CHAPTER - V

EXPERIMENTAL RESULTS AND DISCUSSION

After irradiation of a TLD phosphor, the light intensity from the heated phosphor can be plotted as a function of heating temperature. The resulting curve, except for the black-body radiation from the phosphor, is defined as a glow curve. It is obtained automatically on the chart-recorder by a single pen moving with constant speed corresponds to the uniform heating rate applied. In the present thesis, TL glow curves are presented as plots of TL-intensity versus temperature where the intensity of TL output is presented in ampers. A pure and monovalent impurity (K^+) doped sodium fluoride specimens in powder form were examined in various physical conditions after subjecting them to beta irradiation (2.1×10^3 rad) at room temperature in the temperature region 30-400°C. A series of TL glow curves for each and every specimen were recorded and the typical glow curves are presented in this Section for discussion. The main glow peaks reported in this Section are 120, 150, 165, 190, 300, 360°C. Since the glow curve shapes and peak temperatures are highly sensitive to impurity concentration, pre-heat treatments, and pre-exposure to ionizing radiation, the individual principal glow peak appears as isolated well defined under specific physical condition of the specimen. However, the appearance or disappearance of new peaks or shoulders in the neighbourhood of isolated principal glow peak after various pre-treatments of the specimen results in slight variation in the peak temperatures from those mentioned above. In this respect, the assignment of the particular temperature to a TL glow peak may appear somewhat arbitrary. In spite of this, the peak temperatures mentioned in this thesis are typical and these have been used for the identification of the glow peaks.

The TL behaviours of pure and potassium doped sodium fluoride in untreated and pre-heat treated conditions under the influence of three minutes beta irradiation from Sr^{90} beta source (700 $rad.min^{-1}$) have been studied in the present experiments. The results obtained are presented in Figs.2 to 21 (where Figs.1A & 1B represents the glow curves obtained for NaF without irradiation). In these experiments the phosphor was subjected to three successive thermal cycles irradiated at room temperature under the same experimental conditions, heating them to 400°C with a uniform heating rate of 400°C min^{-1} and then cooling them to room temperature. In all these figures, continuous, dashed and dotted line curves represent the first, second and third thermal cycle respectively.

Figure 1

The thermally stimulated luminescence characteristics of untreated and pre-heat treated NaF without exposure to any radiation have been examined. The results obtained are presented in figures 1A and 1B. It is significant to note that without irradiation the specimens exhibit a well defined peak around 360°C in the first heating run which disappears in the second and subsequent ones. Besides this, the well defined dominant peak at 360°C appears as a hump with lower intensity in 200°C air quenched NaF specimens. And then disappears completely in the specimens quenched from higher quenching temperatures, namely; 400 and 600°C.

Figures 2-5

Thermal glow curves of pure sodium fluoride specimens in four different physical conditions; as-obtained from aqueous solution, obtained after annealing at 200, 400 and 600°C for two hours and subsequently cooled rapidly to room temperature in open air are presented in Figures 2, 3, 4 and 5 respectively. It is seen from Fig.2 that NaF specimen as-obtained from aqueous solution shows well defined glow peaks at 120 and 360°C. Besides this, it is also seen that in successive thermal cycles, there is a generation of strong peak at 150°C and small peak at 300°C along with a reduction of intensity of the peak at 120°C which then appears as shoulder on left side of the peak at 150°C. The peak at 360°C appears dominant and increases in intensity with successive thermal cycles. The NaF specimens annealed and air-quenched to room temperature from 200 and 400°C exhibit peaks at 120 and 150°C along with high temperature peak at 360°C. It is observed that the intensity of 120°C peak falls and that of 150°C rises significantly with increase in the quenching temperature [Curves 1, figures 2, 3 and 4]. Finally the peak at 150°C becomes dominant one in 400°C air quenched NaF. Further, when the specimens undergo thermal cycling the intensity of all peaks increase with increase in number of cycles and a small peak at 300°C is observed. Fig.5 represents the glow curves of the specimen anneald at 600°C and rapidly air-quenched to room temperature. It is clearly seen from curve 1, Fig.5 that the specimen displays a peak at 120 and 190°C in the first heating run. These peaks come up with significant increase in their intensities along with generation of a shoulder at 230°C and a small peak at 300°C in the second and subsequent thermal cycles.

Figures 6-9

Specimens of K^+ doped sodium fluoride with K^+ concentration 200 part per million (ppm) in as-obtained condition and after quenching them from 200, 400 and 600°C in open air were studied for their TL behaviour. The TL glow curves are presented in Figs.6-9.

As obtained NaF:K specimen exhibits well defined peak at 360°C along with small broad peak at 165°C with shoulder at 190°C in the first heating run (curve 1, Fig.6). There is a marked decrease in the intensities of the observed glow peaks during the second and successive thermal cycles.

The TL behaviour of the specimens quenched from 200°C exhibits small peaks at 120 and 165°C along with strong peak at 360°C in the first thermal cycle. The intensities of peaks at 120 and 165°C increase while that of peak at 360°C decreases with execution of further successive heating runs.

Fig.8 represents the thermal glow curves for specimens quenched from 400°C. It is seen from the figure that thermal cyclings induce an enhancement in overall intensity of thermal glow peaks observed at 120, 165 and 360°C along with generation of a shoulder at 190°C in the third thermal cycle. The specimens quenched from 600°C display thermal glow peaks at 120 and 190°C (Curve 1, Fig.9), while the peaks observed at 165 and 360°C in the first heating run of Figs.6,7 and 8 are completely disappeared. Further, when the specimen was subjected to thermal cycling, a marked increase in the intensities of the above mentioned peaks is observed along with generation of shoulder at 230°C and a small peak at 300°C. It is observed that the intensity of newly generated shoulder continues to grow with successive heating run, while that of the peak at 300°C stabilizes itself with further consecutive thermal cycling.

Figures 10-13

Figures 10 through 13 respectively show the TL glow curves of NaF:K (500 ppm) in different physical conditions namely; as-obtained from aqueous solution, obtained after annealing at 200, 400, and 600°C and subsequently cooling to room temperature in open air. It is observed that the TL behaviour of the specimens presented in this batch is more or less similar to those given for the specimen of NaF:K with 200 ppm K^+ concentration under the same physical conditions. There is no significant change in the glow curve pattern by thermal cycling when the concentration of impurity is increased to 500 ppm. There is however, one marked difference namely, the substantial increase in the intensity of glow peak around 360°C with successive thermal cycling, (Fig.11), whereas that presented in Fig.7 under the same physical condition decreases after the first heating run. It is very important to note that the intensity of 190°C glow peak is more than that of 120°C peak in the 600°C air-quenched NaF:K (500 ppm) specimens.

Figures 14-17

Another batch of NaF:K specimens (1000 ppm) obtained by the method of recrystallization from aqueous solution was annealed at three different temperatures namely 200, 400 and 600°C for two hours and subsequently rapidly cooled to room temperature. The untreated and thermally treated specimens were studied for their TL behaviour and the results obtained are presented in Figures 14-17.

The thermoluminescence behaviour of the untreated specimen in the first heating run shows two glow peaks of equal intensities at 120 and 165°C and a shoulder at 190°C along with intense well defined glow peak at 360°C. When the specimen is subjected to thermal cycling, a marked decrease in the intensities of peaks at 120 and 360°C was observed. Besides this, the intensities of the peak at 165°C and the shoulder at 190°C were found growing up with successive heating runs. Further, it is seen that the peak at 165°C appears well defined and isolated, only after the first thermal cycle.

The TL glow curves obtained by specimen quenched from 200°C are more or less identical to the results obtained by the untreated specimen. It is of no consequence to note the increase in the intensity of peak at 120°C which then appear as a hump in thermal cycling process. The most important point to be noted is that the NaF:K (1000 ppm) specimen annealed and air-quenched from 400°C to room temperature, designated as NaF:K(T), displays two equally intensed well defined isolated peaks at 165 and 360°C. The 120°C peak or hump observed in he previous batches, hardly appears in this section on the ascending part of the 165°C glow peak. Further, it is observed that the intensities of these peaks change with successive thermal cycling. Besides this, a shoulder at 190°C and a small peak at 300°C are also discernible in the second and subsequent heating runs. On the other side, the significant change in TL behaviour has been observed when 600°C air-quenched NaF:K(1000 ppm) specimens were examined in identical experimental conditions, unlike 200 and 400°C NaF:K (1000 ppm) specimens, 600°C air-quenched NaF:K (1000 ppm) phosphor results dominant peak at 190°C. The change in glow curve pattern with successive thermal cycle is observed as usual.

Figures 18-21

The characteristic glow curves of NaF:K with K^+ concentration 2000 ppm, were recorded for four different physical conditions, namely; as-obtained from aqueous solution, and heat-treated at 200, 400 and 600°C. The corresponding glow curves are presented in Figs.18,19,20 and 21 respectively. The as-obtained specimen displays a peak at 165°C and a shoulder at 190°C along with high temperature peak at 360°C. The peaks exhibited reduction in intensity, and the overall glow curve pattern remains unaffected during successive thermal cycle (Fig.18). A very small peaks at 120 and 165°C are shown to be displayed by the NaF:K (2000 ppm) quenched from 200°C along with high temperature peak at 360°C in the first heating run Fig.19. The first two peaks are found to be favoured while the latter one is found to be diminished in the intensity during the second thermal cycle. It was observed that the further heating runs do not change glow curve pattern significantly i.e. the glow peaks stabilize themselves. It is seen that the 400°C air-quenched specimen exhibits a glow peak at 165°C with two shoulders of equal intensities at 120 and 190°C on both sides of the peak along with well defined peak at 360°C. It is of significance to note that the thermal cycling favours the 190°C peak and it appears prominent during the third heating run (curve 3, fig.20). It is very clear that the 600°C air-quenched NaF:K (2000 ppm) specimen (fig.21) displays 190 and 120°C glow peaks, between which the former one is predominant. The overall intensity of TL glow curve significantly rises with successive thermal cycles.

Figure 22

The effect of thermal pre-treatment on pure NaF specimens is shown in Fig.22. Sodium fluoride specimens in four different physical conditions, namely; as-obtained from solution, and heat treated at 200, 400 and 600°C, were examined for their TL behaviour after exposure to beta irradiation (2.1×10^3 rad). It is found that as-obtained NaF exhibits well defined glow peaks at

120 and 360°C, between which the latter one is prominent one. The peak at 120°C reduces in strength and peaks in 120-300°C region come up. It is interesting to note that the 400°C air-quenched NaF gives well defined peak at 150°C, while 600°C air-quenched NaF results peaks at 120, 190 and 300°C at the cost of 360°C peak. The intensity of 360°C is found to be decreasing with rise in quenching temperature and found absent in 600°C air-quenched NaF.

Figures 23-26

The lightly doped NaF:K (200 ppm) specimens prepared from aqueous solution subjected to different heat treatments, namely; annealing and air-quenching from 200, 400 and 600°C were exposed to beta radiation (2.1×10^3 rad.). The thermal glow curves exhibited by them and as-obtained NaF:K (200 ppm) were recorded and presented in figure 23. It is clearly seen that the lightly doped as-obtained NaF:K exhibits broad peak at 165°C with the indication of 120 and 190°C glow peaks. The air-quenching from 200°C temperature resolves broad peak into two separate peaks around 120 and 165°C, while that from 600°C brings out 120 and 190°C separately. It is very important to note that air-quenching from 400°C reveals well defined peak at 165°C.

In order to get more information regarding the behaviour of 165°C peak, a series of experiments have been carried out. The TL glow curves for NaF:K specimens with three more different K^+ concentrations, namely; 500, 1000 and 2000 ppm, were recorded in as-obtained condition and also after thermal quenching from 200, 400 and 600°C, after subjecting them to standard beta radiation dose (2.1 x 10^3 rad.). It is clearly seen that in all cases, the peak at 165°C has appeared selectively with maximum strength for the specimens air-quenched from 400°C. It is also observed that the intensity of the peak at 165°C has gradually risen with increase in the K^+ concentration upto optimum concentration of 1000 ppm, and then, it has fallen for the further increase in potassium concentration [Curves 3, Figures 23-26].

Figures 27-30

A series of experiments have been performed to study the effect of potassium concentration on TL characteristics of NaF:K specimens under above mentioned four different physical conditions. The thermally stimulated luminescence behaviour of NaF:K specimens with different K^+ concentrations (200, 500. 1000 and 2000 ppm) are shown in Figs.27-30.

It is observed from Figs.27 and 28 that the increase in the concentration of K^+ ions in the as-obtained and 200°C air-quenched conditions of the specimens does not result significant change in the intensity of the observed glow peak at 165°C. It was mentioned earlier that the intensity of this peak is markedly influenced by the heat treatment. It becomes well defined intensed one, when the specimen is annealed and quenched from 400°C. It is clearly observed from Fig.29, that the glow peak at 165°C becomes more pronounced, isolated and well defined, if, along with the heat treatement, the concentration of potassium in NaF:K is increased to 1000 ppm. Further increase in K^+ ion concentration decreases the intensity of this peak and helps to develop a new peak at 190°C. The peak at 190°C appears well defined when the specimens are quenched from 600°C (Fg.30). Besides this, the high temperature peak, observed at 360°C in Fig.27, 28 and 29, attains the maximum intensity when the concentration of K^+ ion is increased to 1000 ppm, while this peak is completely erased when the specimens are annealed at 600°C for two hours and subsequently air-quenched to room temperature (Fig.30).

Figures 31 & 32

The effect of different beta doses on TL behaviour of as-received and 400°C air-quenched specimens of NaF, and NaF(T) are presented in fig.31A and 31B respectively. The figures clearly demonstrate that as-obtained specimens display 120 and 360°C glow peaks (fig.31A), while 400°C air-quenched NaF substance exhibits TL peaks at 150 and 360°C. Figures 32.A and 32.B display the plots of TL intensity versus incident beta dose for the peaks respectively observed in NaF and NaF(T). It is seen that the peaks intensities grow with increase in beta dose

Figures 33-36

The TL glow curves displayed by 400°C air-quenched NaF:K specimens containing different contents of monovalent potassium impurity, [K^+ concentrations, 200, 500, 1000 and 2000 ppm] after exposure to beta radiation of different doses have been examined and presented in figures 33-36. It is found that in general the TL glow curve intensity rises with increase in beta dose. The peaks at 165 and 360°C are observed isolated and well defined. These peaks are also found growing in intensity with increase in beta dose. The examination of these figures clearly indicates that the specimens of NaF:K(T), 400°C air-quenched NaF:K [1000 ppm], exhibit systematic growth in the intensities of glow peaks at 165 and 360°C with increase in beta dose. It is important to note that the peak at 360°C appears only at 4.66×10^2 rads and above. Further the peaks are seen well defined and isolated (Figs.35A and 35B). Not only this, but the material NaF:K(T) displays significant TL output among others under examination. Besides this, the peak position and the glow curve pattern remains unaltered under the influence of different beta doses ranging from 29 to 14000 rads. The only change observed is the development of hump at 190°C at very high beta dose.

Figure 37

In order to find out appropriate quantityof the NaF:K material in the experimental research work in this thesis, an experiment has been done to investigate the effect of different weights of the material on TL output under standard beta dose. TL glow curves obtained for different quantities of NaF:K(T) specimens under the influence of standard, 2.1×10^3 rads beta dose are presented in figure -37. It is found that the 20mg of NaF:K(T) material results maximum TL output at 165 and 360°C.

Further increase in the quantity of the phosphor does not indicate further significant rise in intensity of TL output. Since 5mg material has shown TL behaviour with identical clarity and glow curve pattern to that resulted by 20mg, the 5mg material of NaF:K(T) is considered as standard quantity of phosphor for dosimetry research.

Figure 38

NaF:K(T) specimens were exposed to different beta radiation doses and TL glow curves have been recorded under the similar experimental conditions. The plots of beta dose versus TL intensities of the peaks at 165 and 360° C are exhibited respectively in figures 38A and 38B. It is clearly seen that the TL output versus dose response is linear through out the given dose range, ranging from 29 - 14000 rad for 165°C glow peak.

Figure 39

In yet another series of experiments, the NaF:K(T) specimens were exposed to a test beta dose (2.1 X 10^3 rad.) and stored at room temperature. The TL glow curves exhibited by them with different duration of room temperature decay after excitation were recorded. It is observed that the glow curve pattern, peak temperature, and peak strength, remain unchanged under the change in post irradiation interval. The plot of TL out put versus room temperature decay time following excitation is presented in Figure 39. The plot does not indicate substantial change in TL intensity of the peak at 165°C. This indicates negligible fading.

Figures 40A, B, C & D

The effect of the magnetic field on TL behaviour of NaF:K(T) specimens has also been examined. In one of the experiments, specimens were irradiated with beta irradiation 2.1 X 10^3 rad and subsequently placed between the two poles of electromagnet. The magnetic field, 3.3 K Gauss was applied by passing one ampere current. The TL characteristics were examined after placing the specimen in the magnetic field for 20 minutes. The TL glow curves have been recorded under the similar experimental conditions after the application of different magnetic fields to the specimen by varying the current of electromagnet to 2, 3, and 4 amperes. In another experiments, the specimens were kept in the magnetic field for 20 minutes without pre beta-irradiation. After completion of 20 minutes time with one ampere current in electromagnet, the specimens were irradiated and then the TL read out was taken. The experiment was repeated for different magnetic fields by passing 2, 3, and 4 ampere current in electromagnet and TL glow curves have been examined. The results obtained in both the cases are presented in Figs. 40 A, B, C and D. In these figures, the dotted line represents the TL glow curves of the specimen first irradiated and then placed in the magnetic field. While the continuous line represents TL glow curve of the specimens, irradiated after application of magnetic field.

It is very interesting to note that application of magnetic fields to pre or post beta irradiated NaF:K(T) phosphors do not significantly change the shape, the nature, the position of peaks and the intensity of the TL glow curve. The minor change in the intensity is discernible with high magnetic field (4 ampere, fig. 40 D).

Figure 41

The effect of concentration of monovalent impurity K^+ on the behaviour of 165° C glow peak has been investigated in the as - obtained and 400° C air - quenched specimens of NaF:K. The results obtained are presented in form of plot of intensity of 165°C glow peak versus the concentration of the impurity K^+. It is seen that in both the conditions, the NaF:K phosphor display optimum intensity at 165° C with 1000 ppm concentration.

Figure 42

A series of experiments have been conducted to investigate the TL sensitivity of the present material. In this respect, TL glow curves were recorded under similar experimental conditions for Nacl, NaF, NaF(T) and NaF:K(T) after subjecting them to standard beta dose of 2.1 X 10^3 rads. Typical glow curves exhibited by them are presented in figure 42. It is significant to note that the NaF:K(T) specimen displays the TL glow curve with the intensity which is comparable with that of dosimetry grade Nacl reported by other people.

Figures 43A, B, & C

In another experiments, TL output of NaF:K(T) phosphor have been recorded with the filters of three different regions, namely ; 320-400 nm, 400-480nm, and 480--560nm, under identical experimental conditions to find out the wavelength of TL emission around 165° C. It is clearly observed from figure 43 B that NaF:K(T) phosphor exhibits substaintial TL output in 400 - 480nm region.

Figure 44

In order to calculate the order of Kinetics, activation energy and frequency factor of the 165° C peak through peak shape method, the glow curve of NaF:K(T) specimen, have been examined systematically under the similar experimental conditions and presented in figure 44. The details of the parameters obtained for 165° C glow peak are described in discussion chapter.

FIGURE-1A: TL GLOW CURVES OF NaF

As-obtained from solution without exposure to beta radiation.

Curves: 1 ___________ 1^{st} Thermal cycle.

2 - - - - - 2^{nd} Thermal cycle.

3 .... 3^{rd} Thermal cycle.

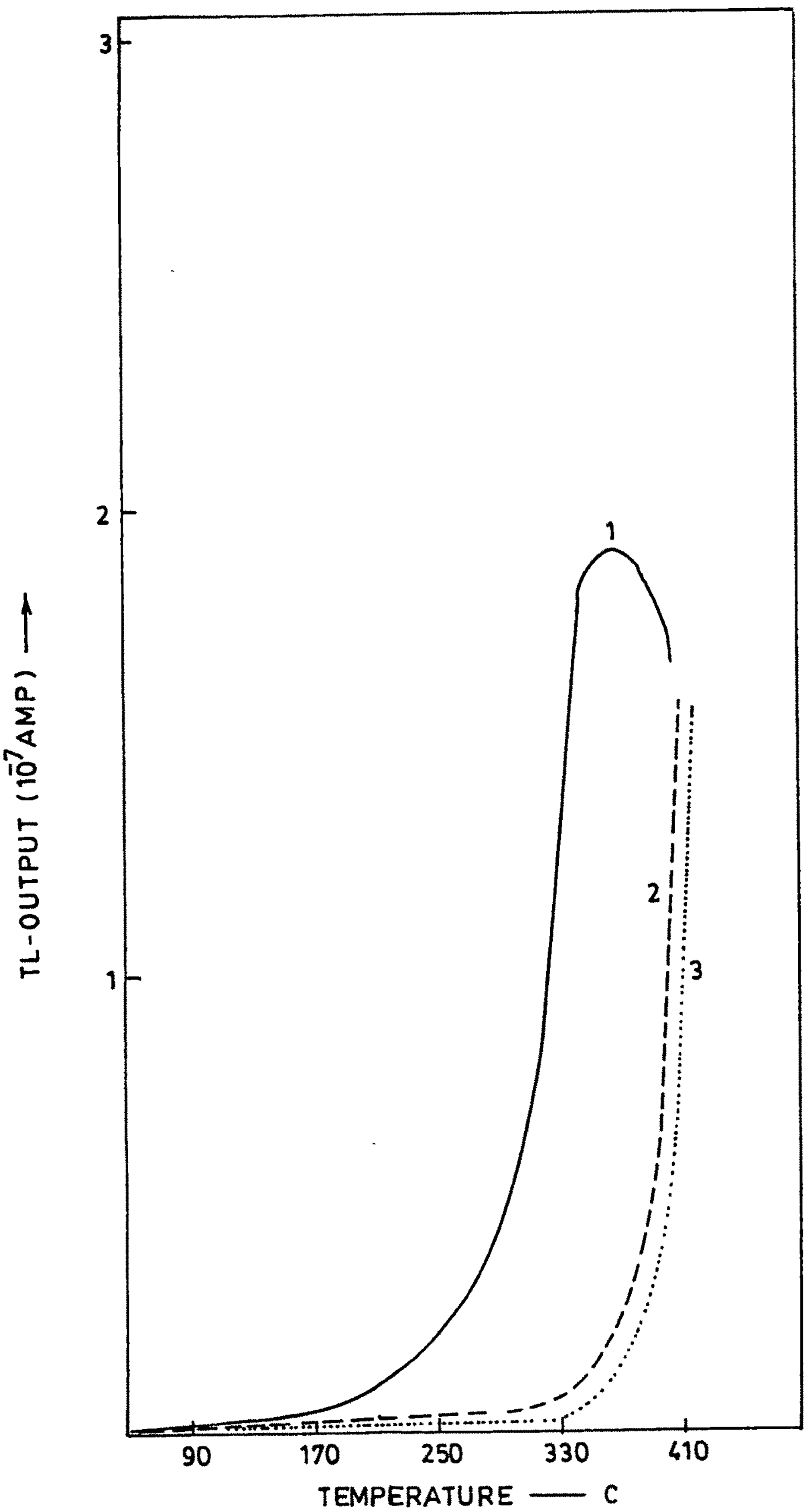


FIG. 1A

FIGURE-1B: TL GLOW CURVES OF untreated and pre-heat reated NaF without exposure to beta radiation.

I : NaF As-obtained from solution.

II : NaF Annealed and air-quenched from 200°C.

III : NaF Annealed and air-quenched from 400°C.

IV : NaF Annealed and air-quenched from 600°C.

Curves: 1 ____________ 1^{st} Thermal cycle.

2 - - - - - 2^{nd} Thermal cycle.

3 .... 3^{rd} Thermal cycle.

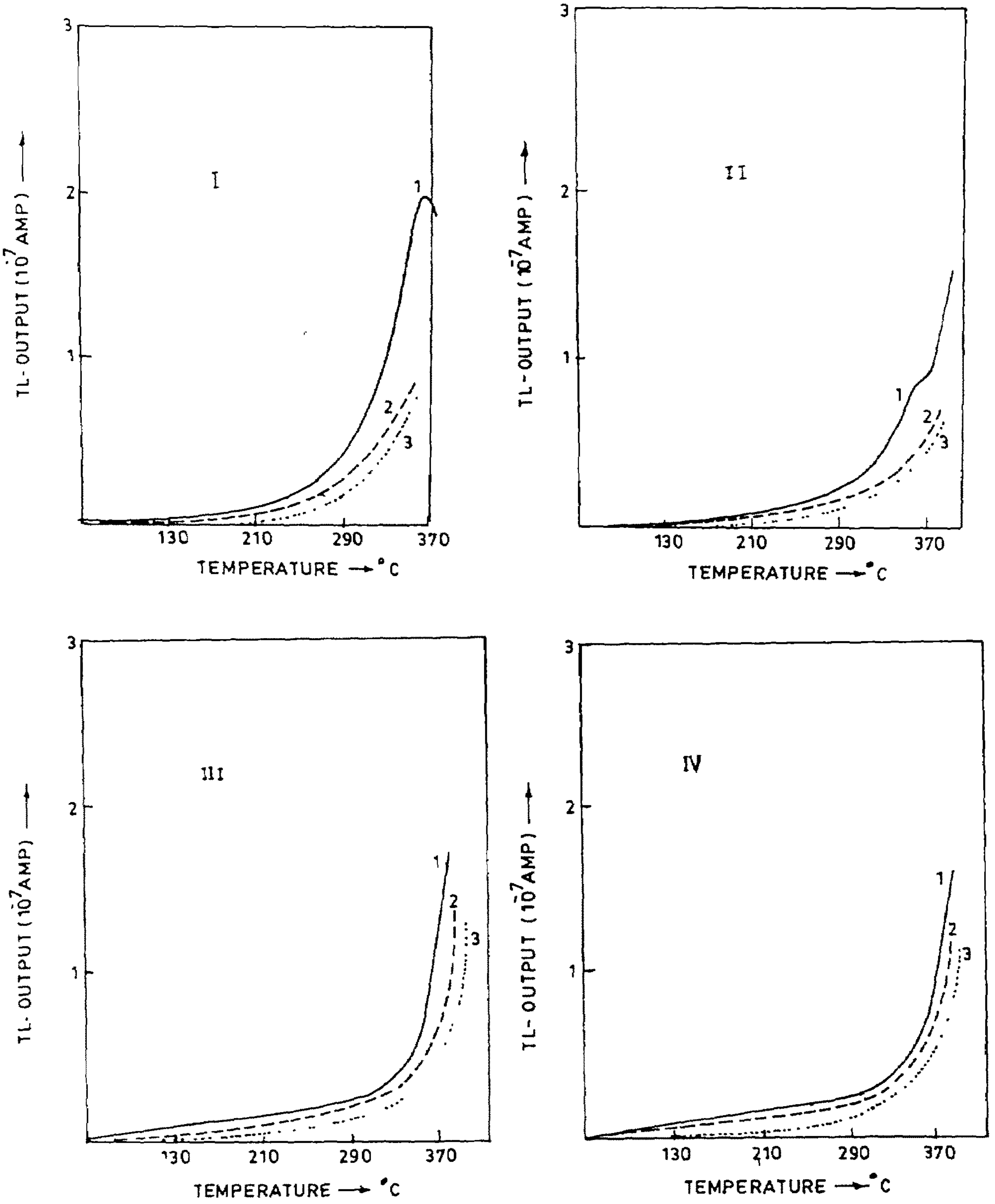


FIG. 1 B

FIGURE-2: TL GLOW CURVES OF NaF

As-obtained from solution.

Beta dose: 2.1×10^3 rads.

The scale on the right relates to peaks 300 and 360°C.

Curves: 1 ________ 1^{st} Thermal cycle.

2 - - - - - 2^{nd} Thermal cycle.

3 .... 3^{rd} Thermal cycle.

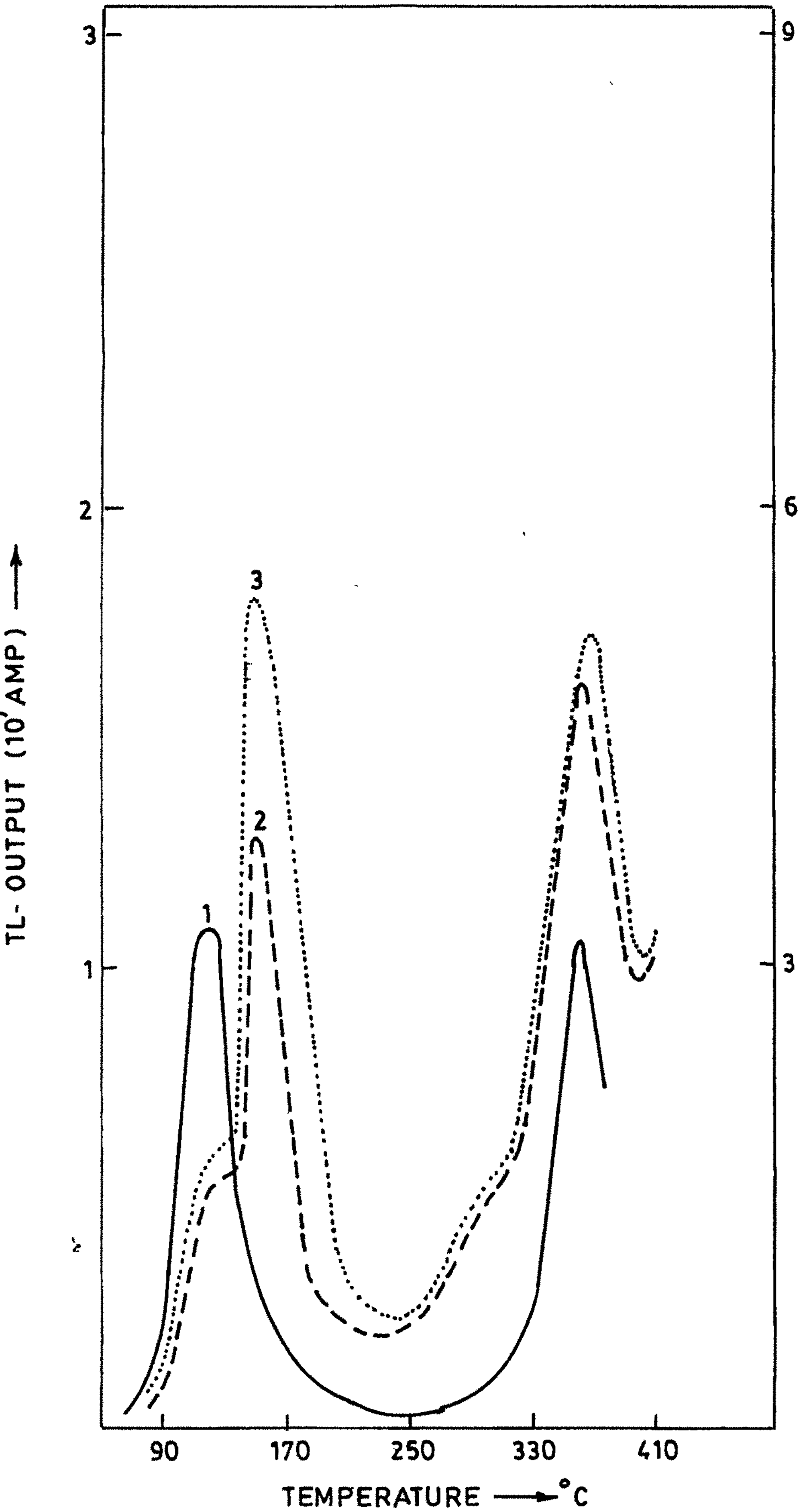


FIG. 2

FIGURE-3: TL GLOW CURVES OF NaF

Annealed and air-quenched from 200°C.

Beta dose 2.1×10^3 rads.

The scale on the right relates to peaks 300 and 360°C.

Curves: 1 ________ 1^{st} Thermal cycle.

2 - - - - - 2^{nd} Thermal cycle.

3 .... 3^{rd} Thermal cycle.

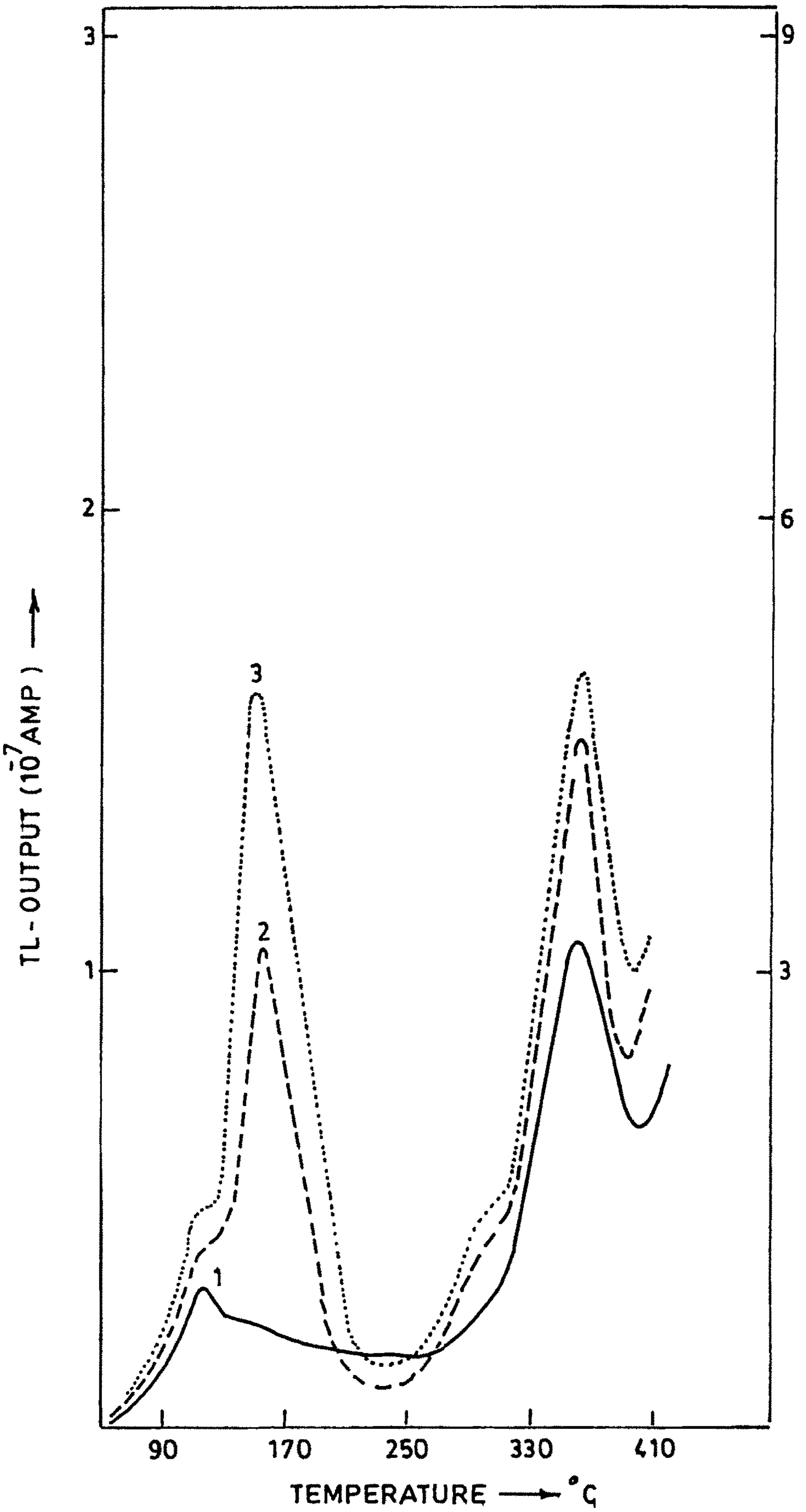


FIG. 3

FIGURE-4 TL GLOW CURVES OF NaF

Annealed and air-quenched from 400°C

Beta dose $2.1x10^3$ rads.

The scale on the right relates to peaks 300 and 360°C.

Curves: 1 ________ 1st Thermal cycle.

2 - - - - - 2nd Thermal cycle.

3 .... 3rd Thermal cycle.

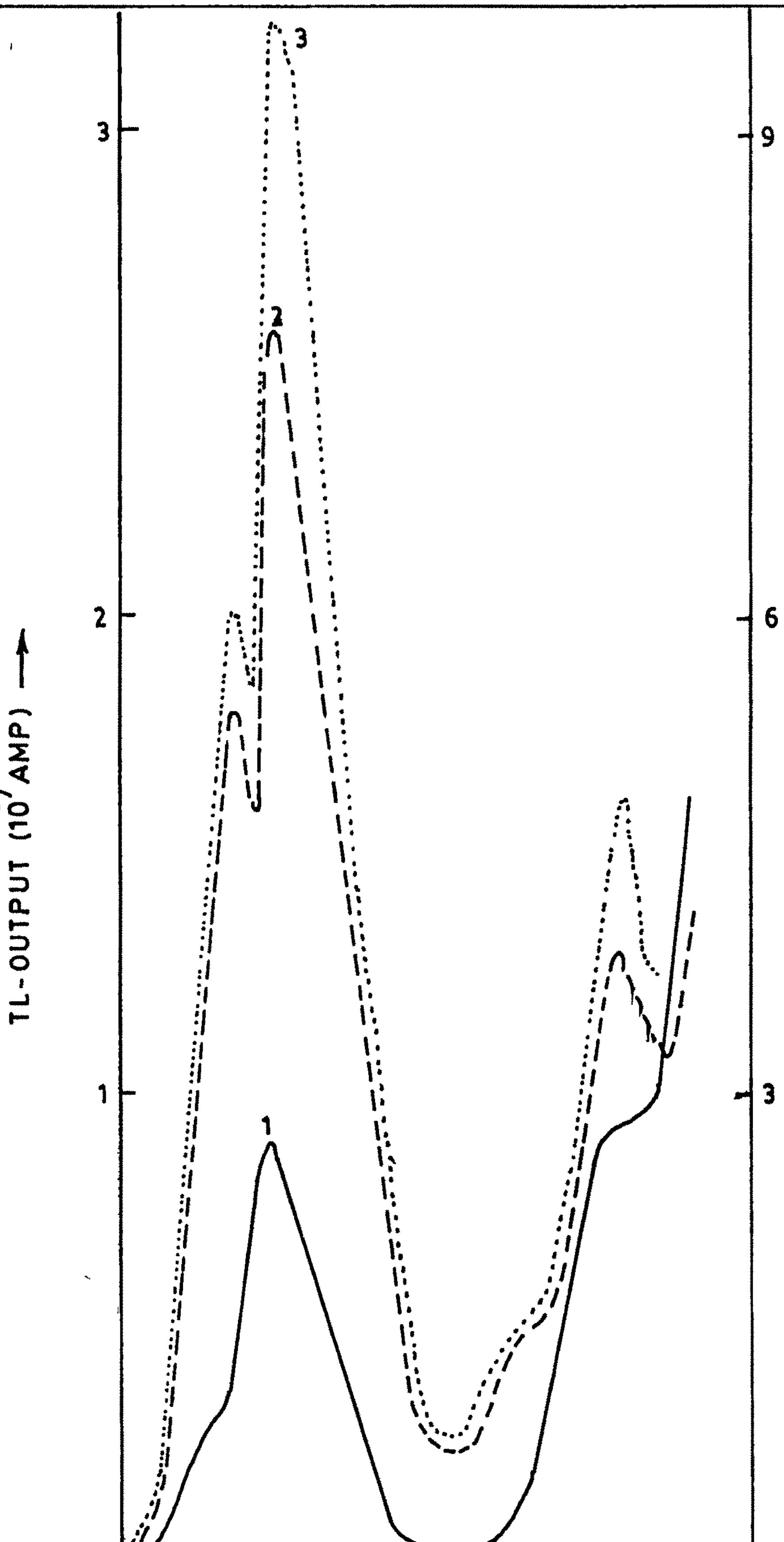


FIG. 4

FIGURE-5: TL GLOW CURVES OF NaF

Annealed and air-quenched from 600°C.

Beta dose 2.1×10^3 rads.

Curves: 1 ____________ 1st Thermal cycle.

2 - - - - - 2nd Thermal cycle.

3 .... 3rd Thermal cycle.

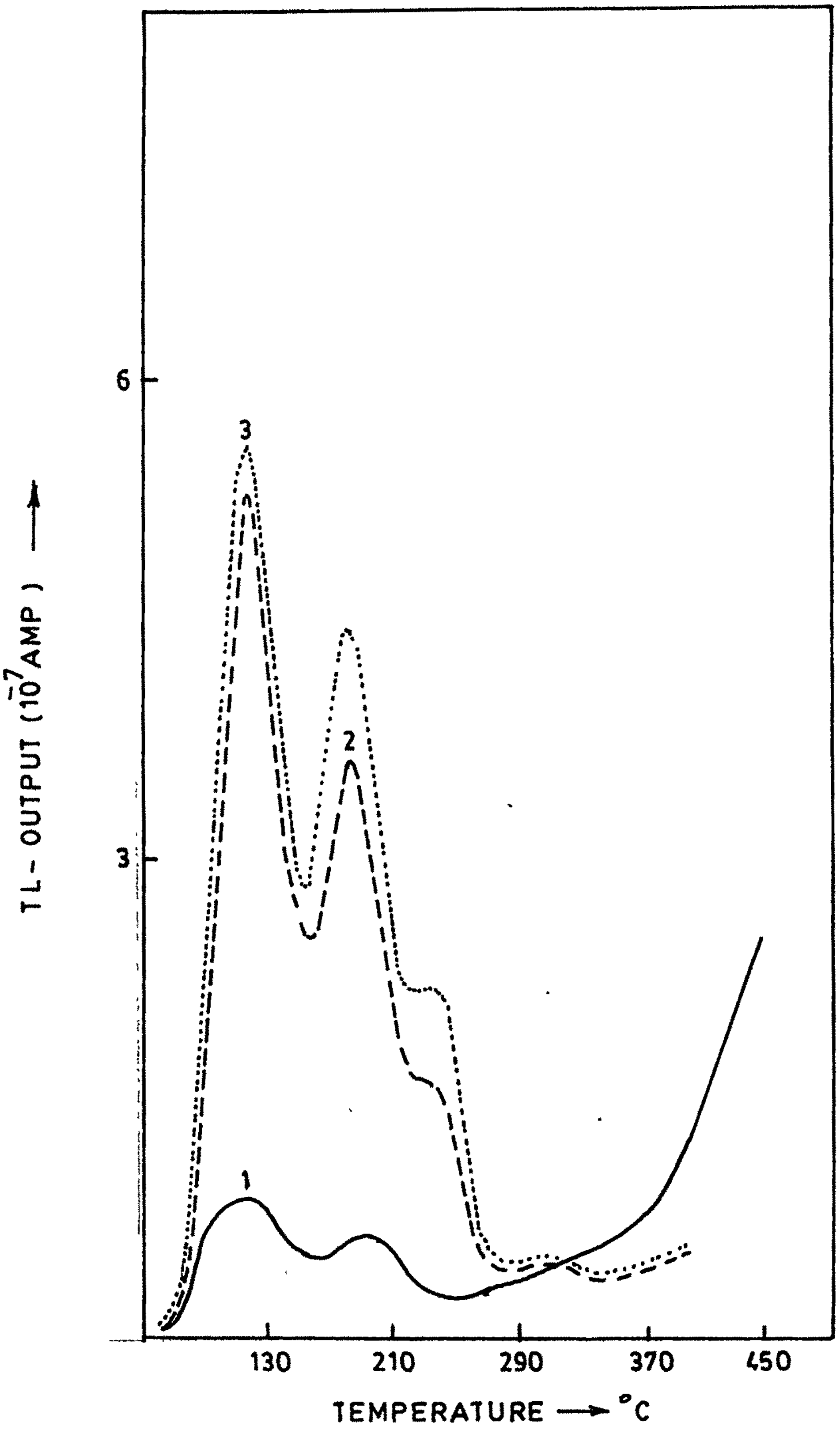


FIG. 5

FIGURE-6: TL GLOW CURVES OF NaF:K (200 ppm)

As-obtained from solution.

Beta dose: 2.1×10^3 rads.

Curves: 1 ________ 1st Thermal cycle.

2 - - - - - 2nd Thermal cycle.

3 .... 3rd Thermal cycle.

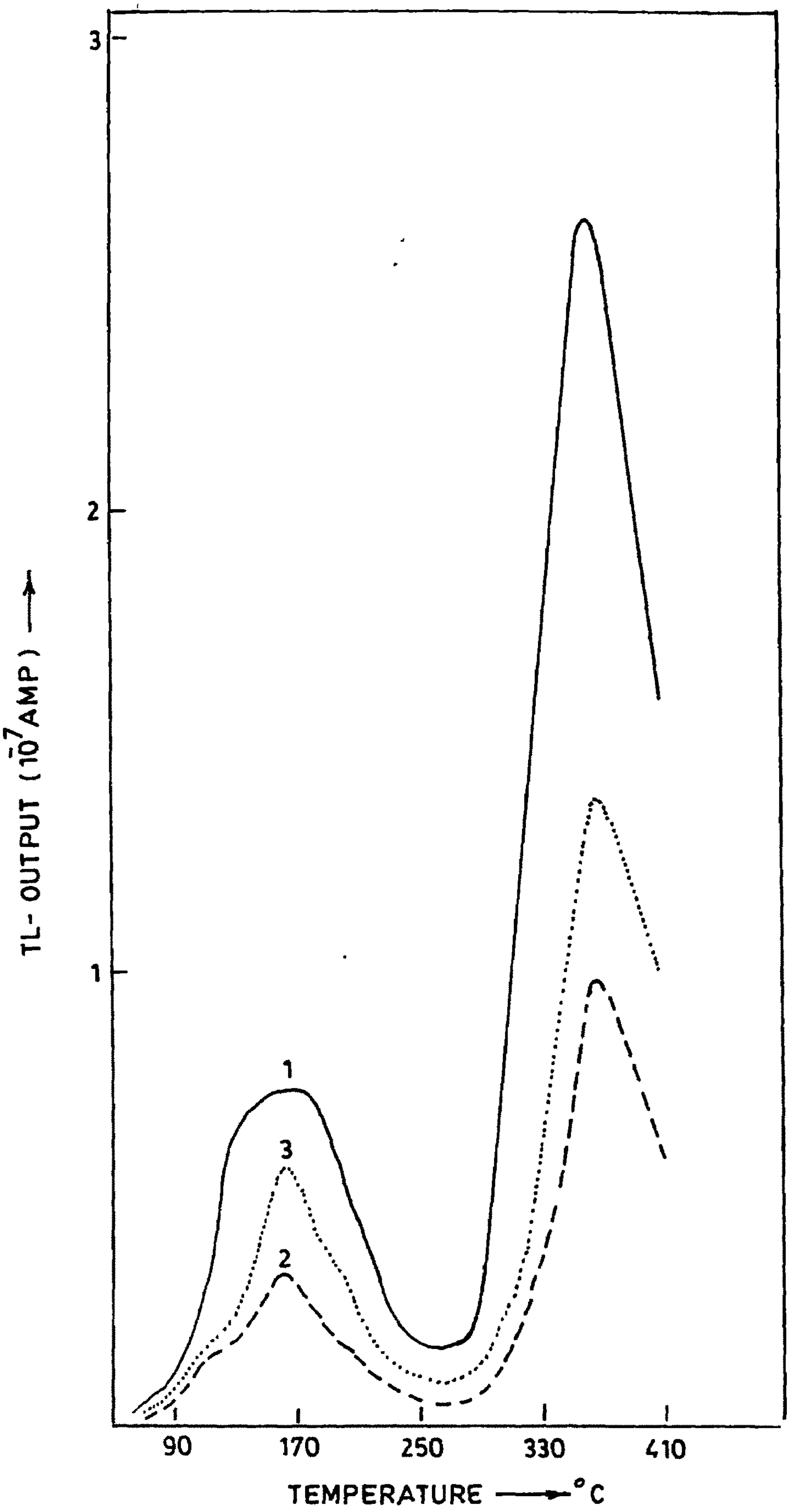


FIG. 6

FIGURE-7: TL GLOW CURVES OF NaF:K (200 ppm)

Annealed and air-quenched from 200°C.

Beta dose: 2.1×10^3 rads.

Curves: 1 ___________ 1st Thermal cycle.

2 - - - - - 2nd Thermal cycle.

3 .... 3rd Thermal cycle.

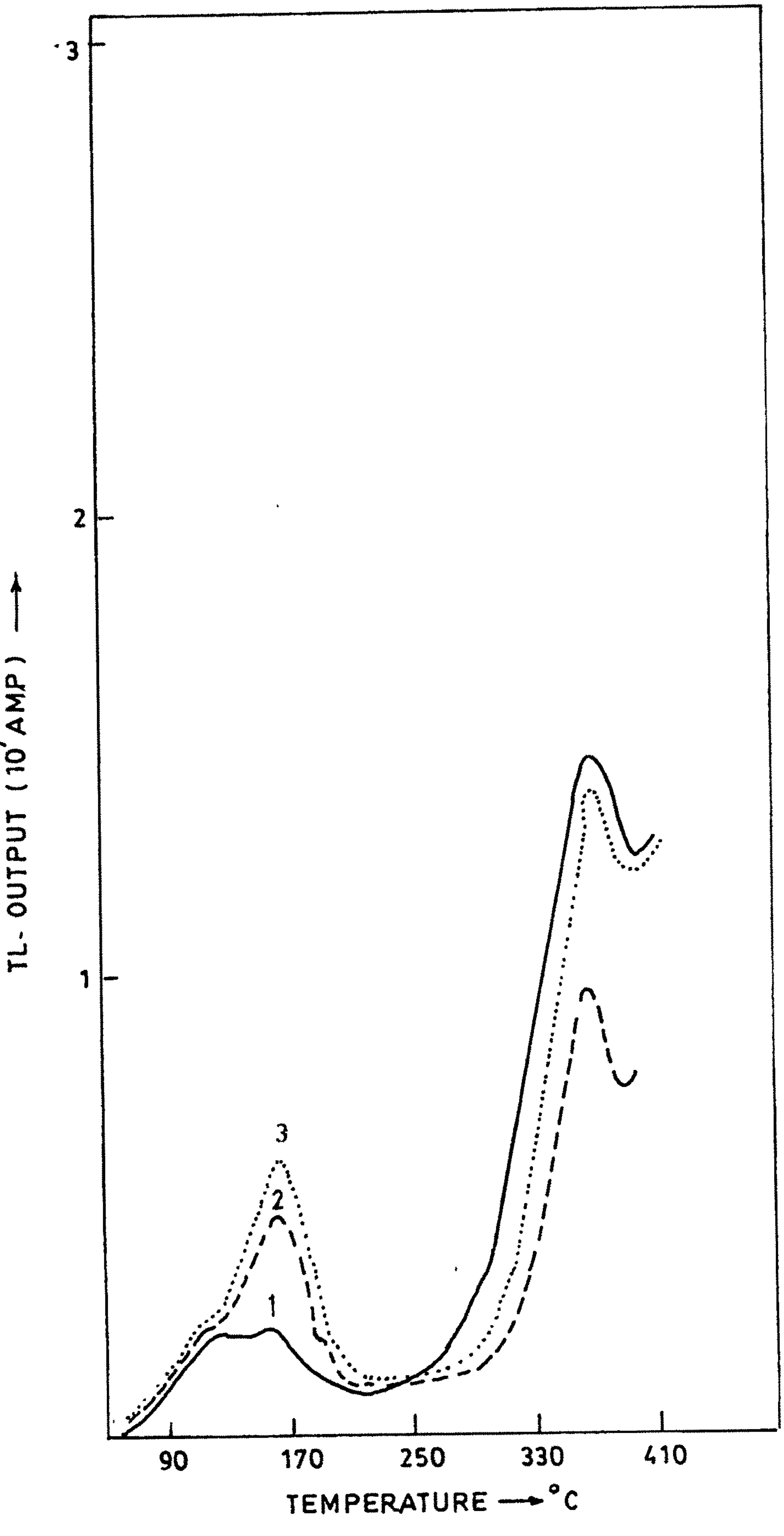


FIG. 7

FIGURE-8: TL GLOW CURVES OF NaF:K (200 ppm)

Annealed and air-quenched from 400°C.

Beta dose: 2.1×10^3 rads.

Curves: 1 ________ 1st Thermal cycle.

2 - - - - - 2nd Thermal cycle.

3 .... 3rd Thermal cycle.

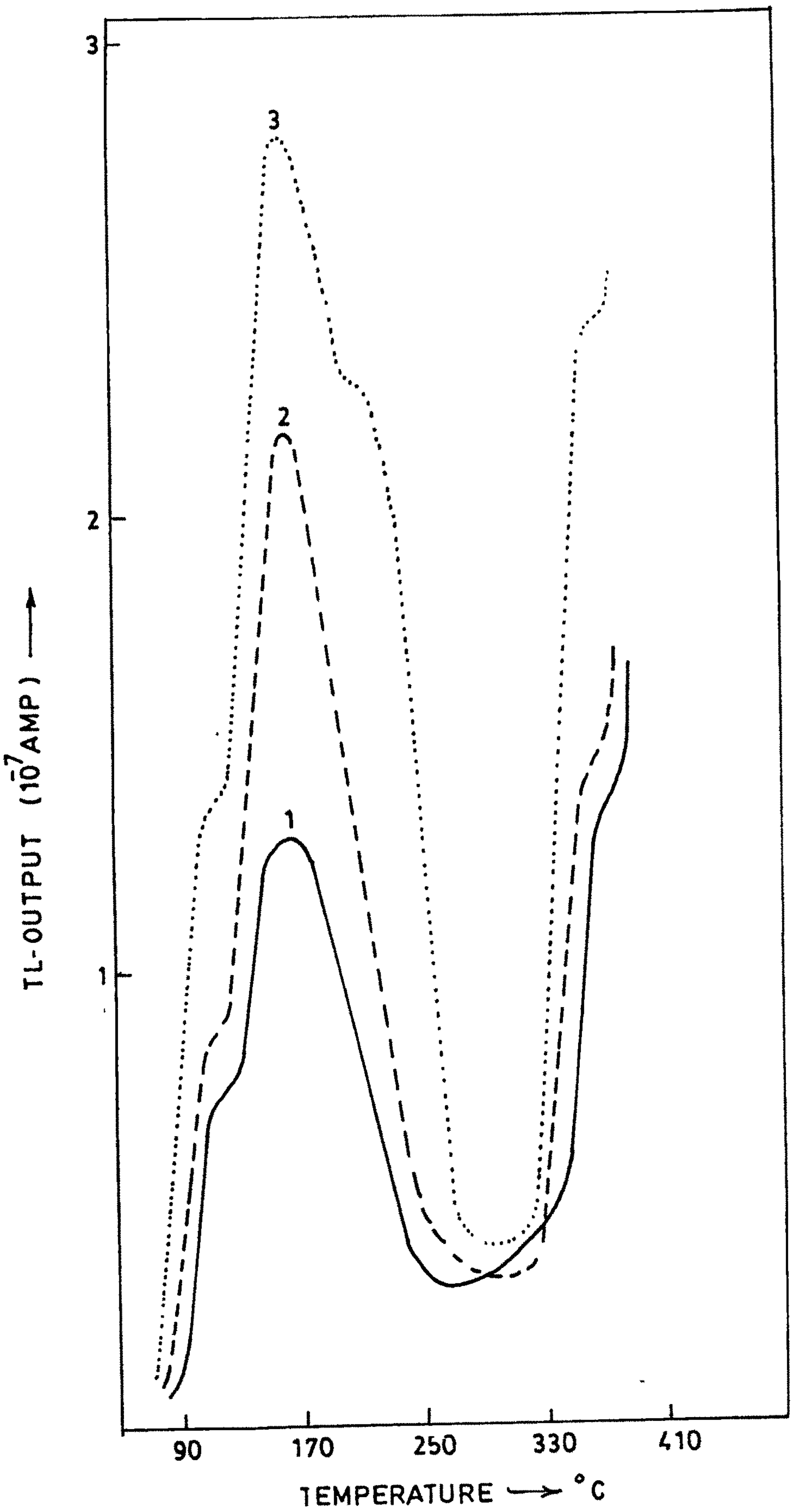


FIG. 8

FIGURE-9: TL GLOW CURVES OF NaF:K (200 ppm)

Annealed and air-quenched from 600°C.

Beta dose: 2.1×10^3 rads.

Curves: 1 ________ 1st Thermal cycle.

2 - - - - - 2nd Thermal cycle.

3 .... 3rd Thermal cycle.

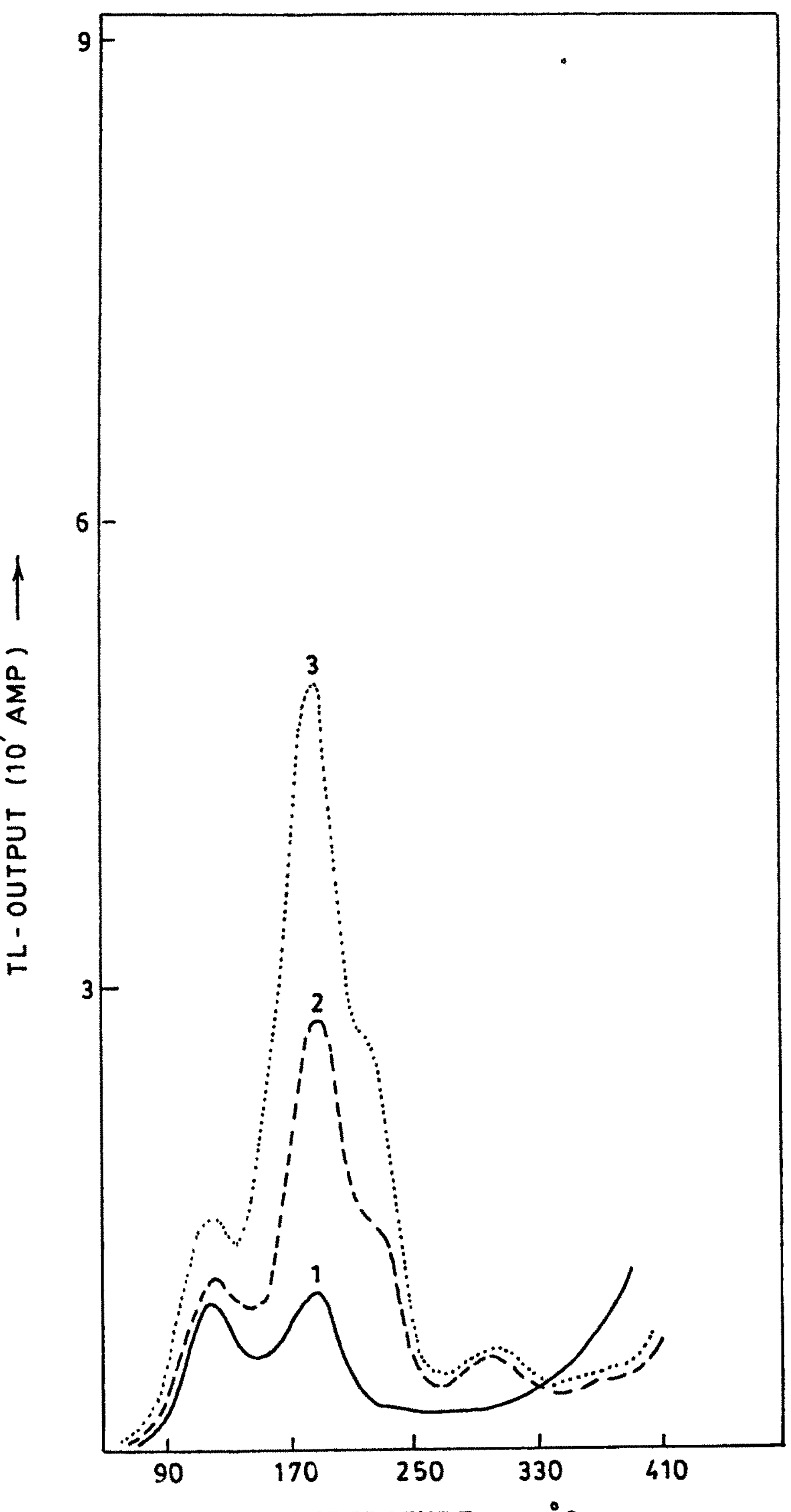


FIG. 9

FIGURE-10: TL GLOW CURVES OF NaF:K (500 ppm)

As-obtained from solution.

Beta dose: 2.1×10^3 rads.

Curves: 1 __________ 1^{st} Thermal cycle.

2 - - - - - 2^{nd} Thermal cycle.

3 .... 3^{rd} Thermal cycle.

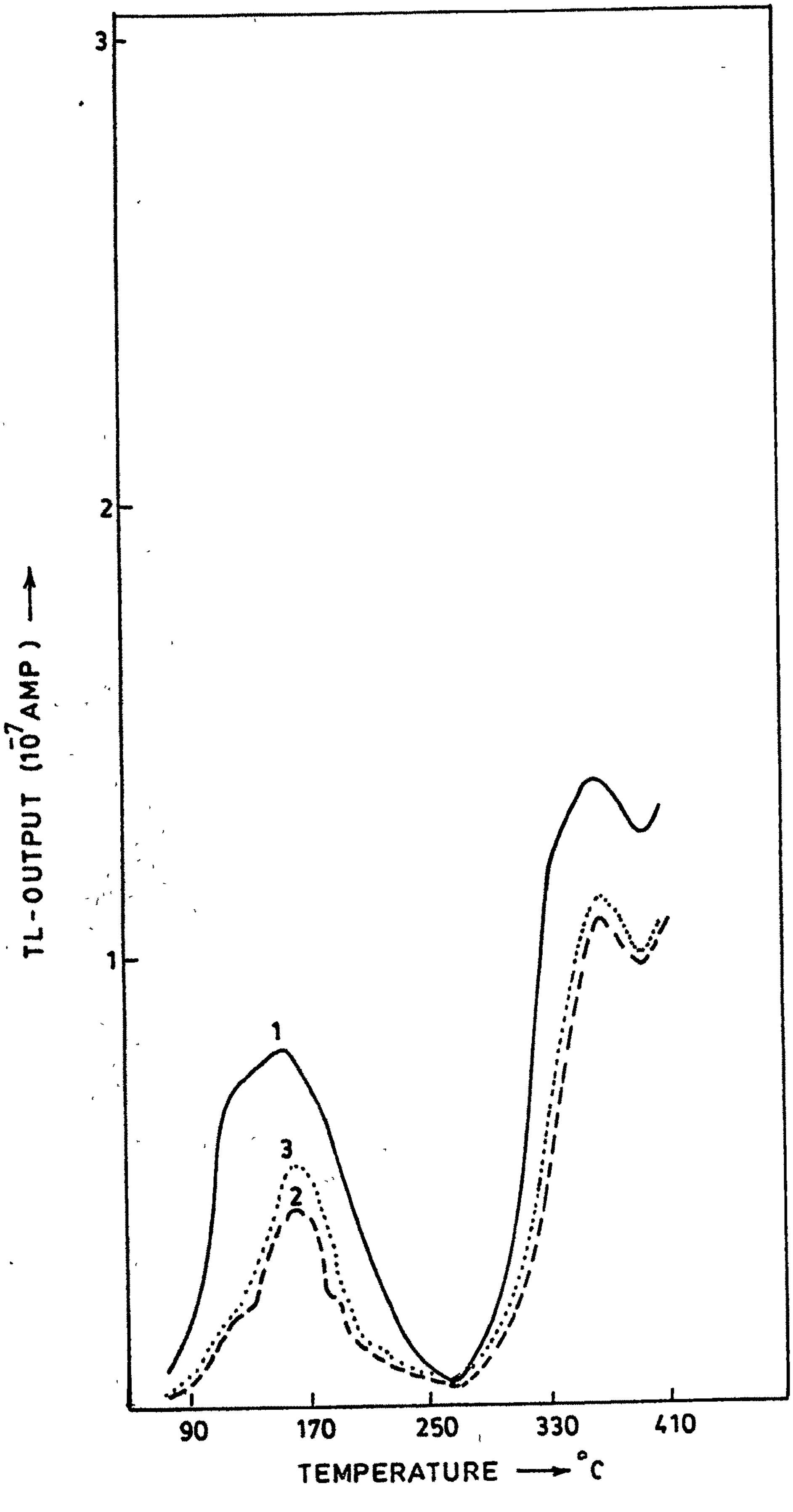


FIG. 10

FIGURE-11: TL GLOW CURVES OF NaF:K (500 ppm)

Annealed and air-quenched from 200°C.

Beta dose: 2.1×10^3 rads.

Curves: 1 __________ 1^{st} Thermal cycle.

2 - - - - - 2^{nd} Thermal cycle.

3 .... 3^{rd} Thermal cycle.

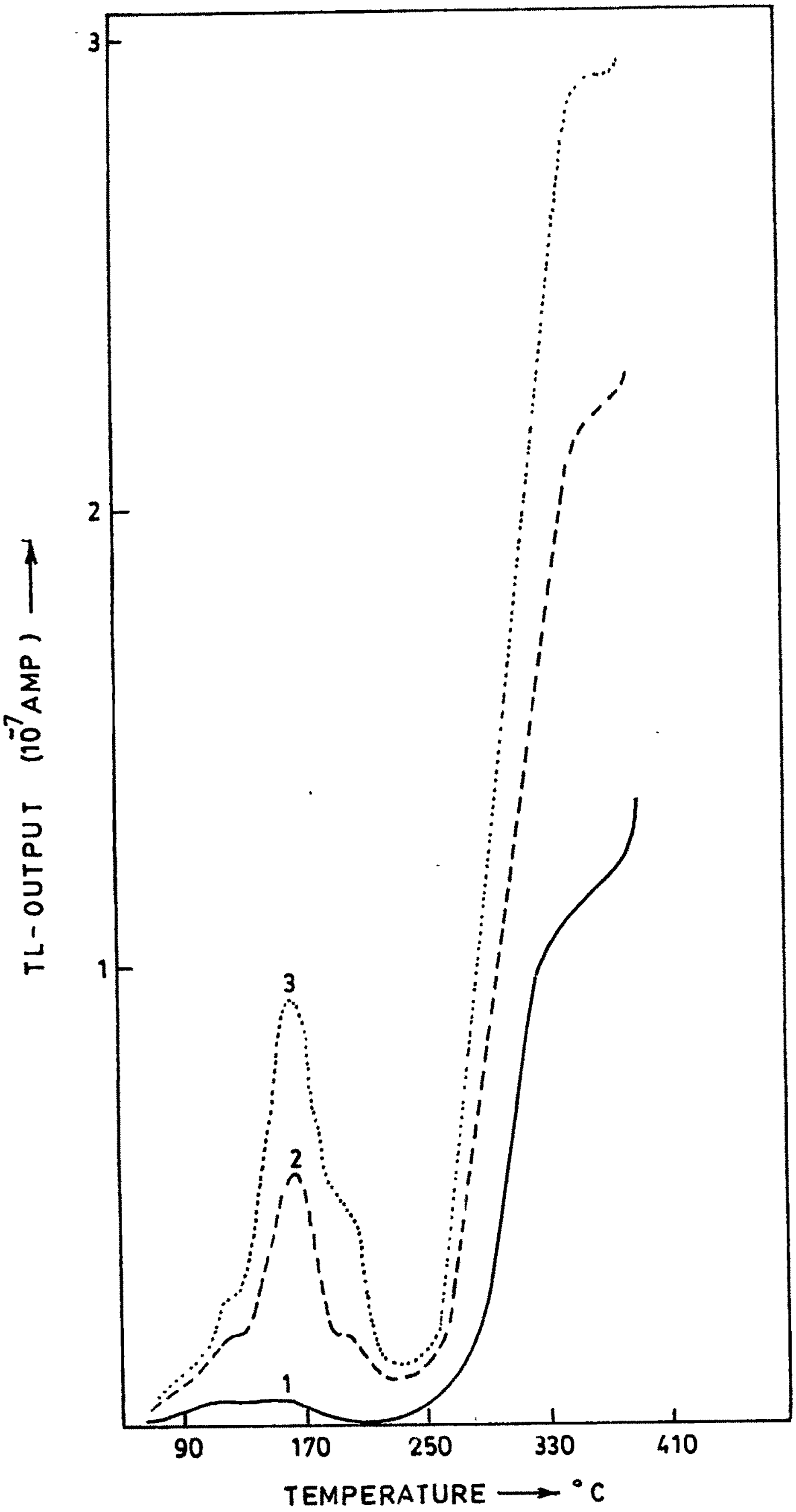


FIG. 11

FIGURE-12: TL GLOW CURVES OF NaF:K (500 ppm)

Annealed and air-quenched from 400°C.

Beta dose: 2.1×10^3 rads.

Curves: 1 ________ 1st Thermal cycle.

2 - - - - - 2nd Thermal cycle.

3 .... 3rd Thermal cycle.

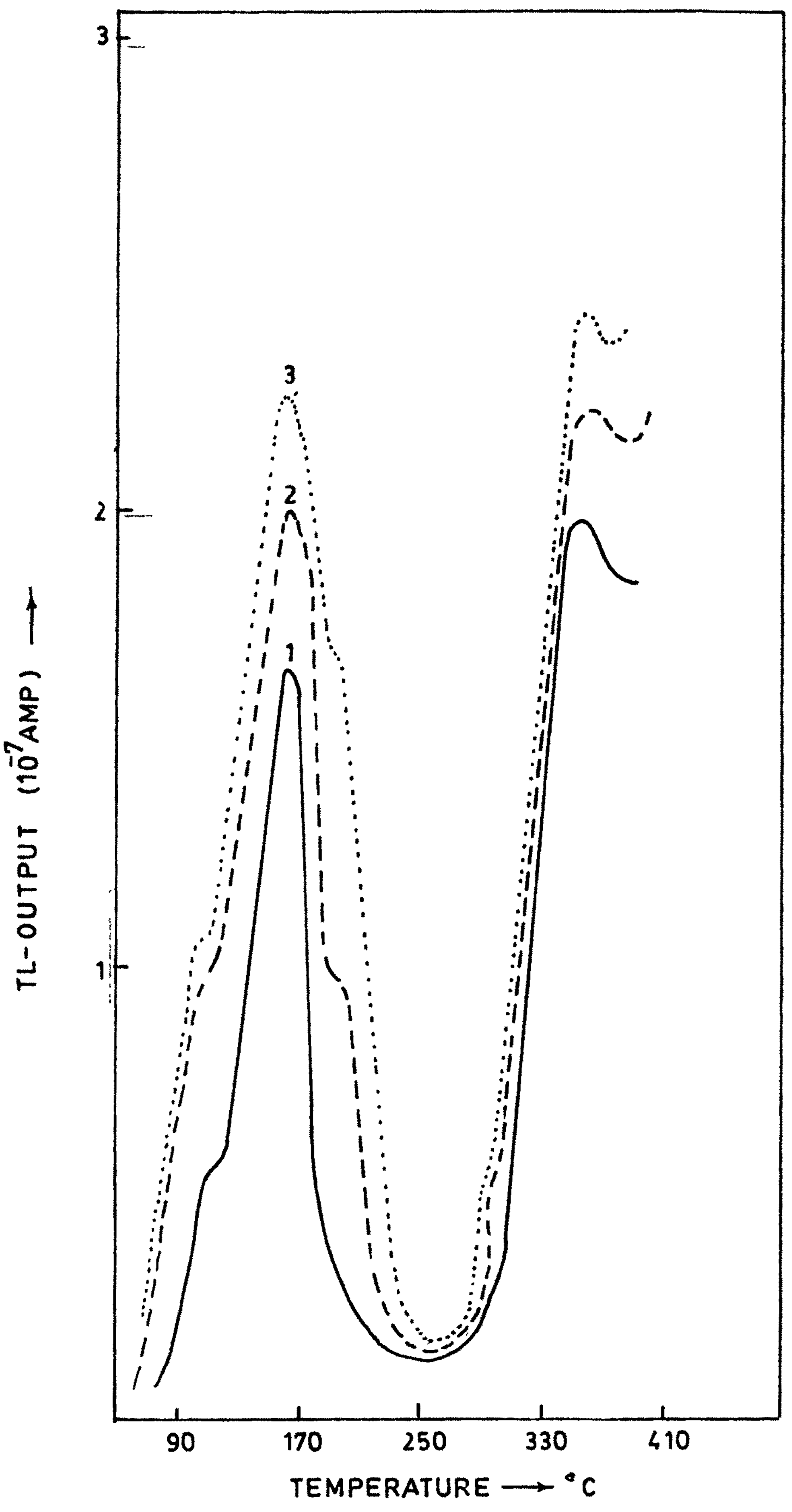


FIG. 12

FIGURE-13: TL GLOW CURVES OF NaF:K (500 ppm)

Annealed and air-quenched from 600°C.

Beta dose: 2.1×10^3 rads.

Curves: 1 ____________ 1^{st} Thermal cycle.

2 - - - - - 2^{nd} Thermal cycle.

3 .... 3^{rd} Thermal cycle.

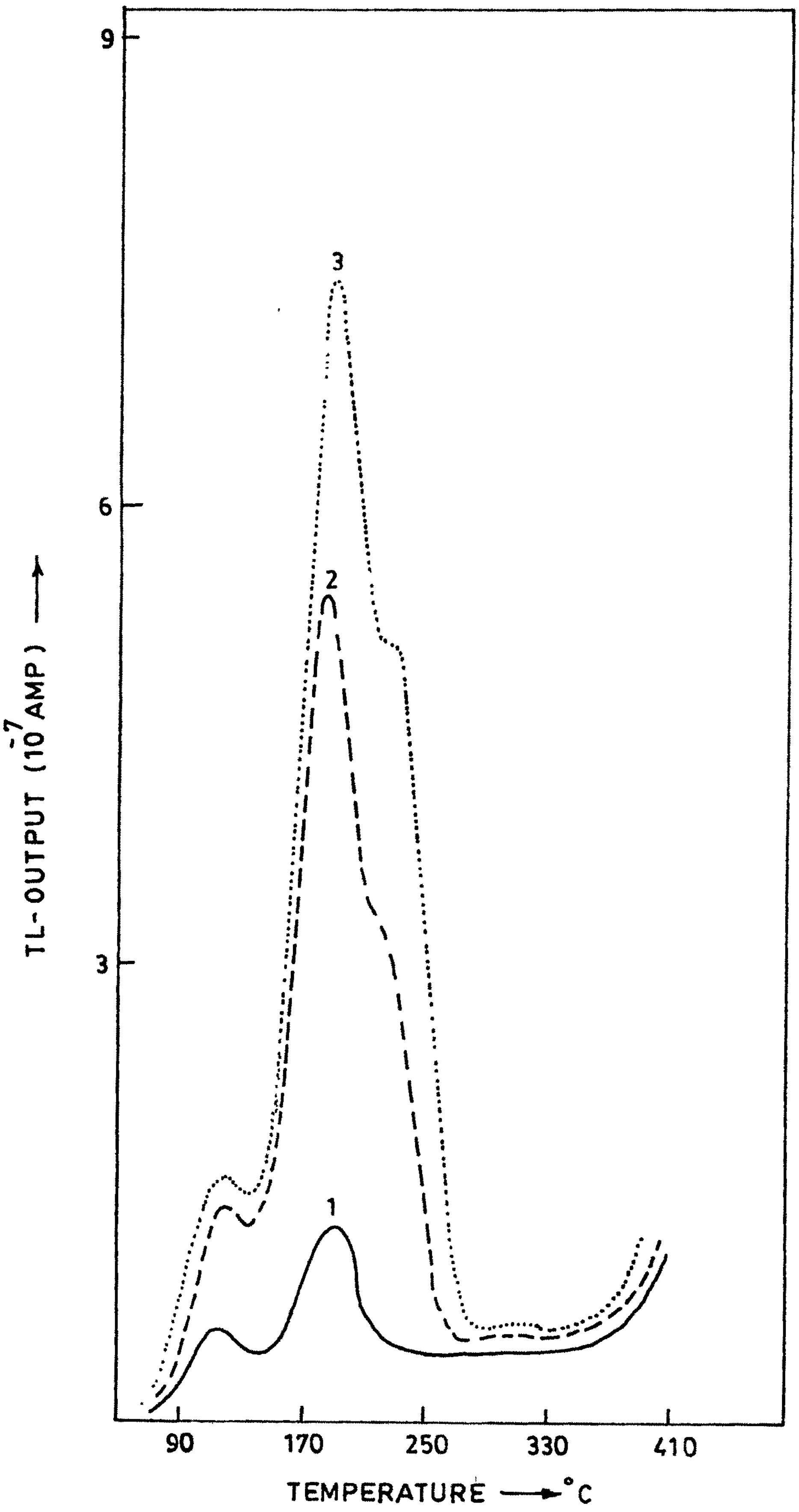


FIG. 13

FIGURE-14: TL GLOW CURVES OF NaF:K (1000 ppm)

As-obtained from solution.

Beta dose: 2.1×10^3 rads.

The scale on the right relates to peaks

360°C.

Curves: 1 __________ 1^{st} Thermal cycle.

2 - - - - - 2^{nd} Thermal cycle.

3 .... 3^{rd} Thermal cycle.

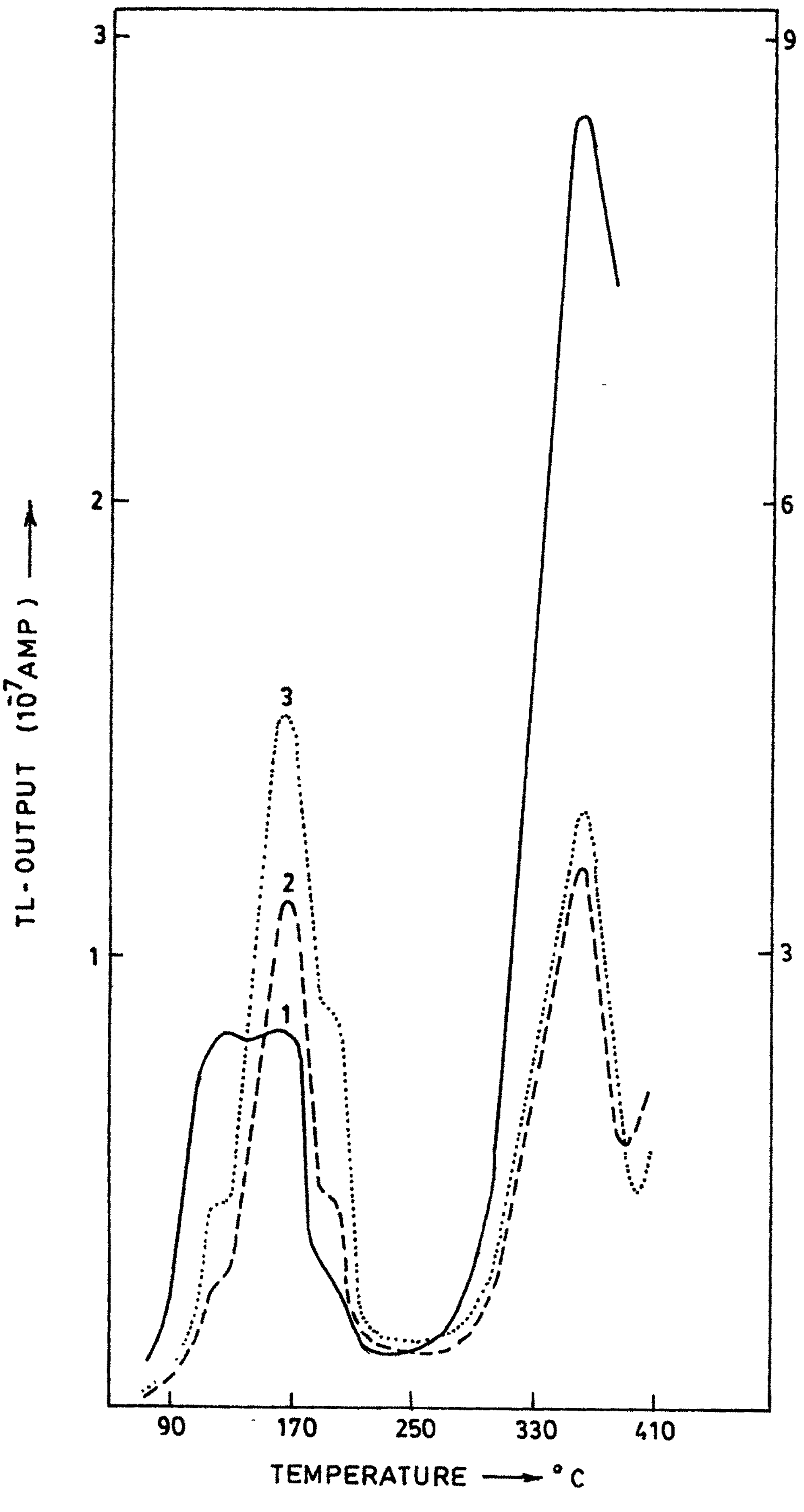


FIG. 14

FIGURE-15: TL GLOW CURVES OF NaF:K (1000 ppm)

Annealed and air-quenched from 200°C.

Beta dose: 2.1×10^3 rads.

The scale on the right relates to peaks 360°C.

Curves: 1 ___________ 1^{st} Thermal cycle.

2 - - - - - - 2^{nd} Thermal cycle.

3 .... 3^{rd} Thermal cycle.

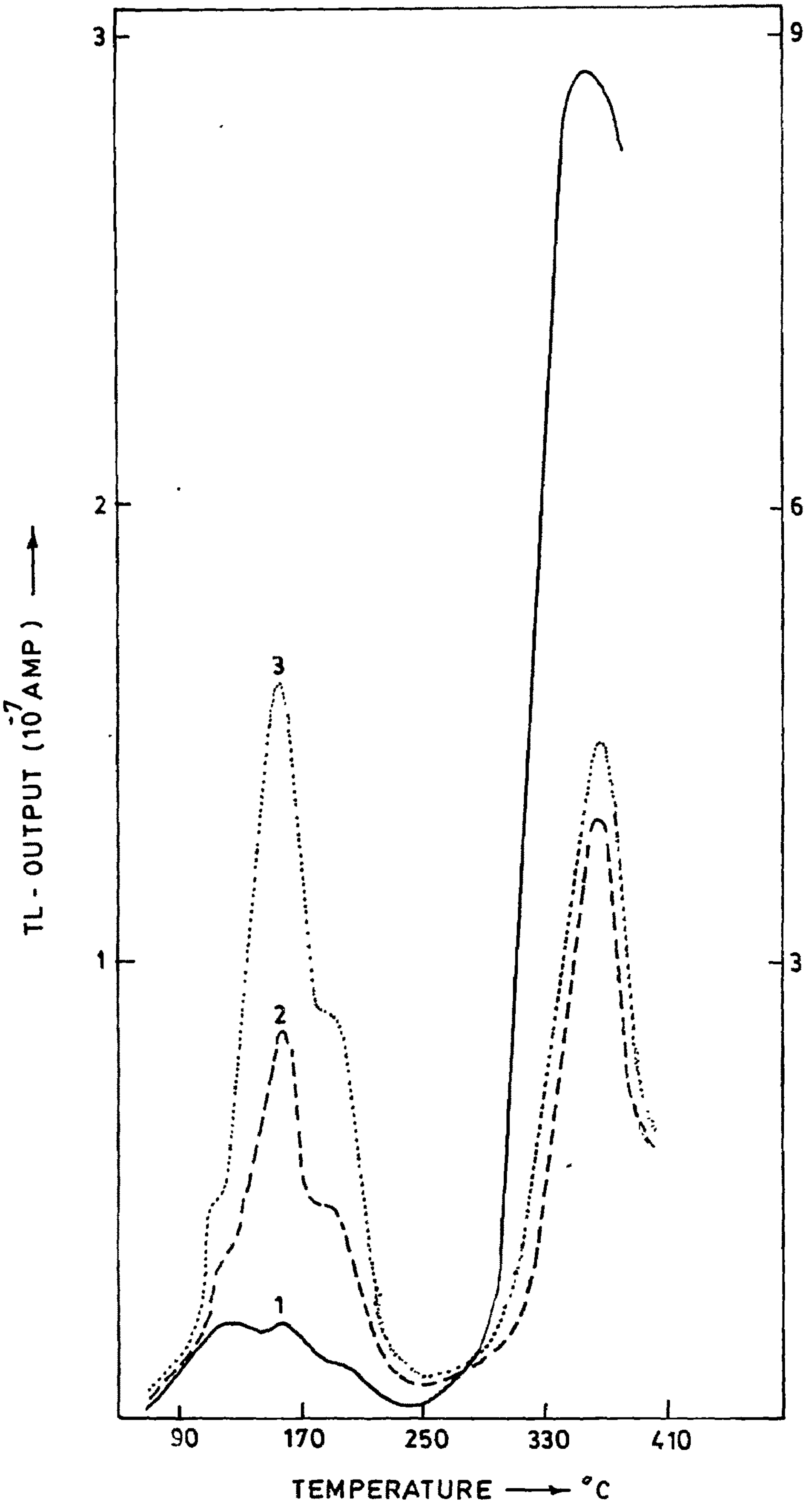


FIG. 15

FIGURE-16: TL GLOW CURVES OF NaF:K (1000 ppm)

Annealed and air-quenched from 400°C.

Beta dose: 2.1×10^3 rads.

The scale on the right relates to peaks 360°C.

Curves: 1 ________ 1^{st} Thermal cycle.

2 - - - - - 2^{nd} Thermal cycle.

3 .... 3^{rd} Thermal cycle.

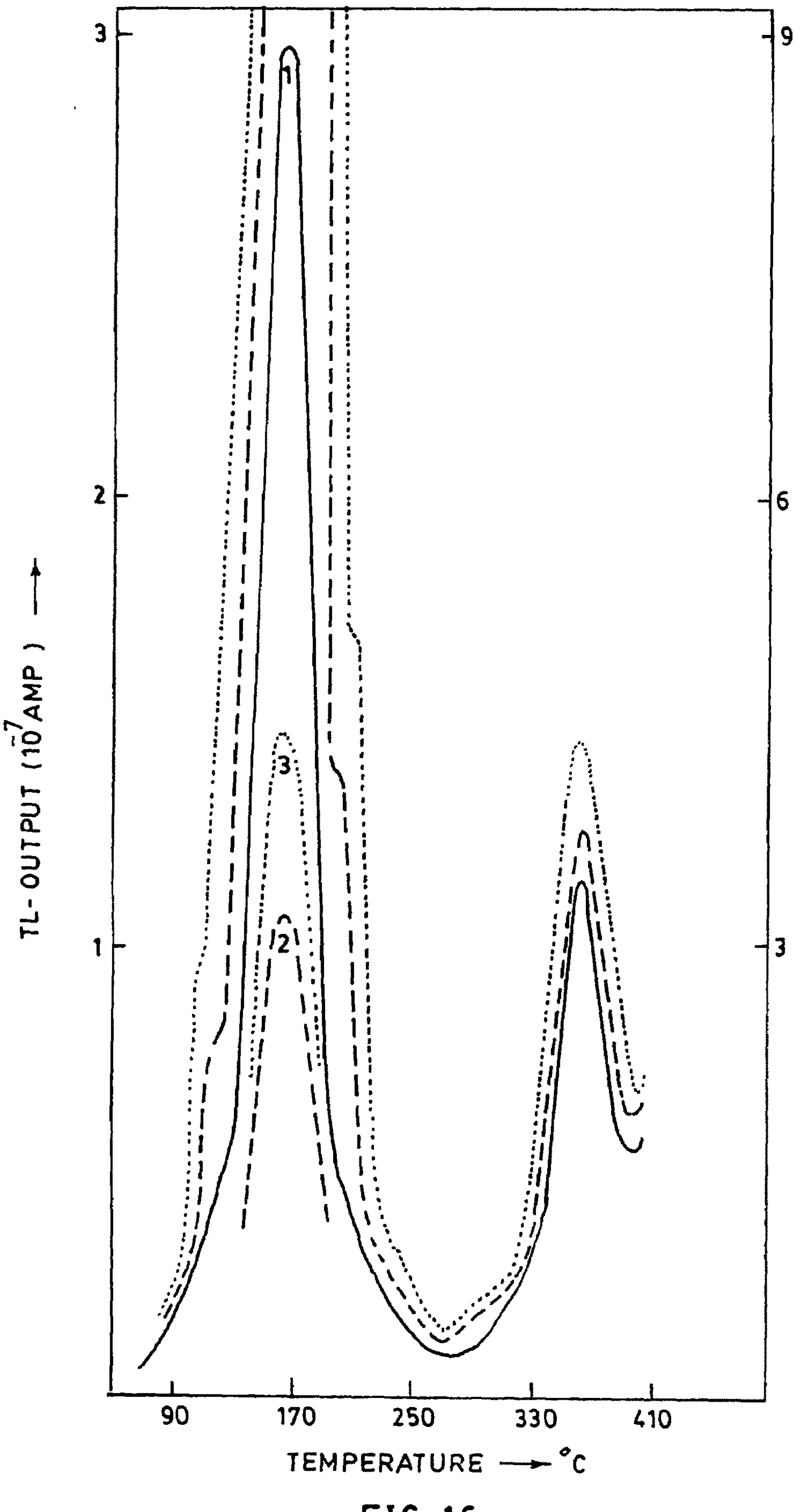


FIG. 16

FIGURE-17: TL GLOW CURVES OF NaF:K (1000 ppm)

Annealed and air-quenched from 600°C.

Beta dose: $2.1x10^3$ rads.

Curves: 1 __________ 1^{st} Thermal cycle.

2 - - - - - 2^{nd} Thermal cycle.

3 .... 3^{rd} Thermal cycle.

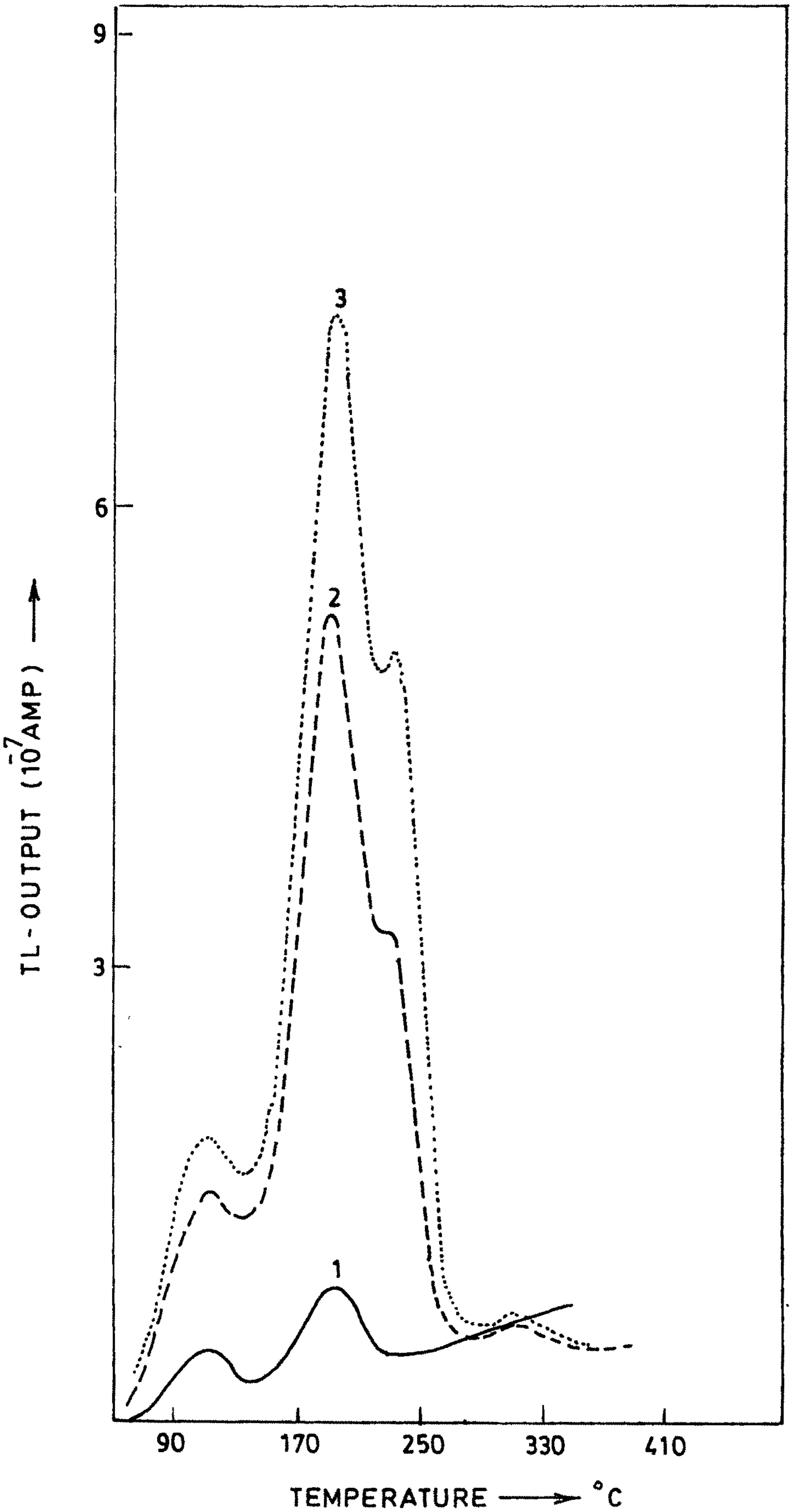


FIG. 17

FIGURE-18: TL GLOW CURVES OF NaF:K (2000 ppm)

As-obtained from solution

Beta dose: 2.1×10^3 rads.

Curves: 1 ________ 1^{st} Thermal cycle.

2 - - - - - 2^{nd} Thermal cycle.

3 .... 3^{rd} Thermal cycle.

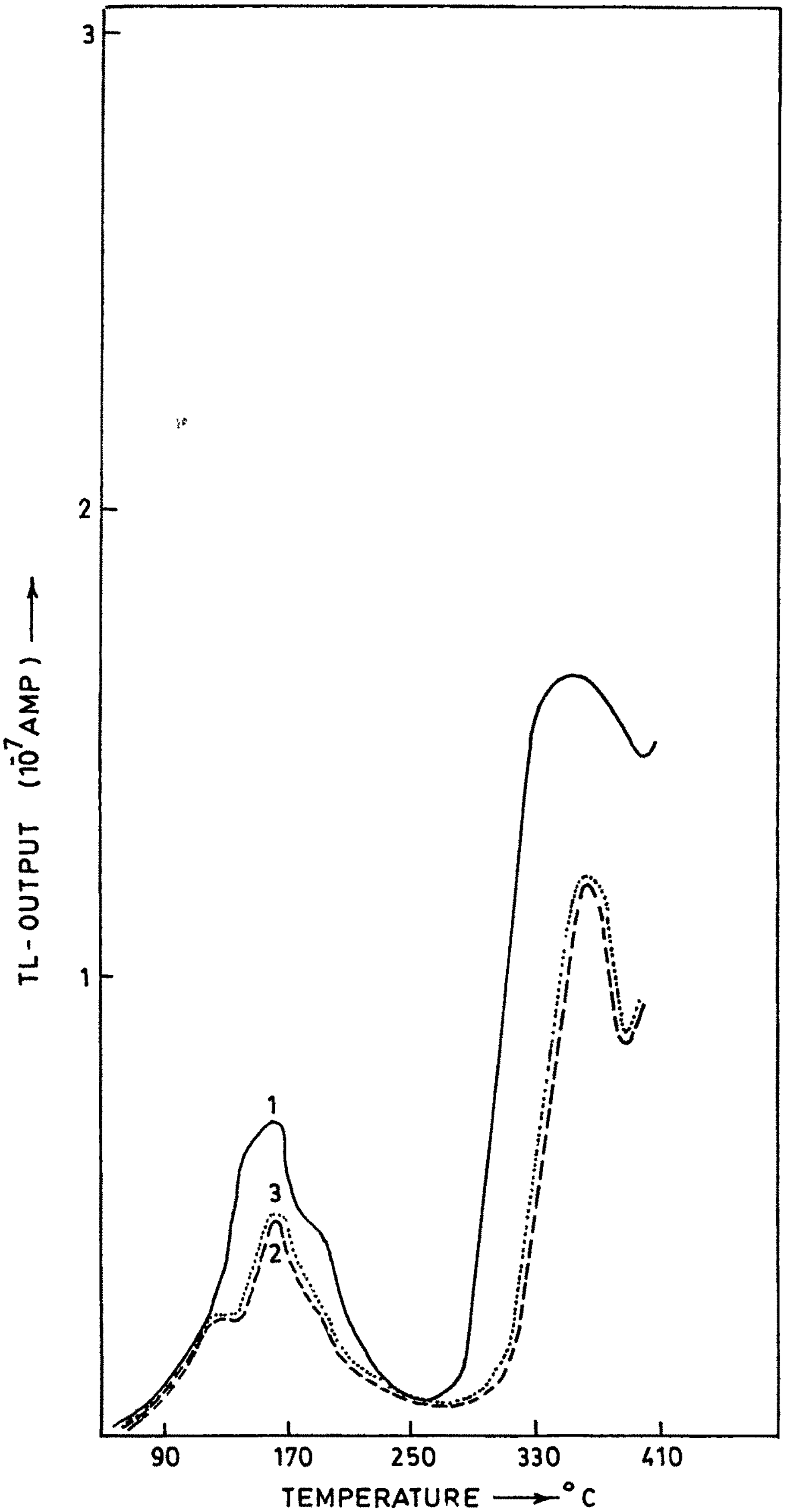


FIG. 18

FIGURE-19: TL GLOW CURVES OF NaF:K (2000 ppm)

Annealed and air-quenched from 200°C.

Beta dose: $2.1x10^3$ rads.

Curves: 1 ________ 1^{st} Thermal cycle.

2 - - - - - 2^{nd} Thermal cycle.

3 .... 3^{rd} Thermal cycle.

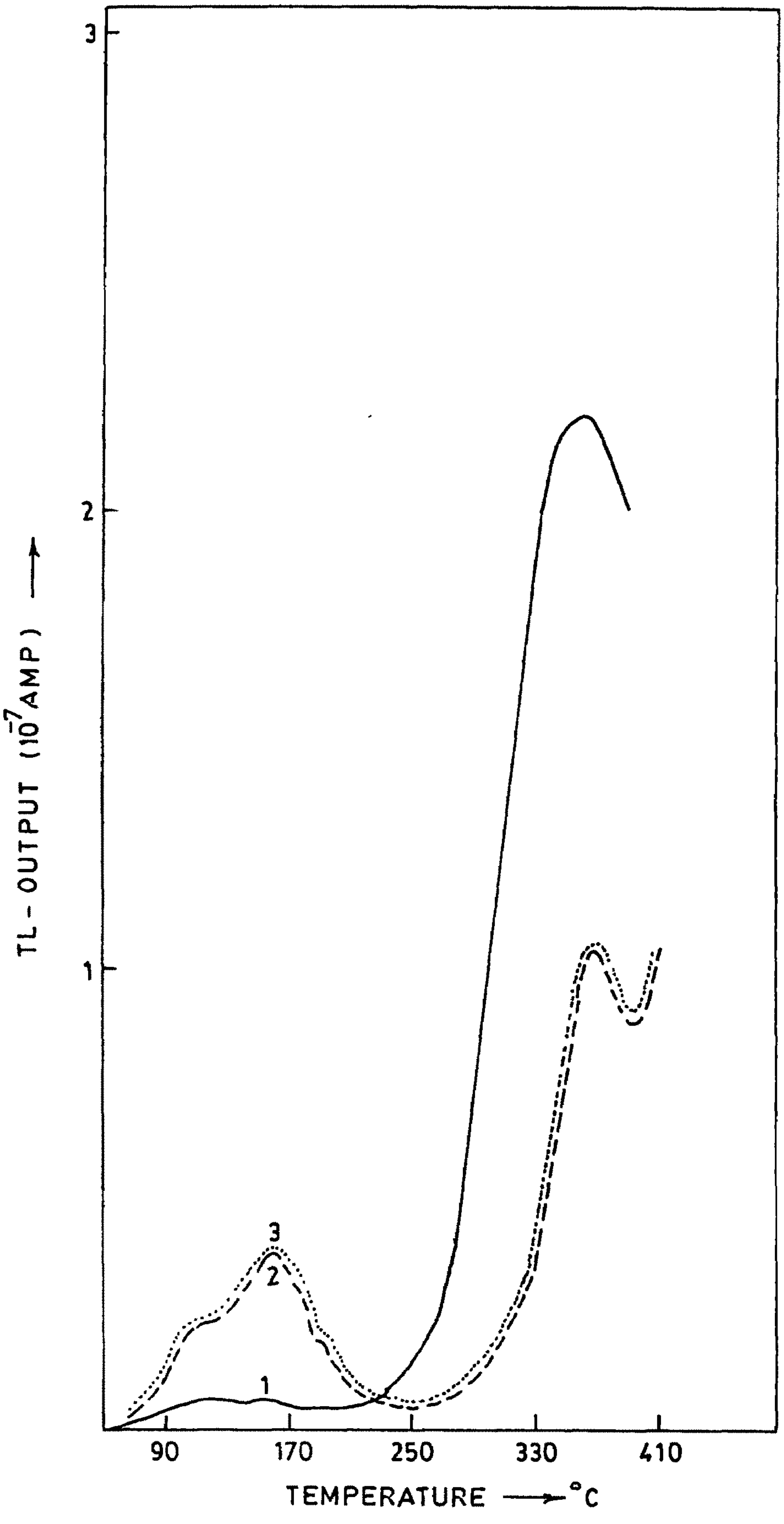


FIG. 19

FIGURE-20: TL GLOW CURVES OF NaF:K (2000 ppm)

Annealed and air-quenched from 400°C.

Beta dose: 2.1×10^3 rads.

Curves: 1 ________ 1^{st} Thermal cycle.

2 - - - - - 2^{nd} Thermal cycle.

3 .... 3^{rd} Thermal cycle.

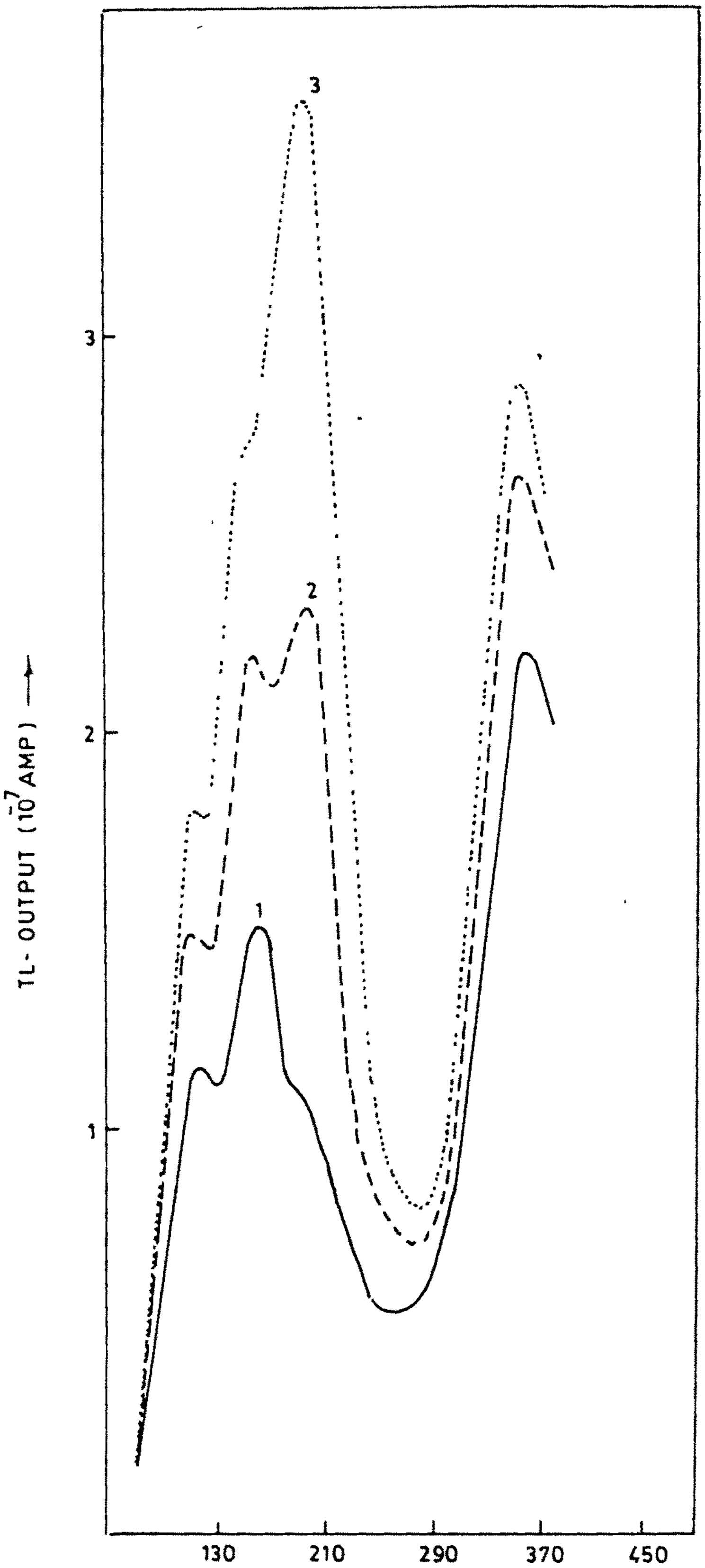


FIG. 20

FIGURE-21: TL GLOW CURVES OF NaF:K (2000 ppm)

Annealed and air-quenched from 600°C.

Beta dose: 2.1×10^3 rads.

Curves: 1 ―――――― 1^{st} Thermal cycle.

2 - - - - - 2^{nd} Thermal cycle.

3 .... 3^{rd} Thermal cycle.

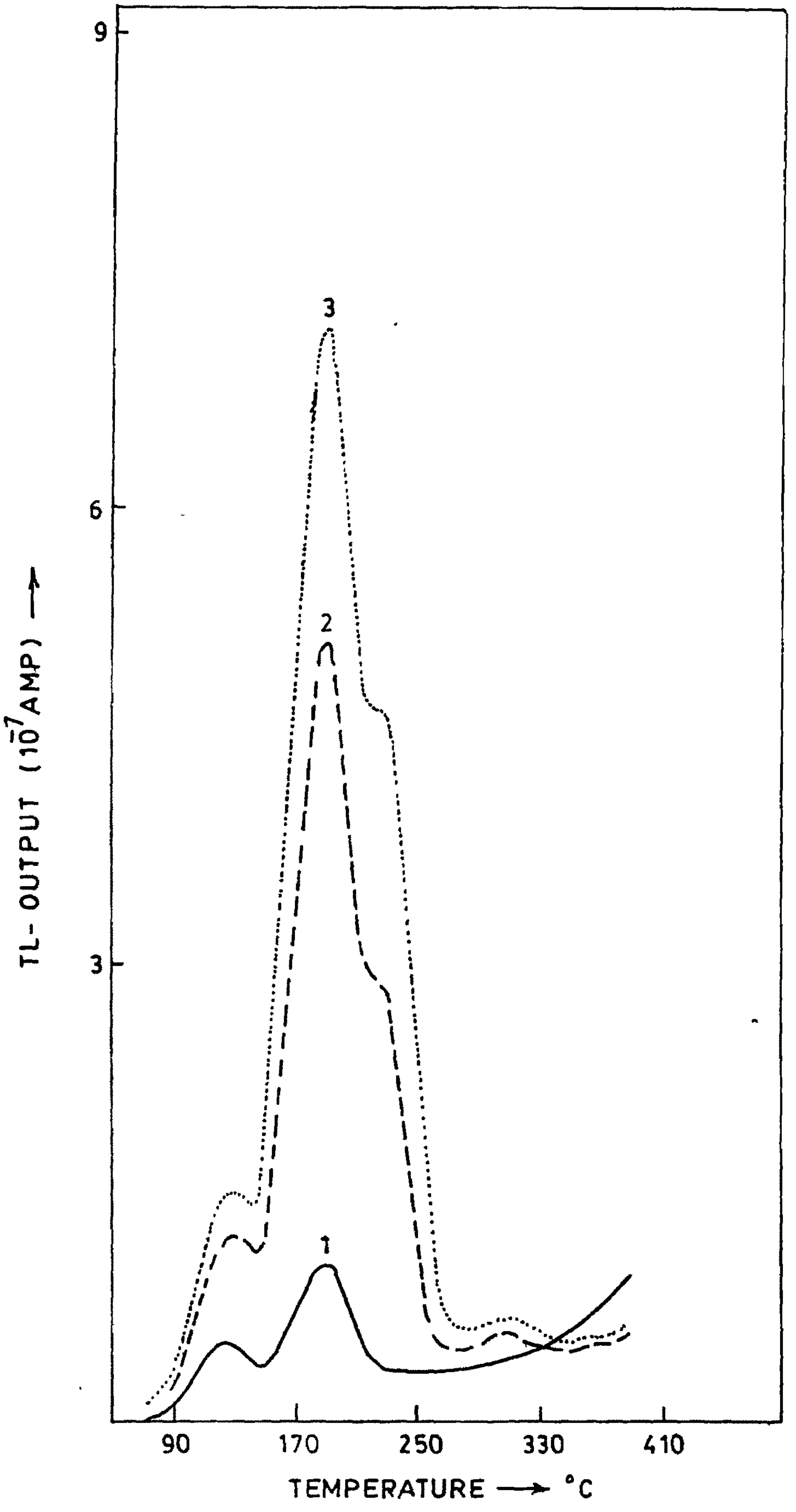


FIG. 21

FIGURE-22: TL GLOW CURVES OF NaF

Beta dose: 2.1×10^3 rads.

Curves: 1 ―――――――― As-obtained from solution.

2 —·—·—·— Annealed and air-quenched from 200°C.

3 — — — — — Annealed and air-quenched from 400°C.

4 .... Annealed and air-quenched from 600°C.

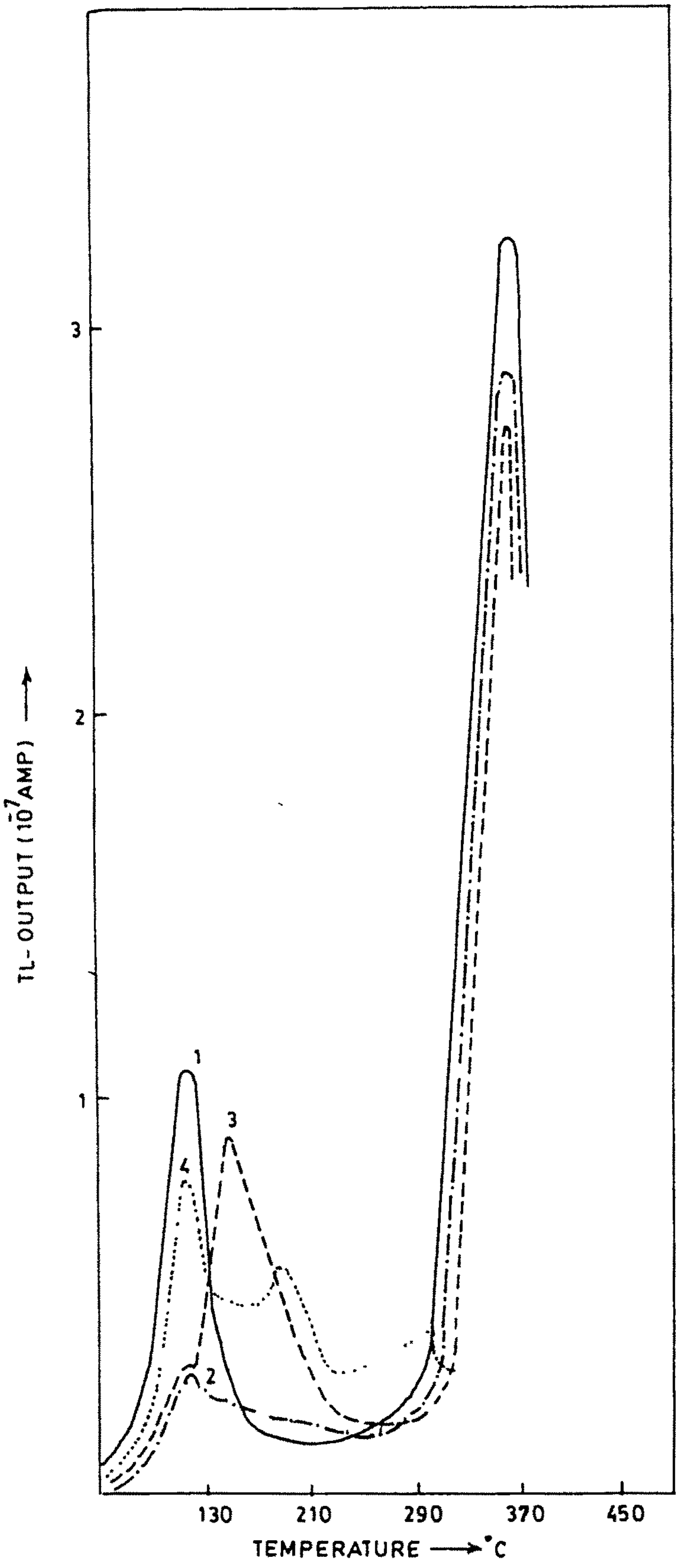


FIG 22

FIGURE-23: TL GLOW CURVES OF NaF:K (200 ppm)

Beta dose: 2.1×10^3 rads.

Curves: 1	______________	As-obtained from solution.
2	_._._._._	Annealed and air-quenched from 200°C.
3	_ _ _ _ _	Annealed and air-quenched from 400°C.
4	....	Annealed and air-quenched from 600°C.

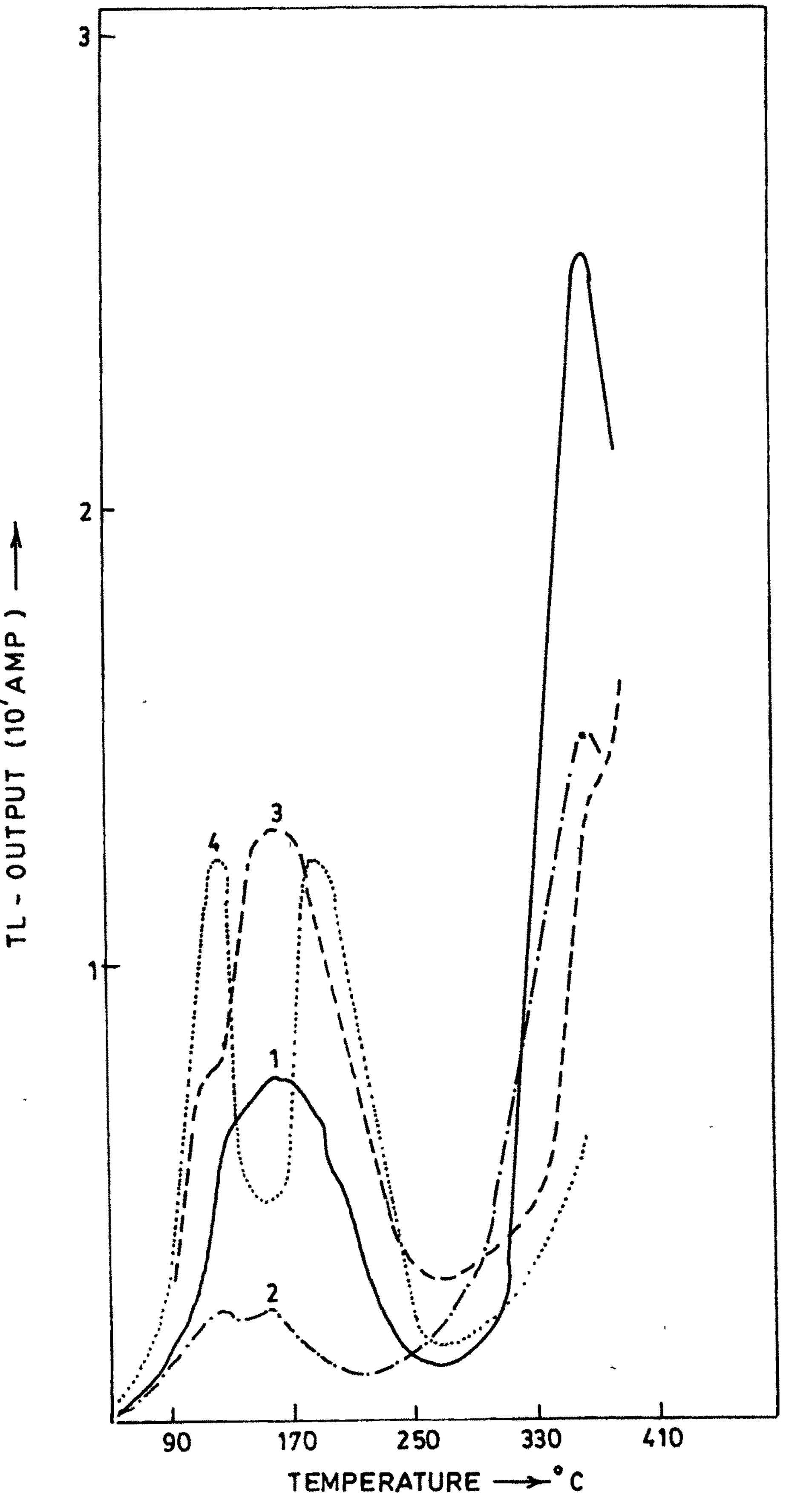


FIG. 23

FIGURE-24: TL GLOW CURVES OF NaF:K (500 ppm)

Beta dose: $2.1x10^3$ rads.

Curves: 1	________	As-obtained from solution.
2	_._._._._	Annealed and air-quenched from 200°C.
3	_ _ _ _ _	Annealed and air-quenched from 400°C.
4	....	Annealed and air-quenched from 600°C.

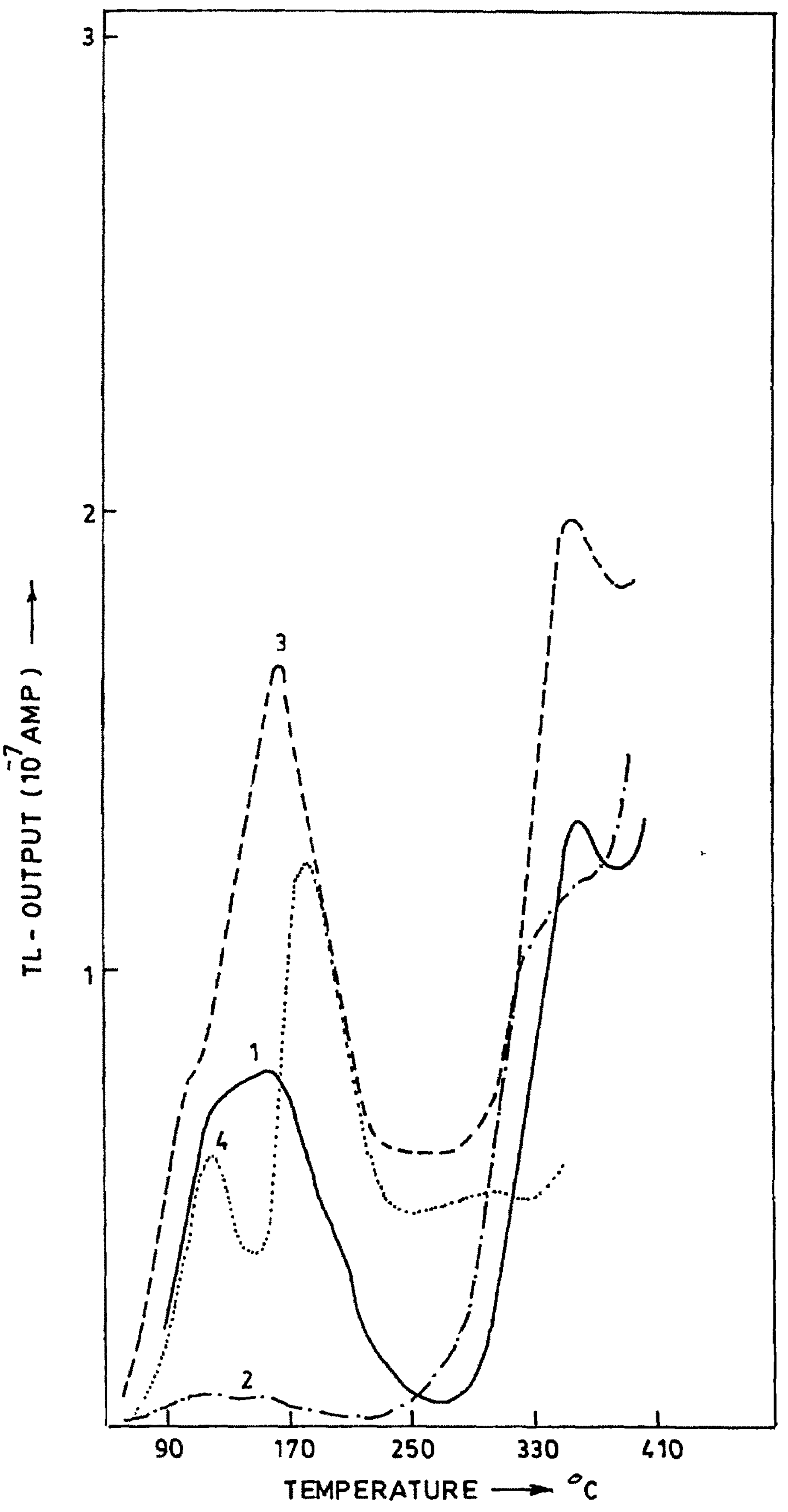


FIG. 24

FIGURE-25: TL GLOW CURVES OF NaF:K (1000 ppm)

Beta dose: 2.1×10^3 rads.

The scale on the right relates to peaks 360°C.

Curves:

1	___________	As-obtained from solution.
2	_._._._._	Annealed and air-quenched from 200°C.
3	_ _ _ _ _	Annealed and air-quenched from 400°C.
4	....	Annealed and air-quenched from 600°C.

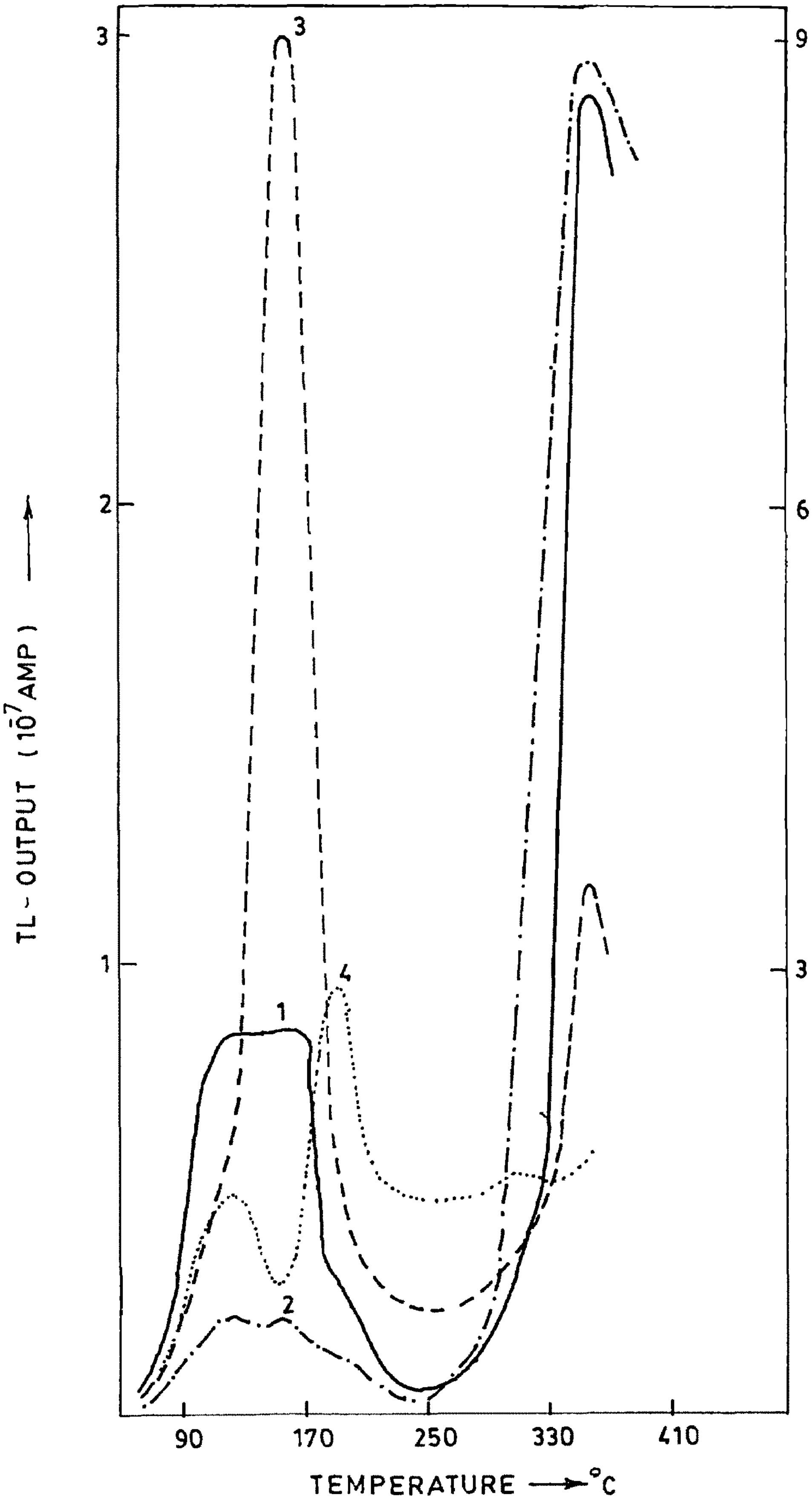


FIG. 25

FIGURE-26: TL GLOW CURVES OF NaF:K (2000 ppm)

Beta dose: 2.1×10^3 rads.

Curves: 1	________	As-obtained from solution.
2	_._._._	Annealed and air-quenched from 200°C.
3	_ _ _ _ _	Annealed and air-quenched from 400°C.
4	....	Annealed and air-quenched from 600°C.

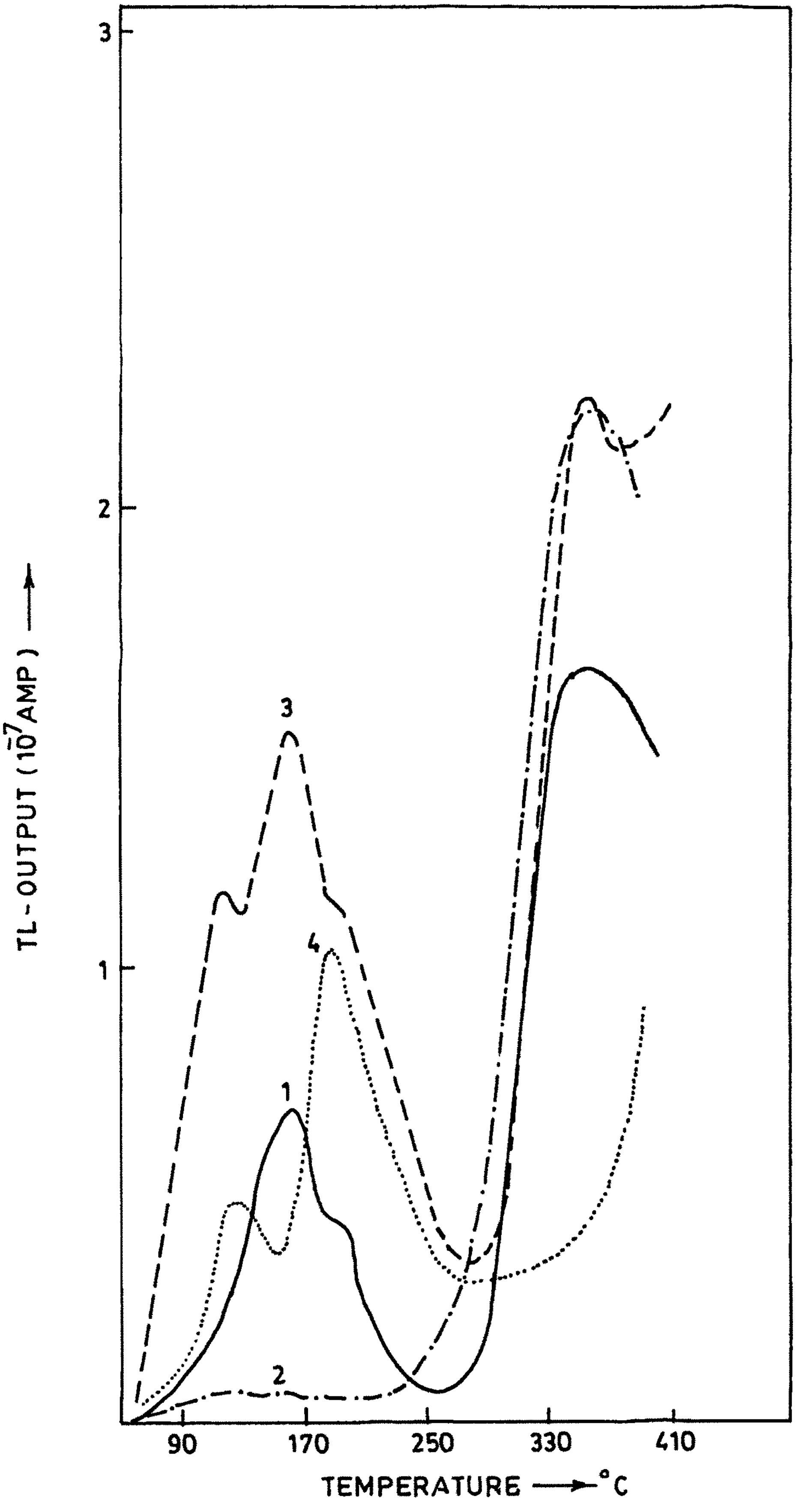


FIG. 26

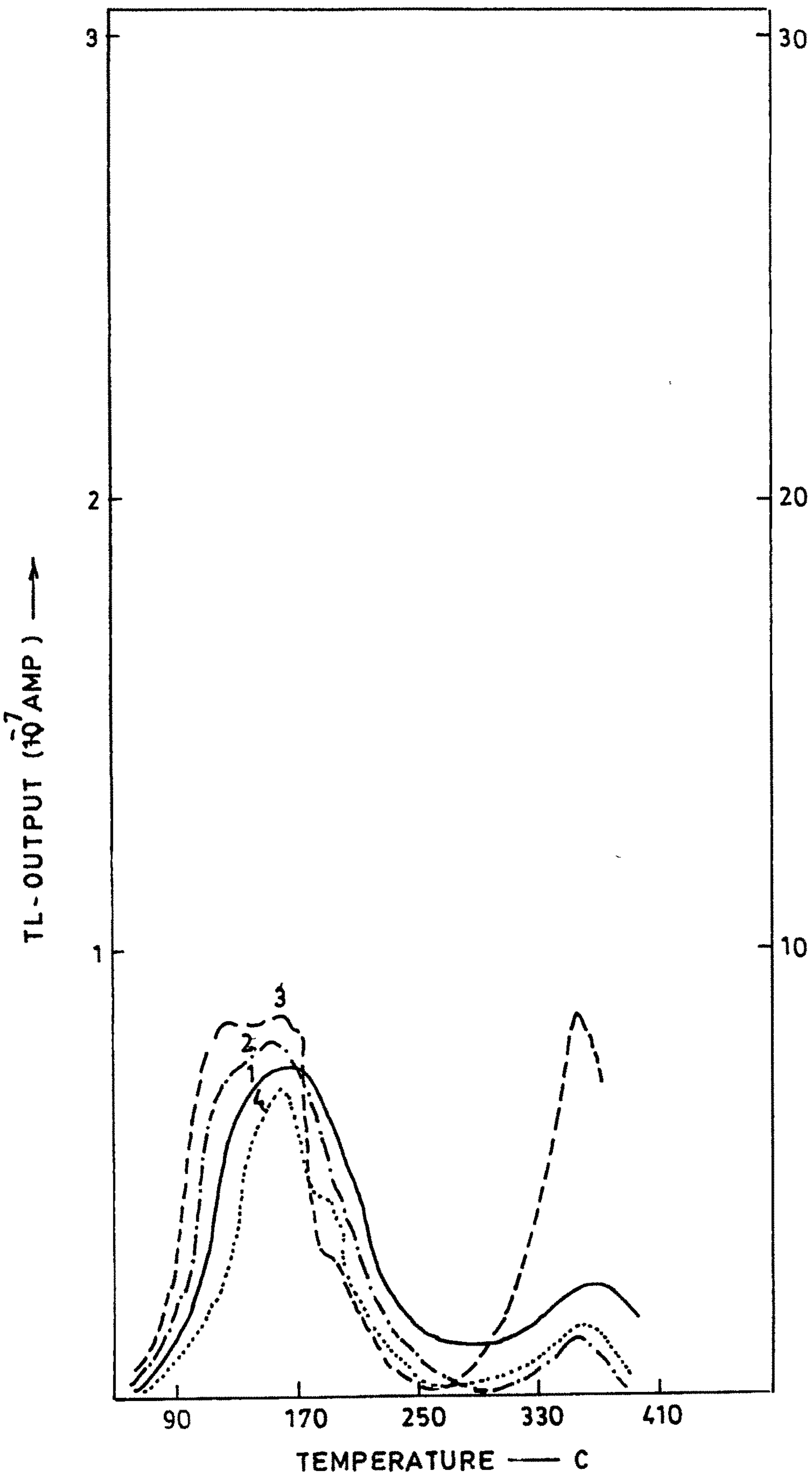
FIGURE-27: TL GLOW CURVES OF NaF:K

As-obtained from solution.

Beta dose: $2.1x10^3$ rads.

The scale on the right relates to peaks 360°C.

Curves:	1	————————	200 ppm
	2	—.—.—.—.—	500 ppm
	3	— — — — —	1000 ppm
	4	....	2000 ppm



TL-OUTPUT (10^{-7} AMP)
3
2
1
30
20
10
3
2
1
4
90
170
250
330
410
TEMPERATURE — C

FIG. 27

FIGURE-28: TL GLOW CURVES OF NaF:K

Annealed and air-quenched from 200°C

Beta dose: $2.1x10^3$ rads.

Curves: 1 ―――――― 200 ppm

2 –·–·–·–·– 500 ppm

3 _ _ _ _ _ 1000 ppm

4 .... 2000 ppm

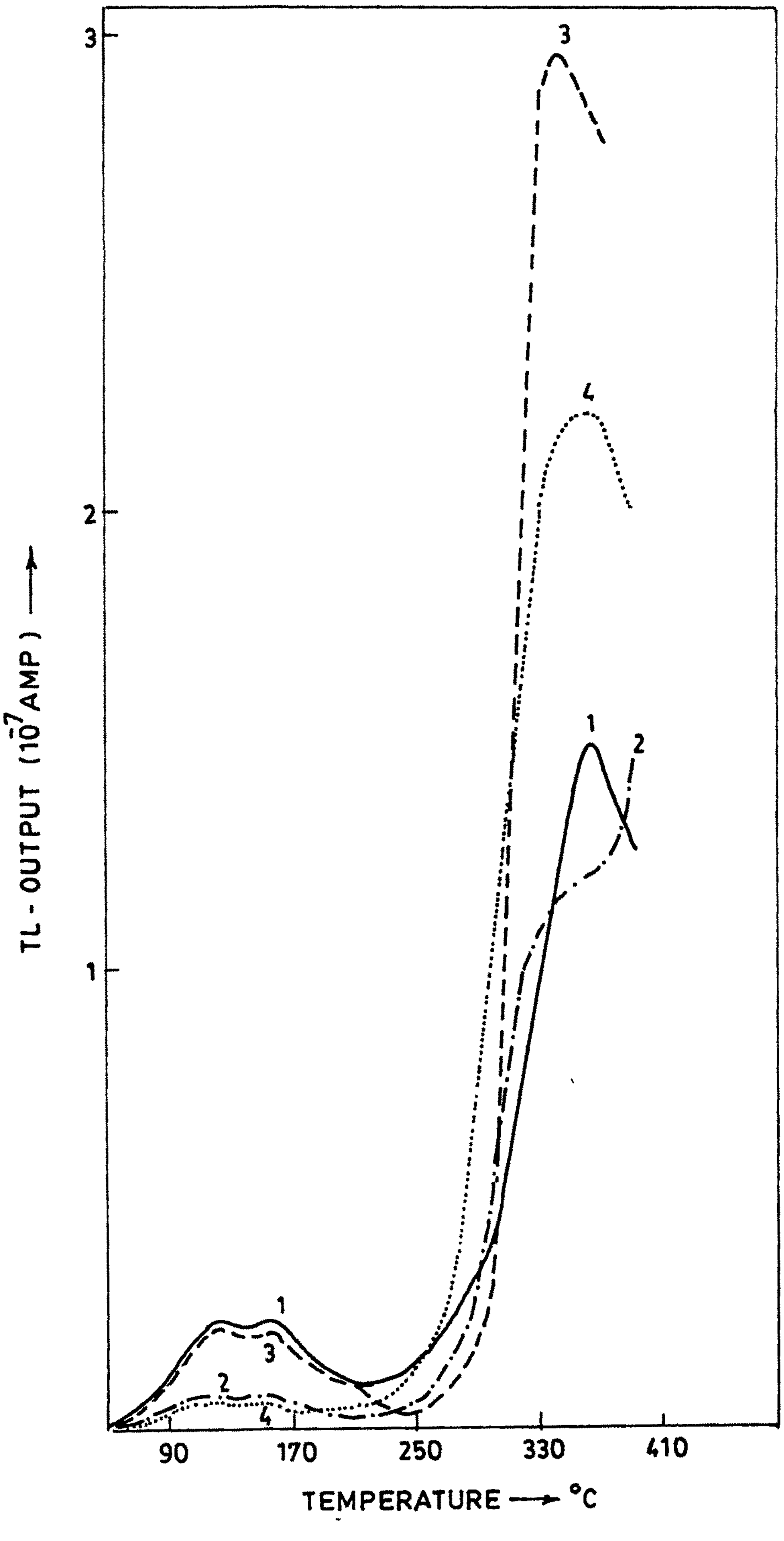


FIG 28

FIGURE-29: TL GLOW CURVES OF NaF:K

Annealed and air-quenched from 400°C.

Beta dose: 2.1×10^3 rads.

Curves: 1 ___________ 200 ppm

2 _._._._._ 500 ppm

3 _ _ _ _ _ 1000 ppm

4 .... 2000 ppm

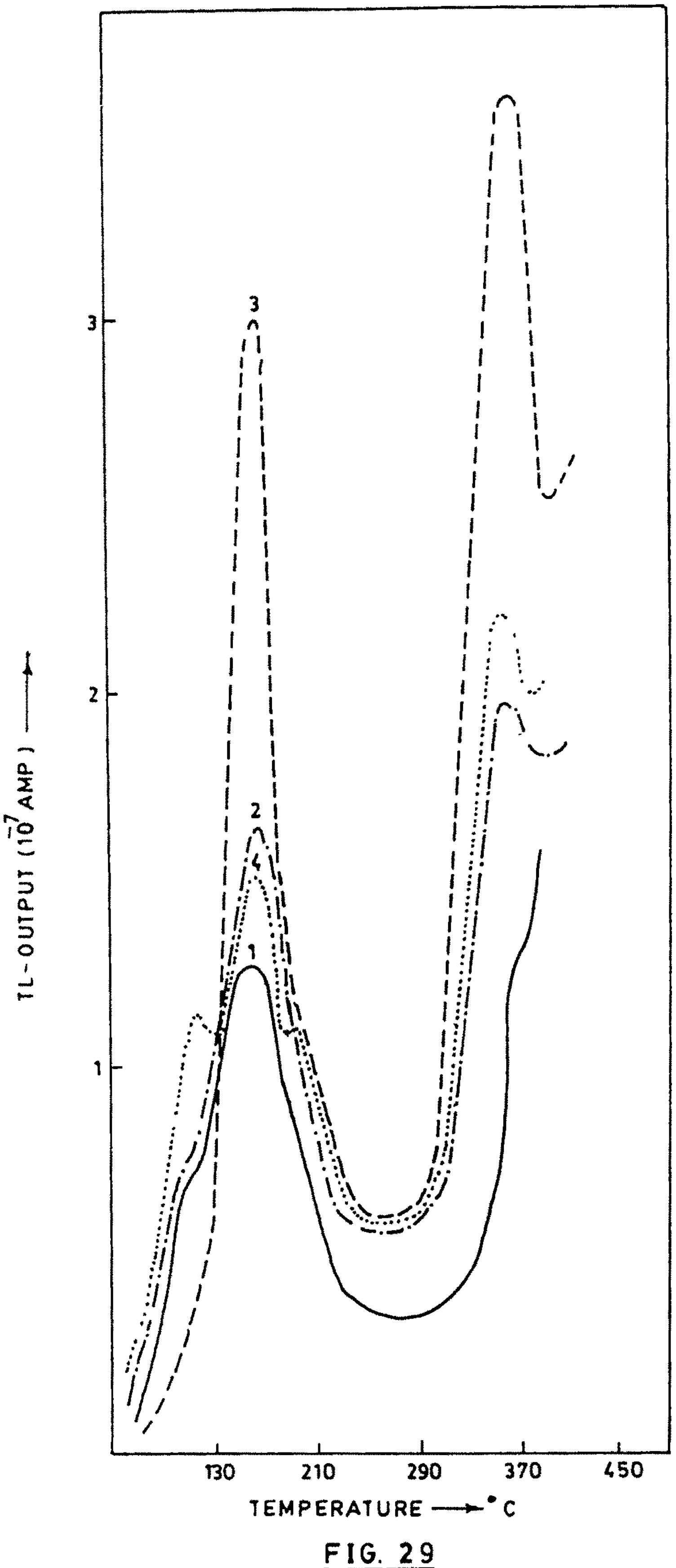


FIG. 29

FIGURE-30: TL GLOW CURVES OF NaF:K

Annealed and air-quenched from 600°C.

Beta dose: 2.1×10^{3} rads.

Curves: 1 ____________ 200 ppm

2 _._._._._ 500 ppm

3 _ _ _ _ _ 1000 ppm

4 .... 2000 ppm

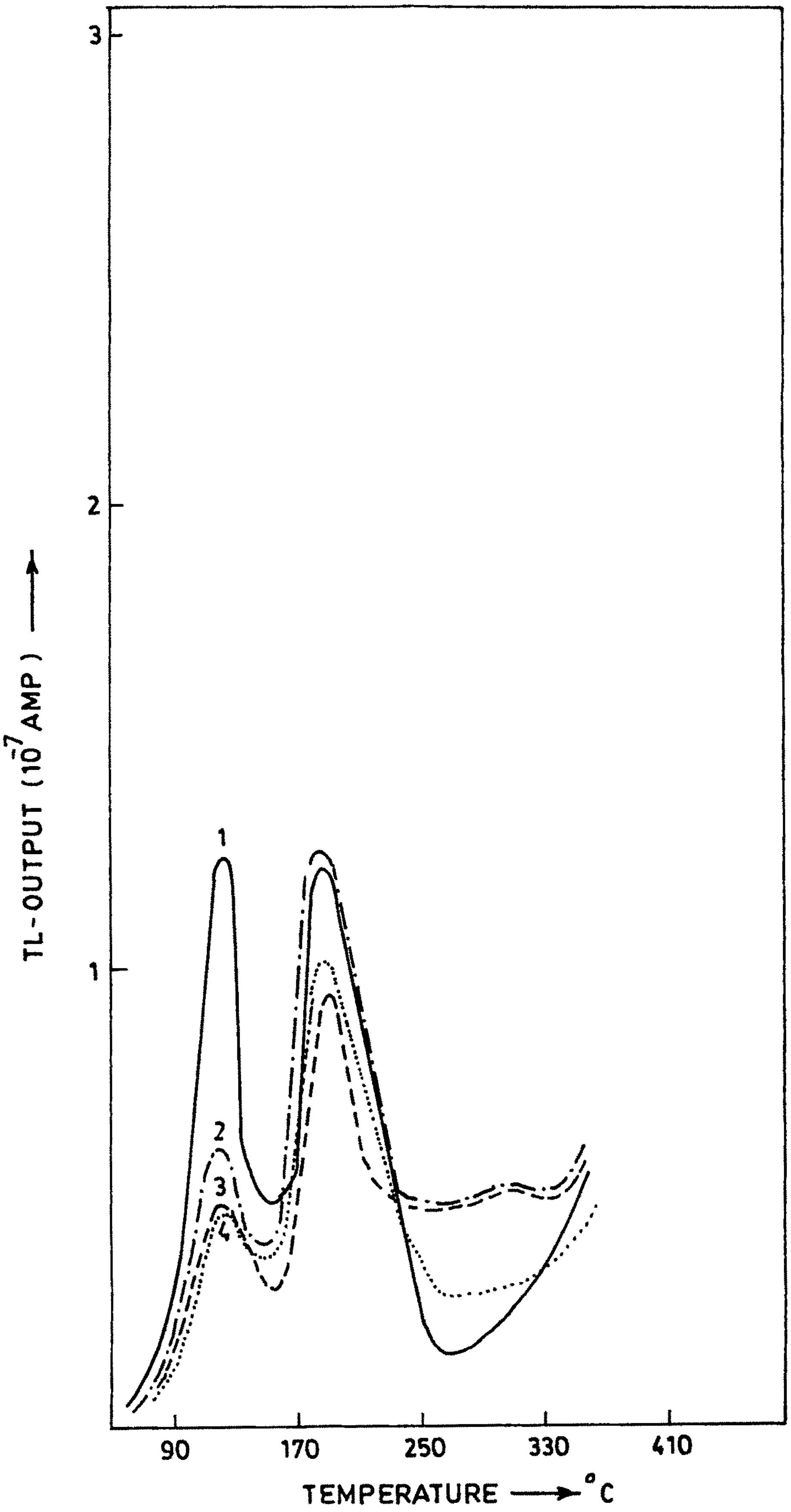


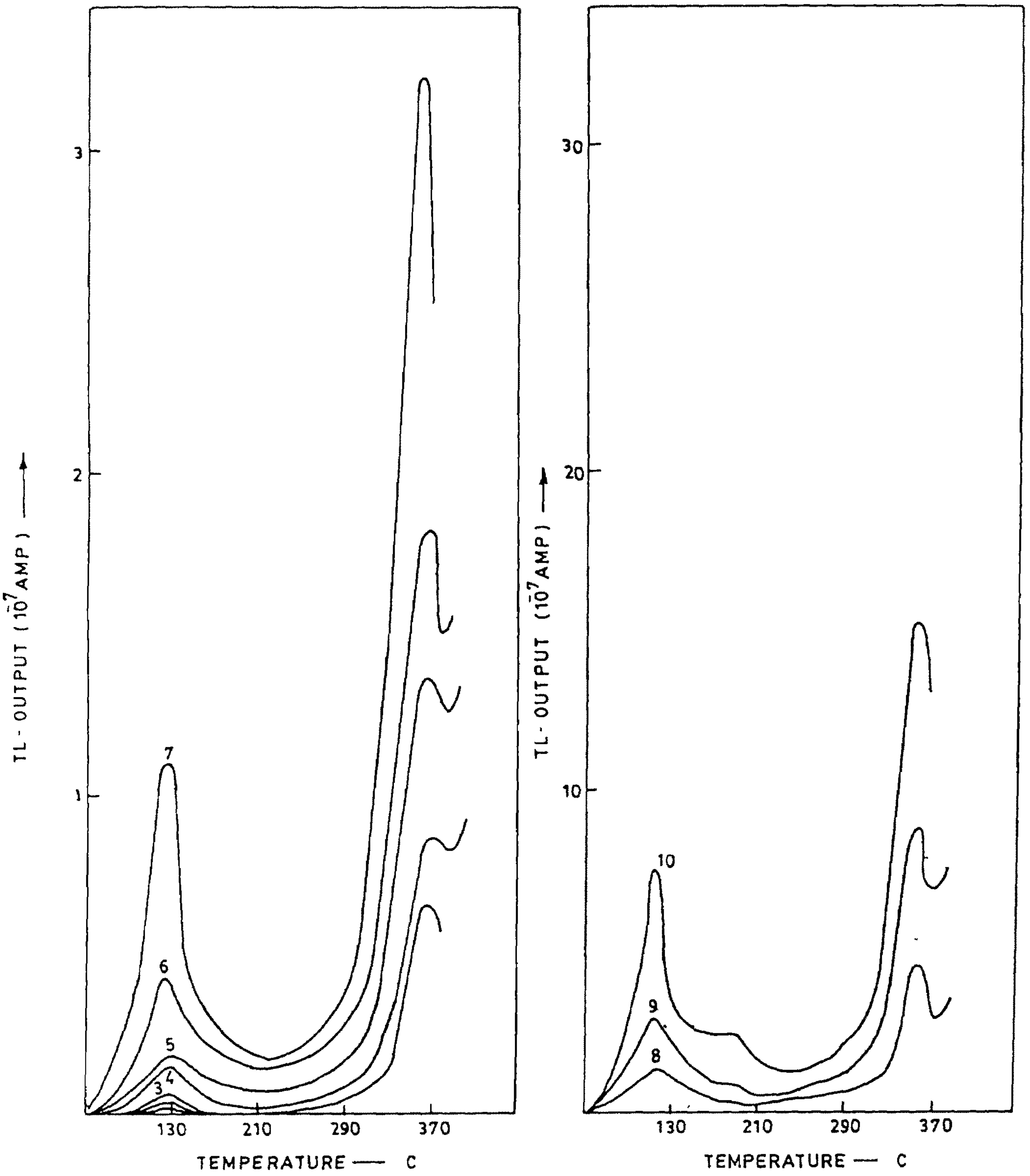
FIG. 30

FIGURE-31A: TL GLOW CURVES OF NaF

As-obtained from solution.

After an exposure to beta radiation of different doses.

Curves: 1	___________	29 rads.
2	___________	58 rads.
3	___________	$1.17x10^2$ rads.
4	___________	$2.33x10^2$ rads.
5	___________	$4.66x10^2$ rads.
6	___________	$7x10^2$ rads.
7	___________	$2.1x10^3$ rads.
8	___________	$3.5x10^3$ rads.
9	___________	$7x10^3$ rads.
10	___________	$1.4x10^4$ rads.



7
6
5
4
3
3
2
1
130
210
290
370
TEMPERATURE — C
TL - OUTPUT (10^{-7} AMP)
10
9
8
30
20
10
130
210
290
370
TEMPERATURE — C
TL - OUTPUT (10^{-7} AMP)

FIG 31 A

FIGURE-31B: TL GLOW CURVES OF NaF(T)

After an exposure to beta radiation of different doses.

Curves: 1	________	$1.17x10^2$	rads.
2	________	$2.33x10^2$	rads.
3	________	$4.66x10^2$	rads.
4	________	7×10^2	rads.
5	________	$2.1x10^3$	rads.
6	________	$3.5x10^3$	rads.
7	________	$7x10^3$	rads.
8	________	$1.4x10^4$	rads.

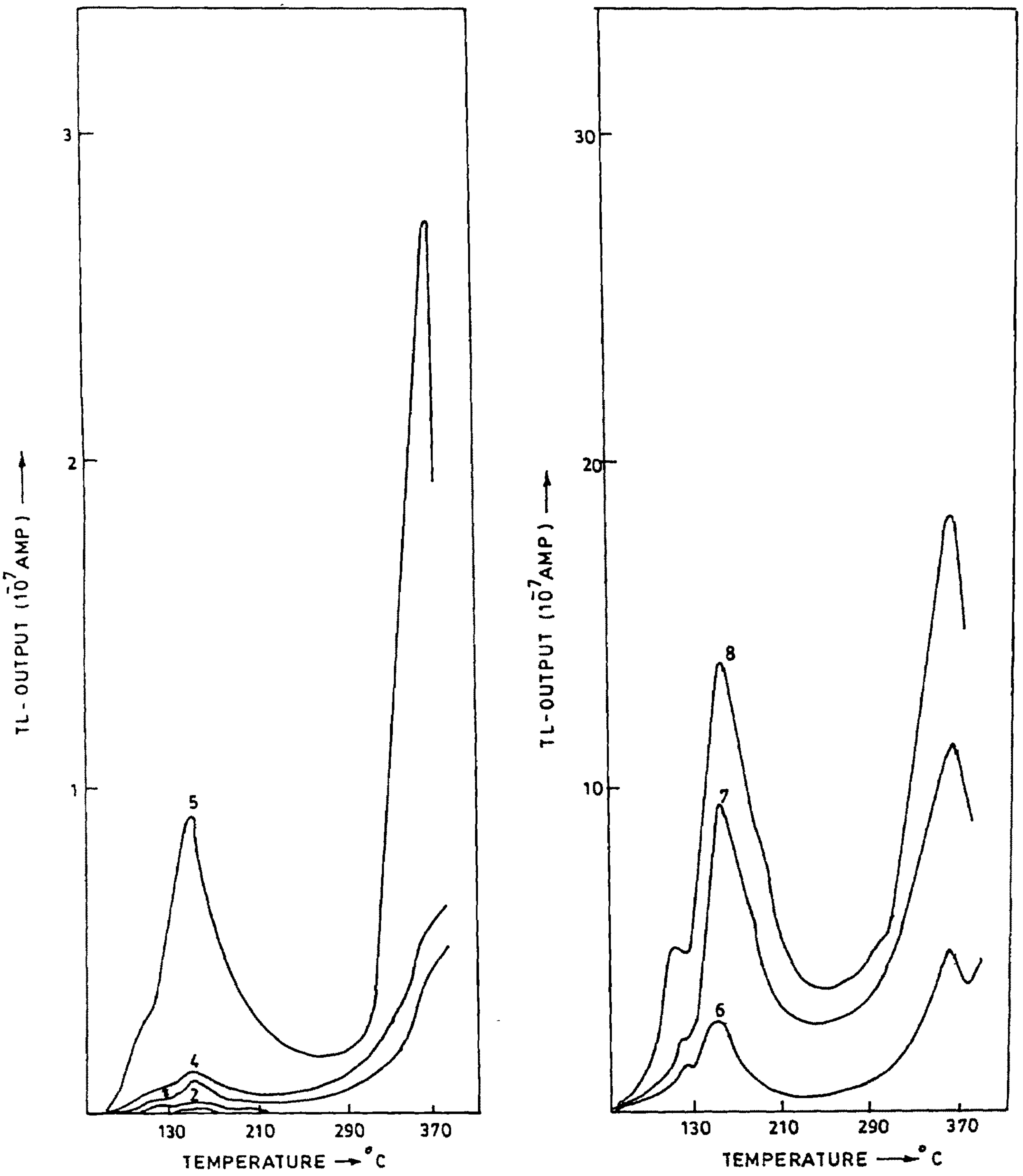

TL - OUTPUT (10^{-7} AMP)
3
2
1
5
4
3
2
130
210
290
370
TEMPERATURE → °C
TL-OUTPUT (10^{-7} AMP)
30
20
10
8
7
6
130
210
290
370
TEMPERATURE → °C

FIG. 31 B

FIGURE-32A: PLOT OF TL OUTPUT VERSUS BETA DOSE

NaF As-obtained from solution.

LINES: ____________ 120°C peak

_ _ _ _ _ _ 360°C peak

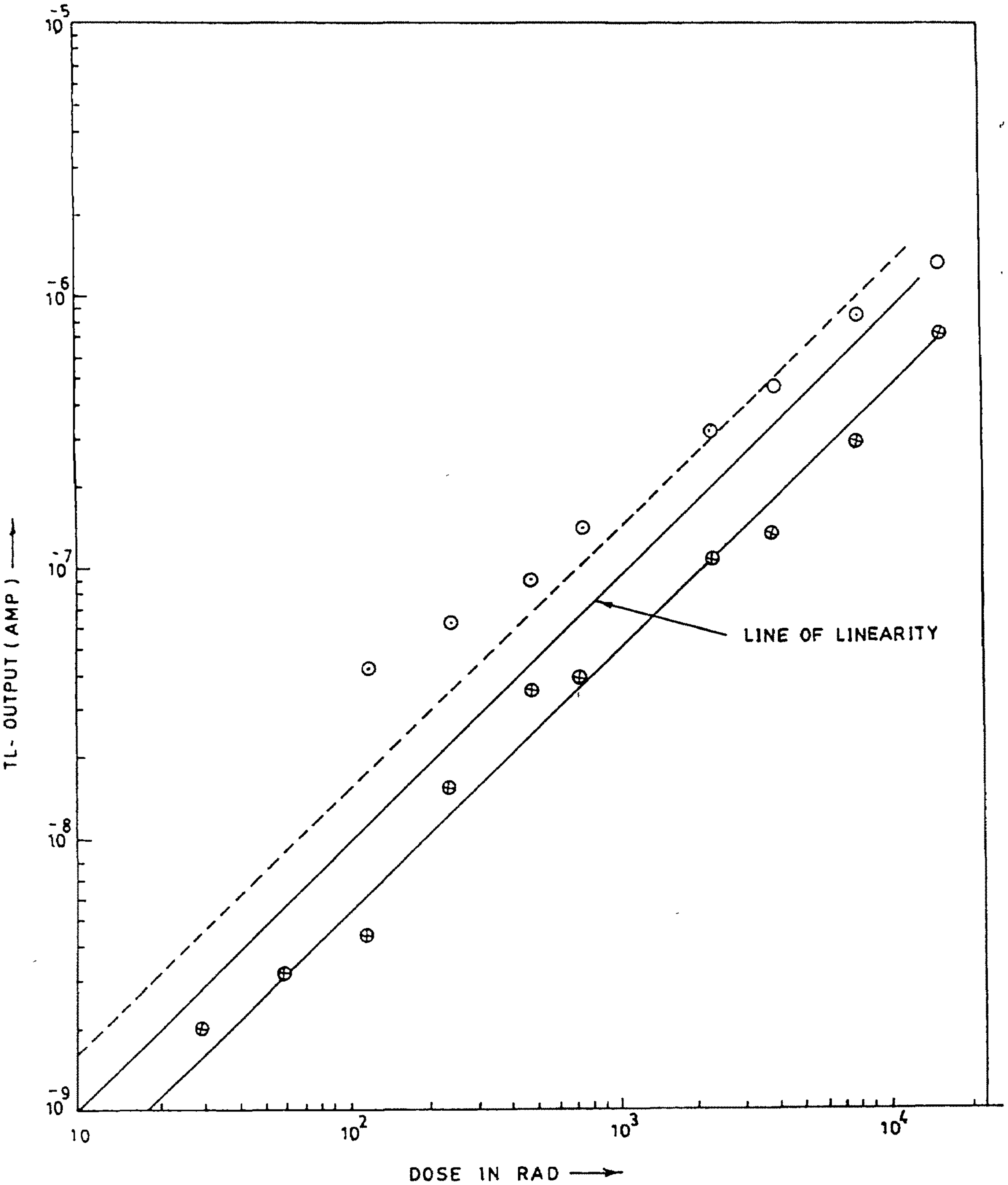
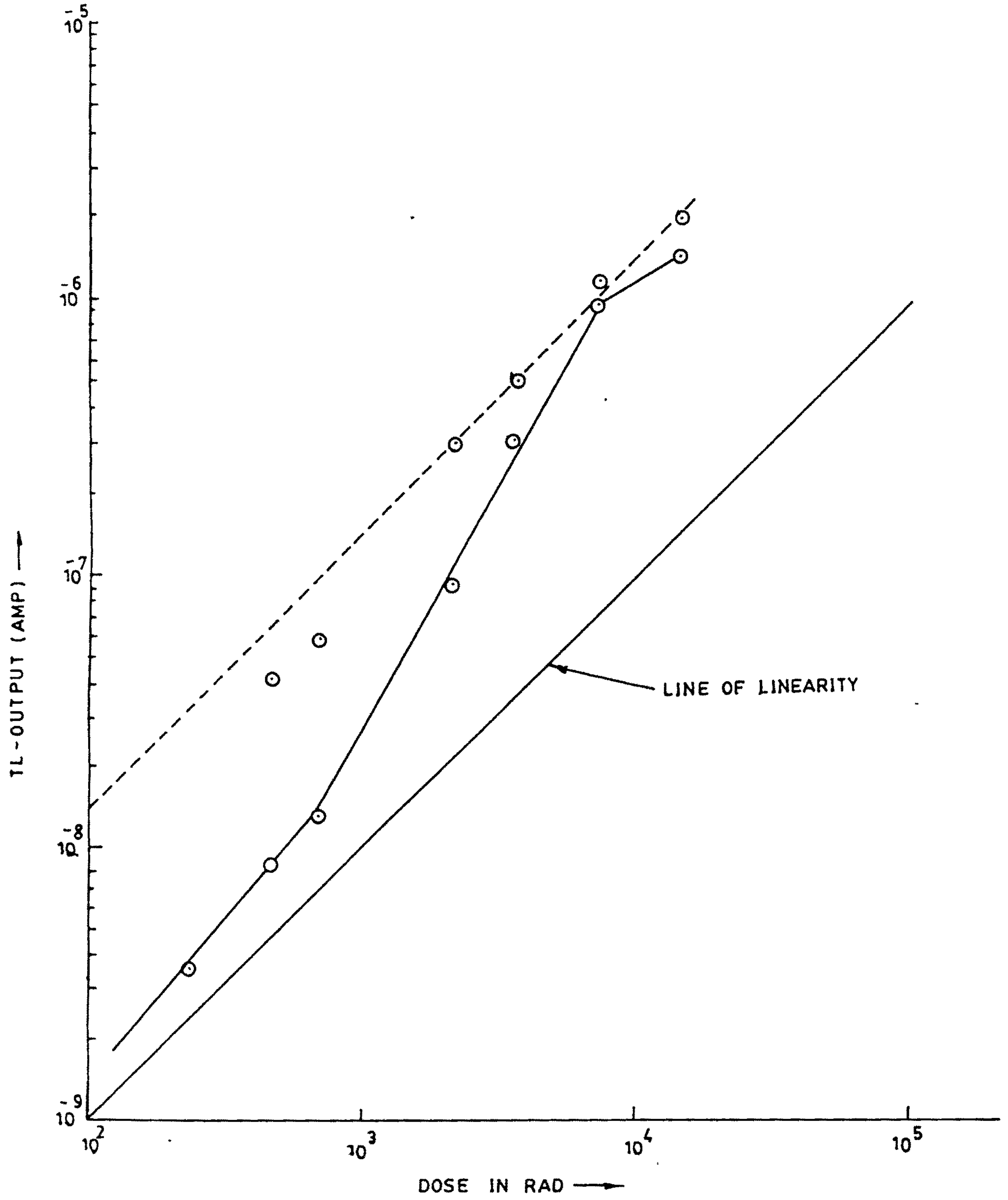

TL- OUTPUT (AMP)
LINE OF LINEARITY
DOSE IN RAD
10
10^2
10^3
10^4
10^{-9}
10^{-8}
10^{-7}
10^{-6}
10^{-5}

FIG. 32 A

FIGURE-32B: PLOT OF TL OUTPUT VERSUS BETA DOSE NaF(T).

LINES: ____________ 150°C peak

_ _ _ _ _ _ 360°C peak



10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
TL-OUTPUT (AMP)
LINE OF LINEARITY
10^2
10^3
10^4
10^5
DOSE IN RAD

FIG. 32 B

FIGURE-33: TL GLOW CURVES OF NaF:K (200 ppm)
Annealed and air-quenched from 400°C.
After an exposure to beta radiation of different doses.

Curves: 1	___________	29 rads.
2	___________	58 rads.
3	___________	1.17×10^2 rads.
4	___________	2.33×10^2 rads.
5	___________	4.66×10^2 rads.
6	___________	7×10^2 rads.
7	___________	2.1×10^3 rads.
8	___________	3.5×10^3 rads.
9	___________	7×10^3 rads.
10	___________	1.4×10^4 rads.

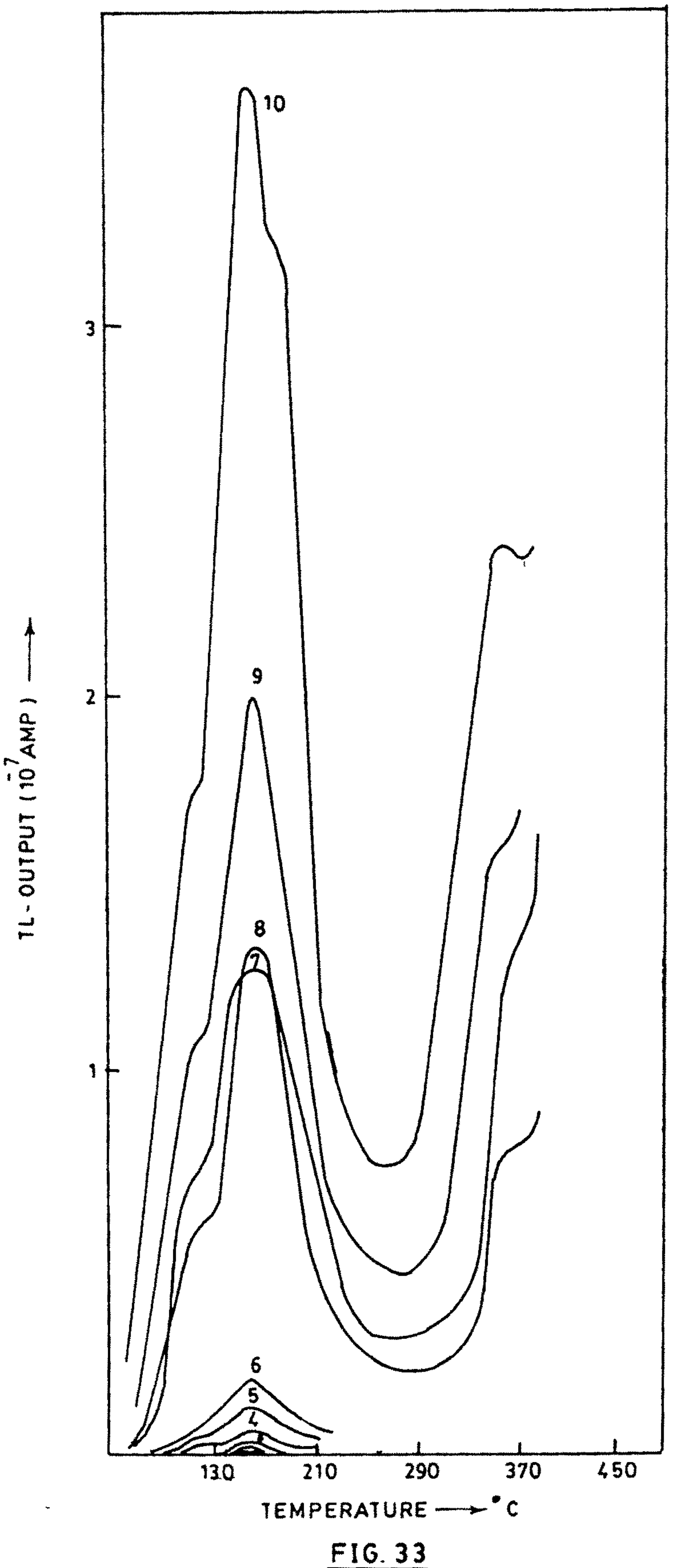

TL - OUTPUT (10^{-7} AMP)
3
2
1
10
9
8
7
6
5
4
130
210
290
370
450
TEMPERATURE → °C

FIG. 33

FIGURE-34: TL GLOW CURVES OF NaF:K (500 ppm) Annealed and qir-quenched from 400°C. After an exposure to beta radiation of different doses.

Curves: 1	____________	29 rads.
2	____________	58 rads.
3	____________	1.17×10^2 rads.
4	____________	2.33×10^2 rads.
5	____________	4.66×10^2 rads.
6	____________	7×10^2 rads.
7	____________	2.1×10^3 rads.
8	____________	3.5×10^3 rads.
9	____________	7×10^3 rads.
10	____________	1.4×10^4 rads.

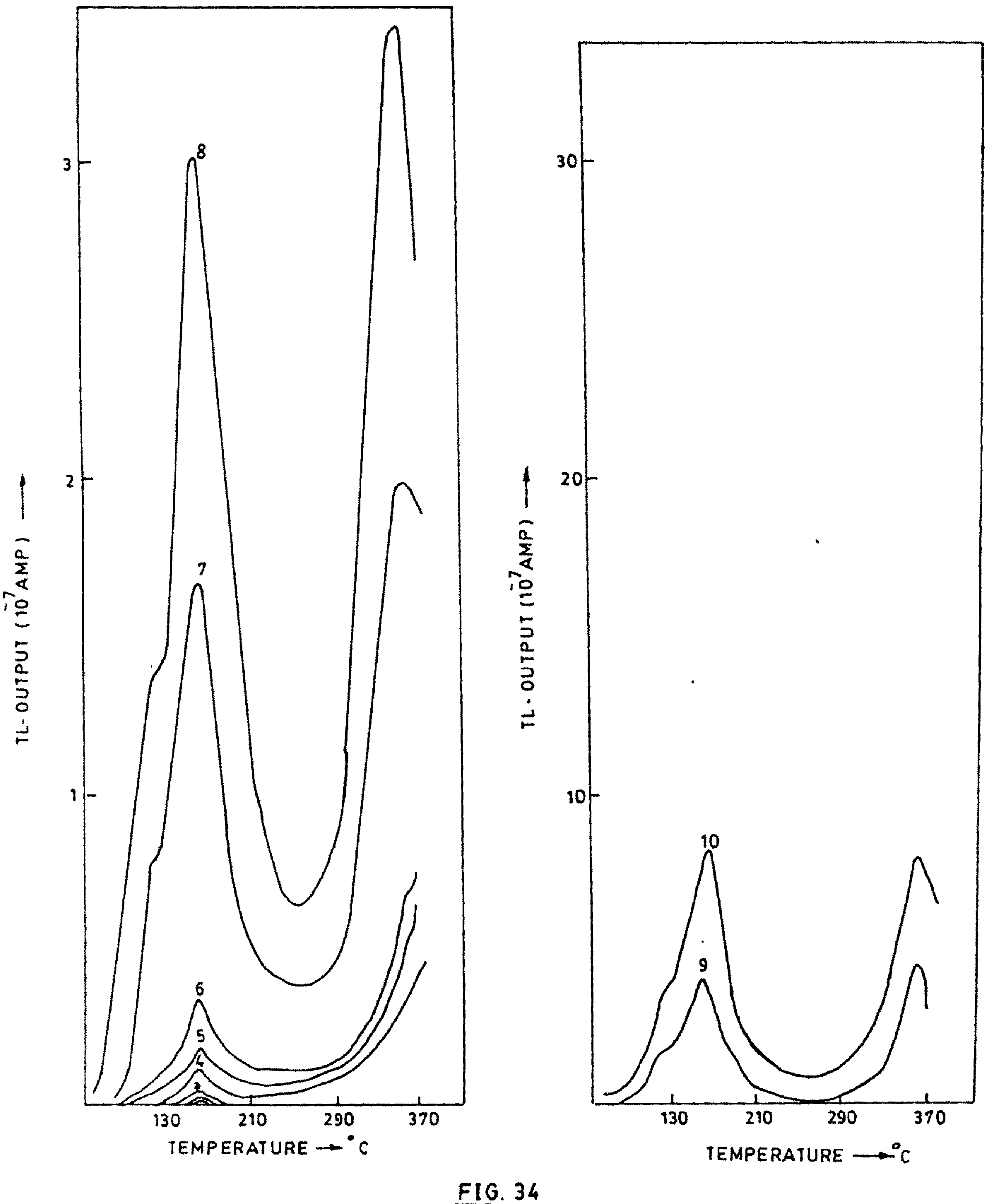

TL-OUTPUT (10^{-7} AMP)
3
2
1
8
7
6
5
4
130
210
290
370
TEMPERATURE → °C
TL-OUTPUT (10^{-7} AMP)
30
20
10
10
9
130
210
290
370
TEMPERATURE → °C

FIG. 34

FIGURE-35A: TL GLOW CURVES OF NaF:K(T)

After an exposure to beta radiation of different doses.

Curves: 1	____________	29 rads.
2	____________	58 rads.
3	____________	1.17×10^2 rads.
4	____________	2.33×10^2 rads.
5	____________	4.66×10^2 rads.
6	____________	7×10^2 rads.
7	____________	2.1×10^3 rads.
8	____________	3.5×10^3 rads.
9	____________	7×10^3 rads.
10	____________	1.4×10^4 rads.

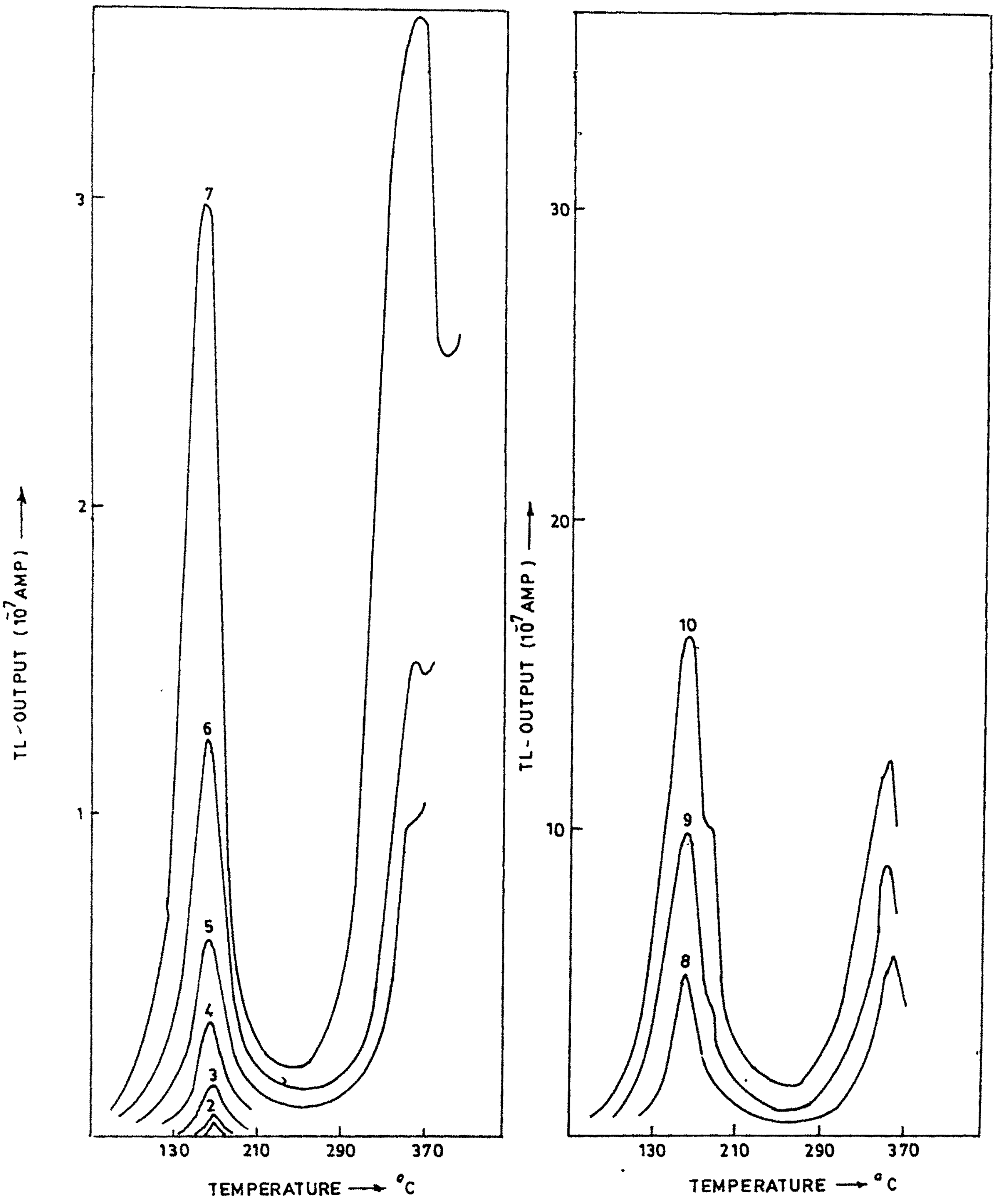

TL-OUTPUT (10^{-7} AMP)
TEMPERATURE → °C
130
210
290
370
1
2
3
7
6
5
4
3
2
TL-OUTPUT (10^{-7} AMP)
TEMPERATURE → °C
10
20
30
10
9
8

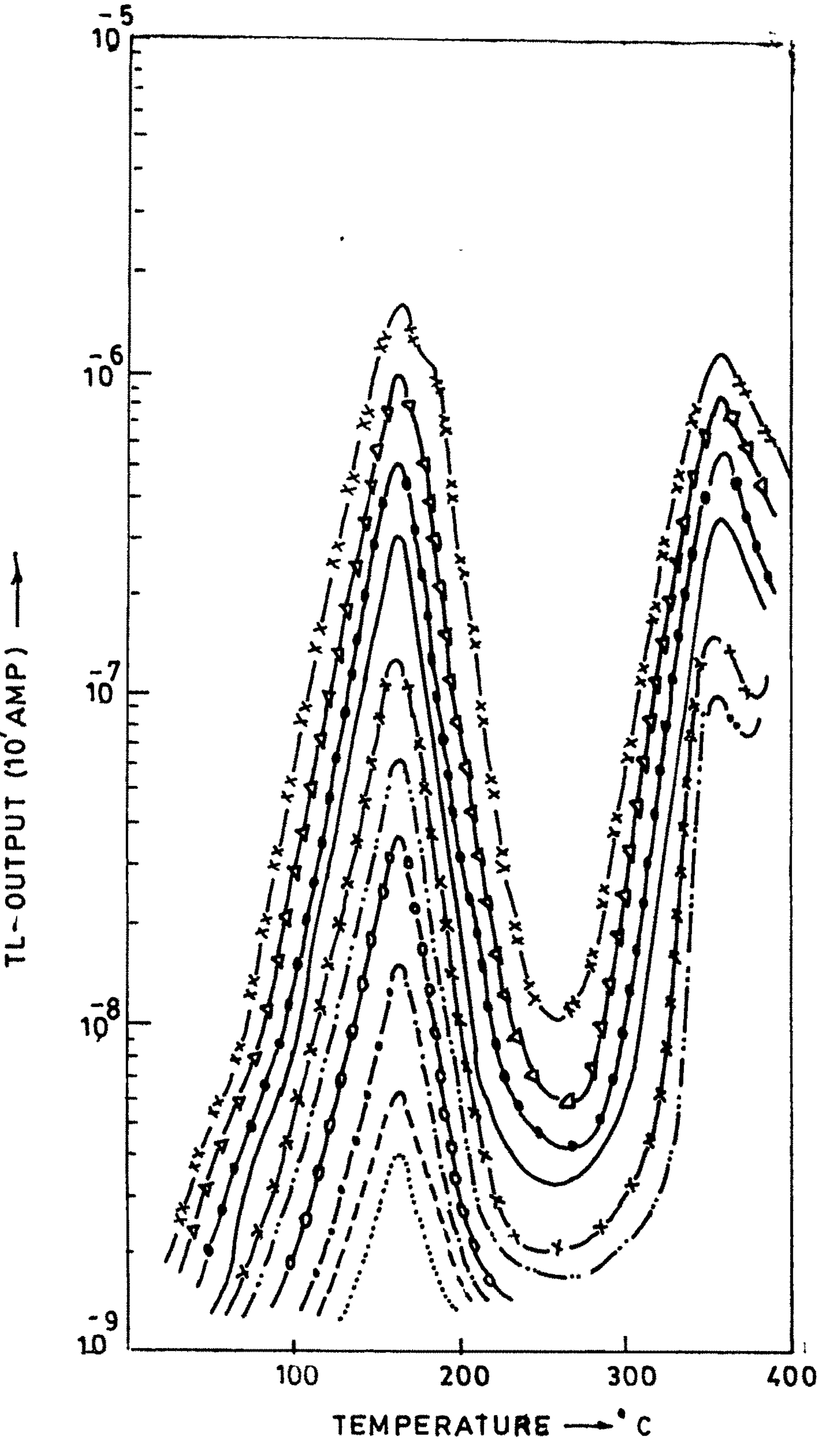
FIG. 35 A

FIGURE-35B: TL GLOW CURVES OF NaF:K(T)

(using semi-log paper)

After an exposure to beta radiation of different doses.

Curves:	
....	29 rads.
_ _ _ _ _	58 rads.
-.-.-.-.-.-	1.17×10^{2} rads.
—0—0—0—	2.33×10^{2} rads.
—..—..—	4.66×10^{2} rads.
—X—X—X—	7×10^{2} rads.
————	2.1×10^{3} rads.
—●——●—	3.5×10^{3} rads.
—△—△—△—	7×10^{3} rads.
—XX—XX—	1.4×10^{4} rads.

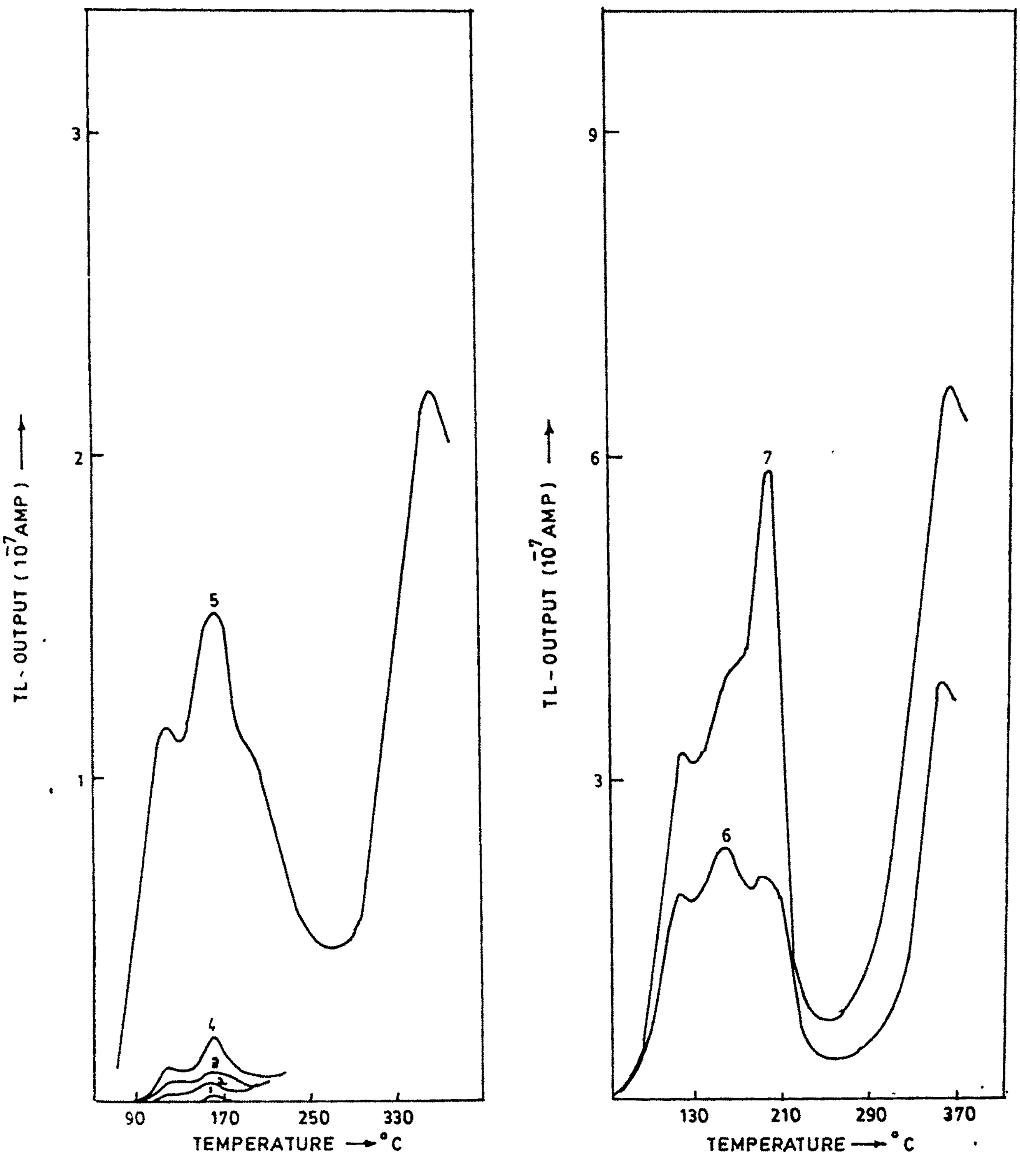


10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
TL-OUTPUT (10^{-7} AMP) →
100
200
300
400
TEMPERATURE → °C

FIG. 35 B

FIGURE-36: TL GLOW CURVES OF NaF:K (2000 ppm)
Annealed and air-quenched from 400°C.
After an exposure to beta radiation of
different doses.

Curves:	1	____________	1.17×10^{2} rads.
	2	____________	2.33×10^{2} rads.
	3	____________	4.66×10^{2} rads.
	4	____________	7×10^{2} rads.
	5	____________	2.1×10^{3} rads.
	6	____________	7×10^{3} rads.
	7	____________	1.4×10^{4} rads.



3
2
1
TL - OUTPUT (10^{-7} AMP)
5
4
90
170
250
330
TEMPERATURE → °C
9
6
3
TL - OUTPUT (10^{-7} AMP)
7
6
130
210
290
370
TEMPERATURE → °C

FIG. 36

FIGURE-37: TL GLOW CURVES OF DIFFERENT WEIGHTED QUANTITIES OF NaF:K(T)

Beta dose: $2.1x10^3$ rads.

Curves: _ _ _ _ _ 3 mg.

.... 5 mg.

-.-.-.-.- 10 mg.

—X—X—X— 15 mg.

__________ 20 mg.

—..—..— 25 mg.

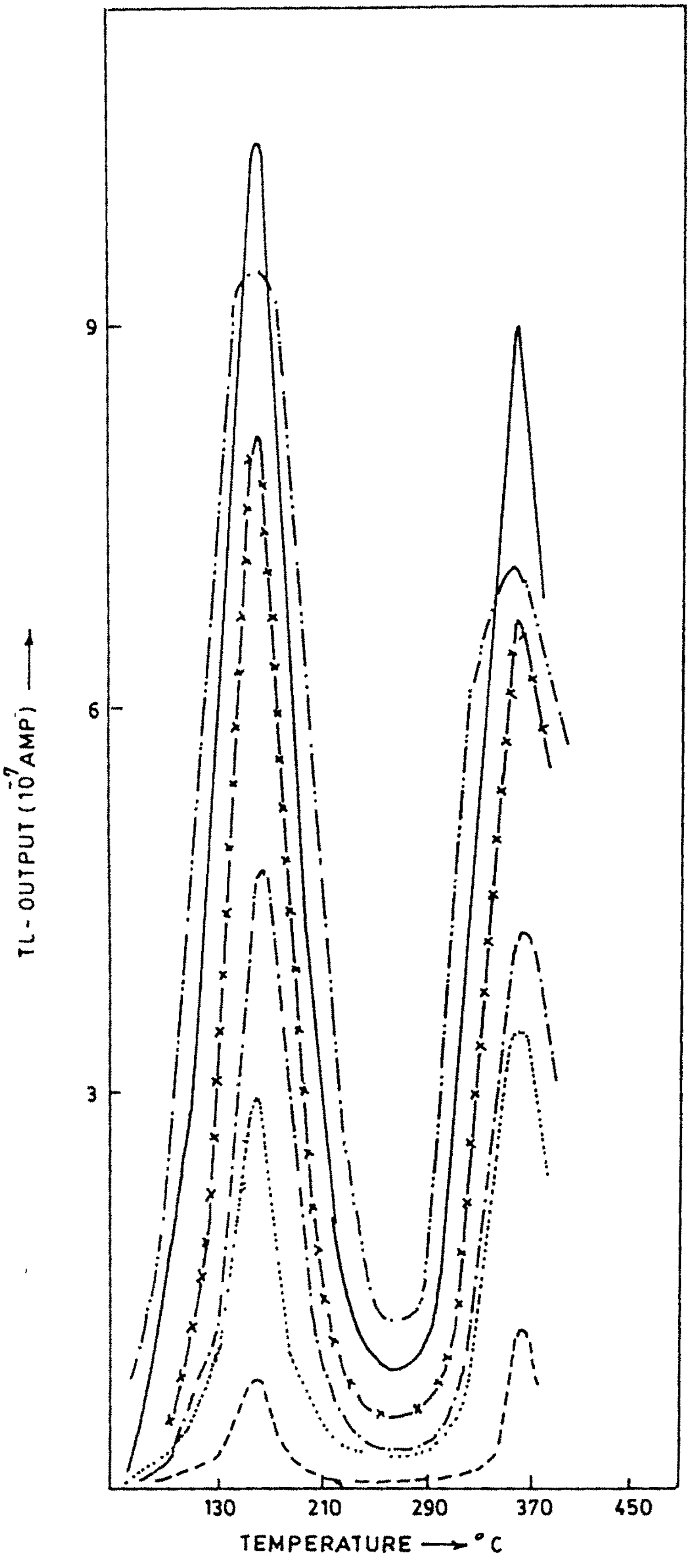
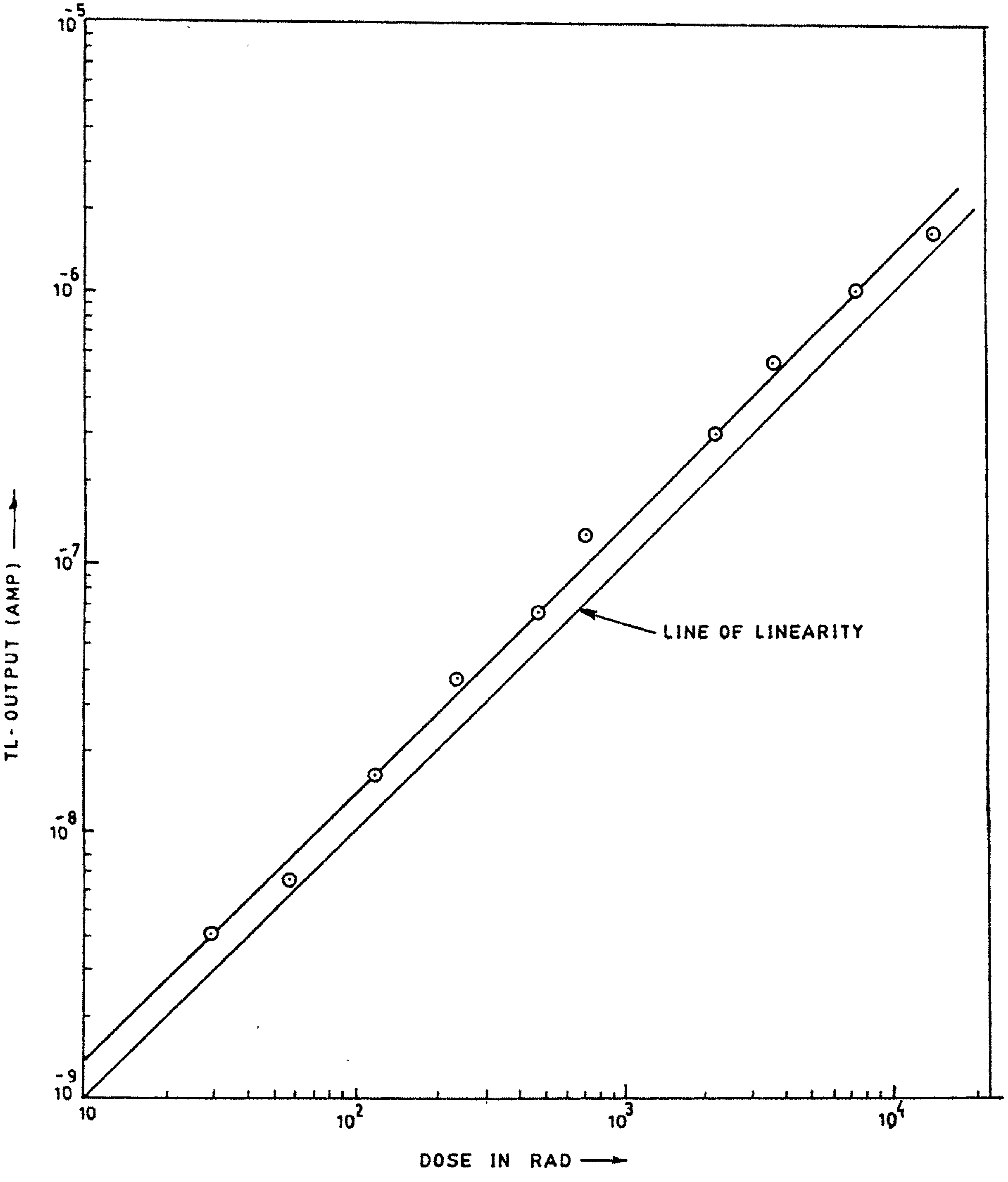


FIG. 37

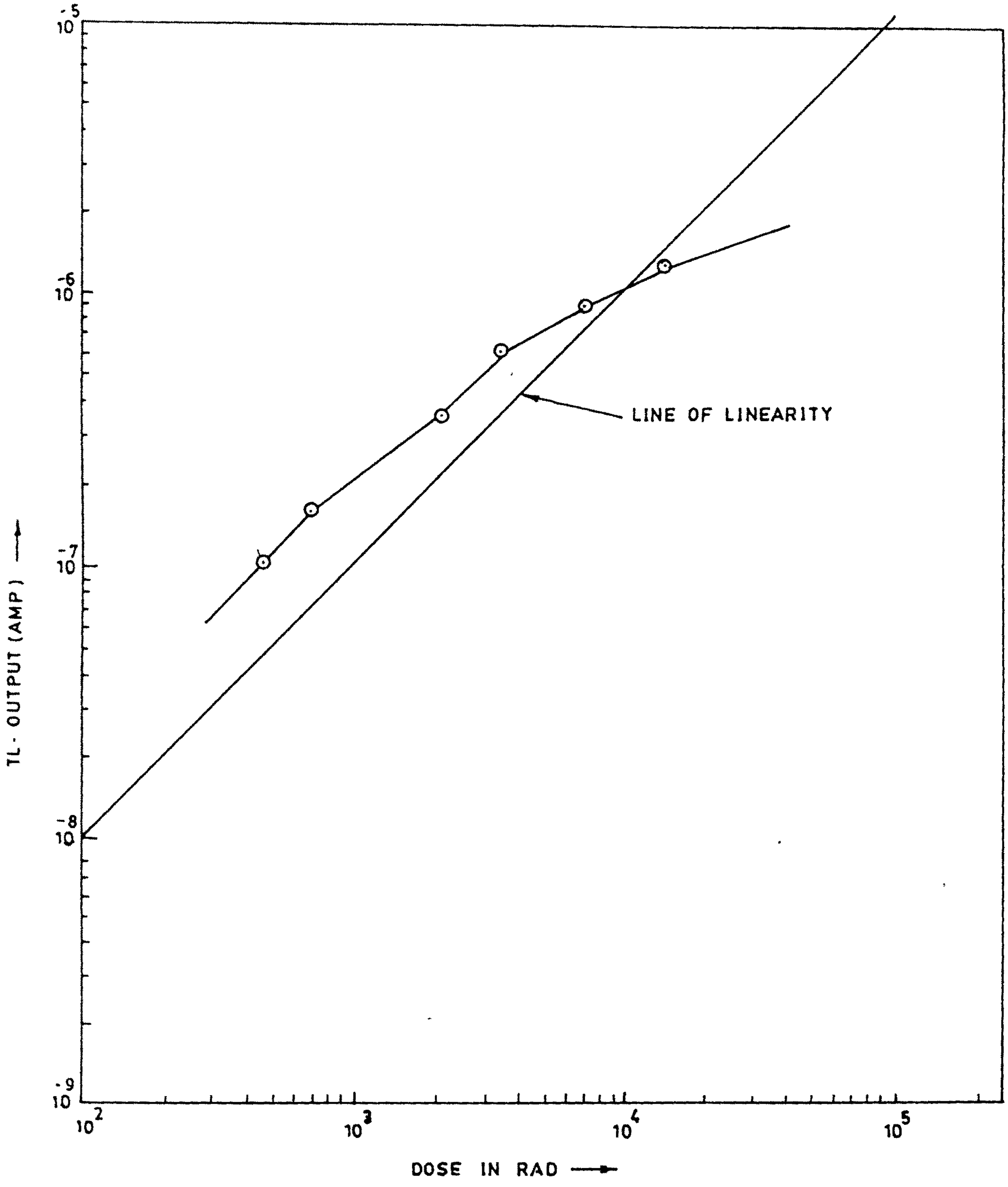
FIGURE-38A: PLOT OF TL OUTPUT VERSUS BETA DOSE FOR 165°C PEAK IN NaF:K(T).



10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
TL-OUTPUT (AMP)
LINE OF LINEARITY
10
10^2
10^3
10^4
DOSE IN RAD

FIG. 38 A

FIGURE-38B: PLOT OF TL OUTPUT VERSUS BETA DOSE FOR 360°C PEAK IN NaF:K(T).



10^-5
10^-6
10^-7
10^-8
10^-9
TL - OUTPUT (AMP)
LINE OF LINEARITY
10^2
10^3
10^4
10^5
DOSE IN RAD

FIG. 38 B

FIGURE-39: PLOT OF TL OUTPUT AT 165°C VERSUS DECAY TIME IN HOURS AFTER EXCITATION.

Beta dose: 2.1×10^3 rads.

NaF:K(T)

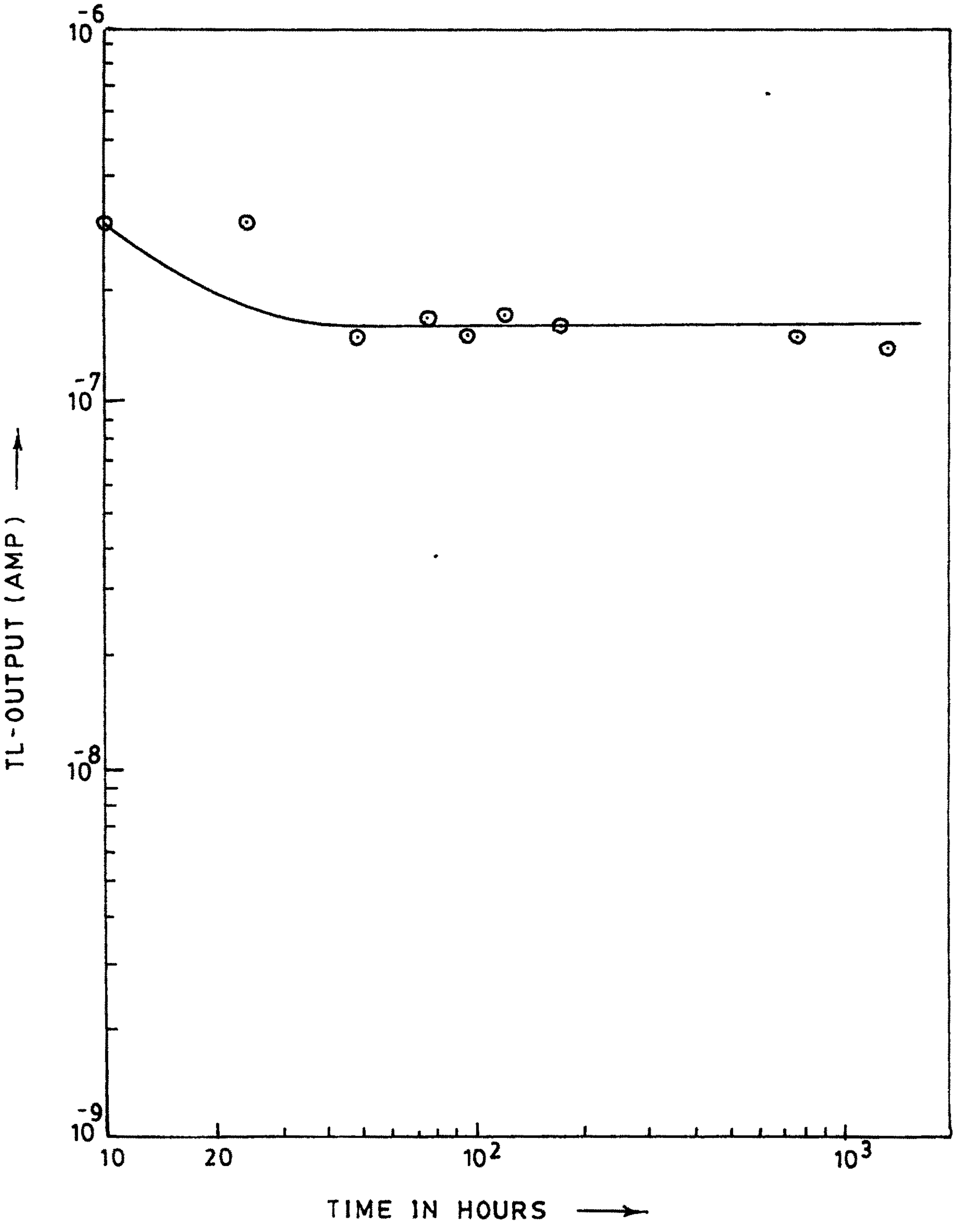


FIG. 39

FIGURE-40: TL GLOW CURVES OF NaF:K(T)

Beta dose: 2.1×10^3 rads.

Curves:	Application of magnetic field (20 minutes) after excitation.
___________	Application of magnetic field(20 minutes) before excitation.
40A	3.3 k Gauss
40B	6.6 k Gauss
40C	9.6 k Gauss
40D	13.2 k Gauss

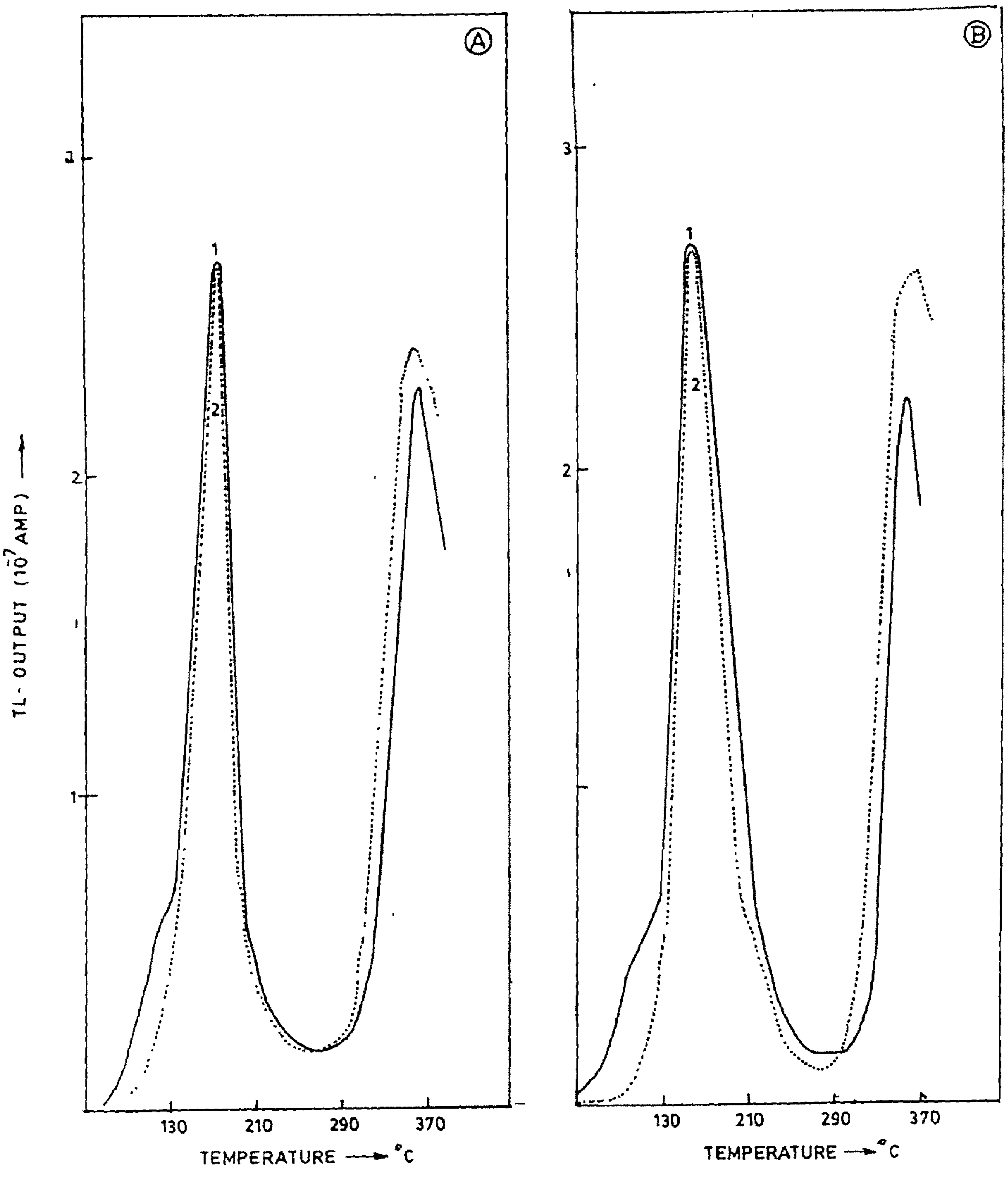


FIG 40

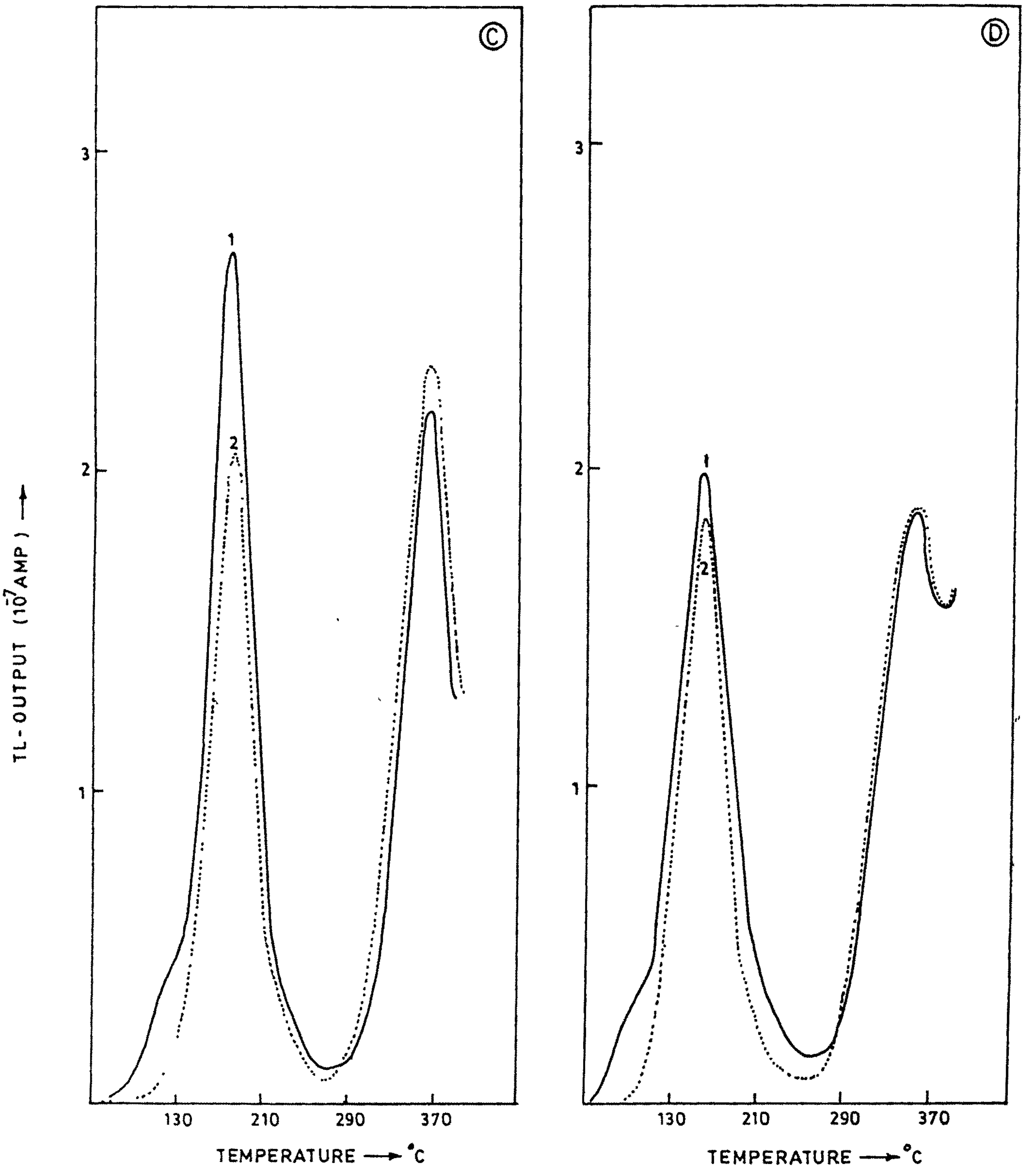


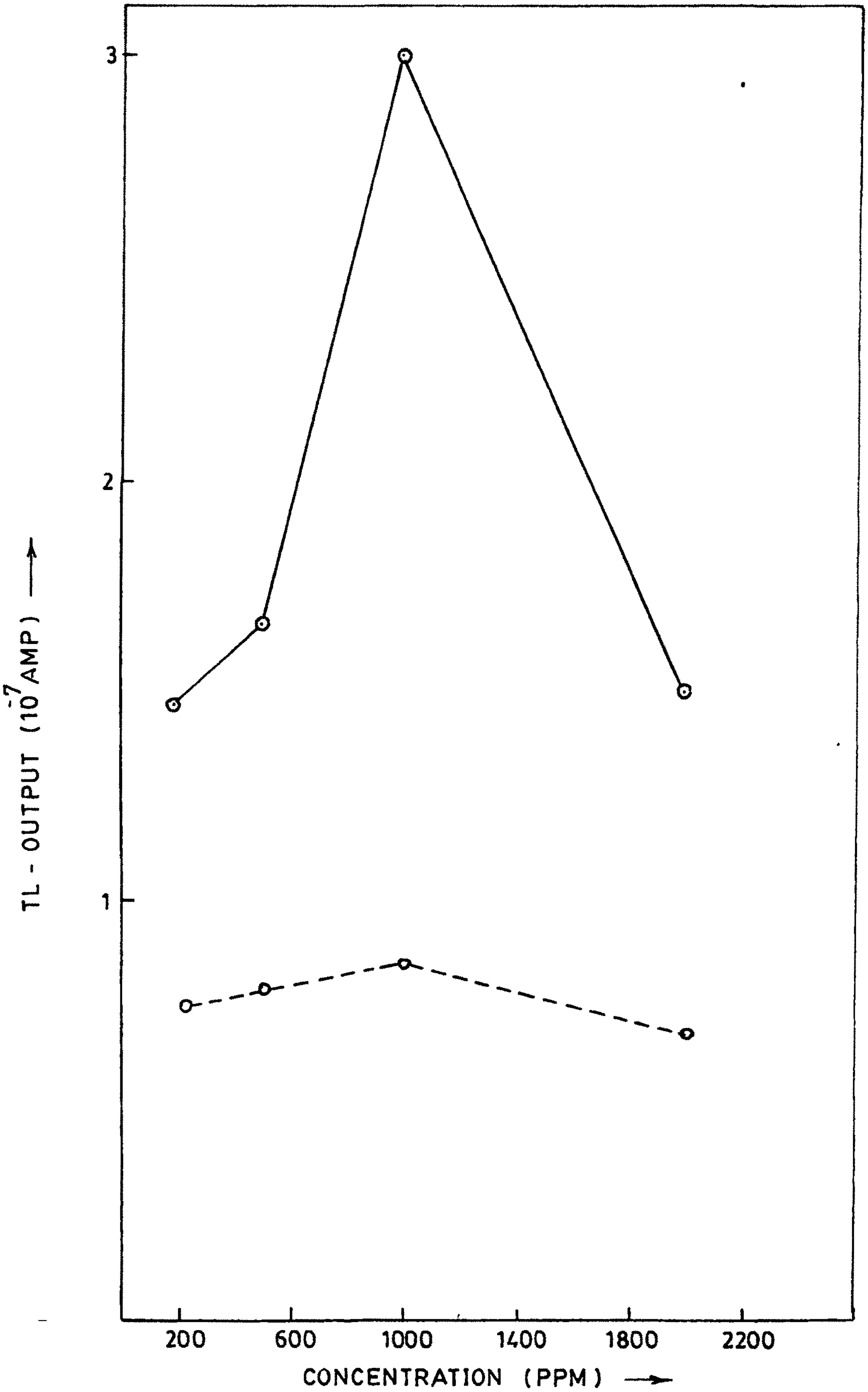
FIG 40

FIGURE-41: RESPONSE OF TL OUTPUT AT 165°C PEAK VERSUS K^+ CONCENTRATION.

Beta dose: 2.1×10^3 rads.

Curves: ―――――― NaF:K(T)

_ _ _ _ _ NaF:K As-obtained from solution.



3
2
1
TL - OUTPUT (10^{-7} AMP) →
200
600
1000
1400
1800
2200
CONCENTRATION (PPM) →

FIG. 41

FIGURE-42: TL GLOW CURVES OF

Beta dose: $2.1x10^3$ rads.

(A) NaF:(T)

(B) NaF:K(T)

(C) NaCl. As-obtained from solution.

(D) NaF. As-obtained from solution.

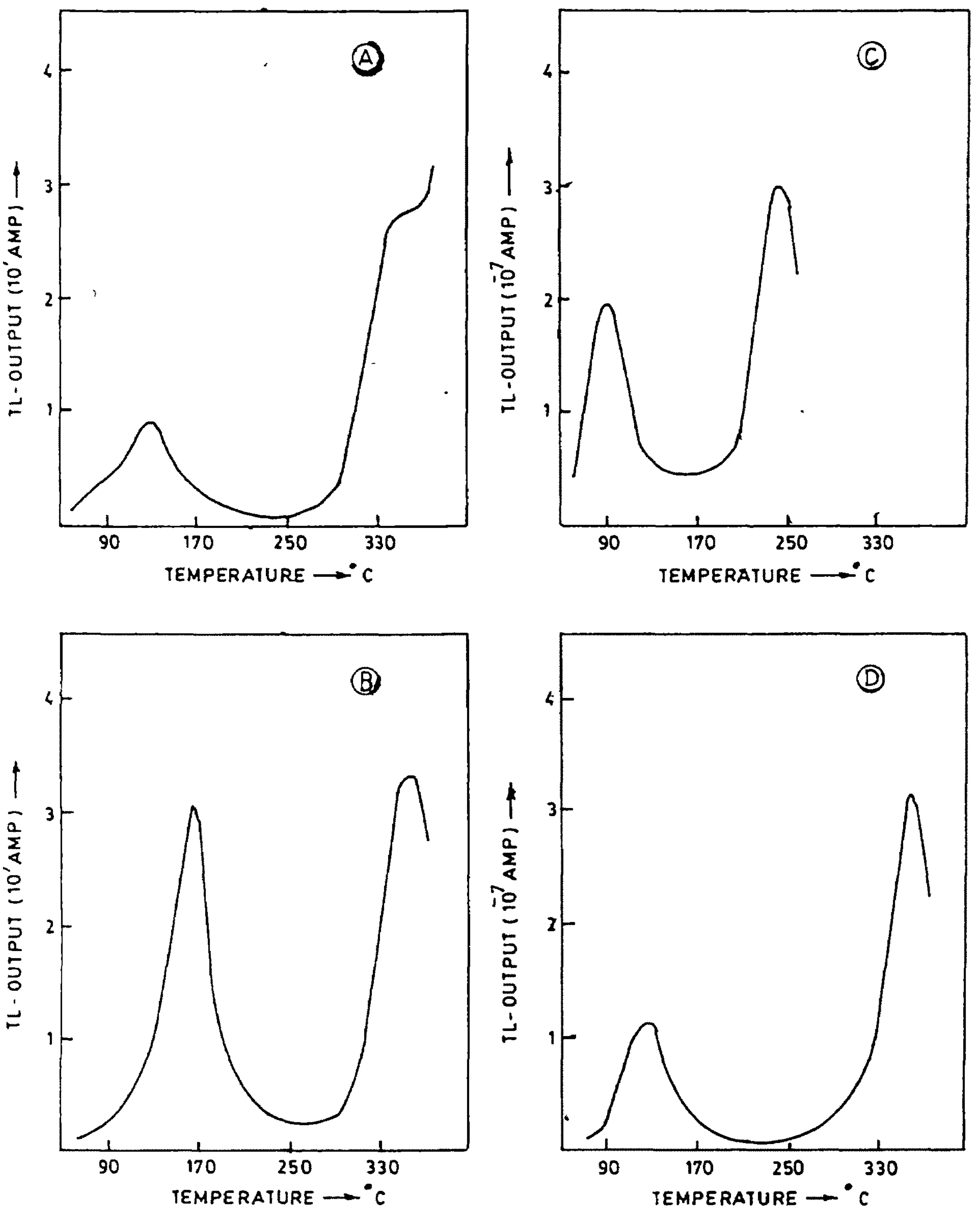

A
B
C
D
TL-OUTPUT (10'AMP)
TL-OUTPUT (10⁻⁷AMP)
TEMPERATURE → °C
90
170
250
330
1
2
3
4

FIG. 42

FIGURE-43: TL GLOW CURVES OF NaF:K(T) RECORDED WITH DIFFERENT FILTERS.

Beta dose: 3.5×10^3 rads.

Curves: (A) .... 320 - 400 nm

(B) ________ 400 - 480 nm

(C) _ _ _ _ _ 480 - 560 nm

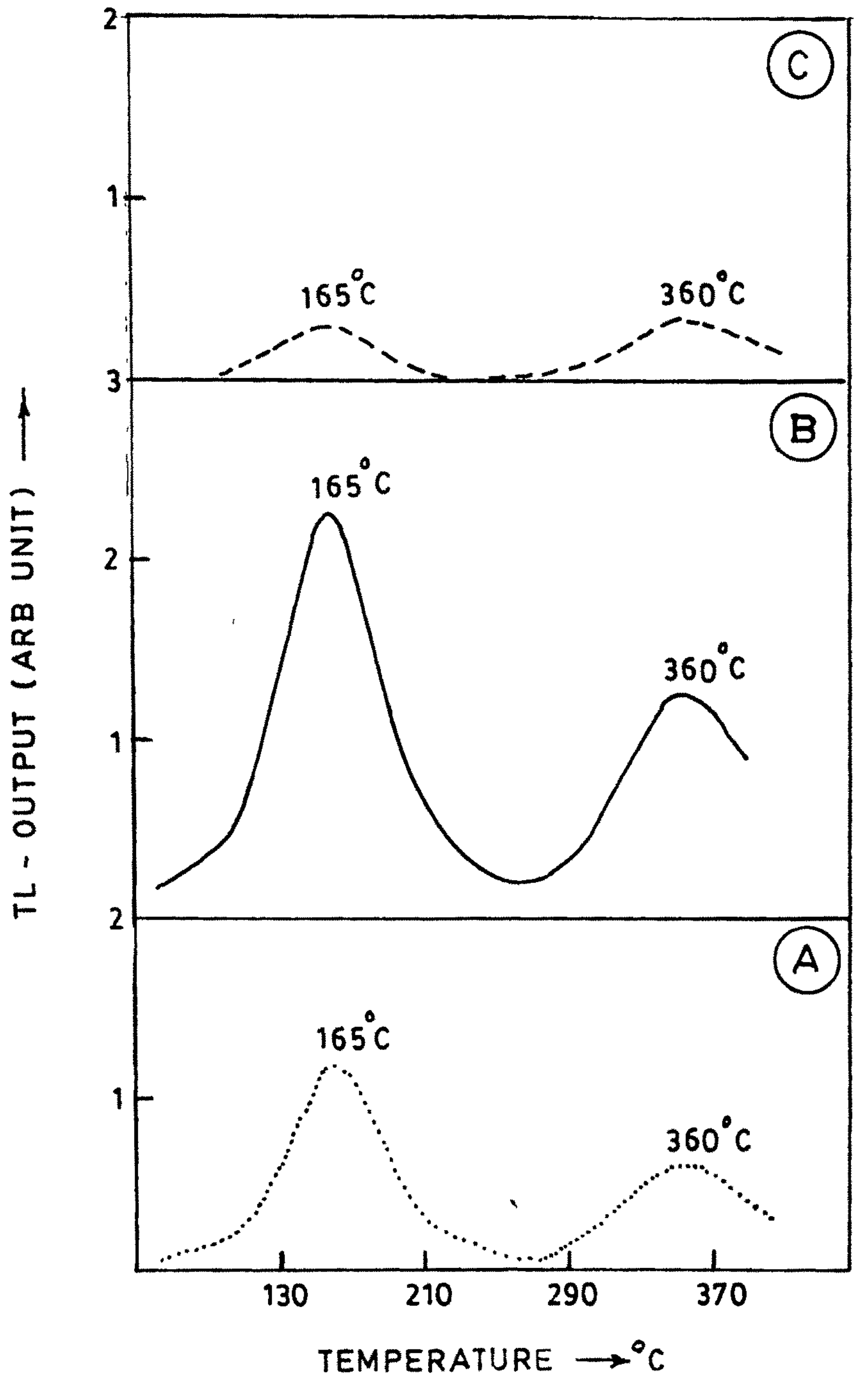

C
B
A
165°C
360°C
165°C
360°C
165°C
360°C
2
1
3
2
1
2
1
TL - OUTPUT (ARB UNIT)
130
210
290
370
TEMPERATURE →°C

FIG. 43

FIGURE-44: GLOW CURVE OF NaF:K(T)

Beta dose: $2.1x10^3$ rads.

[Peak shape method].

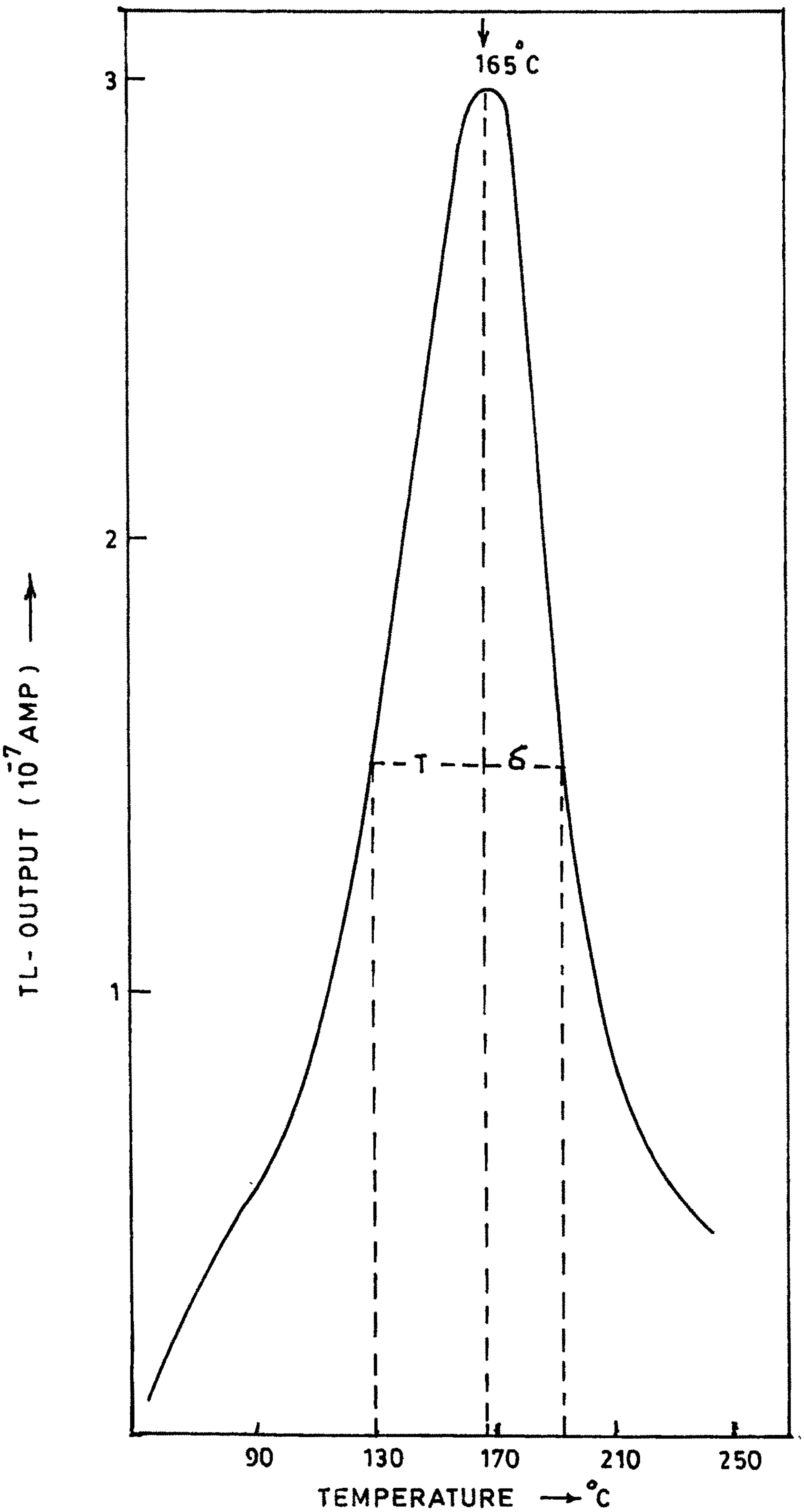


FIG. 44