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Dosimetric properties of KNO_3 pellets mixed with sensitizing compounds

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Abstract

Potassium nitrate (KNO_3) in pellet form has been used as dosimetric material for high-gamma dose measurements in the industrial applications of radiation. The evaluation technique is based on the changes observed in the optical properties of solutions prepared with irradiated and non-irradiated pellets, respectively, by means of spectrophotometric analysis. Aiming to increase the applicable dose range, by retarding the decomposition of the nitrate ions (NO_3^-) to nitrite ions (NO_2^-), sensitizing compounds like $Ba(NO_3)_2$, KBr and MnO_2 were mixed with pure KNO_3 before preparing the pellets and the dosimetric properties of the new compounds were then evaluated. The following parameters were studied: absorption spectra before and after irradiation, sensitizer concentration, signal stability, linear dose range and dose rate dependence between 1.70 and 5.65 kGy/h. Using this method the dose range could be extended from 150 kGy, obtained using KNO_3 to 600 kGy, or more, using MnO_2 (40%).

Keywords: Dosimetry; Gamma radiation; High dose

1. Introduction

Gamma ray induced decomposition of nitrate compounds has been studied by several researchers. The products formed are NO_2^- and $O^\bullet$ (Parwate and Garg, 1984; Patil and Chiplunkar, 1991; Pogge and Jones, 1970), and the determination of nitrite concentration has been made by the modified Shinn's method (Dorda and Muñoz, 1985; Shinn, 1941).

Potassium nitrate (KNO_3) in pellet form has been used as dosimetric material for high gamma dose measurements in the industrial applications of radiation (Dorda and Muñoz, 1985). The evaluation technique is based on the changes observed in the optical properties of solutions prepared with irradiated and non-irradiated pellets, respectively, by means of spectrophotometric analysis.

Some additives are capable to enhance or to reduce the decomposition rate of nitrites. Aiming to increase the useful dose range, by retarding the decomposition of the nitrate ions (NO_3^-) into nitrite ions (NO_2^-), sensitizing compounds like $Ba(NO_3)_2$, KBr and MnO_2 were mixed with pure KNO_3 before preparing the pellets and the dosimetric properties of the new compounds were evaluated. The following parameters were studied: absorption spectra before and after irradiation, sensitizer concentration, signal stability, linear dose range and dose rate dependence between 1.70 and 5.65 kGy/h.

2. Experimental

The mixtures of the compounds $Ba(NO_3)_2$, KBr and MnO_2 with KNO_3 were prepared by mixing required weights, varying between 40% and 100% of KNO_3, grinding in agate mortar and having its particle size standardized to <80 mesh. The mixtures were cold

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pressed in to pellet form and sealed in polyethylene film pouches.

The gamma irradiations were carried out using a Gammacell 220 source installed at the Radiation Technology Center at IPEN-CNEN/SP.

The irradiations were always performed in electronic equilibrium conditions at room temperature. The gamma dose range was studied between 200 and 600 kGy.

The dose rate dependence response was evaluated between 1.7 and 5.65 kGy/h for gamma dose of 20 kGy.

The pellets, after and before irradiation, were prepared by modified Shinn's method for spectrophotometric analysis on Shimadzu UV-2001PC spectrophotometer. The pellets were dissolved in pure water (tridistilled), and an indicative coloring solution, prepared by mixing solutions A and B in the proportion of 5:1, respectively. The solution A was prepared dissolving 2 g of sulfanilamide in 1 l of solution 30% of glacial acetic acid. The solution B was prepared dissolving 1 g of *N*-1 naphthylethylene-diamine in 1 l of solution 30% of glacial acetic acid, was added to indicate the presence of NO_2^- in the solutions. The value of absorbance was determined for each solution 10 min after preparation (Dorda and Muñoz, 1985; Shinn, 1941).

Each point represents the average of three measurements and the error bars the standard deviation of the mean (1σ).

3. Results and discussions

The maximum color intensity of the solution is obtained 10 min after preparation. The solutions are stable during a period of 1 h, that permits the dose evaluation with high quality guarantee. The pellets irradiated and non-irradiated can be stored by long periods without any change in their characteristics.

The absorbance was determined for absorbed doses from 200 to 600 kGy. The results are shown in Figs. 1–3

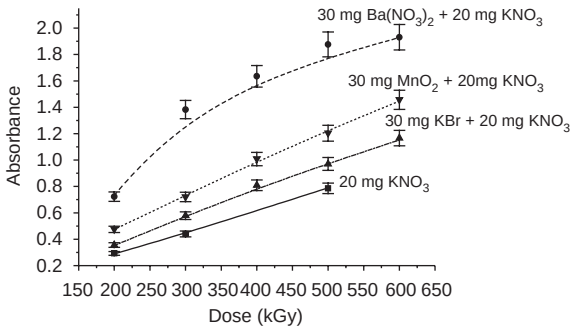

Fig. 1. Dose-response of absorbance ($\lambda = 540$ nm) for mixtures of 30 mg $Ba(NO_3)_2$, KBr and MnO_2 and 20 mg KNO_3 irradiated with gamma rays ^{60}Co.

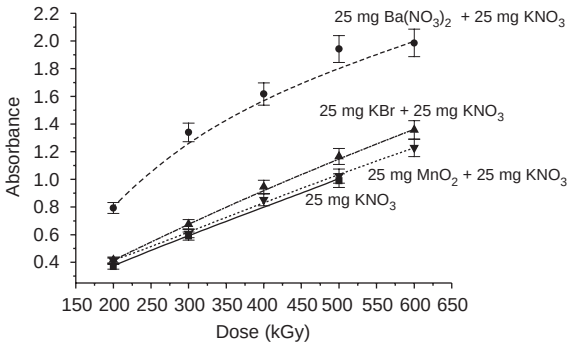

Fig. 2. Dose-response of absorbance ($\lambda = 540$ nm) for mixtures of 25 mg $Ba(NO_3)_2$, KBr and MnO_2 and 25 mg KNO_3 irradiated with gamma rays ^{60}Co.

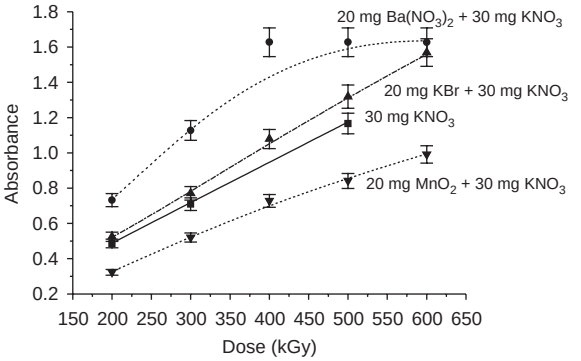

Fig. 3. Dose-response of absorbance ($\lambda = 540$ nm) for mixtures of 20 mg $Ba(NO_3)_2$, KBr and MnO_2 and 30 mg KNO_3 irradiated with gamma rays ^{60}Co.

for the mixtures of $Ba(NO_3)_2/KNO_3$, KBr/KNO_3 and MnO_2/KNO_3, respectively.

The reproducibility of the method was evaluated preparing different batches of pellets and evaluating the optical response for different doses and it was found to be better than $\pm 2\%$ (1σ) from batch to batch.

The mixture of 20 mg MnO_2/30 mg KNO_3 gives better results in terms of decomposition rate. The decomposition rate of nitrate ions into nitrite ions is reduced, extending the useful range. In the case of the mixture above the dose range was extended up to 600 kGy, without signal saturation.

No dose rate dependence in the range from 1.70 to 5.65 kGy/h was observed. The fluctuation observed was smaller than 5%.

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