World Applied Sciences Journal 15 (2): 261-264, 2011
ISSN 1818-4952

Luminescence Study of 14-Phenyl-14*H*-Dibenzo [a,j] xanthenes as an Organic Liquid Scintillator When Exposed to Low-Energy Gamma Rays

[1]Ali Akbar Mehmandoost-Khajeh-Dad, [1]Nasrin Salehi and [2]Majid Ghashang

[1]Department of Physics, Faculty of Science,
University of Sistan and Baluchestan, Zahedan, Iran
[2]Department of Chemistry, Faculty of Science,
University of Sistan and Baluchestan, Zahedan, Iran

Abstract: Scintillation properties of *14-phenyl-14H-dibenzo[a,j]xanthenes* (called material A) is studied. Cyclohexan is used as a solvent, whilst Anthracene and Naphthalene are used as secondary solutes. The response of the scintillator to low energy Gamma-rays is detectable. Our study shows that the addition of material A (0.01 mol L^{-1}) to the solution of Anthracene-Naphthalene-Cyclohexan, improves the detection efficiency of the solution by 35%.

Key words: Organic Scintillator · Gamma detection · 14-phenyl-14*H*-dibenzo [a,j] xanthenes

INTRODUCTION

The presently known organic scintillators are compounds whose molecules contain one or more benzene rings [1]. Organic scintillators are characterized by their short decay times which are of the order of 10^{-8} sec. Scintillation detectors are widely used in the experimental particle and nuclear physics. They have also other applications like homeland security, environmental monitoring, nuclear fuel processing, high level waste management, medical imaging, nuclear non-proliferation and X-ray diffraction. This type of scintillators have been under continuous investigation for many years [2,3] for their unique properties, like their distinguished timing properties. Nowadays, development of new organic luminescent materials has attracted a great attention [4]. A short review of some new scintillation materials, scintillation detectors and scintillation systems for registration of gamma-rays, X-rays, neutrons and neutrinos is given in [5].

Xanthenes include wide range of organic materials possessing biological and therapeutic properties such as antibacterial, antiviral activities. They are candidates for the photodynamic therapy (PDT), which PDT is a method of treating tumors by combined use of a photosensitizer and light. In this method, photosensitizers are injected directly into malignant tissue and by using the specific wavelength light excites the photosensitizer drug, this cause killing the tumor cells [6]. Furthermore, benzoxanthenes are used as dyes [7] in laser technologies [8] and in fluorescent materials [9].

An extensive investigation of the effect of small amounts of secondary solute on the fluorescence of organic crystals was carried out by Bowen *et al*. [10]. The addition of naphthalene to some liquid scintillators improves the scintillation yield [11]. Experiments with mixed solvents are described where relatively small concentrations especially of naphthalene and o-diphenylbenzene act in some way as a second solute. It is found that the energy migrates from the original solvent to the second solute and then to the main fluorescent molecule. This intermediate energy transfer can change the light emission curve completely [12]. A study on the properties of the anthracene-doped naphthalene crystal can be found in the literature [13]. It is shown that the pulse height of the mixed crystal is 10 times greater than that for pure naphthalene crystal.

In the research reported in this paper we have focused on the optical aspects of a novel scintillator system utilizing chemical scintillation components. The optical absorption-emission spectra and detection efficiency of low energetic gamma rays emitted from ^{137}Cs radio nuclei have been investigated. The process of optical absorption and scintillation of material A is schematically illustrated in Fig. 1.

Corresponding Author: Ali Akbar Mehmandoost-Khajeh-Dad, Department of Physics, Faculty of Science, University of Sistan and Baluchestan, Zahedan, Iran. Tel: +98-541-8056220.

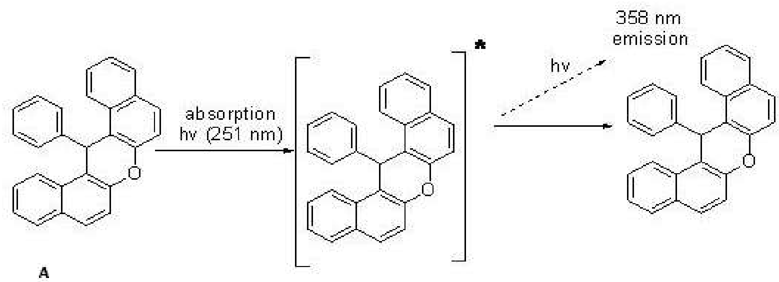

Fig. 1: Mechanism of the fluorescence process of 14-phenyl-14*H*-dibenzo[a,j]xanthene [9] .

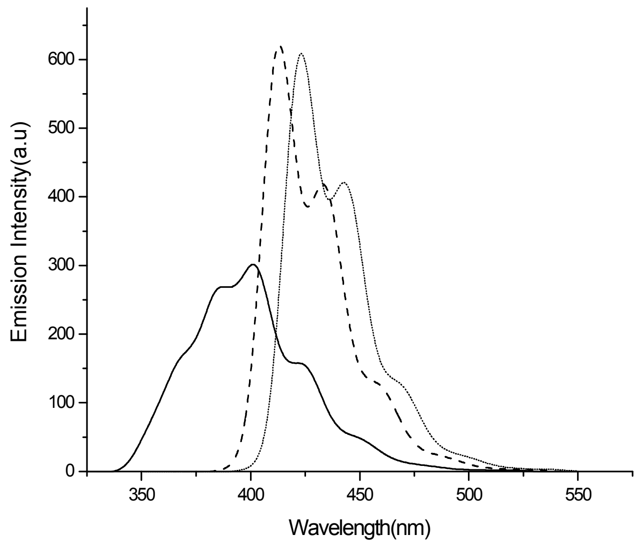

Fig. 2: Solid line shows the emission spectra of the material A diluted in Cyclohexan while exited by photons with 324 nm wavelength. The solid line has a maximum at 401 nm. Dashed line shows the emission spectra of the solution of Naphthalene-Anthracene-Cyclohexan while exited by photons with 324 nm wavelength. The dashed line has a maximum at 413 nm. Dotted line shows the emission spectra of the material A- Naphthalene-Anthracene-Cyclohexan exited by photons with 361 nm wavelength. The dotted line has a maximum at 423 nm wavelength.

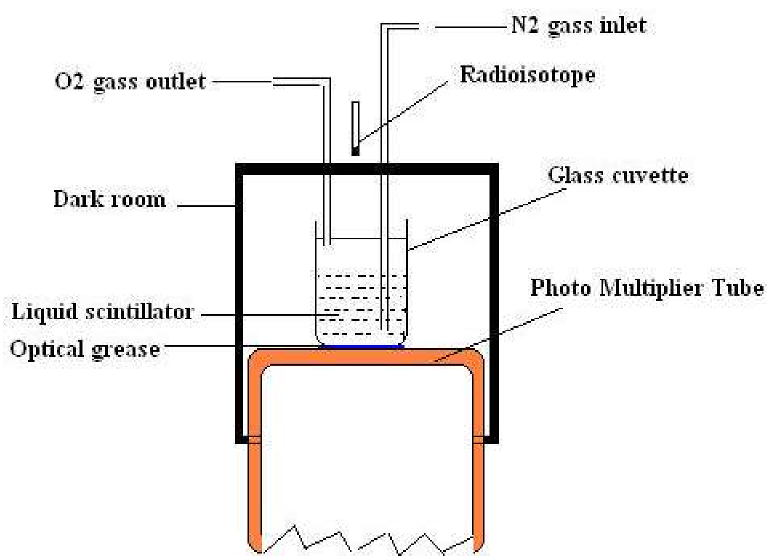

Fig. 3: Setup used to measure the detection efficiency of material A in different solvent.

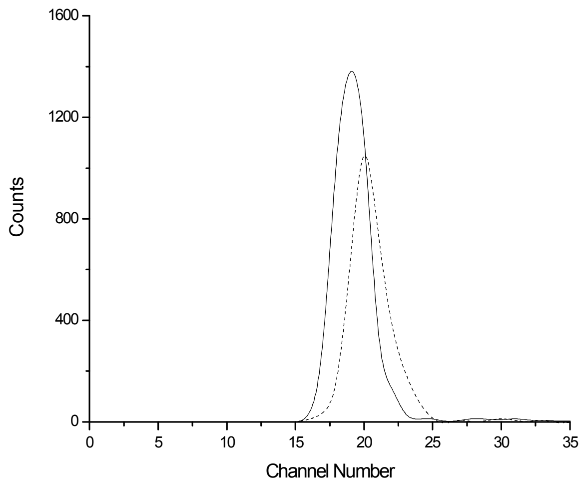

Fig. 3: Pulse height spectra of the gamma detection system for a Cs-137 source. The solid line represents the response of the system while material A is added to the solution of Naphthalene -Anthracene-Cyclohexan. The detection efficiency of the system is improved by 35%.

Sample Preparation and Fluorescence Properties: All reagents and materials were purchased from Merck chemical company [14] and used without further purification. The material A was synthesized according to the reported procedure proposed by [15] and then more purification was carried out by the re-crystallization in di-ethyle Ether.

A LS-3 Perkin Elmer [16] fluorescence spectrophotometer was used to measure fluorescence properties of the scintillator. The absorption spectrum was measured with a Specord S100 Analytik Jena [17] UV spectrophotometer. The luminescence of the material A) 0.01 mol L^{-1}) diluted in Cyclohexan was studied through measuring the emission spectrum, see Fig. 2. The densities of several components were tested. The maximum intensity of the spectrum occurred at 401 nm wavelength, while excited by photons with 324 nm wavelength. Since the commercially available Photomultiplier throughout the text Tubes (PMT's) are usually more sensitive to the wavelength around 430 nm, one has to use wavelength shifters. The dotted line in Fig. 2 shows that the solution of the material A - Naphthalene (as secondary solute; 0.1 mol L^{-1}) - Anthracene (as secondary solute; 0.01 mol L^{-1}) - Cyclohexan can be used as a good candidate for the liquid scintillator when used with common PMT's. A comparison between the emission spectra of the solution of Naphthalene-Anthracene-Cyclohexan with material A-Naphthalene-Anthracene-Cyclohexan has been made in Fig. 2. Although the solution of Naphthalene-Anthracene-Cyclohexan has already scintillation properties, but our studies show that the addition of material A will improve the detection efficiency of the solution by 35%, as shown in the Fig. 3.

Low Energy Gamma Rays Detection System: In order to measure the detection efficiency of various liquid scintillators, the set-up shown in Fig. 3 was used. The experimental setup consists of a HAMAMATSU-R1307 PMT [18] a suitable base and Pre-amplifier and a cell (1 inch in diameter and 2 inches in height) containing the solution. The photocathode of the PMT is sensitive to detect photons with 300 to 600 nm wavelength. However, the maximum detection efficiency of the system happen about 430 nm wavelength.

Since oxygen destroys the scintillation process [19], the cell has two pipes for bubbling N_2 gas into the solution and to removes the oxygen. This process improve the detection efficiency by a factor of 15%.

While the cell is filled with the liquid scintillator, a gamma emitter source is put on top of the cell. The gamma rays passing through the cell may leave part of their energies in the solution, causing the scintillator to emit photons via the scintillation process. The photons impinge on the photocathode of the PMT and they are converted to an electric pulse which is finally processed by a Multi Channel Analyzer. The height of the electronic pulse is proportional to the energy loss of the radiation inside the scintillator. The experimental setup for the measurement is located in a dark room in order to reduce the background. The pulse height spectra of the material A (0.01 mol L^{-1}) -Naphthalene (as secondary solute; 0.1

mol L^{-1}) -Anthracene (as secondary solute; 0.01 mol L^{-1}) in Cyclohexan as our new scintillation system for detection of low energy gamma rays of a ^{137}Cs source is shown in Fig. 4. The spectra is background subtracted. Due to the presence of a lot of noise with small height, a threshold is used in the setup.

Although in the Fig. 2 the material A has a role of a wavelength shifter, but surprisingly we see from the Fig. 4 while material A is added to the solution of Naphthalene-Anthracene-Cyclohexan, the detection efficiency of the system is increased by a factor of 1.35. Increasing the detection efficiency of detectors, is of great importance in experimental nuclear physics.

Summary and Conclusion: Scintillation properties of *14-phenyl-14H-dibenzo[a,j]xanthenes* (called material A) diluted in Cyclohexan is studied. Naphthalene and Anthracene were used as secondary solutes. Although the material A has a role of a wavelength shifter in the liquid scintillator, but surprisingly the detection efficiency of the low energy gamma rays detection system is increased by 35%.

REFERENCES

1. Pringsheim, P., 1949. Fluoresence and Phosphoresence. Interscience publishers. New York.
2. Reynolds, G.T., F.B. Harrison and G. Salvini, 1950. Liquid Scintillation Counters. Phys. Rev., 78(4): 488-488.
3. Ghal-Eh, N., G.R. Etaati and M. Mottaghian, 2010. Monte Carlo Simulation of Inorganic Scintillators Response to Gamma Rays: A Comparative Study. World Applied Sciences J., 8(6): 784-788.
4. Ross, H., J.E. Noakes and J.D. Spaulding, 2000. Liquid scintillation counting and organic scintillators. Sci.,
5. Koroleva, T.S., B.V. Shulgin, C.H. Pedrini, V. Yu, Ivanov, D.V. Raikov and A.N. Tcherepanov, 2005. New scintillation materials and scintiblocs for neutron and γ-rays registration. Nuclear Instruments and Methods in Physics Res. A., 537: 415-423.
6. Ion, R.M., 1997. Photodynamic therapy of cancer: A photocatalytic process or a photosensibilization process. Prog. Catal., 2: 55.
7. Banerjee, A. and A.K. Mukherjee, 1981. Chemical aspects of santalin as a histological stain. Stain Technol., 56(2): 83-85.
8. Ahmad, M., T.A. King, Do-K. Ko, B.H. Cha and J. Lee, 2002. Performance and photostability of xanthene and pyrromethene laser dyes in sol-gel phases. J. Phys. D: Appl. Phys., 35(13): 1473-1476.
9. Knight, C.G. and T. Stephens, 1989. Xanthene-dye-labelled phosphatidylethanolamines as probes of interfacial pH. Studies in phospholipid vesicles. Biochem. J., 258: 683-687.
10. Bowen, E.J., E. Mikiewicz and F.W. Smith, 1949. Resonance Transfer of Electronic Energy in Organic Crystals. Proc. Phys. Soc. A., 62(1): 26-32.
11. Fust, M. and H. Kallmann, 1955. Enhancement of Fluorescence in Solutions Under High-Energy Irradiation. Phys. Rev., 97(3): 583-587.
12. Kallman, H. and M. Furst, 1951. Fluorescence of Solutions Bombarded with High Energy Radiation (Energy Transport in Liquids) Part II. Phys. Rev., 81(5): 853-864.
13. Balamurugan, N., A. Arulchakkaravarthi and P. Ramassamy, 2006. Scintillation characteristics on anthracene-doped naphthalene crystal for 137Cs gamma-ray source. Nuclear Instruments and Methods in Physics Research A., 568(2): 767-771.
14. http://www.merck.com.
15. Wu, Y.C., L. Liu, D. Wang and Y.J. Chen, 2006. Efficient synthesis of 3-arylaminopyrroline -2-ones by the tandem reaction of anilines and β,-unsaturated -ketoesters. J. Heterocycl. Chem., 43(4): 949-955.
16. http://www.perkinelmer.com.
17. http://www.analytikjenauk.co.uk.
18. Hamamatsu, Inc. Photomultiplier R1307 data sheet. http://www.hamamatsu.com.
19. Pringle, R.W., L.D. Black and S. Sobering, 1953. A New Quenching Effect in Liquid Scintillators. Phys. Rev., 92(6): 1582-1583.