The Response Of The Nuclear Track Detectors To Some Of Etching and external Parameters

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Abstract:

The aim of this paper to find the effect of some etching parameters, like(the time and angle of irradiation of etching, time of radiation, angle of radiation incident , temperature and concentration of etching solution, type of detector, type of etching solution and the energy of incident particle) on registers properties of nuclear track detectors , diameter and number of tracks, the bulk etching velocity V_B , track Diameter growth velocity V_D , track etching velocity V_T **,** etching ratio V , efficiency η , sensitivity S , and the critical angle θ_C .We find the diameters of alpha particles tracks emitted from ^{226}Ra source with energy 5.48Mev increase with increasing the etching time ,the temperature of etching solution while it is decrease with increasing on incident radation and the energy of incident particle ,there was no effect of radiant time on tracks of alpha particles. Beside, it is noted that the larger tracks were found in CN-85 , LR115 , PM-355,CR-39 detectors respectively keeping the other variables to be stable.The effect the KOH is more than NaOH solution, no effect in etching time irradiation angle, the energy of incident particle, and radiant time on bulk Etching Velocity V_B whose values varying when temperature , concentration and type of detectors were changed . regarding numbers of tracks its increases with increasing the temperature, concentration of etching solution to a particular point and then it gets reversed , that is the numbers of tracks stars decreasing. The numbers of tracks increase with increasing the etching time, irradiation time and energy of incident particles. Finally we find the numbers of tracks decrease with increasing the radiation angle..

key words: solid state detectors, nuclear tracks detectors , CR-39 detector, nuclear track, etching solution , chemical etching.

I- Introduction

Solid state nuclear track detectors (SSNTDs) are frequently used in various research fields. However, the principle of work of these detectors is based on their ability to detect and register charged particles as the latent tracks. The required process to enlarge the primary latent tracks is called chemical etching (CE)[1,2] or alternatively electrochemical etching (ECE)[3] by which the latent tracks grow slowly and become visible. Yet to now, many works by using solid state materials to evaluate the geometrical and morphological characteristics of nuclear tracks[4, 5, 6], are mainly focused on some developed and fast access methods to find the best relations between geometrical characteristics of tracks and the properties of initial incident particles [7]. Studies show that nuclear track evaluations using the recent developed methods based on the theoretical and practical aspects of modern optics can be accurate as well as the conventional methods (such as using the optical microscopes) but faster than using the traditional methods[8]. Impact of irradiation on polymers is expanded through studying the etching variables including :

1: Bulk Etching Velocity V_B which is calculated from the following equation[4,9]:

$$V_B = \frac{1}{2A\rho}\left(\frac{\Delta m}{\Delta t}\right)\times 10^4 \quad \ldots. \quad (1)$$

in which Δm : the mass of material removed from the detector through an etching time Δt hour, A : the surface area of the detector before etching (cm^2), ρ : the density of the detector (gm / cm^3) while 10^4 is to transform the unit V_B to become μm / hr [4,9]

2: The Track Diameter Growth Velocity V_D: The Track Diameter Growth Velocity is defined as the measure of expansion of the tracks of the incident particles for a unit of time during the etching process. V_D can be measured through the following formula[4]

$$V_D = \frac{d}{t} \quad \ldots \ (2)$$

3: Track etching velocity V_T : When the track etching velocity is constant and when the incidence particle is vertical on the detector, the track etching velocity V_T is determined by the formula[9] :

$$V_T = V_B\,\frac{4V_B^2 + V_D^2}{4V_B^2 - V_D^2} \quad \ldots .\ (3)$$

The unit for V_T is μm/ hour

4: Etching ratio (V) : The etching ratio is calculated as following

$$V = \frac{V_T}{V_B} \quad \ldots .\ (4)$$

The values for V must more than unity and this is the main condition for the track to appear which means that $V_T > V_B$.

5: Efficiency and sensitivity (η ,S) : The efficiency of etching is defined by the formula .

$$\eta = 1 - \frac{V_B}{V_T} \quad \ldots .(5)$$

While the etching sensitivity of is given by the formula

$$S = \frac{V_T}{V_B} - 1 \quad \ldots .\ (6)$$

6: The Critical Angle θ_C : when the angle in which the incident particles on the detector was less than θ_c, no track appears on the detector despite the length of etching time.

The critical angle is determined as following[4,9]

$$Sin\theta_C = \frac{V_B}{V_T} \quad \dots (7)$$

The work of plastic NTDs is qualitatively presented in Fig.1. When a particle crosses such a detector the polymeric chains along its path are affected giving origin to the so-called "latent track". In the case of a particle with an electric charge Z and velocity β (= v/c), the produced damage can be related to Z/β. The latent tracks become visible under an optical microscope after chemical etching, typically in

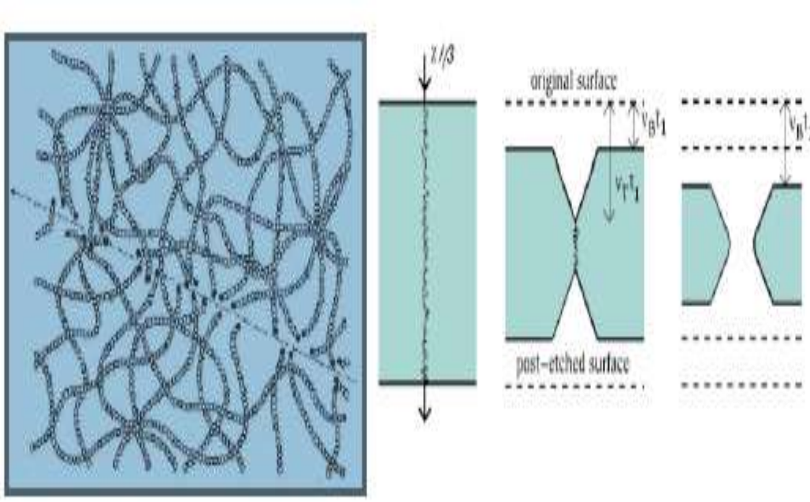

Figure 1. (left) The breaking of polymeric chains of plastic NTD by a crossing particle; (right) cross-view of the formation of the track after etching for two different times [10].

aqueous solution of NaOH or KOH – for the materials considered here - when the etching velocity along the latent track (v_T) is larger than the one for the bulk of the material (v_B). The temperature and concentration of the etching bath are chosen according to the type of application. For a through going particle, in the initial stage of the etching two cones are formed on both sides of the detector. The size and shape of such cones depend on the energy loss of the incident particle; the measurement of the cone base area or heights allows, through an appropriate calibration, to determine the characteristics of the particle [11].

There are a number of environmental factors that effect the response of nuclear track detectors including ultrasonic waves, electric field, light ions, temperature degrees, high pressure, high dose of electromagnetic rays, available oxygen in addition to the time of etching , time of radiation , angle of radiation incident , temperature of etching solution ,concentration of etching solution, type of detector, type of etching solution and the energy of incident particle, the storage conditions, humidity [4,9,12,13] Besides, there are factors concerning the detector itself that affect the sensitivity of nuclear detectors i.e. the purity of the monomer and the molecular structure of the polymer, the conditions of polymerization in addition to the resistance to oxidation. in this paper we will knew the effect some of these factors on registers properties of nuclear track detectors , that are include ; diameter of tracks, numbers of tracks, bulk Etching Velocity V_B , track Diameter Growth Velocity V_D, track etching velocity V_T, etching ratio (V), efficiency and sensitivity (η ,S)) and the critical Angle θ_C).

II :Metods:

1: The effect of temperature of etching solution (T) with invariable of parameters **(Eα=3Mev, Rt=2min, Et =2hr , θ_R =90^o,NaOH,CR-39,N=8). three** pieces of CR- 39 detectors were chosen with(1x2)cm^2 dimensions, and irradiated with 3Mev alpha particle at 90 incident angle with irradiation time 2 mint and etching by NaOH solution with different temperatures (50,60,80 ^{o}C) at 8 normality with two hours etching time .

2: The effect of concentration of etching solution (N) with invariable of of parameters (**Eα=3Mev, Rt=2min, Et =2hr , θ_R =90^o,NaOH,CR-39,T=^{0}70). three** pieces of CR- 39 detectors were chosen with(1x2)cm^2 dimensions, and irradiation with 3Mev alpha particle at 90 incident angle with irradiation time 2 mint and etching by NaOH solution with different concentrations (3,6,8N) at 70^{o}C with two hours etching time .

3: The effect of time etching of (**Et**) with invariable of of parameters (**Eα=3Mev, Rt=2min, T =70^{o}C , θ_R =90^o,NaOH,CR-39,N=8).**

three pieces of CR- 39 detectors were chosen with(1x2)cm^2 dimensions, and irradiation with 3Mev alpha particle at 90 incident angle with irradiation time 2 mint and etching by NaOH at 8N and 70C with different etching time (1,2,3 hr) .

4: The effect of time irradiation (**Rt**) with invariable of parameters (**Eα=3MeV, T =70^{o}C, Et =2hr , θ_R =90^o,NaOH,CR-39,T=^{0}70).**

three pieces of CR- 39 detectors were chosen with(1x2)cm^2 dimensions, and irradiation with 3Mev alpha particle at 90 incident angle with different irradiation time (1,2,3 mint)and etching by NaOH solution at at 7Normality and70C with two hours etching time .

5: The effect of irradiation angle (**θ_R**) with invariable of parameters (**Eα=3MeV, Rt=2min, Et =2hr , T =70^{o}C,NaOH,CR-39,N=8).**

three pieces of CR- 39 detectors were chosen with(1x2)cm^2 dimensions, and irradiation with 3Mev alpha particle at different incident angle (30,45,60 **θ_R**) and etching by NaOH solution at 7Normality and70C with two hours etching time .

6: The effect of type of solution with invariable of parameters (**Eα=3MeV, Rt=2min, Et =2hr , θ_R =90^o,CR-39,T=^{0}70).**

two pieces of CR-39 detectors were chosen with (1x2)cm^2, and irradiation with 3Mev alpha particle at 90 **θ_R** incident angle and etching by different solution (NaOH, KOH) at 7Normality and 70C with two hours etching time .

7: The effect of type of detector with invariable of parameters (**Eα=3Mev, Rt=2min, Et =2hr, θ_R =90^o, NaOH,N=8).**

four of detectors (CN-85, LR115, PM-355,CR-39) were chosen with(1x2)cm^2 dimensions, and irradiation with 3Mev alpha particle at 90 **θ_R** incident angle and etching by NaOH solution at 7Normality and 70C with two hours etching time .

8: The effect of energy of incident particles (**Eα**) with invariable of parameters (**T=^{0}70), Rt=2min, Et =2hr , θ_R =90^o,NaOH,CR-39,T=70^{o}C).**

six pieces of CR- 39 detectors were chosen with (1x2)cm^2 dimensions, and irradiation with different alpha particles energy (1.5,2,**3M**ev) at 90 **θ_R** incident angle and etching by NaOH solution at 7 Normality and70C with two hours etching time .

After the etching process, the detectors pieces were rinsed in water and blotted with a fine textured cloth to prevent the surface from being scratched and in the same time remove any etching residues. The masses were weighed using a sensitive balance with an accuracy of 10^{-4} g. The diameters of particle tracks and number of tracks were calculated by a light microscope. By using the equations(1 to 7) we can find the etching variable that include bulk Etching Velocity V_B , track Diameter Growth Velocity V_D , track etching velocity V_T **,** etching ratio (V) , efficiency and sensitivity (η, S) and the critical Angle θ_C).

III. Results and Discussion :

Fig.(2) shows the relation between temperature of equines (T) and the radius of tracks, tracks radius increase with increasing the temperatures of etching equines because the increase in the temperatures of the etching solution unchanged of other parameters especially concentration solution will increase the kinetic energy of the particles (OH^+ ions) . which attack the materials ,the increase in the energy of the particles will results in the analyses of detector materials in addition to an increase in the thickness of the removed material from the surface the detector. This in turn leads to increase of the diameters etching tracks and increase in the track Diameter Growth Velocity V_D. Fig.(2b) shows the relation between Temperature of equines (T) and the number of tracks. The number of tracks increases with increasing the temperatures of etching equines because –it didn't changes with change of etching solution temperatures but increase in the appear time of tracks. Table(2) shows The etching Variables of the effect of Temperature of equines (T) at constant the rest of parameters (Et=3hr, Rt=2min, θ_R =90^o, NaOH,CR-39, N=8. Eα=3MeV. The values V_B,V_T and V_D of increase with increasing the Temperature of equines (T), but the values of θ_C, η and S decrees with increasing the Temperature in the of equines (T) .Fig.(3a) shows the relation between concentration of equines (N) and the radius of tracks, tracks radius increase with increasing the concentration of etching equines because the increase in the concentration of the etching solution , means increasing the number of detector material responsible for acq solution of polymer, these for the increase in the number of collisions means increasing the number of particle which acquire taken limited energy because of these collisions with constant the other of variable (espatially the temperature of etching solution, which leads to increasing the number of the particles witch have greet energy . these in turn leads to increase the speed of interaction and the quantity of the removed from the surface of detector. Consequently an increases in the diameters etching tracks and increase in the track Diameter Growth Velocity V_D will accurse. Fig.(3b) the relation between concentration of materials equines (N) and the number of tracks. The number of tracks increases with increasing the concentration of etching equines. Table(1) shows The etching Variables of the effect of concentration of equines (N) at constant the rest of parameters (Et=3hr, Rt=2min, θ_R =90^o, NaOH, CR-39, T=70^{o}C. Eα=3Mev. The values V_B,V_T and V_D of increase with increasing the concentration of equines (N), but the values of θ_C, η and S variable with decreasing and increasing with the concentration of equines.

Table(1) the effect temperatures of equines on nuclear track detectors

T(°C)	V_B(μm/hr)	V_T(μm/hr	V_D(μm/hr	$θ_C$	η	S
٥٠	1.4	1.4	0.06	90.0	0	0
٦٠	2.11	2.22	0.83	71.1	0.054	0.057
٧٠	3.11	3.31	1.36	69.69	0.063	0.067

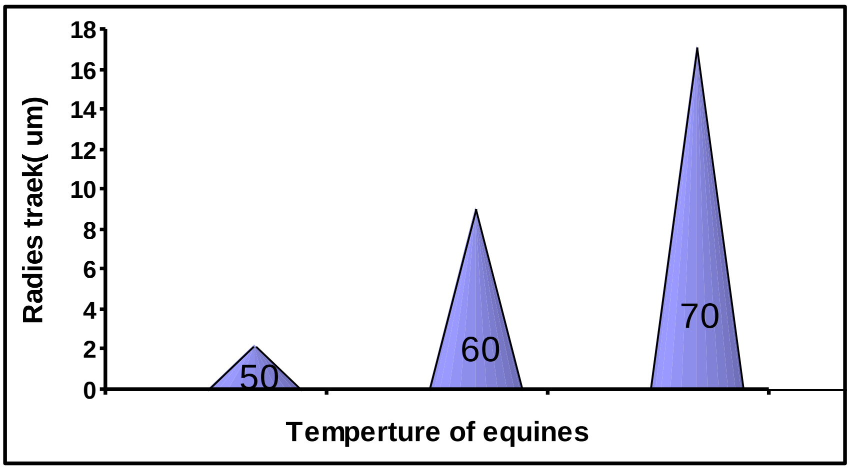

Fig.(2a) the relation between Temperature of equines (T) and the radius of tracks .

Table(2)The effect concentration of equines (N) on nuclear track detectors

N	V_B(μm/hr)	V_T(μm/hr	V_D(μm/hr	$θ_C$	η	S
4	2.7	3.79	2.58	45.4	0.29	0.40
6	3.99	6.03	4.3	41.43	0.34	0.51
8	6.4	9	6.53	45.3	0.28	0.39

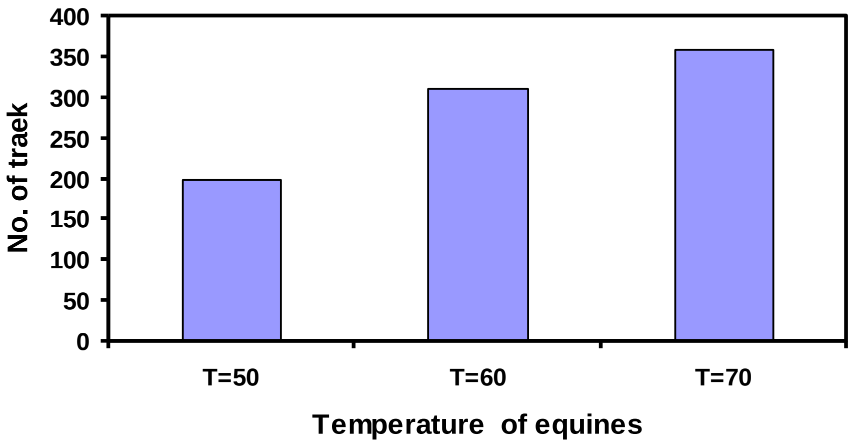

Fig.(2b) the relation between Temperature of equines (T) and the number of tracks.

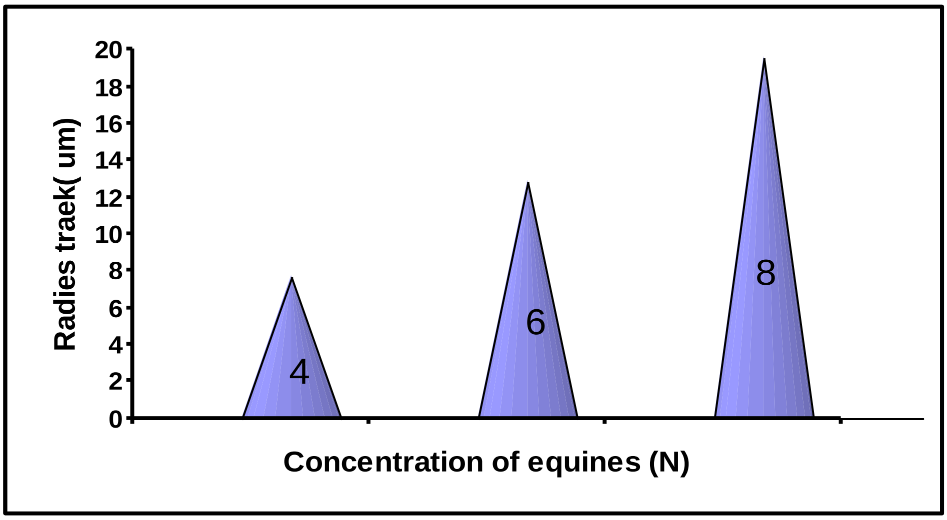

Fig.(3a) the relation between concentration of equines (N)and tracks radius.

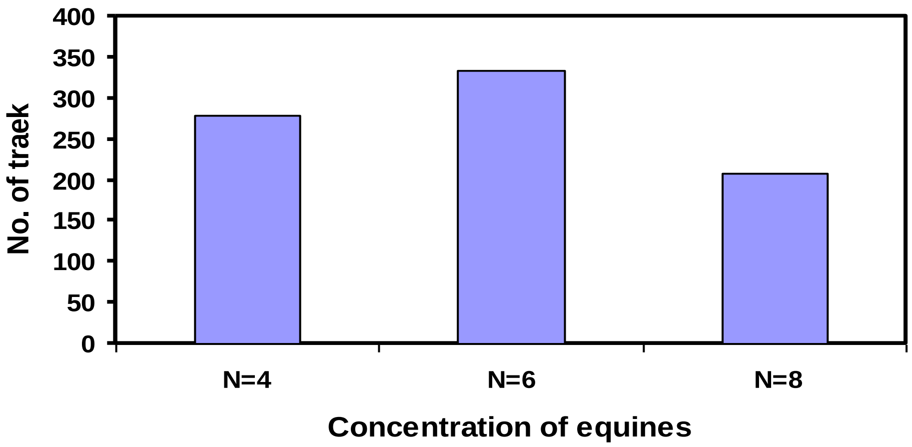

Fig.(3b) the relation between concentration of equines (N)and number of tracks

the values of θ_C decrese with Fig.(4a)shows the relation between etching time (Et) and radius of tracks. , radius increase with increase with decreasing of the etching time (Et) because etching time increasing lead to increase in the thickness of the removed material from the surface the detector. This in turn leads to increase of the diameters etching tracks.

Fig.(4b)shows the relation between etching time (Et) and the number of tracks. The number of tracks increase with increasing of the etching time (Et). Table(3) shows The etching Variables of the effect of etching time (Et)at constant the rest of parameters Eα =3mev, Rt=2min, T=70^{o}C, θ_R = 90^o,NaOH, CR-39,N=8). The value V_B is constant at the increasing alpha particle energy (Eα),V_T and V_D increase with increasing of the alpha particle energy (Eα), but the increasing of the etching time (Et), and η and S increase with the increasing of the etching time (Et).

Fig.(5a) shows the relation between irradiation time (Rt)and tracks radius., radius are constant with the increasing of the irradiation time (Rt) .Fig.(5b) shows the relation between irradiation time (Rt) and the number of tracks. The number of tracks increase with increasing of the irradiation time (Rt) because the increase in the irradiation time means increasing in the incident alpha particles in area units, these is lead to increase in the number of tracks.

Table(4) shows The etching Variables of the effect of irradiation time (Rt) at constant the rest of parameters (Et=3hr, Eα=3Mev, T=70^{o}C, θ_R =90^o, NaOH, CR-39,N=8). The value V_B is constant at the increasing of irradiation time (Rt),V_T and V_D increase with increasing of the irradiation time (Rt), but the values of θ_C decrease with the increasing of the irradiation time (Rt) ,and η and S increase with the increasing of irradiation time (Rt).

Table(3)The effect etching time (Et) on nuclear track detectors.

Et (hr)	V_B(μm/hr)	V_T(μm/hr	V_D(μm/hr	θ_C	η	S
2	1.3	6.27	2.15	11.9	0.79	4
٣	1.3	6.27	2.15	11.9	0.79	٤
٤	1.3	12.06	2.36	6.18	0.89	8.34

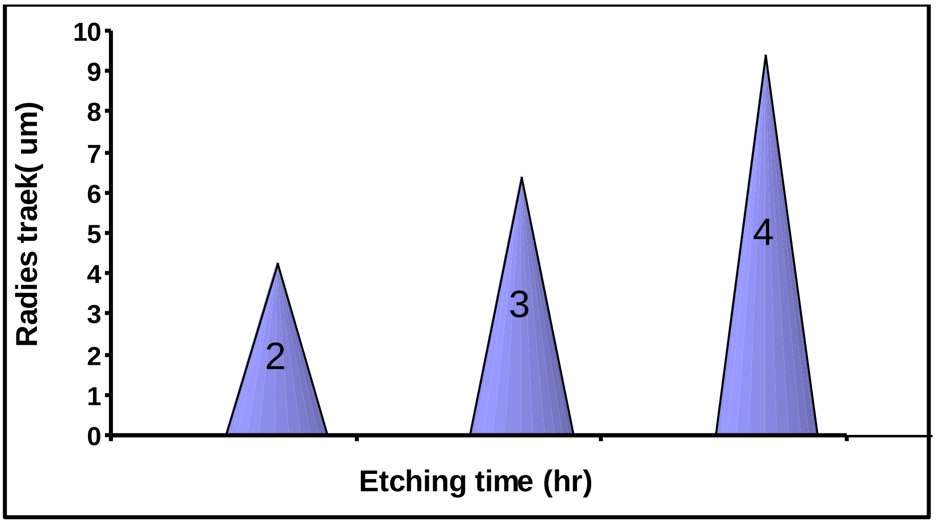

Fig.(4a) the relation between etching time (Et) and radius tracks .

Table(4) the effect irradiation time (Rt) on nuclear track detectors.

Rt(min)	V_B(μm/hr)	V_T(μm/hr	V_D(μm/hr	θ_C	η	S
1	1.3	6.27	2.15	11.9	0.79	4
2	1.3	6.27	2.15	11.9	0.79	٤
3	1.3	9.25	2.29	8.01	0.86	6.19

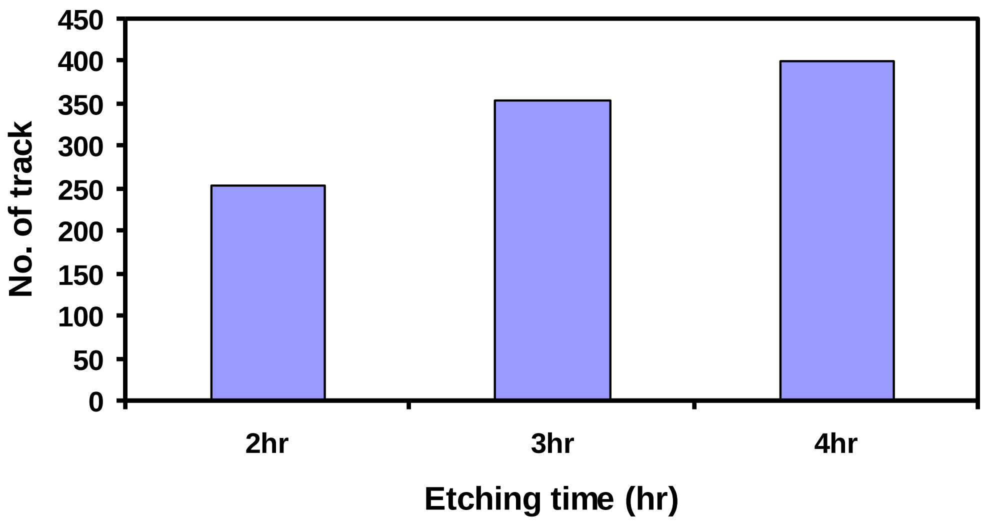

Fig.(4b) the relation between etching time (Et) and number of tracks .

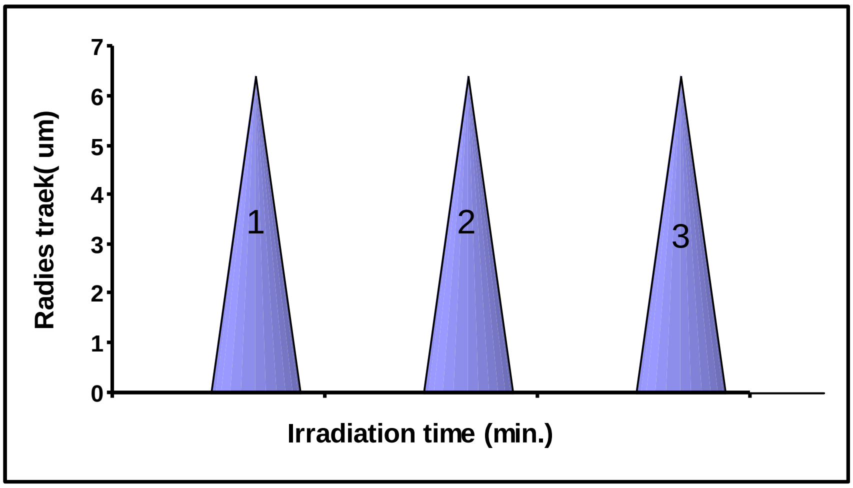

Fig.(5a) the relation between irradiation time (Rt)and tracks radius

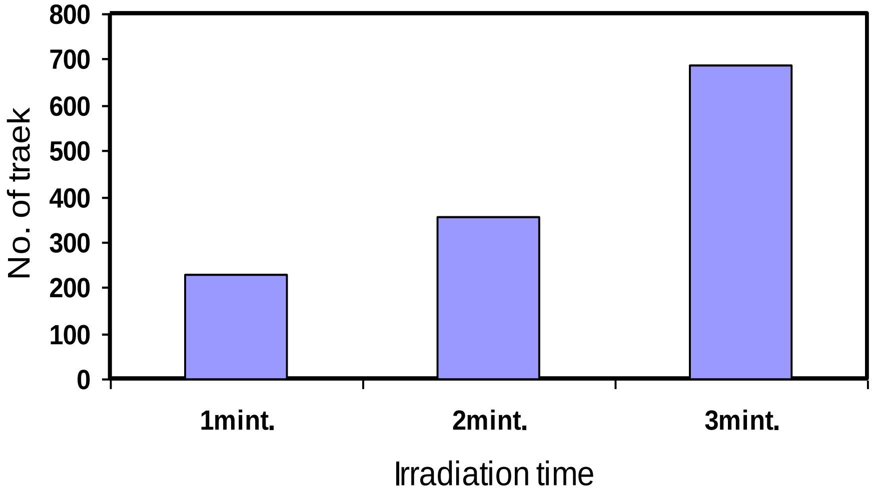

Fig.(5b) the relation between irradiation time (Rt) and number of tracks.

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Fig.(٦a) the relation between radiation incident angle (θ_R) and radius tracks, radius decreas with increasing the radiation incident angle (θ_R) because the increasing in the incident area of alpha particle lead to increase in the area of etching track radius .

Fig.(6b) the relation between radiation incident angle (θ_R)and number of tracks. The number of tracks decrees with increasing the radiation incident angle (θ_R). Table(5) shows The etching Variables of the effect of radiation incident angle (θ_R) at constant the rest of parameters (Et=3hr, Rt=2min, N=8 =90^o, NaOH,CR-39, T=70^{o}C. Eα=3Mev. The values V_B,V_T and V_D DECRES with increasing the radiation incident angle (θ_R), but the values of θ_C, η and S increase with the decreasing of radiation incident angle (θ_R).

Fig.(7a) the relation between alpha particle energy (Eα) and radius of tracks. diameter increase with decreasing alpha particle energy (Eα) because the particle of its law energy losses its energy with fast inside the detector and its form tracks near in the surface of detector because its stopping power will be high , these lead to the rang of alpha particle will be small and it can appear this latent track with small etching time. the particle of its small stopping power and its rang is high in the detector , these particle loss its energy on a long distance in the detector compare with its law energy these lead to appear process need to long etching time. Fig.(7b) the relation between alpha particle energy (Eα)and number of tracks. The number of tracks increases with increasing in alpha particle energy (Eα).

Table(6) shows The etching Variables of the effect of energy of alpha particles incident (Eα) at constant the rest of parameters (Et=3hr, Rt=2min, T =70^{o}C , θ_R =90^o,NaOH,CR-39,N=8).

The value V_B is constant at the increasing alpha particle energy (Eα) ,V_T and V_D increase with increasing of the alpha particle energy (Eα), but the values of θ_C increase with increasing of the alpha particle energy (Eα),and η and S decrease with the increasing alpha particle energy (Eα),

Table(5)The effect radiation incident angle on nuclear track detectors

Θ_R	V_B(μm/hr)	V_T(μm/hr	V_D(μm/hr	θ_C	η	S
30	1.9	19.63	4.08	5.55	0.90	9.42
60	1.55	12.62	2.79	7.05	0.87	7.15
90	1.33	8.84	2.32	8.65	0.85	5.66

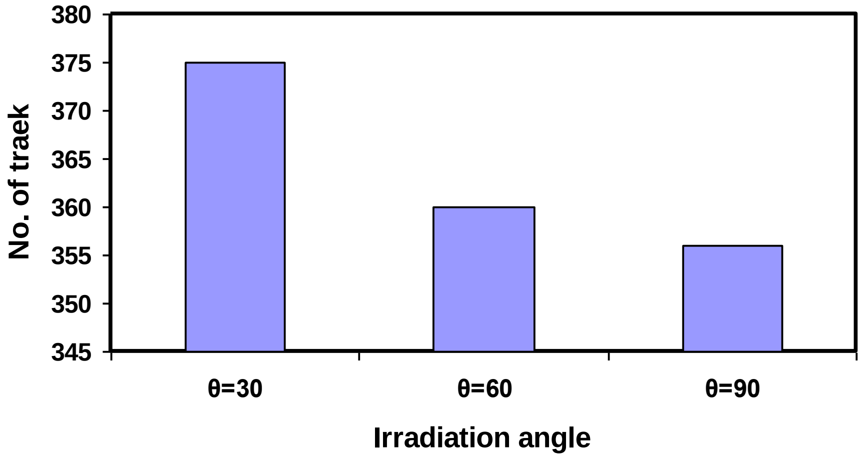

Fig.(6b) the relation between radiation incident angle (θ_R)and tracks radius .

Table(6)effect energy of alpha particles incident (Eα) on nuclear track detectors.

Eα(Mev)	V_B(μm/hr)	V_T(μm/hr	V_D(μm/hr	θ_C	η	S
2	1.3	11.75	2.87	6.45	0.88	7.9
٣	1.3	6.27	2.15	11.9	0.79	٤
٤	1.3	3.09	1.72	24.8	0.58	1.38

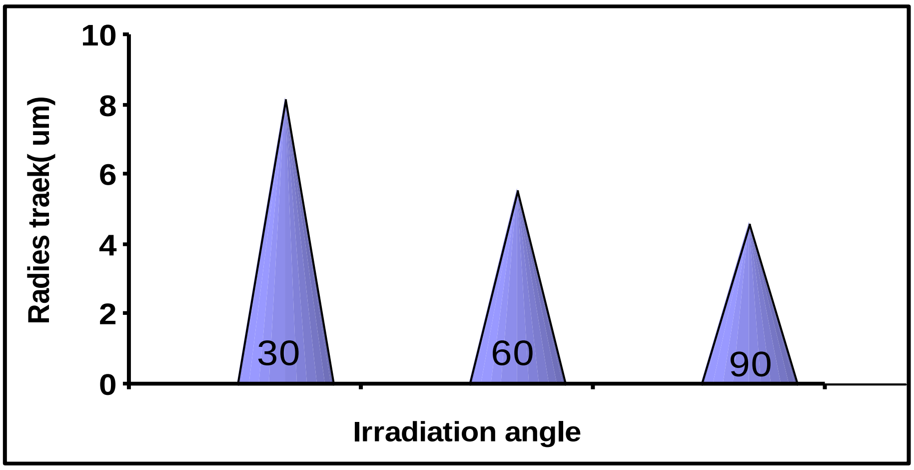

Fig.(6a) the relation between radiation incident angle (θ_R)and number of tracks .

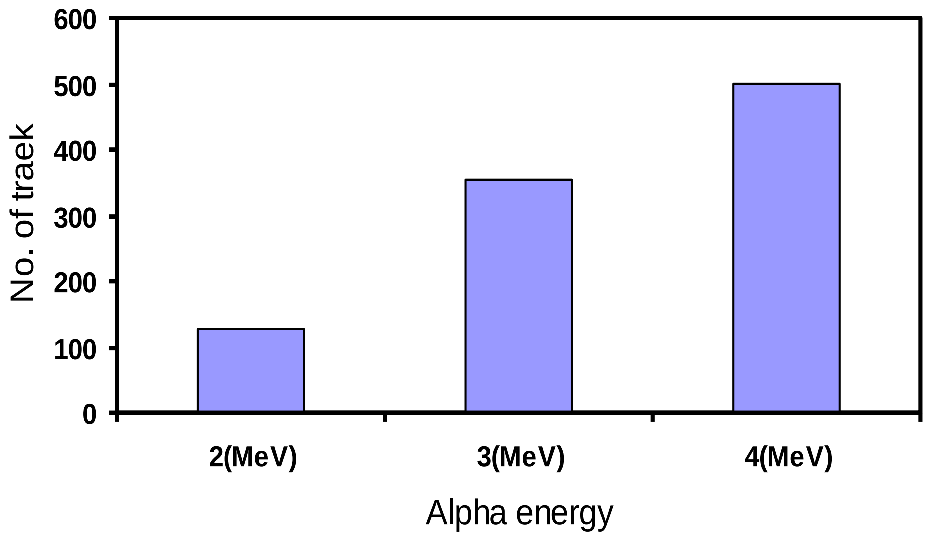

Fig.(7b) the relation between alpha particle energy (Eα)and number of tracks .

Fig (8) shows the relation between the radius tracks and the type of equines. Radius tracks at KOH solution bigger more than the radius tracks of NaOH solution because this effect independent upon the type of equines t. Table (7)shows the effect of the effect of the type of equines on the etching Variables at constant the rest of parameters (Et=3hr, Rt=2min, T =70^{o}C, θ_R =90^{o}, Eα=2Mev,CR-39,N=8).The values V_B,V_T and V_D of KOH solution are bigger than the values of NaOH solution, but the values θ_C, η and S of NaOH solution are more than the values of KOH solution .

Fig(9) shows the relation between the radius tracks and the type of detectors ,the large tracks were in the CN-85, LR115, PM-355,CR-39 detectors respectively with constant invariable. because this effect independent upon the type of detector and the chemical formula of the type of detectors.

Table(7)The effect type of equines on nuclear track detectors.

Equines	V_B(μm/hr)	V_T(μm/hr	V_D(μm/hr	θ_C	η	S
NaOH	2.27	7.48	6.22	28.78	0.58	1.088
KOH	3.11	13.25	6.77	7.68	0.86	6.52

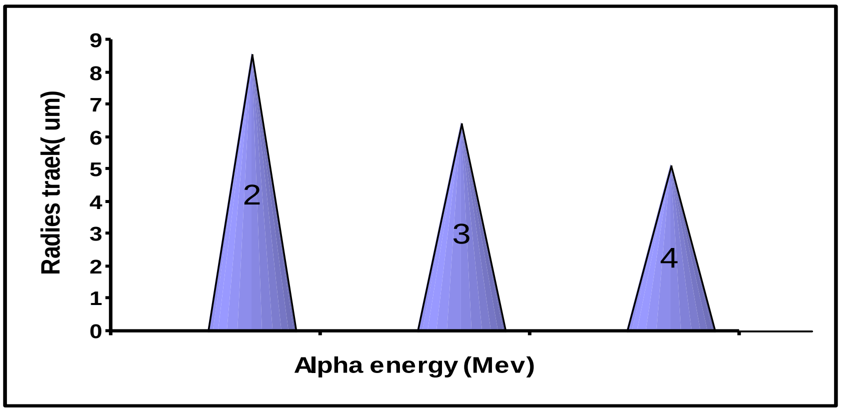

Fig.(7a) the relation between alpha particle energy (Eα) and radius of tracks .

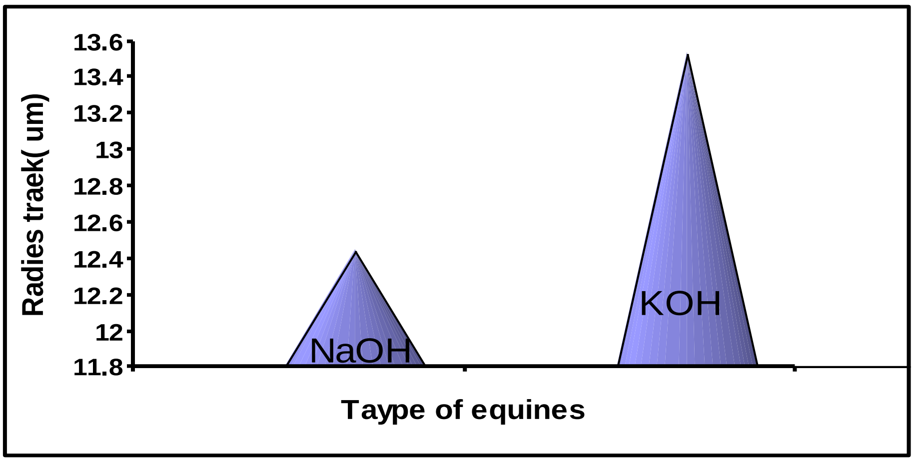

Fig.(8a) the relation between the type of equines and radius of tracks

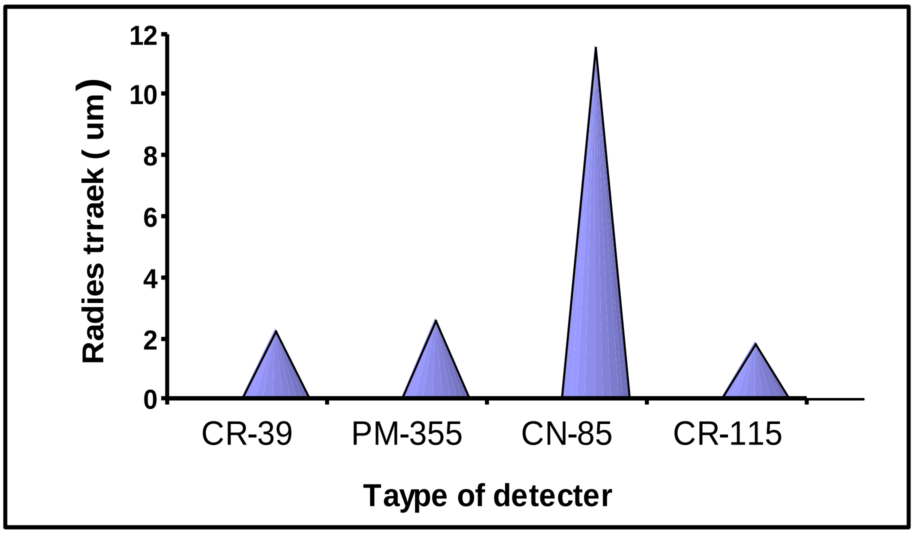

Fig.(9) the relation between the type of detectors and radius of tracks

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استجابة كواشف الأثر النووي لبعض العوامل القشطية

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الملخص:

في هذا البحث تم التعرف على تأثيربعض العوامل القشطية (زمن القشط ،زمن التشعيع ، زاوية التشعيع ، تركيز محلول القشط ، درجة حرارة محلول القشط ،نوع الكاشف المستخدم ،طاقة الجسيم الساقط ،نوع محلول القشط) على الخصائص التسجيلية لكواشف الاثر النووي والتي اشتملت على تغير اقطار الآثار وعددها وسرعة نمو القطر V_D وسرعة القشط العام V_B والأثر V_T والزاوية الحرجة θc وكفائه η وحساسية الكاشف S . تبين إن أقطار اثار جسيمات إلفا المنبعثة من المصدر المشع ^{226}Ra وبطاقة 5.48Mev تزداد بزيادة كل من زمن القشط وتركيز المحلول القاشط ودرجة حرارته وتتناقص هذه الاقطار بزيادة زاوية التشعبع وطاقة الجسيمة الساقطة فيم لم يكن لزمن التشعبيع تأثير على أقطار الآثار ووجد أيضا إن اكبرالاثارقطرا كانت في الكاشف CN 85 ثم لتاثير الكاشف LR115 ثم , PM355 ومن ثم CR-39 بثبوت بقية المتغيرات إما بالنسبة لتا ثير نوع المحلول القاشط فتبين إن المحلول KOH كان تاثيرة ايجابيا أكثر من المحلولNaOH وتبين انه لاتاثير لزمن القشط وطاقة الجسيمة الساقطة وزمن التشعيع و زاوية التشعيع على معدل سرعة القشط العام VB فيما تراوحت قيمها بين الزيادة والنقصان عند تغير كل من تركيز محلول القاشط .و درجة حرارته ونوع الكاشف والمحلول المستخدمان .اما فيما يخص عدد الاثار فقد وجد ان عدد الاثار يزداد مع زيادة تركيز ودرجة محلول القشط الى حد معين ثم تبدا عملية معاكسة حيث تقل عدد الاثار بزيادة التركيز ودرجة حرارة المحلول القاشط كما وجد ان عدد الاثار يتناقص مع زيادة زاوية التشعيع ووجد ان عدد الآثار يزداد بزيادة طاقة ألجسيمه الساقطة وزمن التشعيع وزمن القشط ضمن المدى المستخدم.

الكلمات المفتاحية: كواشف الحالة ألصلبه ، كواشف الأثر النووي ،CR-39 ، الأثر النووي ، محاليل القشط