EUR 338.e

EUROPEAN ATOMIC ENERGY COMMUNITY - EURATOM

# SELF-ABSORPTION IN SOURCES OF BETA EMITTERS

by

G. BERTOLINI, G. SEGRE and O. TERRACINI

1963


Joint Nuclear Research Center
Ispra Establishment - Italy

Nuclear Chemistry Service

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Printed by IMPRIMERIE L. VANMELLE, S.A., GHENT
Brussels, May 1963

**E U R 3 3 8.e**

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Brussels, May 1963, pages 18 — figures 6

A description is given of the measurements carried out in this laboratory in order to determine the self-absorption in pure beta sources.

The beta efficiency, $\varepsilon_\beta$, has been determined for $E^\beta_{max}$ ranging from 160 to 1390 KeV and sources superficial density ranging from 0.05 to 0.6 mg/cm$^2$.

Use has been made of the nuclides : Nb-95, Co-60, Sc-46, Na-22, Au-198 and Na-24.

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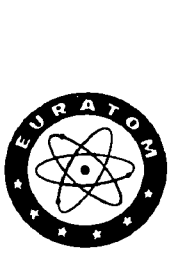


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# SELF ABSORPTION IN SOURCES OF BETA EMITTERS


## S U M M A R Y

A description is given of the measurements carried out in this laboratory in order to determine the self absorption in pure beta sources.

The beta efficiency, $\varepsilon_\beta$, has been determined for $E_{\beta_{max}}$ ranging from 160 to 1390 KeV and sources superficial density ranging from 0.05 to 0.6 mg/cm$^2$.

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## INTRODUCTION

The chief sources of error in the absolute 4pi beta counting are the following:

a) Source mount, gas and walls backscattering

b) Source mount absorption

c) Source self absorption

The first two factors can be readily measured, while the third one, which depends also on the thickness of the deposited material in every point of the source and on the dimensions of the crystals in the source, is difficult to determine.

Many authors (1, 2, 3, 4, 5, 6) have examined the above problem and the methods suitable to measure the self-absorption. These are:

1) Beta measurement of sources of the same nuclide at different concentrations (1). A curve is obtained of activity vs. concentration that, extrapolated to infinite dilution, should give the true disintegration rate. - This method has its weak point in the fact that the size of the crystals seems to be more dependable on the solution temperature and stirring than on the concentration. At high dilution the only parameter varying with the concentration, all the other conditions of deposition being constant, is therefore the average distance among the crystals and, then, the disintegration rate obtained by this extrapolation is not the true one.

2) Beta measurement of sources in which the size of the crystals is determined by electron microscope. (2)

3) Beta measurement of sources distilled under vacuum (4) and whose superficial density is determined by spectrophotometry. The true specific activity is obtained by extrapolation to zero superficial density of the plot of apparent specific activity measured in 4pi counter (3, 6) vs. source superficial density.

4) Beta-gamma coincidences counting (5). - The absolute disintegration rate $N_o$, is obtained by the 4pi beta-gamma coincidence method.
The plot of $N_\beta / N_o$, where $N_\beta$ is corrected for backscattering and absorption in source mount, vs. the superficial density of the source, gives the amount of error due to the self-absorption as a function of superficial density.

In this work use has been made of the above method.

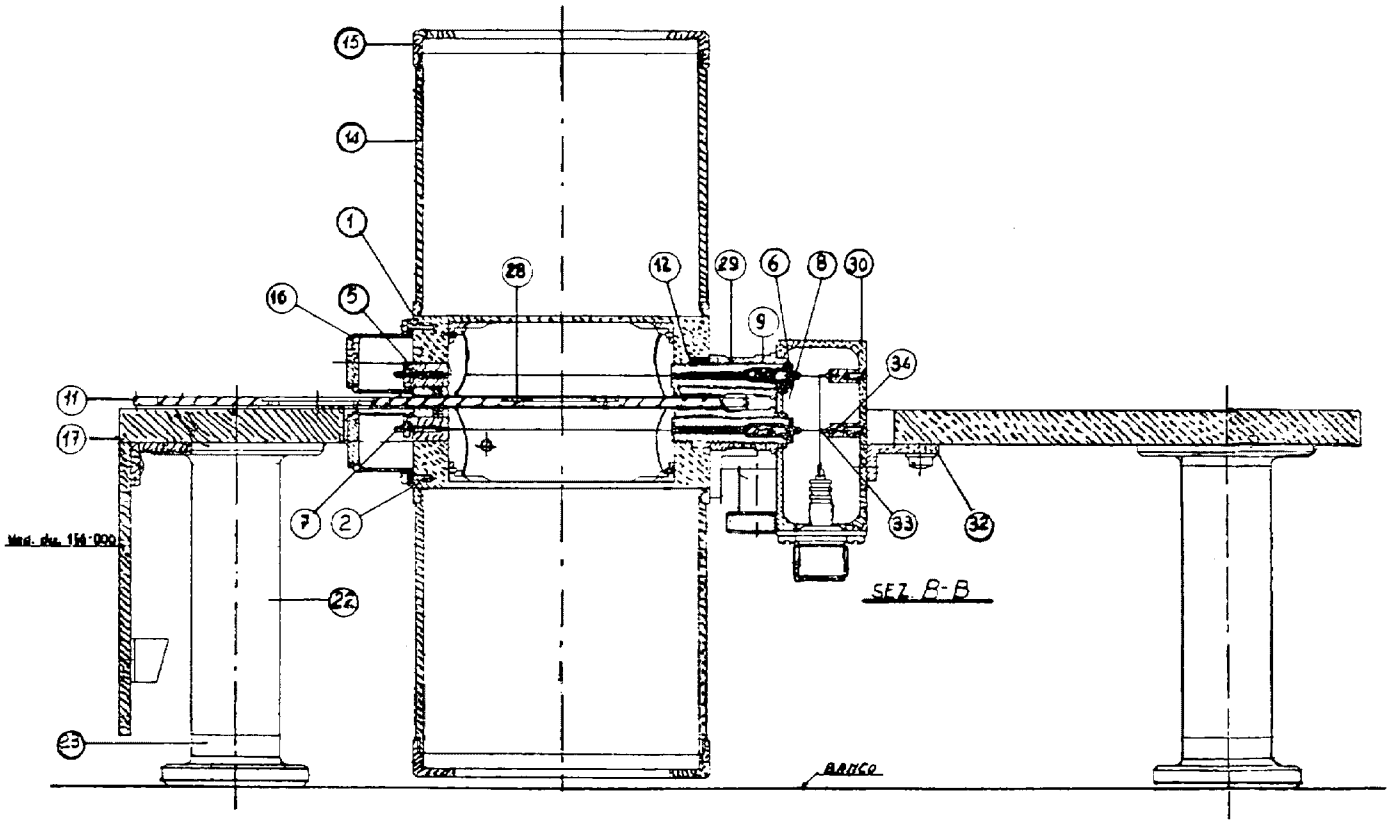



Fig. 1 - 4pi counter "pill-box" for 4pi beta-gamma coincidences. -

## EXPERIMENTAL

### 1) Apparatus

Fig. 1 shows the apparatus used for the coincidences measurements. - This experimental arrangement is similar to that used by Campion (7). - In the beta channel a 4pi "pill-box" $CH_4$ flow counter is used, which works in the proportional region; in the gamma channel a NaI(Tl) 3"x3" scintillator. The block scheme of the apparatus is shown in fig. 2.

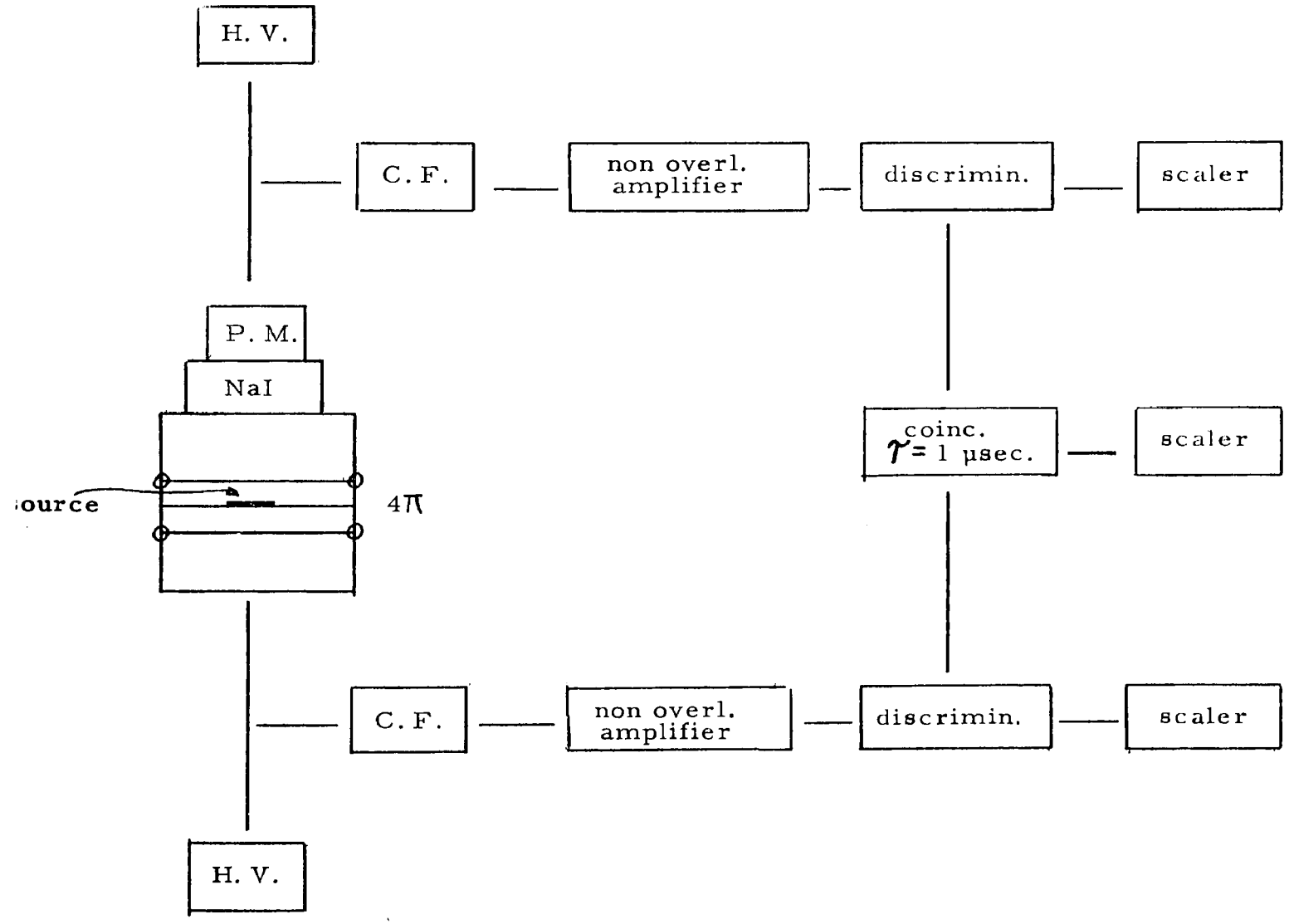



Fig. 2 - Block diagram of the experimental apparatus.

## 2) Sources deposition methods

An examination of the following methods has been carried out making use of a Co-60 solution. The superficial density of the source was about $4 \times 10^{-2}$ $\mu g/cm^2$. - The errors reported are the root-mean-square deviation from the mean value of the $\varepsilon_\beta$ values of 5 sources for each method.

### a) Simple evaporation

An aliquot (10 - 50 $\lambda$) of the Co-60 active solution is deposited on the film by micropipette and dried under an infrared lamp located about 30 cm above the source. The temperature at the source level is about 60°C.
The deposits examined at the metallographic microscope show irregular agglomerates of crystals preferencially distributed at the borders and center of the original drop (fig. 3-1).

### b) Colloidal silica treatment

After deposition as in a) of the active solution, a 10 - 20 $\lambda$ drop of silica solution is added to the first drop and the whole is dried under infrared lamp.
The colloidal silica used is Ludox S. M. DuPont containing 15% of colloidal silica, with particle diameter 7 m$\mu$ and with surface area, B. E. T. method, 400 $m^2/gr$ of silica. The dilution used was $10^3$; with lower dilutions lower $\varepsilon_\beta$ values are obtained.

### c) Ammonia method

The sources are deposited and dried as in a). - Then a drop of water is added and the sources are redried under infrared lamp in an $NH_4OH$ atmosphere. - A cobalt ammonia complex is probably formed (fig. 3-2) (2).
According to Merritt et al. the ammonia treatment is limited to elements which form insoluble hydroxides (5).

### d) Insuline treatment

A drop of a solution of insuline obtained by a 100 times dilution of a 20 vol. solution was used to wet the film.
After allowing a few minutes for the spreading of the wetting agent,

the drop is reabsorbed. - The active solution is then deposited and dried as in a). - The examination at the metallographic microscope shows a better uniformity than that obtained by the simple evaporation method. - In fig. 4 is shown comparison plot of $\varepsilon_\beta$ vs. sources sup. dens. ranging from 0.05 to 0.6 mg/cm$^2$ for sources obtained by insuline and ammonia treatment.

e) Electrospraying method

The active material is dissolved in a volatile solvent (acetyl acetone, acetone, ether, alcohol) and an aliquot (1 - 10 $\lambda$) is introduced in a glass capillary containing a thin platinum wire. Applying a potential difference of 5000 V between the source mount the platinum wire the solution is ejected.
The examination at the metallographic microscope shows a uniformity better than that obtained by the other methods. (fig. 3-4).
The coincidence counting of three sources gave a mean value for $\varepsilon_\beta$ of 0.98.
The method is however not quantitative and, therefore, is not suitable for the purposes of this work.

In table I an intercomparison is reported of the above described methods. - In the present work the ammonia method is used hence forth for the Co-60 sources.

T A B L E I

| Preparation method | $\varepsilon_\beta$ |
|---|---|
| Simple evaporation | 0.785 ± 0.037 |
| Colloidal silica treatment | 0.861 ± 0.005 |
| Ammonia method | 0.883 ± 0.007 |
| Insuline treatment | 0.905 ± 0.011 |

3) Carrier solutions and sources preparation

In table II are shown the nuclides used, with their decay characteristics. - The gamma reported are only those detected in the coincidence measurements.

The sources have been deposited on plastic films of polyvinyl chloride (VINW) of superficial density ranging from 5 to 10 $\mu g/cm^2$ (9). - The films have been coated with a thin layer of gold on both sides by vacuum evaporation.

T A B L E II

| Nuclide | $T_{\frac{1}{2}}$ | $E_{max}\beta$ (MeV) | $E\gamma$ (MeV) |
|---|---|---|---|
| Nb-95 | 35 d | 0.158 | 0.765 |
| Co-60 | 5.2 y | 0.312 (99%) | 1.17; 1.33 |
| Sc-46 | 84 d | 0.360 | 0.885; 1.118 |
| Na-22 | 2.6 y | 0.540 | 1.275 |
| Au-198 | 2.69 d | 0.960 (98.6%) | 0.411 |
| Na-24 | 14.9 h | 1.39 | 1.37; 2.754 |

In order to obtain a plot of the $\varepsilon\beta$ vs. superficial density of the sources for every beta emitter, carrier solutions have been used.

The area of the sources being about 0.5 $cm^2$ and assuming that the beta particle absorption is indipendent of the atomic number, the concentration of the solutions has been so calculated as to give deposits varying from 0.05 to 0.6 $mg/cm^2$. - The carriers used for the various nuclides are shown in table III.

T A B L E III

| Nuclide | Carrier solutions |
|---|---|
| Na-22 | NaCl |
| Na-24 | NaCl |
| Sc-46 | $ScCl_3$ |
| Co-60 | $Co(NO_3)_2$ |
| Au-198 | $HAuCl_4$ |
| Nb-95 | $H_2C_2O_4$ |

## DATA

In fig. 5 are shown the beta efficiencie vs. superficial density plots for the various nuclides examined.

In fig. 6 are shown the plots of beta efficiencies vs. $E_{max}^{\beta}$ for various superficial density of the sources.

## DISCUSSION OF THE RESULTS

The main sources of error in our measurements are:

a) Preparation of the carrier solution
b) Pipetting of the carrier and active solution
c) Non uniformity of the deposits

a) The error introduced by weighing and diluting may always be kept under 1%.

b) The error made by depositing a 50 $\lambda$ drop from a micropipette (for our purposes, this is the optimum size) has been measured to be $\simeq$ 1.5%.

The total error due to items (a) and (b), should not, therefore, exceed 2%.

c) In order to evaluate the dispersion in $\varepsilon_\beta$, five sources each time have been measured.

- The dead time of the beta channel of our apparatus has been measured to be 1.5 μsec for counting rates $< 10^3$ c/s, which is our case. - The error is therefore neglectable in comparison with the previously discussed errors.

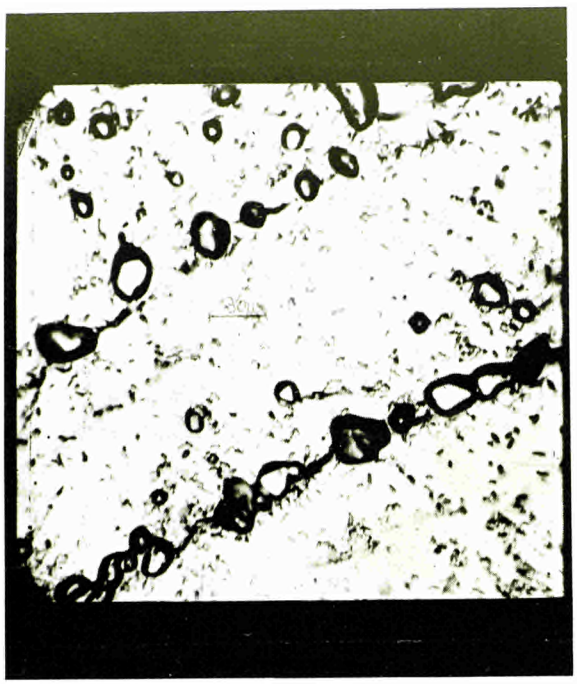
- The resolving time ($\tau$) of the coincidence unit was 1 μsec.

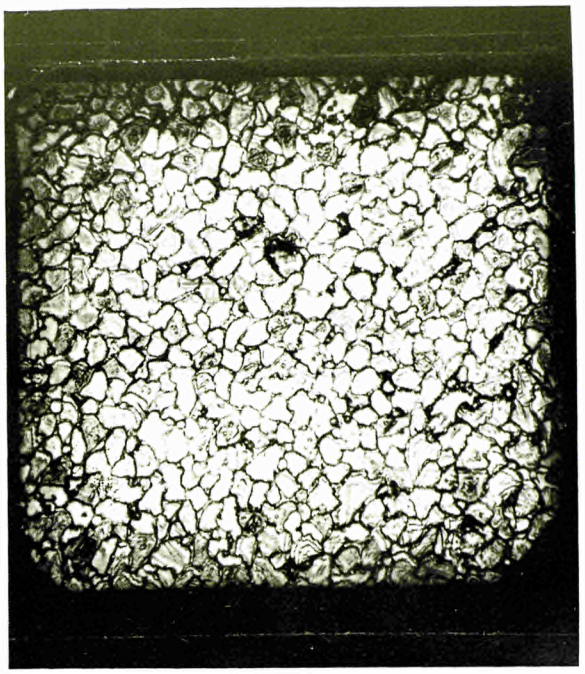
The standard deviation of the $\varepsilon_\beta$ is taken to represent the uncertainty of the data.

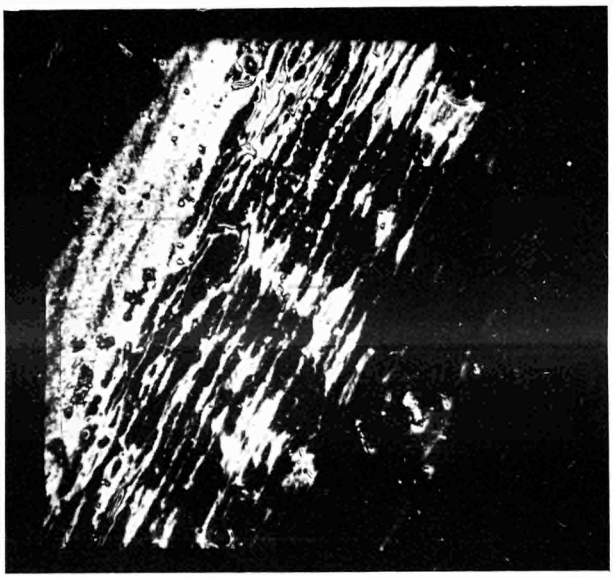
The reported data show, as expected, an increase of standard deviation with increasing superficial density.

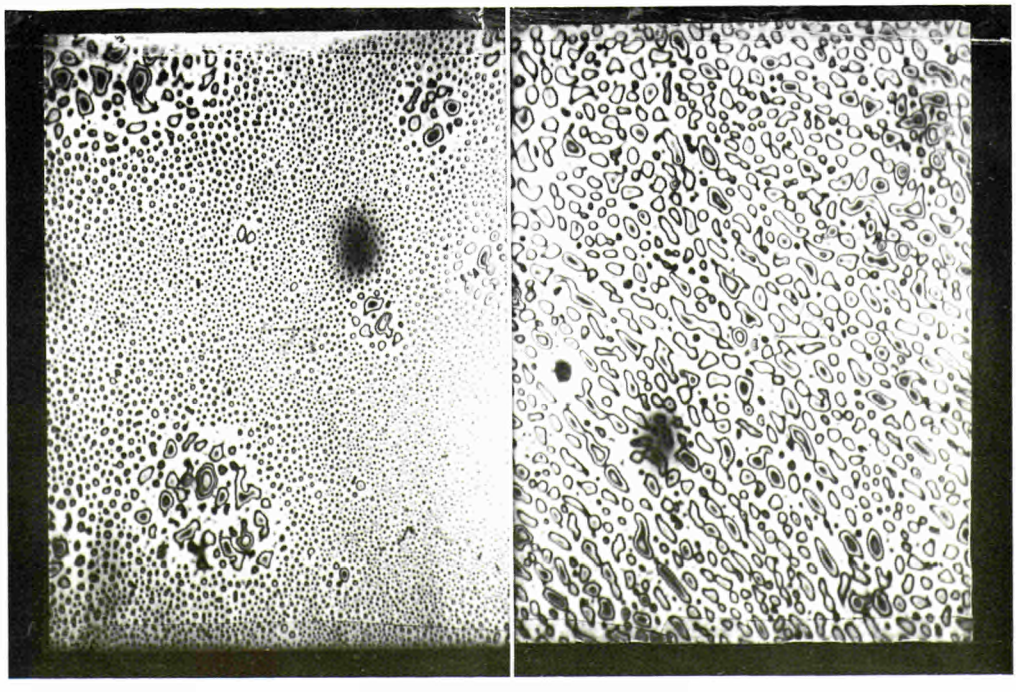
## ACKNOWLEDGEMENTS

We deeply thank Dr. Anna Maria Del Turco and Mr. Renato Lanz for help given in sources preparation and Dr. Roberto Fantechi for helpful discussions.





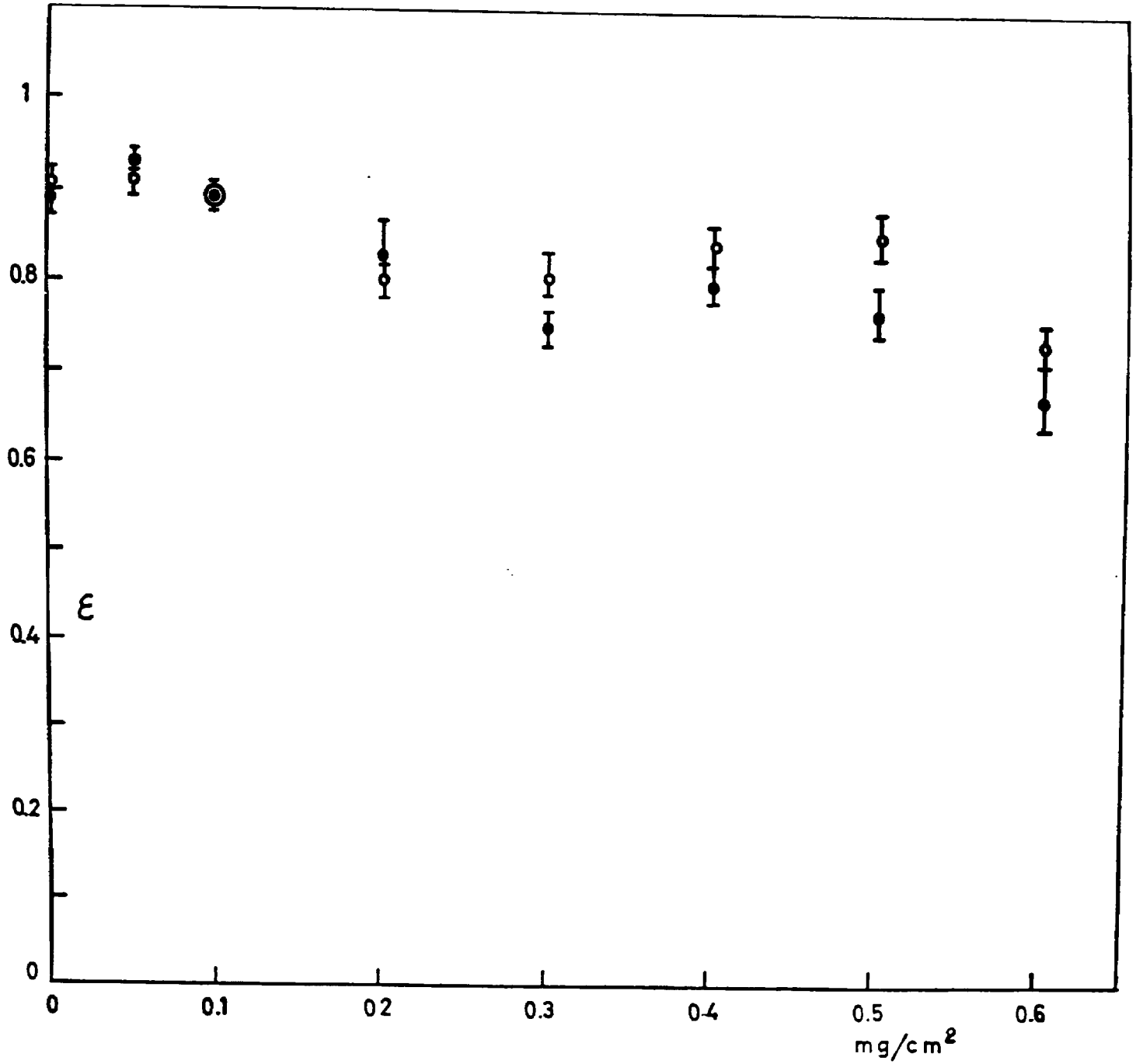




Photographs of sources viewed at the metallographic microscope ( magnification 165 )

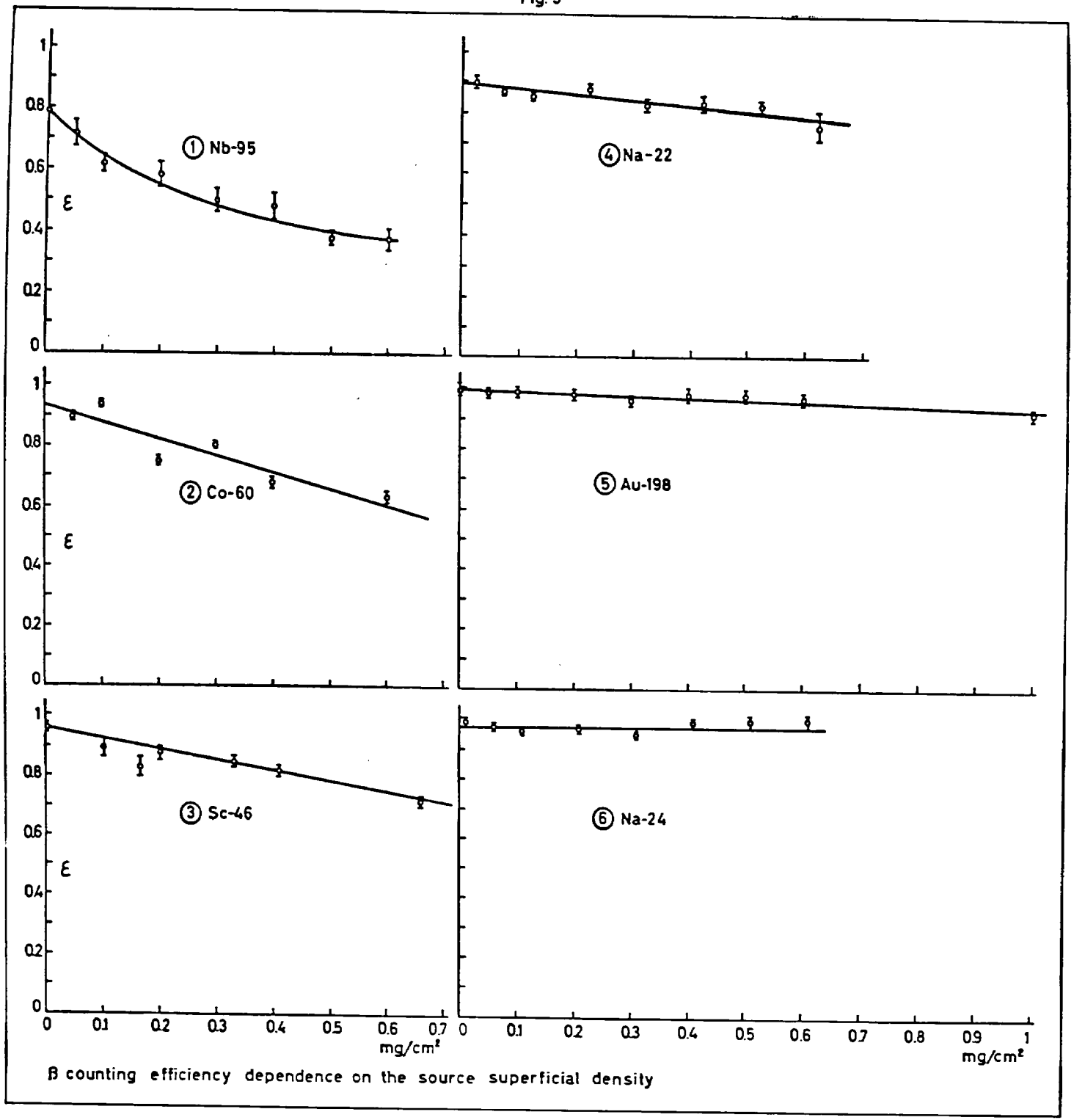
Fig. 3

Fig 4



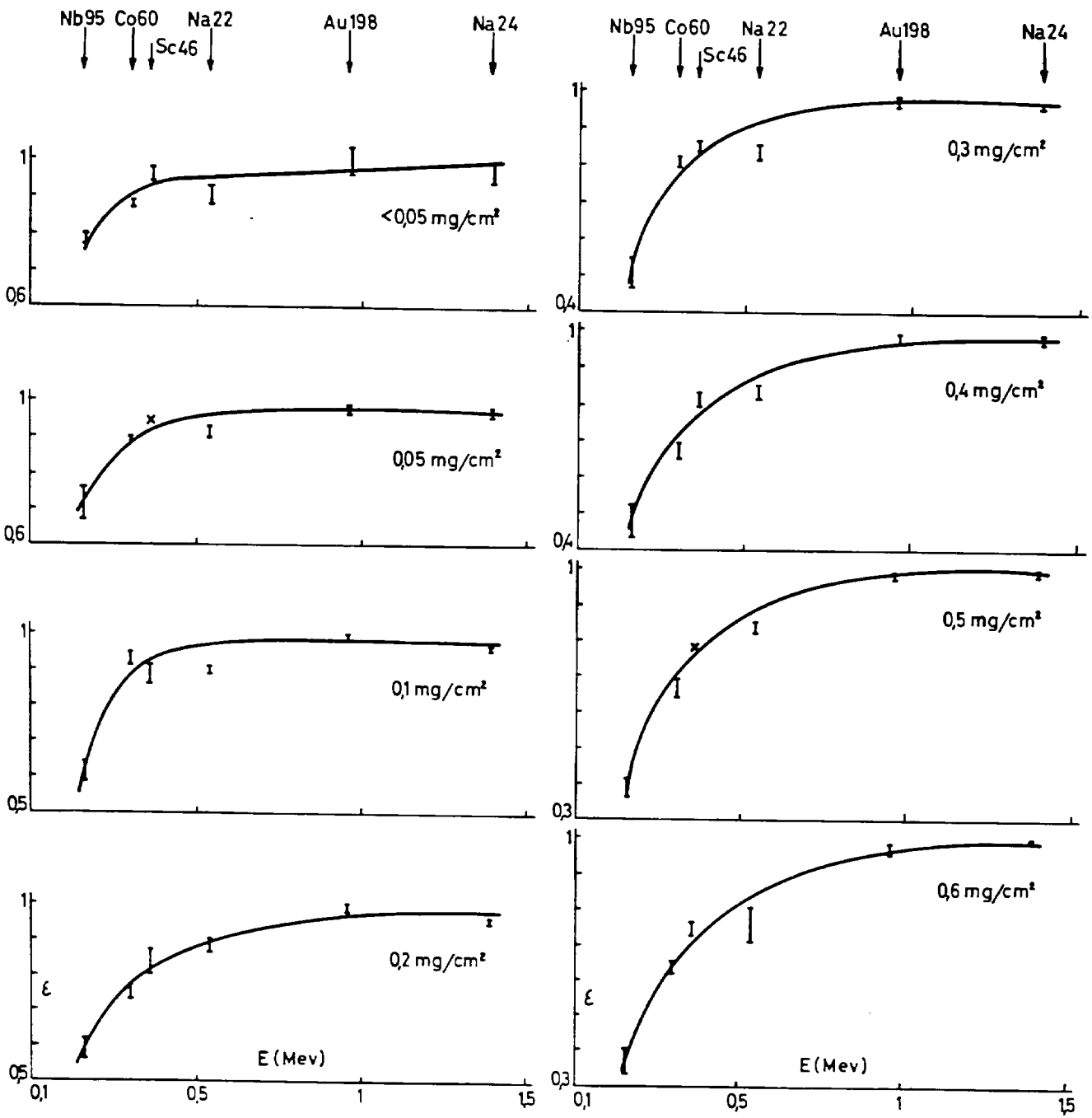

β counting efficiency as a function of sup. dens. for Co 60 sources deposited with ( o ) and without ( • ) insuline

Fig. 5




β counting efficiency dependence on the source superficial density

Fig. 6




ß counting efficiency as a function of max. ß energy (E) for superficial densities ranging from < 0.05 to 0.6 mg/cm²

## BIBLIOGRAPHY

1) R. C. Hawkings, W. F. Merritt, J. H. Craven - "The maintenance of radioactive standards with the 4pi proportional counter" Proc. of Symposium on the Maintenance of Standards (1951)

2) H. H. Seliger, A. Schwebel - "Standardization of beta-emitting nuclides" - Nucleonics 12, No. 7, 54 (1954)

3) B. D. Pate, L. Yaffe - "Disintegration rate determination by 4pi counting - Part I" - Can. J. Chem. 33, 610 (1955)

4) B. D. Pate, L. Yaffe - "Disintegration rate determin ation by 4pi counting - Part IV" - Can. J. Chem. 34, 6265 (1956)

5) J. S. Merritt, . G. U. Taylor, P. J. Campion - "Self-absorption in sources prepared for 4pi beta counting" - Can. J. Chem. 37, 1109 (1959)

6) L. Yaffe, J. B. Fishman - "Self-absorption studies with a 4pi beta proportional flow counter" - Metrology of Radionuclides - 185-198 - I. A. E. A. (1960)

7) P. J. Campion - "The standardization of radioisotopes by the beta-gamma coincidences method using high efficiency detectors" CRP 746 (1958)

8) D. J. Carswell, J. Milsted - "A new method for the preparation of thin films of radioactive material" - J. Nucl. Energy 4, 51 (1957)

9) M. Bresesti, F. Girardi, G. Segre, O. Terracini - "Utilizzazione di copolimeri cloroacetovinilici nella preparazione di film sottili da usarsi in contatori 4pi" - C N I 2 (1958)

CDNA00338ENC