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Spectrophotometric evaluation of a Nickel-based complex solution for use as a radiation dosimeter

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Abstract

In this paper, the spectrophotometric properties of a colored solution complex ($Ni(NO_3)_2.6H2O$+ Methyl Orange (MO)) were investigated as a stable chemical dosimeter with a simple synthesis and low cost for use in radiation processing. The maximum absorbance was observed at 460 nm. This solution was irradiated at three different concentrations by ^{60}Co gamma-ray. The results showed that this solution can be used as a dosimeter has a linear response in the 50-1500 Gy range with acceptable stability up to 40 days.

Keywords: Chemical dosimeter, Spectrophotometry, Nickel complex, Methyl orange, Gamma irradiation.

Introduction

Chemical dosimeters are one of the most widely used dosimetry systems. Radiochromic solutions are a type of chemical dosimeter that work based on the color change in solution due to radiation. This color change can be read by changing the optical absorbance of the solution using a spectrophotometer [1]. Several studies have been done on different solutes and solvents, dosimetry range, and different dosimetric properties. Many dosimeters exist in liquid and are applied in high-dose-dosimetry applications and gels are used for the lower dose ranges [2, 3].

In 2014, Aqueous solutions of the organic dye Rhodamine B were found to be useful in measuring radiation doses in the range 0.1–2 kGy and the absorption peak was observed at a wavelength of 544 nm. the absorbance readings are stable for at least 60 days in dark at room temperature [4].

Recently, a complex solution dosimeter based on the Nickel nitrate and 1,5-diphenylcarbazone was investigated to measure irradiation doses in the 20-1000 Gy range with a linear response. Good repeatability (4.12%), simple construction, low cost, and minimum detectable dose of 20 Gy, make this dosimeter a suitable option for use for radiation processing of agricultural products [5].

Nitro blue tetrazolium (NBT) solution dosimeters were prepared and investigated based on radiation-induced reduction of NBT by Rabaeh et al. Dosimetric properties for these dosimeters were investigated. The absorbance was increased with the absorbed dose in the dose range 5- 30 Gy. The stability of solution dosimeters after irradiation was very high up to 30 days. The effects of pH, irradiation temperature, and additives were investigated in this work [6].

In this paper, were trying to increase the dose range and stability of the nickel-based complex solution at previous work [6] by changing the ligand and optimizing the pH of the nickel solution complex.

Experimental

A 0.014g of $Ni(No_3)_2.6H_2O$ (Mw 290.7 g/mol, MERCK, Germany), and 0.016 g Methyl Orange (Mw 327.3 g/mol, MERCK, Germany) was dissolved in 50 mL ethanol and distilled water respectively, to prepare 1 mM stack solutions. The solutions were stirred separately at room temperature for 3 h to ensure the homogenous dye stock solutions. The appropriate volume of stock solutions was mixed and diluted with distilled water and ethanol solvent (volume ratio of 1:1) to obtain concentrations 0.06, 0.03, and 0.02 mM of Ni and MO. The volume ratio was obtained by experiments to achieve maximum absorbance and stability.

Samples were irradiated with a GC-220 irradiator at a dose rate of 1.17 Gy/s. This irradiator was calibrated using ferrous sulfate (Fricke) reference dosimeter [7]. The absorption spectra of the solutions were measured in the 400 to 800 nm wavelength range, by BECKMAN Coulter-Du 800 UV-Vis spectrophotometer. The pH of the samples was measured by METTLER TOLEDO (ASCC-14180) digital pH meter.

Results and discussion

Hydrochloric acid (HCl) and sodium hydroxide (NaOH) solution (0.1 M) were used to adjust the pH of the solution in all samples. Figure 1 shows the optimal pH with the best absorbance and stability at 0.06+0.06 mM concentration is 5.1. At higher pHs sedimentation was observed. So this PH is selected as optimal.

The absorption spectra of 0.06 mM Ni and 0.06 mM MO for an un-irradiated and irradiated solution are shown in Figure. 2. the main absorbance band peaking shows at 460 nm, and absorbance decreases with an increase in doses. Figure 3 shows the dose-response in terms of the change in the absorption peak measured at a wavelength of 460 nm versus the absorbed dose for the dose ranges of 50-3000 Gy for three concentrations. The linear area of the response curve is in the range of 50-1500Gy with R^2=0.99.

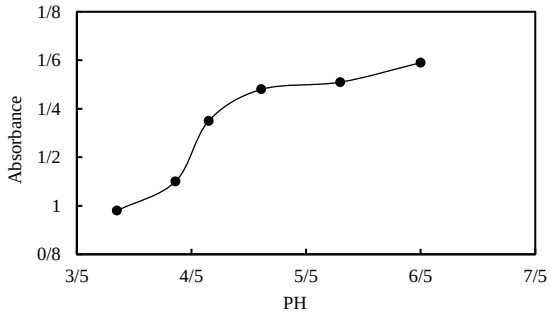

Fig 1- Effect of pH on the absorbance of the Ni/MO solution. Absorbance is increased by PH increasing. At PH more than 5.1 sedimentation was obsereved in solutuon.

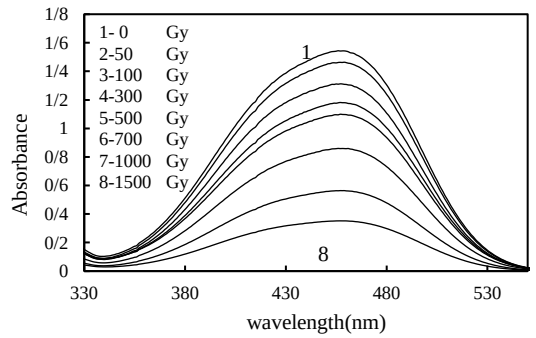

Fig. 2- The absorption spectra of Ni/ MO complex solution irradiated to different absorbed doses, [0.06 +0.0.06 mM].

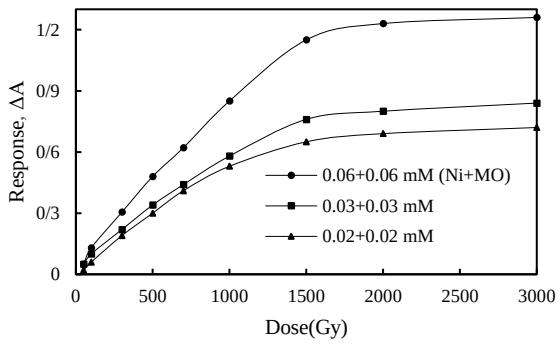

Fig. 3-the dose-response curves of the Ni/ MO complex solution at 460 nm for different concentrations: ΔA = A0-Ai where A0 and Ai are the optical absorptions at 460 nm wavelength for the unirradiated and irradiated solution, respectively.The response is saturaed in absobed dose more than 1500 Gy.

Figure 4 shows the stability of the dosimeter (0.0.06+0.0.06 mM) before and after irradiation in environmental conditions. In Figure.4, the absorbance at 460 nm has acceptable stability up to 40 days before and after irradiation.

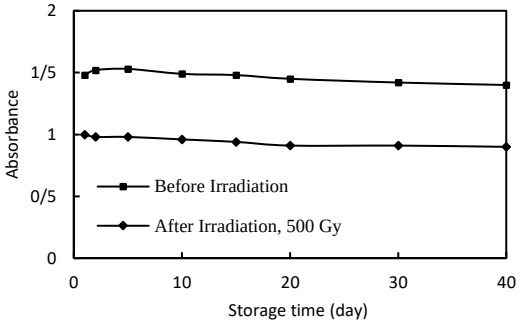

Fig. 4- Stability of the liquid Ni/MO complex before and after irradiation as a function of storage time (stored in environmental conditions).

Conclusions

A Ni/MO solution was made and irradiated with a ^{60}Co source to investigate its spectrophotometric properties for use as a routine dosimeter. The results showed that after optimizing the pH value on 5.1, this solution has a linear response in the 50-1500 Gy range. In absorbed dose more than 1500 Gy ther response was saturated. Also, this solution has acceptable stability up to 40 days before and after irradiation. Finally, this solution was proposed as a simple construction and low-cost routine dosimeter which has a more dose range and stability than the previously introduced nickel-based dosimeter.

References

[1] J. W. T. Spinks and R. J. Woods, "An introduction to radiation chemistry," NEW YORK, A WILEY-INTERSCIENCE PUBLICATION, 1988.

[2] S. Gafar and M. A. El-Ahdal, "Radiochromic fuchsine-gel and its possible use for low dosimetry applications," *Advances in Polymer Technology*, vol. 35, pp. 146-151, 2016.

[3] F. Aldweri, K. Rabaeh, and K. Al-Ahmad, "Novel radiochromic dosimeters based on Calcein dye for high dose applications," *Radiation Physics and Chemistry*, vol. 139, pp. 1-4, 2017.

[4] W. Beshir, and et. al. "Application of solutions of Rhodamine B in dosimetry," *Applied Radiation and Isotopes*, vol. 89, pp. 13-17, 2014.

[5] V. Babaei, and et. al. "Dosimetric characterization of a Nickel complex for routine use in radiation processing," Applied Radiation and Isotopes, vol. 179, 2022.

[6] K. A. Rabaeh, and et. al. "Novel radio-chromic solution dosimeter for radiotherapy treatment planning," *Physica Medica*, vol. 29, pp. 374-378, 2013.

[7] ASTM standard practice E1026, "Practice for using the Fricke reference standard dosimetry system," ASTM Internatioanl, b. West Conshohocken, PA,

2004.