Article
JOURNAL OF UNIVERSITY OF BABYLON
For Pure and Applied Sciences (JUBPAS)
Vol.33 ; No.4 | 2025

Measurement of Nuclear Track Parameters for LR-115, CR-39, and CN-85 Detectors

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قياس معلمات المسار النووي لكاشفات (LR-115, CR-39 and CN-85)

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مديرية تربية القادسية، الديوانية، العراق.

Accepted:	2/12/2025		Published:	31/12/2025

ABSTRACT

In this study, three different types of commercial solid detectors (CR-39, CN-85 and LR-115) were used for alpha particle detection, which are the most common and widely used in scientific laboratories for alpha particle detection. The detectors were cut and irradiated with a 570 kBq Americium (Am-241) radioactive source for 3 hours. After that, the detectors were immersed in NaOH solution for chemical scraping at different temperatures. An optical microscope was used to calculate the tracks of alpha particles, which are the traces and diameters of the alpha particles resulting from the irradiation, as well as the sensitivity and scraping efficiency of the detectors. Through calculations and practical results, it became clear that the LR-115 detector had the highest alpha path density (602 tr./mm²), while the CR-39 detector showed the largest path diameter (2µm), highest sensitivity (1.667), and highest efficiency (0.398) compared to the other detectors.

Keywords: CR-39, CN-85, LR-115, Alpha particle, Detector efficiency.

INTRODUCTION

Polymer detectors (SSNTDs) currently used to detect heavy ionizing radiation simple and do not require large or complex electronic devices to create the nuclear track inside them [1], [2]. The detectors are transparent and sensitive when they collide with heavy charged particles such as alpha and protons and fissionable neutron fragments[3],[4].The polymer detectors have uses in various fields such as medicine, nuclear physics, space science, the study of neutron fission, and the detection of charged particles because they are inexpensive, abundant, easy to use, and highly effective[5],[6],[7]. The detectors of CN-85, LR-115 and CR-39 are organic reagents that contain carbon bonds in their structure. The bonds break when they react with ionizing radiation [8]. Damage areas (hidden traces) formed in detectors can be visualized and searched for by scraping the corroded area with suitable alkaline chemical solutions such as NaOH and KOH. Extensive research has been conducted to understand how traces are formed and their path within the detector. Traces resulting from the etching process can be directly measured, along with the length, depth, and thickness of the tracks removed from the track surface. The shape and evolution of trace patterns can also be tracked as the etching process progresses, which are a challenging task in nuclear track detector applications, especially surface traces. The direct length was measured and the major and minor axes of the

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impact aperture were used to accurately calculate many track parameters [1], [9], [10]. (V_B) is the rate at which the thickness is removed from the detector surface over time by the chemical solution. The track etching rate is the amount of surface thickness remaining on the detector material over a period of time toward the depth of the track along the particle's path [11].

Researchers Chong et al., studied LR-115 ray trajectories to create an etching path. The detector was exposed to different doses of X-rays before and after irradiation. The results showed a significant increase with exposure to high doses of X-rays before alpha irradiation. The V_B and diameter increased significantly with exposure compared to the unexposed polymer [12]. The researchers Khalil and Al-Jabouri used CR-39 detector in this study to measure the V_B, and V_T, and scraping rate at different incidence angles. The tracking rate and etching rate were calculated. The results showed that the tracks do not depend on the inclination of the alpha particle, but rather on the normal position on the detector surface, i.e., there is no difference between the perpendicular and oblique results[13]. Falah also conducted the factors affecting the bulk etching rate of CR-39 at varying temperatures, times, and NaOH concentrations. He etched CR-39 with NaOH, and the bulk etching rate increased with increasing solution and temperature. The optimum etching conditions were 6.25N NaOH solution concentration at 70°C for 3 hours[14] . Also, Qasim and Saeed used a 10 µm thick solid state nuclear trace detector (LR-115) to measure the bulk etch rate (V_B) using an Americium Am-241 alpha particle source. The detector was cut into small pieces and irradiated with different energies. The alpha particle diameters were then measured. The results showed that the bulk etch rate (V_B) does not depend on the energy of the ionizing alpha particles [15]. The aim of this research was to study three types of commercial solid state nuclear trace detectors CR-39, LR-115, and CN-85 to determine which one is more efficient and sensitive to ionizing alpha particles.

MATERIAL AND METHOD

Reagent Materials

Three detectors (SSNTDS) were used in this work. Allyl glycol carbonate (CR-39): Its density is 1.32 g/cm³, its thickness 500 mm, and its chemical formula is $C_{12}H_{18}O_7$. It was manufactured by Pershore Ltd, UK. Cellulose nitrate manufactured by Pershore Ltd, UK. Cellulose nitrate (CN-85): The CN-85 detector is a 9 cm x 12 cm cellulose nitrate sheet with a thickness of 100 ml. Its density is 1.42 g/cm³ and its chemical formula is C6H8O9N2. It was manufactured by Kodak Pathé from France.LR-115 is cellulose nitrate, it consists of a 12-µm-thick, deep-red, sensitive cellulose nitrate layer on a 100 mm-thick polyester backing. A track penetrating the thin red layer produces a black hole against a red background. This gives the LR-115 high optical contrast and makes track counting easier.

Irradiation of Detectors

The detectors were cut into small squares (1.5×1.5 cm²) and irradiated with Am-241 radioactive source for 3 hours and placed in diract with the detector, as shown in Figure 1A

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Chemical Etching

Commercial solid detectors were etched to obtain irradiation results in glass test tubes containing the etching solution corresponding to each detector. 250 ml of distilled water was placed in a sealed glass tube. A thermometer was also placed inside a water bath at a specific temperature to control and verify the chemical etching temperature. Etching of the CR-39 detector was carried out under standard conditions at 6.25 N of sodium hydroxide, 70 °C, and 6 hours [2]. The CN-85 and LR-115 detectors were etched with 2.5 N of sodium hydroxide at a temperature of 60 °C of 3 hours. The quantity was placed in a sensitive balance, as shown in figure 1B and1C.The track counting technique used measured by light microscope was used to observe and calculate the density and diameters of alpha particle tracks, as shown in figure 1D.

Calculation

- Mean Diameter (D)

The average diameter of alpha can be found using a 40x magnification microscope lens by taking twelve views under the microscope to calculate the density of the traces.

- Track Density (ρ)

To calculate the track density of alpha particles, a 10x magnification lens with an area of 0.0676 m^2 was used, as shown in Figure D, and the average track density was calculated using equation (1) [15]

$$\rho = \frac{N}{A} \qquad \textbf{(1)}$$

Where

ρ is the track density, N: is the track mean and A is the viewing area of the microscope lens.

- Bulk Etching Rate (V_B): The Bulk etching rate is an important scanning. To measure V_B, we must measure some physical changes in the tracks resulting from the reaction in. This rate was calculated by measuring the diameter of the detector tracks after two etching s and calculating the rate of change in diameter after etching, during the change In time, and (V_B) was calculated using equation (2) [2].

$$V_B = D/2t \qquad (2)$$

D is the mean diameter of the alpha particle tracks, and t is the etching time of the solid-state detector.

- Track Etching Rate (V_T)

The diameter ratio method was used to determine its value, which can be calculated using the following equation (3) [2]

$$V_T = V_B \frac{1+(\frac{V_D}{V_B})^2}{1-(\frac{V_D}{V_B})^2} \qquad (3)$$

Where V_D is the average diameter of the paths calculated from the slope of the relationship (4) [16].

$$V_D = \frac{\triangle D}{\triangle t} \qquad (4)$$

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- Detector Sensitivity (V)

Detection sensitivity can be calculated from the ratio of the bulk excavation rate to the track excavation rate using the following equation (5) [17].

$$V = \frac{V_T}{V_B} \qquad (5)$$

- Etch Efficiency (η)

The etching efficiency is defined as the ratio between the bulk etching rate (V_B) and the tracer etching rate (V_T) [17].

$$\eta = 1 - \frac{V_B}{V_T} (6)$$

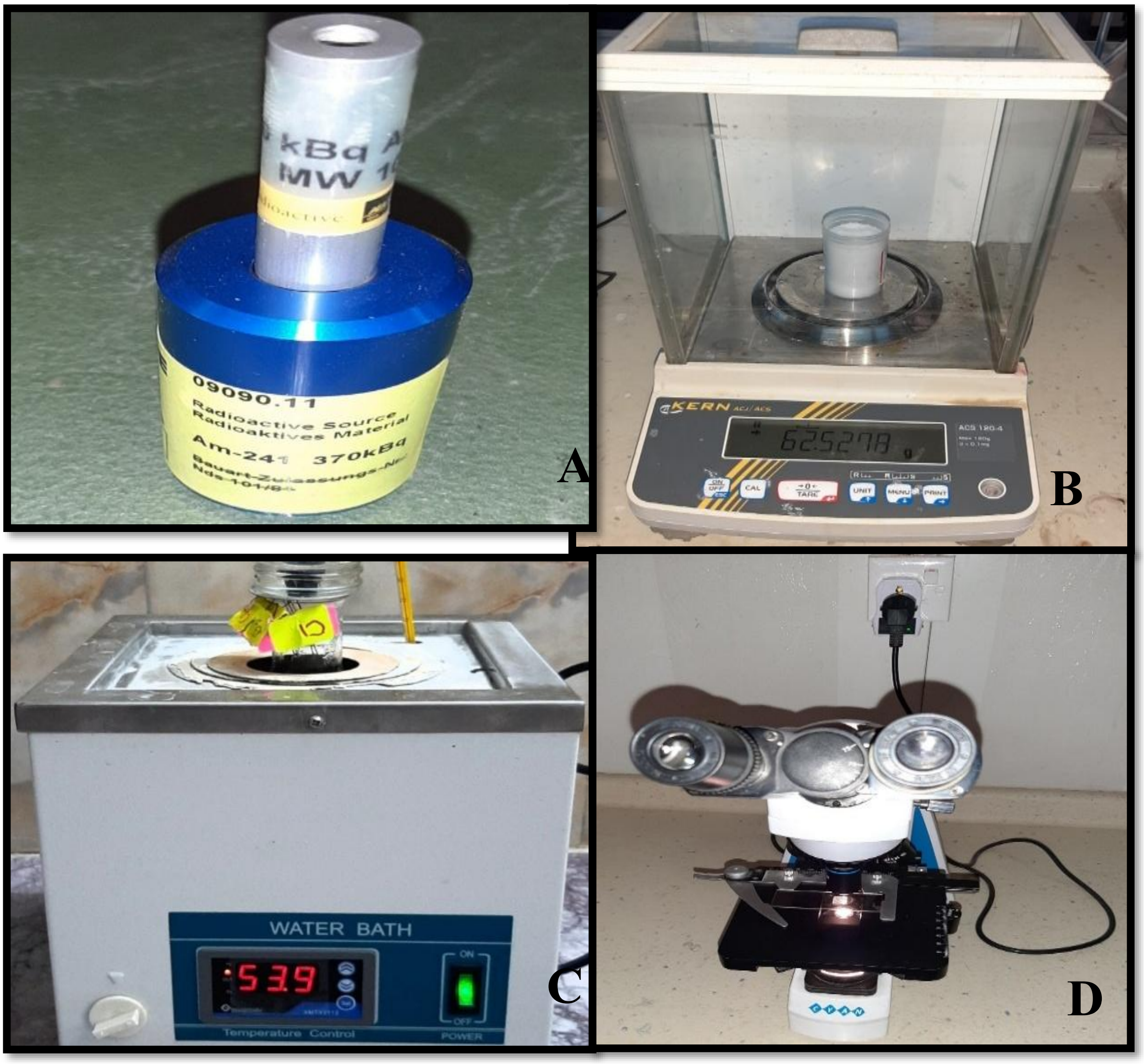

Figure (1) A indicates the radioactive source of alpha particles Am-241, while B indicates the sensitive balance. C the water bath etching device at different temperatures and D indicate the optical microscope to view the paths of ionized alpha particles in commercial detectors.

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RESULTS AND DISCUSSION

In this study, three commercial detectors (CR-39, LR-115, CN-85) were used and irradiated with an alpha particle source, Am-241, for three hours. The detectors were then etched with a NaOH solution and air-dried. A light microscope was used to view the results. The table below shows the measured parameters for the different detectors. The highest trace density value was observed in the LR-115 detector (602 tr./mm²), due to its flexibility, as its polymer bonds are easily broken and react with radiation, as shown in Figure 2A. The trace density in the CR-39 detector was (470 tr./mm²), as shown in Figure 2D, while the lowest value was in the CN-85 detector (421tr./mm²), as shown in Figure 2B. The highest value of the average diameter in the CR-39 detector was (2µm), while the average diameter of the LR-115 was (1.7µm), as shown in Figure 2, and the lowest average diameter was in the CN-85 detector (1.4µm). The V_B value was highest in the LR-115 detector was (0.283µm/h), as it is a thin detector with a large layer removed in less time, resulting in the appearance of alpha tracks. The V_B value in the CN-85 detector was (0.233µm/h) while the lowest value was in the CR-39 detector (0.166µm/h). The V_T track scraping rate had the highest value in the LR-115 detector (0.363µm/h) and its average value in the CR-39 detector (0.276µm/h), while the lowest value in the CN-85 detector was (0.327µm/h). The sensitivity of the CR-39 detector was the highest compared to the detectors, with a value of (1.667), while the sensitivity of the LR-115 detector was the lowest (1.285). The sensitivity of the CN-85 detector was (1.403), which is higher than the sensitivity of the LR-115 detector. The efficiency of the CR-39 detector was the highest value (0.398) among the detectors, and this is consistent with many studies, as it has distinctive characteristics of efficiency, sensitivity, and tolerance to different scraping conditions of time and temperature, as it was scraped for 6 hours at a temperature of 70 °C. As for the efficiency of the CN-85 detector, it was (0.287) which was scraped, along with the LR-115 detector, for 3 hours at a temperature of 60 °C, which are considered standard conditions for them. As for the LR-115 detector, it was the least efficient (0.220) among the detectors.

Table: The results of the parameters for CR-39, LR-115 and CN-85

Detectors	T (°C)	T (h)	D(µm)	ρ(tr./m²)	V_B(µm/h)	V_T(µm/h)	V	η
LR-115	60	3	1.7	602	0.283	0.363	1.285	0.220
CR-39	70	6	2	470	0.166	0.276	1.667	0.398
CN-85	60	3	1.4	421	0.233	0.327	1.403	0.287

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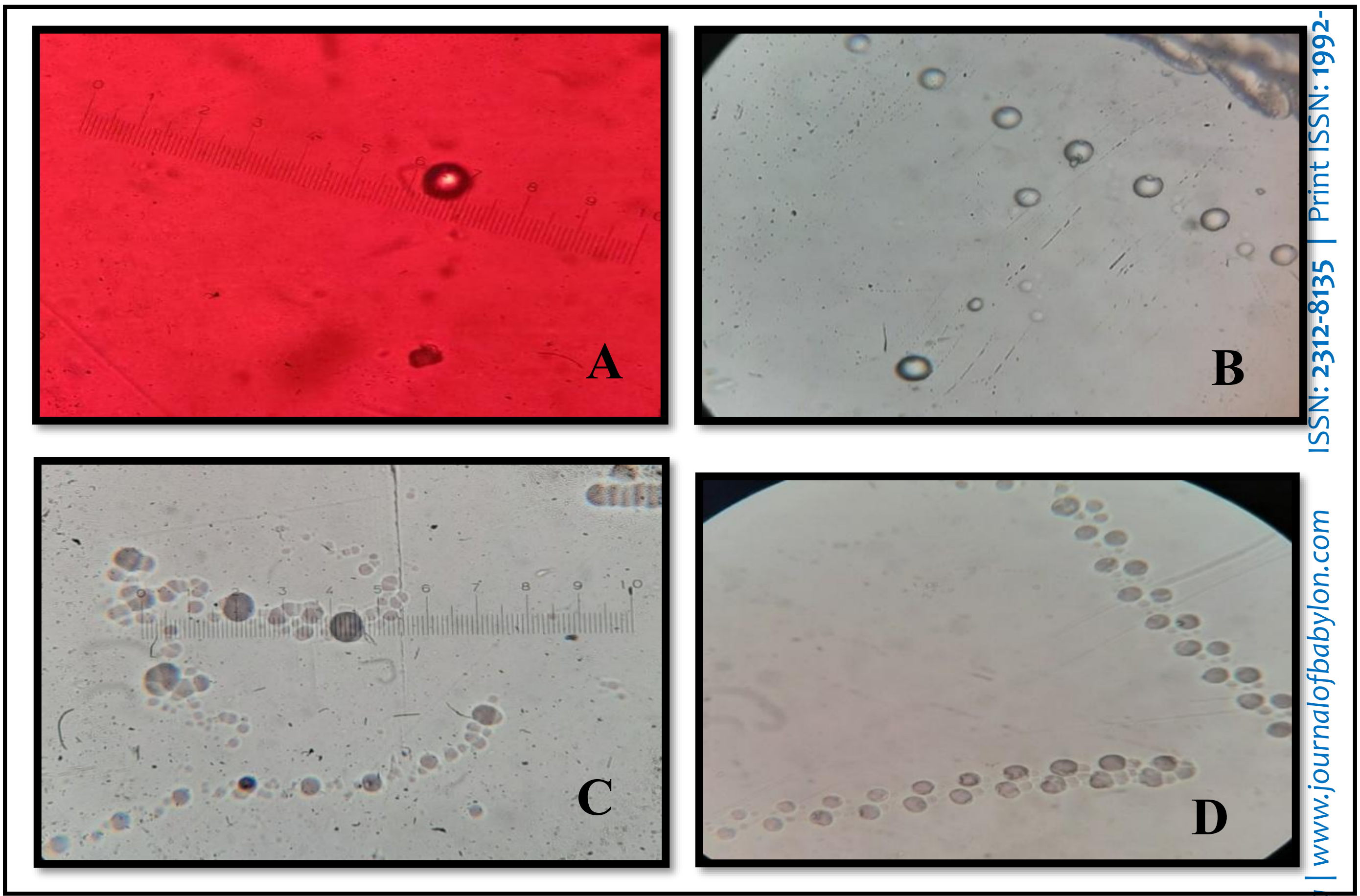

Figure (2). A shows: traces and diameters of LR-115 detector, B shows: traces of CN-85, C and D show: traces and diameters of CR-39.

CONCLUSIONS

Commercial solid nuclear trace detectors (CR-39, CN-85, and LR-115) were used to measure alpha particles tracked from the Am-241 source for three hours. The LR-115 detector was found to have the highest alpha particle track density (602 tr./mm²) due to the flexibility and elasticity of the detector, which makes it easy to penetrate and break its weak polymer bonds for the alpha particles interacting with it. This is consistent with previous studies [17]. The CR-39 detector showed the largest diameter (2μm), highest sensitivity (1.667), and highest efficiency (0.398), and it can withstand high temperatures for several possible hours. This is not possible with the other detectors used due to the rigidity of the detector and its resistance to different scraping conditions. This is consistent with previous studies [16].

Acknowledgements

Thanks to all the staff for their supported the completion of this research.

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Conflict of interests:

There are non-conflicts of interest.

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الخلاصة

في هذه الدراسة تم استخدام ثلاث انواع مختلفة من الكواشف الصلبة التجارية الأكثر شيوعاً واستخداماً في المختبرات العلمية للكشف عن جسيمات ألفا وهي (CR-39, CN-85, LR-115). تم تقطيع الكواشف وشعيعها بواسطة مصدر مشع الامريشيوم Am-241 ذو طاقة 570 KBq لمدة 3 ساعات بعد ذلك تم إدخال الكواشف في محلول NaOH بدرجات حرارة مختلفة لغرض القشط, ثم استخدام المجهر الضوئي لحساب مسارات جسيمات ألفا وهي آثار واقطار جسيمات ألفا الناتجة من التشعيع، وأيضا حساسية وكفاءة القشط للكواشف. ومن خلال الحسابات والنتائج العملية تبين لنا ان كاشف LR-115 هو أعلى كثافة لمسارات ألفا ($602\ tr./mm^2$)، بينما كاشف CR-39أظهر اكبر قطر المسار (2μm) وأعلى حساسية (1.667) وأعلى كفاءة(0.398) مقارنة بالكواشف الأخرى .

الكلمات المفتاحية: CR-39, CN-85, LR-115_، جسيمات ألفا، كفاءة الكاشف