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Effect of light intensity and wavelengths on photodegradation reactions of riboflavin in aqueous solution

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Abstract

A study of the effect of light intensity and wavelengths on photodegradation reactions of riboflavin (RF) solutions in the presence of phosphate buffer using three UV and visible radiation sources has been made. The rates and magnitude of the two major photodegradation reactions of riboflavin in phosphate buffer (i.e., photoaddition and photoreduction) depend on light intensity as well as the wavelengths of irradiation. Photoaddition is facilitated by UV radiation and yields cyclodehydroriboflavin (CDRF) whereas photoreduction results from normal photolysis yielding lumichrome (LC) and lumiflavin (LF). The ratios of the photoproducts of the two reactions at 2.0 M phosphate concentration, CDRF/RF (0.09–0.22) and CDRF/LC (0.54–1.75), vary with the radiation source and are higher with UV radiation than those of the visible radiation. On the contrary, the ratios of LF/LC (0.15–0.25) increase on changing the radiation source from UV to visible. The rate is much faster with UV radiation causing 25% degradation of a 10^{-5} M riboflavin solution in 7.5 min compared to that of visible radiations in 150–330 min.

Keywords: Riboflavin; Photolysis; Photoaddition; Buffer effect; Light intensity and wavelength effect

1. Introduction

A large number of drug substances absorb radiations in the ultraviolet and/or visible region and are thus sensitive to light. They undergo photodegradation in liquid media or in the solid state on exposure to light [1–7]. The nature and magnitude of photochemical reactions depend upon the intensities and wavelengths of light [8–14] and control of these factors is critical in photostability studies of drugs and drug formulations [15–18]. Various ultraviolet and visible radiation sources [19–29] have been used to study the photodegradation of riboflavin and analogues. Riboflavin (RF) undergoes simultaneous photoaddition and photoreduction reactions in phosphate buffer giving rise to cyclodehydroriboflavin (CDRF), and formylmethylflavin (FMF), lumichrome (LC) and lumiflavin (LF), respectively [20,25]. The influence of UV and visible radiation sources on the variations in degradation product distribution and reaction rates of some vitamins [30–35], other drugs [36–38], herbicides [39,40], and polymers [41] has been studied.

The present work involves a quantitative study of the photodegradation reactions of riboflavin in the presence of phosphate buffer using three different radiation sources to evaluate the effect of light intensity and wavelengths on degradation product distribution and kinetics of the reactions. Some related work on these reactions has recently been reported [25,26].

2. Materials and methods

The materials and methods of photolysis using a 125 W medium pressure mercury vapour lamp (MP lamp) (Applied Photophysics Ltd., UK) [emission at 254, 313, 366 and 436 nm (Fig. 1) corresponding to the wavelengths of RF absorption (Fig. 2)], thin-layer chromatography of

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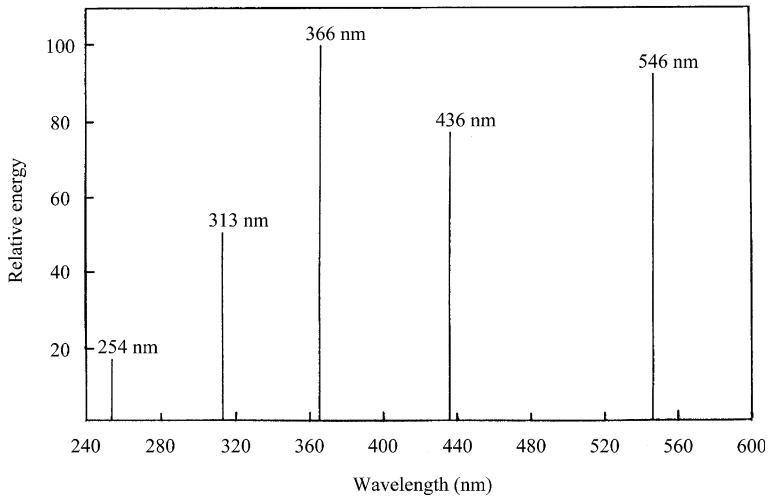

Fig. 1. Spectral emission of 125 W medium pressure mercury vapour lamp.

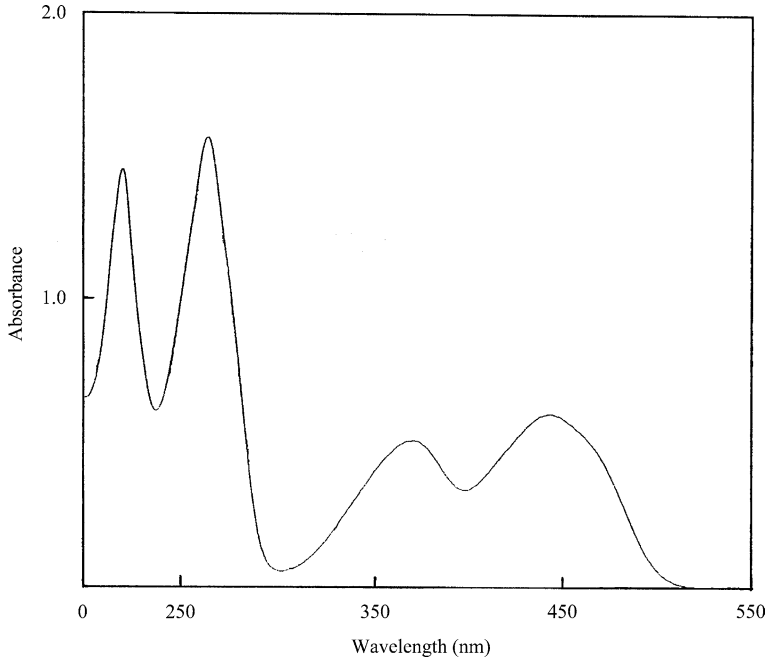

Fig. 2. Absorption spectrum of 5×10^{-5} M riboflavin at pH 7.0 (phosphate buffer).

photolysed solutions, and spectrophotometric assay of RF and photoproducts have previously been described [25]. The following method of photolysis was also used in this study.

2.1. Photolysis with visible lamps

An aqueous solution of riboflavin (10^{-4} M, 200 ml) containing 0.05–2.00 M Na_2HPO_4 (adjusted to pH 7.0) was placed in a 250 ml volumetric flask (Pyrex) and irradiated with a Philips HPLN 125 W high pressure mercury vapour fluorescent lamp (HP lamp) [emission at 405 and 436 nm (Fig. 3) corresponding to the wavelengths of RF absorption], or a Philips 150 W tungsten lamp (TN lamp) (continuum over the range 350–2000 nm) (Fig. 4) fixed at a distance of 30 cm from the centre of the flask. The temperature of the solution was maintained at 25 ± 1 °C during irradiation. The solution was continuously stirred by bubbling a stream of air into the flask. Samples were withdrawn at appropriate intervals for chromatography and assay.

2.2. Light intensity measurements

The intensities of the MP, HP and TN lamps were determined by potassium ferrioxalate actinometry [42] under the conditions described for the MP lamp [25] and for the HP and TN lamps (Section 2.1).