Journal of Radiation Research and Applied Sciences xxx (2018) 1–5

HOSTED BY

ELSEVIER

Contents lists available at ScienceDirect

Journal of Radiation Research and Applied Sciences

journal homepage: http://www.elsevier.com/locate/jrras

Spectrophotometric properties of azo dye metal complex and its possible use as radiation dosimeter

S.M. Gafar*, M.A. El-Kelany, S.R. El-Shawadfy

Radiation Protection and Dosimetry Dept., National Center for Radiation, Research and Technology, NCRRT, Egyptian Atomic Energy Authority, P.O. Box 029, Nasr City, Cairo, Egypt

A R T I C L E I N F O

Article history:
Received 17 September 2017
Received in revised form
8 January 2018
Accepted 13 January 2018
Available online xxx

Keywords:
Dosimetry
Gamma-radiation
Liquid

A B S T R A C T

The current work describes the physico-chemical studies of two dosimetry systems. Aqueous solution of 1, 5 diphenyl carbazone (DPC) incorporating with chromium (III) to form a colored azo dye metal complex in two methods liquid and gel. Under the effect of γ-irradiation, the colored complex undergoes visual color change from red to colorless. The prepared complex can be used as a dosimeter and applicable in dose range 0.2–6; 0.02–1 kGy for both dosimetry systems. Electrical conductivity was measured and reflecting its application as sensor. The dosimetric characteristics of this complex solution were investigated spectrophotometrically at λ_{max} at 540 nm. Complex sensitivity for γ-radiation, pre and post-irradiation storage under different conditions were illustrated. Moreover, the applications of these results of metal uptake resembles to dosimeter.

1. Introduction

Dosimetry is the science of dose measurement. It represents a very essential function of radiation processing (Kattan, Daher, & AlKassiri, 2011). Chemical dosimeters rely on their radiation produced color change used for identification of irradiated and unirradiated products in sterilization of both medical or pharmaceutical products, and food irradiation applications (Gafar & El-Ahdal, 2014; Gafar, El-Kelany, & El-Ahdal, 2017). According to their sensitivity towards various dosimetric studies factors, (dose rate; light; humidity; temperature; etc.) (Gafar & El-Ahdal, 2014). pH indicators can exist in a chemical equilibrium keto-enol tautomeric form having different colors (Beshir, 2013). Many dosimeters can be exist in liquid and applied in high dose-dosimetry applications (Kovac et al., 1999), and others can exist in gel form to achieve the dosimeter requirements applications in low dose-dosimetry applications (Gafar & El-Ahdal, 2015). In addition to, gel dosimeters were previously prepared for low-dose applications in the dose range 1–200 Gy (Babic, Battista, & Jordan, 2009; Davies & Baldock, 2008), on a radiochromic dye and natural material. Moreover (Gafar & El-Ahdal, 2015; Gafar, El-Kelany, El-Ahdal, & El-Shawadfy, 2014), developed a two new gel dosimetry systems based on the addition of Toluidine blue–O dye and fuchsine acid cyanide dye to gelatin, which are useful for radiation processing in the range of 1–150 Gy and 1–170 Gy; respectively. Furthermore, gelatin enhanced sensitivity of the dyed gel mixture (Gafar & El-Ahdal, 2015). More advantages of this gel-complex its preparation was easy, low cost and it has an easy quality control, its good stability over 30 days except the first 5 days and more sensitive toward gamma rays up to 170 Gy. Azo dye derivatives such as 1,5 diphenyl carbazone are widely used in various applications as textile, printing, agrochemical, wastewater treatment, and pharmaceutical industries, this is due to the presence of –N=N- azo group, color changes accompanying one-electron reduction and oxidation of the azo dyes (Zielonka et al., 2004). New method has been developed for detection of Cr (VI) (Bergamini, dos Santos, & Zanoni, 2007). Moreover, there are many suggested reactions between the DPC and Cr (III) to form complex DPC-Cr (VI) it has many applied outcome in the field of water treatment (Tunceli & Turker, 2002). Cr (III) is very important for maintaining insulin, lipids, while Cr (VI) is more toxic substance for human and living cells (Martone, Rahman, Pamuku, & Kingston, 2013; Russo et al., 2005), but it can be used in a wide range of many industrial processing as alloy steel, leather, painting, pigments, and dyestuff industries (Hathaway, Proctor, & Hughes, 1991, p. 178). DPC was the most agents for complexing

* Corresponding author.
E-mail address: gafarsameh@yahoo.com (S.M. Gafar).

Peer review under responsibility of The Egyptian Society of Radiation Sciences and Applications.

https://doi.org/10.1016/j.jrras.2018.01.004

and spectrophotometric determination of Cr (VI) (Marczenko, 1986). Many studies have been based on the spectrophotometric determination of chromium after its reaction with 1–5 diphenylcarbazide (DPC) that is an inexpensive and sensitive procedure and permits the speciation of chromium (Andrade, Rocha, & Baccan, 1985). On the other hand, many works have been based on the spectrophotometric determination of (Cr) after the reaction with 1–5 diphenylcarbazide (DPC) that is an inexpensive and sensitive procedure and permits the speciation of chromium (Malakhova, Chernysheva, & Brainina, 1991). 1,5-Diphenylcarbazide (DPC) is an organic compound commonly used for the determination of Cr(VI) by ultraviolet–visible (UV–vis) spectrometry, though it is not an ideal way due to limited sensitivity and requiring harsh measurement condition. The complex solution is then quantified by a UV-VIS spectrometer at 540 nm according to literature (Qingjun et al., 2007). The goal of this paper is the development of new prepared liquid/gel colored DPC/Cr complex dosimetry systems, many advantages of this method that is easy-operation, cost-effectiveness, high selectivity and sensitivity, and applicable for wastewater treatment, removal of toxic industrial materials and seafood for the determination of Cr (VI), food irradiation processing, medical sterilization, seed production and as sensor.

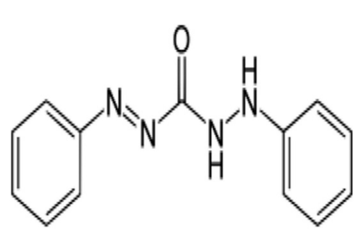
2. Materials and methods

2.1. Preparation of liquid dosimeter

Cr $(NO_3)_3$ and, 1,5 diphenyl carbazone (purchased from New Jersey Co., USA) were used. A stock solution of DPC/Cr-complex was prepared by dissolving 0.4 g of Cr $(NO_3)_3$ and 0.08 g DPC in a mixture of water and acetone (1/3 v/v). Then different concentration of Cr $(NO_3)_3$ 0.32, 0.24 and 0.16 $mmolL^{-1}$ and 0.536, 0.402, 0.268 $mmolL^{-1}$ of DPC were mixed to form the final form liquid complex. The solution was kept well stirred for about 3 h.

2.2. Preparation of gel samples

Gelatin from porcine skin (300 blooms, G2500, Sigma-Aldrich) was dissolved in distilled water at 70 °C in a water bath, and then the complex solution (dyed-metal), was added from a stock solution. The mixture was continuously stirred, the solution color was violet. Clear and transparent gel samples were dripped from pipette into 1 cm thickness glass test tube, which immediately placed in a refrigerator at approximately 4 °C for 4 h. Furthermore, three different concentrations of Cr $(NO_3)_3$, DPC the complex 0.4, 0.2, and 0.296 $mmolL^{-1}$ and 0.67, 0.335, and 0.496 $mmolL^{-1}$ gelatin concentration are 20% w/w of gelatin (that is, the mass of gelatin relative to the mass of the final gel). Besides, the reason for choosing gelatin is due to its structure that containing a polypeptide chain in which various amino acids linked by them, (–NH–CO–). The complex will diffuse within gelatin physically through a weak hydrogen bond between the dyed-metal complex and gelatin. Upon γ-irradiation, these bonds were broken and the effect of γ transfer directly to the complex, so this is considered the main cause to the effective role of gelatin to enhance sensitivity (Gafar & El-Ahdal, 2015; Hayashi et al., 2010). Scheme 1 shows the molecular structure of azo Diphenyl carbazone "DPC".



Scheme 1. Diphenyl carbazone azo dye.

2.3. Apparatus

The absorption spectra of both unirradiated and irradiated liquid and gel samples were recorded in the wavelength range of 200–800 nm using a UVIKON 860 spectrophotometer (Kontron Co. Ltd., Switzerland). Moreover, three samples at each absorbed dose were measured and the average is calculated. The electrical conductivity was measured at room temperature using the Adwa Hungary KFT conductivity meter (Adwa industrial measurements—Hungary).

Irradiation carried out with the ^{60}Co Gamma chamber 4000A irradiation facility (manufactured at Bhabha Atomic Research Centre, India). The absorbed dose rate in the irradiation facility was measured to be 6.25 $kGyh^{-1}$.

3. Results and discussion

3.1. Absorption spectra

By using UV–Vis Spectrophotometer, Fig. 1 investigates the absorption spectra of unirradiated solutions of Cr(III) (greenish color) and DPC (orange color) were measured in 500 and 480 nm; respectively, that after mixed they give a new red color peaking at 544 nm. Fig. 2 displays the absorption spectra of unirradiated gel samples of DPC/Cr-complex, and irradiated to different radiation absorbed doses over the dose range 20–1000 Gy in case of gel samples. It shows main absorbance band peaking at 544 nm, which it characteristic to the red color of the developed complex (DPC/Cr). A decrease in absorbance with an increase in radiation dose was observed. Fig. 3 depicts the absorption spectra of unirradiated and irradiated liquid samples of DPC/Cr-complex, where irradiated to different radiation absorbed doses over the dose range from 0.2 to 6 kGy. Furthermore, it shows main absorbance band peaking at 540 nm, up on γ-rays the amplitude of this peak decrease with the increase of radiation dose. Moreover, a comparative study between two dosimetry systems will discuss in order to explain more sensitivity toward gamma radiation and both of two applications.

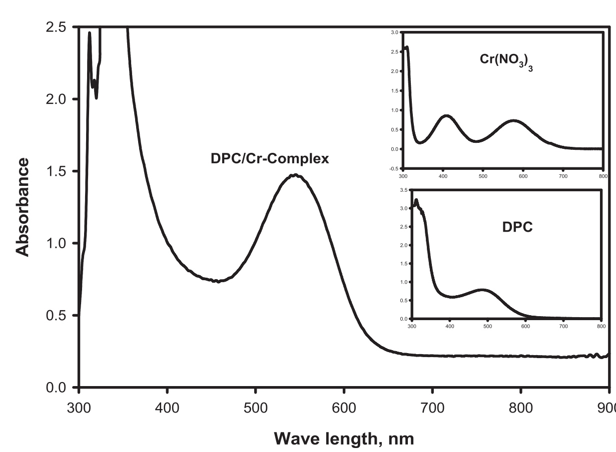


Fig. 1. The absorption spectra of unirradiated Cr (III), DPC and DPC/Cr-complex unirradiated.

Please cite this article in press as: Gafar, S. M., et al., Spectrophotometric properties of azo dye metal complex and its possible use as radiation dosimeter, Journal of Radiation Research and Applied Sciences (2018), https://doi.org/10.1016/j.jrras.2018.01.004