The Radiolysis of Pyrogallol Red

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Abstract. The radiolysis of pyrogallol red solution (PGR) by gamma radiation has been studied spectrophotometrically. The decrease in absorbance of the characteristic band of pyrogallol red at 490 nm and pH 4 gives a reproducible response and an accurate means of dosimetry for the dose ranges 0.02–1.5 kGy.

Key words: Radiolysis; pyrogallol red; gamma radiation.

Radiation processing is an active developmental technology. Dosimetry is the radiation dose measurement using a radiation sensitive indicator (dosimeter) of which at least one of its properties changes when exposed to radiation. This change must be measurable and correlated to the absorbed dose. Various reference standards [1–7], transfer and routine dosimeters [8–11] have been suggested and realized.

In the present work, pyrogallol red (1,2,3 trihydroxybenzene sulfonophthalein) which is commonly used as a chromogenic agent for the determination of various transition metal ions [12–13] was examined for use as a dosimeter. The action of γ-radiation on pyrogallol red electronic absorption characteristics, dose response and irradiation stability have been discussed.

Experimental

Reagents

All reagents were of analytical grade. Pyrogallol red (10⁻³ M and 5 × 10⁻⁴ M) solutions were prepared by dissolving 0.1 and 0.05 g of PGR (Merk, 99% purity), respectively, in 250 ml methanol. The solutions were not sensitive to natural light or fluorescent light. Acetate buffer solutions of pH = 4.0 (2.2 M acetic acid and 0.5 M sodium acetate) were used.

Apparatus

Irradiation was carried out using a ⁶⁰Co γ-ray irradiator chamber of type 4000 A (India). The absorbed dose rate in water measured using a Fricke dosimeter was found to be 0.02 kGy/min. Pyrogallol red was exposed to doses of 0.02, 0.1, 0.3, 0.5, 1.0 and 1.5 kGy.

The absorption spectra of the irradiated and non-irradiated solutions of PGR were measured in the wave length range from 200 to 600 nm, with a UVIKON 860 spectrophotometer.

Results and Discussion

The spectra of the irradiated and nonirradiated solutions of 10⁻³ M PGR solutions are shown in Fig. 1. All spectra are normalized to the value of the absorbance at a wavelength of 490 nm. It can be seen that following irradiation the absorption maxima at 490 nm and pH 4.0 is significantly decreased while a new band at 390 nm is created due to structural changes including the production of quinoid form. The strength of this effect increases with increasing dose. A working pH of 4.0 was used because the oxidation rate of PGR is fast for the pH from 1.67 to 3.93 and a band shift to 520 nm has been noticed over the pH range from 5 to 6.25.

Figure 2 shows the response curve of 5 × 10⁻⁴ M PGR (pH 4) in terms of the change in optical density (ΔA = A₀ − Aₗ) at 490 nm wavelength, versus the absorbed dose where A₀ and Aₗ are optical densities of nonirradiated and irradiated PGR solutions, respectively. The absorbance measurements were made in 1-cm cells and at 25°C against water as a reference blank. At each absorbed dose the standard deviation was 1.5–3%.

The effect of relative humidity during irradiation on the response of 10⁻³ mol/l PGR solutions was
investigated by irradiating the solutions to a suitable dose of about 1.2 kGy at different relative humidities (Fig. 3). The variation in response (ΔA) at 490 nm as a function of the relative humidity during irradiation indicated a relatively flat response in the range of 0–60% and a reduced sensitivity at higher humidities.

The effect of temperature during irradiation was investigated by irradiation of 10^-3 mol/l PGR solutions with a dose of 0.5 kGy at different temperatures (0, 25, 30 and 40°C) using liquid thermal baths [10]. It was found that the influence of temperature is small.

On this basis, 25°C was chosen as the working temperature. The long time colour stability of 10^-3 and 5 × 10^-4 mol/l PGR solutions was tested by storing the solutions at 25±0.1°C and a relative humidity of 35% in the dark and under laboratory fluorescent lights. The absorbance of the solutions was measured at 490 nm, for PGR solutions of pH 4.0 irradiated with 0.5 kGy at different intervals during the storage period (Fig. 4). The results indicate that solutions stored in the dark are stable for about 3 months. Whereas solutions stored under ambient light are stable for only 1 month after which the absorbance gradually decreases.

This dosimeter can be used for low and moderate doses of gamma rays (0.02–1.5 kGy). This offers several advantages over other chemical dosimeters used in

**Fig. 1.** The absorption spectra of nonirradiated and irradiated PGR solutions at different absorbed doses and pH 4.0, t = 25°C

**Fig. 2.** Difference ΔA of the absorption at 490 nm of non-exposed and an exposed PGR solution 5 × 10^-4 M in methane, pH = 4, t = 25°C

**Fig. 3.** Variation of the absorption response, (ΔA), at 490 nm for a PGR solution 10^-3 M in methane as a function of relative humidity during irradiation with a dose of about 1.2 kGy

**Fig. 4.** Variation of ΔA(ΔA,−ΔA) at different intervals during a period of 50 days at pH = 4, t = 25°C, 0.5 kGy, [PGR] = 5 × 10^-4 M in methane. ☐ Under ambient light, ▽ In the dark