in the entire visible region are due to π–π∗ transition of this molecule[15].

Fig.(3) shows the dose–response functions as a function of net absorbance $(\Delta A)/cm^{-1}$ ($\Delta A = A_0 - A_i$, where A_0 is absorbance before irradiation and A_i is absorbance after irradiation) dose at 300nm of the unirradiated and irradiated solutions. The dose–response range increases with the increase of dose. The useful dose range for this mixture is 0–25 Gy.

Generally, irradiation of aqueous solutions with ionizing radiation produces hydrogen atoms, hydrated electrons, hydrogen peroxide, hydroxyl radicals and their byproducts. The determination methods for hydroxyl radicals are potentially applicable as a chemical dosimeter for determining the intensity of ionizing radiation[16]. To know the exact possible byproducts in current studied sample, a detailed investigation is underway.

Conclusion

The 4-hydroxy Coumarin was synthesized successfully. This compound was explored for possible chemical γ-radiation sensor. This understudy dosimeter exhibited good sensitivity to γ-radiation up to dose of 25 Gy. The present compound may be used as potential candidate for γ-radiation environment.

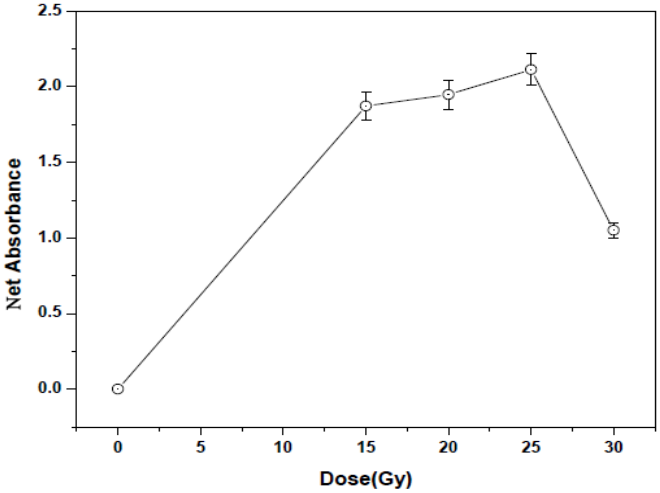

Fig.(3). Shows net absorbance (at 300nm) of 4-hydroxy coumarin after exposing to various doses.

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