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Alpha track registration and revelation in CR-39 using new etching method for ultratrace alpha radioactivity quantification in solution media

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Abstract: A CR-39 based method was developed for measuring the ultra-trace alpha radio activities in aqueous samples having curie levels of γ/β-radio activities. The chemical etching method was optimized to reveal the alpha tracks in CR-39. This new chemical etching method involved the use of a phase transfer catalyst tetraethylammonium bromide which reduced the track revelation induction time without deteriorating the track-etch parameters. The alpha track-etch parameters such as bulk-etch rate, track-etch rate, induction time, and the critical angle of alpha track registration were measured at 60 and 70 °C, with and without using a phase transfer catalyst in the chemical etching for the comparison and optimization. The track registration efficiency of CR-39 in the solution medium was measured using the samples having known alpha activity of ^{mix}Pu, and value obtained was found to be $(4.42 \pm 0.12) \times 10^{-4}$ cm. The registration efficiency value thus obtained was corroborated with the expected efficiency expected from the calculated range of alpha particles in the solution. This CR-39 based method was employed to quantify the alpha activity, as low as 0.2 Bq mL^{-1}, in the aqueous radiopharmaceutical samples having the curie levels of γ/β radio activities.

Keywords: alpha-radioactivity quantification; alpha tracks; CR-39; solution medium; track registration efficiency.

1 Introduction

Solid state nuclear track detectors (SSNTD) have the special features which make them extremely valuable for studies related to the emissions of extremely low rates of charged particles [1–5]. These special features are: (i) SSNTDs are insensitive to high background radiations, making studies possible on the specific, rare and low cross-section nuclear reactions, (ii) a wide variety of detectors, with different sensitivities, are well suited for specific experimental requirements, (iii) integrating nature of the detectors allows to record the events over a long period of time without any deterioration of the detector's efficiency or problems arising due to the background noises, (iv) SSNTD are amenable to fit in the different geometrical arrangements such as 2π, 4π, forward, and backward recoil geometry, (v) SSNTD can be used in any size depending upon requirements, (vi) SSNTD is a non-electronic technique, therefore, there is no possibility of an electronic break down [6, 7]. SSNTD based techniques have been extensively used for the monitoring of alpha emitting actinides in biological samples [8–11], waste discharges generated at nuclear facilities [12, 13], decontamination sites [14], soil and natural water samples [15, 16], hot particles in the environment [17] etc. For analytical applications, the track registration in SSNTD from the solution medium offers several advantages including the minimum sample manipulation and homogeneous track distribution in the detector [18].The values of alpha track registration efficiencies (K_{wet}) of the plastic detectors in the solution media have been determined by Uma et al. [19] and Joshirao et al. [13] as 4.5×10^{-4} cm (cellulose nitrate) and 1.3×10^{-3} cm (CR-39), respectively, for the alpha particles emitted by ^{241}Am source. Though two different detectors were used, these values differ by a factor of 3. Hence, there is a need to determine an accurate value of K_{wet} for registering the alpha tracks in CR-39 (workhorse of SSNTD) in a solution for quantifying the alpha radioactivity especially in radiopharmaceutical samples (generators: ^{99}Mo→^{99m}Tc; ^{90}Sr→^{90}Y) derived from the fission having curie levels of γ/β radio activities.

The latent tracks, formed by the charged particles in SSNTD, must be enlarged by the suitable etching for visualization under a transmission optical microscope [6, 7]. In general, the chemical etching of alpha tracks in CR-39 plastic detector is carried out in 6 N NaOH at 60 and 70 °C [6]. There are several known experimental factors that may affect chemical etching of the particle tracks in the plastic

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