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M.E.Medhat, M.A.Ali*, M.Fayez Hassan*

ANALYSIS OF SOME EGYPTIAN COSMETIC SAMPLES BY FAST NEUTRON ACTIVATION ANALYSIS

*Experimental Nuclear Physics Department, Nuclear Research Centre, Cairo, Egypt

INTRODUCTION

From the beginning of neutron activation analysis in the late 1930s, the neutron source has been the factor limiting its widespread use [1]. In contrast to the funding requirements, radiological safety support, governmental regulation and often negative public interest associated with nuclear reactors, one finds the small accelerator as a neutron generator system particularly accessible. Neutron activation using neutron generators, the so-called fast neutron activation analysis (FNAA) or 14 MeV FNAA has gone through a long developmental history. The use of 14MeV FNAA can be helpful in the determination of certain elements, which can not be measured via (n,γ) reactions. There exist various fast neutron reactions such as (n,p), (n,α) and (n,2n) leading to short lived gamma-ray emitting nuclides which may be successfully be utilized in rapid elemental analysis with 14 MeV neutrons. Many publications about the application of 14 MeVFNAA have been appeared in the literature papers Ehmann et al [2], Bahal and Pepelnik [3] and Perelnik [4,5] demonstrated the precise and accurate determination of elemental composition of different materials. Today the development of low voltage neutron generator (NG) is used in this field, neutrons are produced in continuous mode by creating deuterium ions and accelerating these ions into a tritium or deuterium target according to the following reactions: $^{3}H(d,n)^{4}He$ with E_n=14 MeV or $^{2}H(d,n)^{3}He$ with E_n=2.5 MeV.

In this work, 14MeV FNAA was applied for the determination of Na, Mg, Al, Si, K, Cl, Ca and Fe in two domestic brands of face powder in Egypt.

EXPERIMENTAL SETUP

In the present study, the 14MeV-neutron activation analysis was performed with NG model (A-1254). It consists of four main parts: the accelerator, cooling and vacuum unity, and power supply and remote control console. Deuterium gas is moved through palladium leak assembly into the ion source. Ions are generated using a penning ion source and accelerated under 190 KV. The target is isolated from the rest of the accelerator tube. All of these parts are under vacuum about 10^{-8} tr. The general scheme of this model is shown in fig.1. During the study, the effective flux measured by a calibrated Aluminum foil monitor was 10^{8} n.cm^{-2}.s^{-1} at a distance 1 cm.

Two brands of Egyptian face powder, labeled as sample 1, and sample 2 respectively were chosen. About 2g of cosmetic sample were weighted and pressed under a pressure of 200 Kg/cm^2 for three minutes and placed into polyethylene capsules with 13mm diameter and 8 mm height. For the blank test correction an empty polyethylene capsule was used. The polyethylene capsules with the samples and blank were placed about 15 mm away from the target. The samples were irradiated for 300 seconds then transferred by pneumatic system within 30s to the counting position.The irradiated samples were counted using a high resolution gamma-ray spectrometer which consists of a high pure germanium detector (the typical detector specification was relative efficiency 25 %, energy resolution of 1.9 KeV at 1332.5 KeV of Co^{60} and a peak to Compton ratio of 54:1).

The other associated electronics consists of an H.V model ORTEC 660, an amplifier of type TC-243 TENNELEC and a computerized cart analyzer.

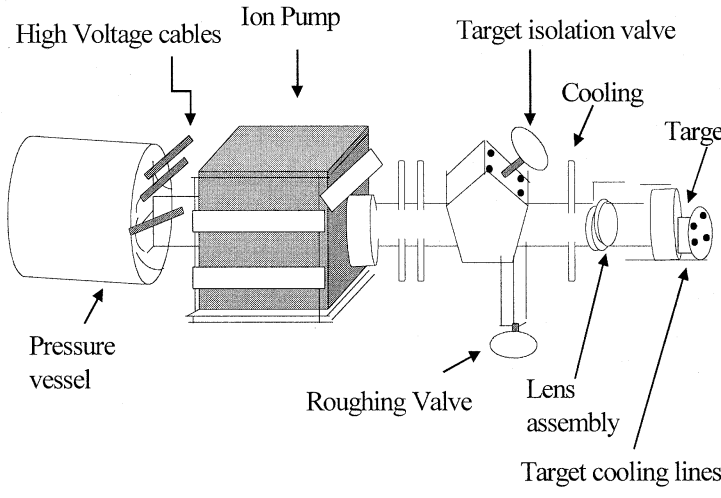

Fig.1 Structure of the neutron generator model M-f physics (A-1254).

RESULTS AND DISCUSSION

The concentration of a certain element (C) within a sample at the end of the irradiation can be obtained from the well-known activation equation:

$$C = \frac{P}{M\,[N_A / A]\,h\,\phi\sigma z f\,\Omega\varepsilon} \qquad 1$$

where P is the full energy peak area; M is the total mass of the sample; N_A is Avogadro number; A is the atomic weight of the element; h is the isotopic abundance; ϕ is the effective flux measured by a calibrated Al foil monitor; σ is the reaction cross-section; f is the relative gamma ray intensity; Ω is the counting solid angle (corrected for photon absorption); ε is the full energy peak efficiency of the gamma detector, and Z is the time factor;

$$z = \left(1 - e^{-\lambda t_i}\right) e^{-\lambda t_c} \left(1 - e^{-\lambda t_m}\right) / \lambda \qquad 2$$

where t_i is the irradiation time; t_c is the cooling time; t_m is the counting time and λ is the decay constant. The efficiency values ε in the region 50 –2000 was obtained by fitting the following empirical function to the experimental points:

$$\ln(\varepsilon) = \sum_{i=0}^{n} \sum_{j=0}^{m} k_{ij}\, d^j \left(\ln(E)\right)^i \qquad 3$$

where k_{ij} is the fitting parameters and d is the distance from the surface detector.

Evaluating the results of FNAA, a major problem is that fast neutrons may lead to neighboring isotopes to produce the same radionuclide through different reactions. Such interference can be correctly, if the contributing element is accurately detected by a second reaction channel. According to Bahal and Pepelnik [2], if there is interference by an element i, with a concentration of C_i and producing the same isotope, the total peak area P_T is given by

$$P_T = P_u + P_i$$

where P_u and P_i are the numbers of peak counts due to the unknown element and the interfering element respectively. The concentration of the unknown element can be calculated by this equation.

The concentration of, Na, Mg, Al, Si, K, Cl, Ca and Fe determined in two domestic face powder samples labeled as sample 1 and sample 2 are summarized in Table .1

Table1: Concentration of major elements (in %) in two types of Egyptian natural cosmetics

Element	Reaction	σ mb	E_γ KeV	Interference	Sample1	Sample2
Na	$^{23}Na(n,p)^{23}Ne$	41	439.9	Mg	0.051±0.013	0.113±0.028
Mg	$^{26}Mg(n,p)^{24}Na$	181	1368.5	Al	0.388±0.047	0.426±0.047
Al	$^{27}Al(n,p)^{27}Mg$	75	843.7	Si	0.134±0.024	0.105±0.030
Si	$^{29}Si(n,p)^{29}Al$	135	1273	-	0.509±0.053	0.347±0.042
K	$^{41}K(n.p)^{41}Ar$	52	1293.7	-	0.092±0.012	0.032±0.021
Cl	$^{35}Cl(n,2n)^{34m}Cl$	7.2	146.4	-	0.130±0.028	0.0890±0.045
Ca	$^{44}Ca(n,p)^{44}K$	44	1157.0	-	0.032±0.006	0.021±0.001
Fe	$^{56}Fe(n,p)^{56}Mn$	123	846.8	-	0.132±0.026	0.080±0.019

* *Errors are expressed as standard deviation.*

Sodium

Sodium was determined by the 439.9 KeV gamma line of the ^{23}Ne isotope ($T_{1/2}$ =37.2 s) produced of the $^{23}Na(n,p)^{23}Ne$ reaction (Figs 1 and 2. The interference from the $^{26}Mg(n, \alpha)^{23}Ne$ was taken into account.

Magnesium

The most sensitive reaction for this element is the $^{26}Mg(n,\alpha)^{23}Ne$ reaction. The isotope ^{23}Ne is also produced by ^{23}Na (n,p) reaction, which is more sensitive and rather strong interference (92.5 %) and therefore leads to a large error in the Mg determination if ^{23}Ne is used. An alternative reaction for the determination of this element is the $^{26}Mg(n,p)^{24}Na$ reaction with gamma line 1368.5 KeV, $T_{1/2}$ =14.959h.The possible interference produced by the $^{27}Al(n, \alpha)^{24}Na$ reaction was considered and the necessary correction was considered. The effect of the $^{23}Na\ (n,\gamma)^{24}Na$ was omitted since the thermal neutron contribution is small.

Aluminum

The most sensitive reaction for this element is the $^{27}Al(n,p)^{27}Mg$ reaction with gamma line 843.7 KeV, $T_{1/2}$ =9.462min . The interference due to $^{30}Si(n,\alpha)^{27}Mg$ reaction was corrected for using the gamma line 1273.3 KeV of the $^{30}Si(n,p)^{29}Al$ reaction.

Silicon

The most sensitive reaction for this element is the $^{28}Si(n,p)^{28}Al$ reaction with gamma line 1779.0 KeV, $T_{1/2}$ =2.241 min, but also the interference from the reaction $^{31}P(n,\alpha)^{28}Al$ reaction is done. So, to solve this interference, the $^{29}Si(n,p)^{29}Al$ reaction, producing gamma line 1273.3 KeV ($T_{1/2}$ = 6.56 min , Figs 3 and 4) was used for silicon determination.

Potassium

Potassium be determined by the $^{41}K(n.p)^{41}Ar$ ($T_{1/2}$ = 1.82 h) at the 1293.7 KeV (Figs 3 and 4). The interference of $^{44}Ca(n,\alpha)^{41}Ar$ was corrected for using the 372.8 KeV gamma line of the $^{44}Ca(n,p)^{44}K$ reaction.

Clarion

The $^{35}Cl(n, 2n)^{34m}Cl$ has been used for the determination ($T_{1/2}$ = 32.0 min, Fig 3 and 4). There is no interference problem.

Calcium

The $^{44}Ca(n,p)^{44}K$ reaction has been used for the determination of calcium. The 1157.0 KeV gamma-line ($T_{1/2}$ = 22.13 min, Fig 3 and 4) was used for the determination. There is no interference problem.

Iron

Iron is determined by $^{56}Fe(n,p)^{56}Mn$ reaction. The 846.8 kV gamma-line ($T_{1/2}$ = 2.75 h, Figs 3 and 4) was used for the determination. The interfering reaction $^{59}Co(n, \alpha)$ was left out consideration, since the gamma ray spectrum does not indicate the presence of Co, the other possible interfering reaction $^{55}Mn(n, \gamma)$ was neglected since the thermal neutron contribution is small.

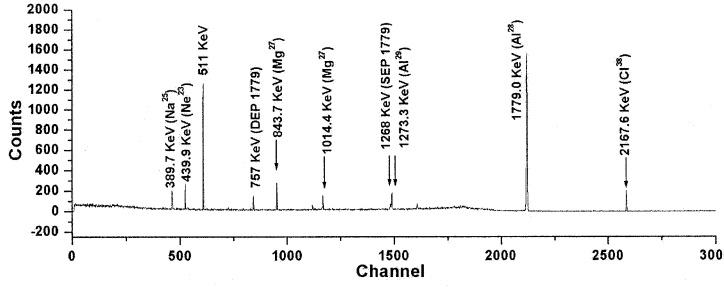

Fig.1 Gamma ray spectra of neutron activated sample of face powder (Sample 1) irradiation time = 300 s, cooling time = 30 s, counting time =100 s.

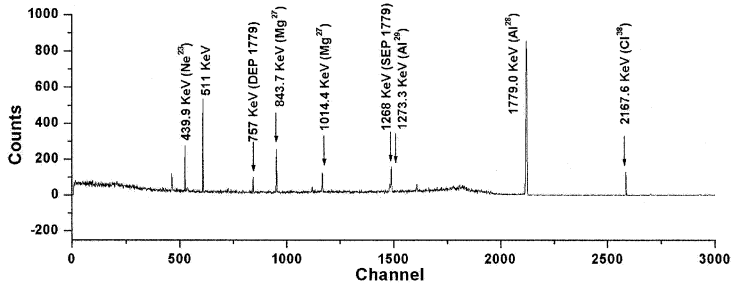

Fig.2 Gamma ray spectra of neutron activated sample of face powder (Sample 2) irradiation time = 300 s, cooling time = 30s, counting time =100 s.

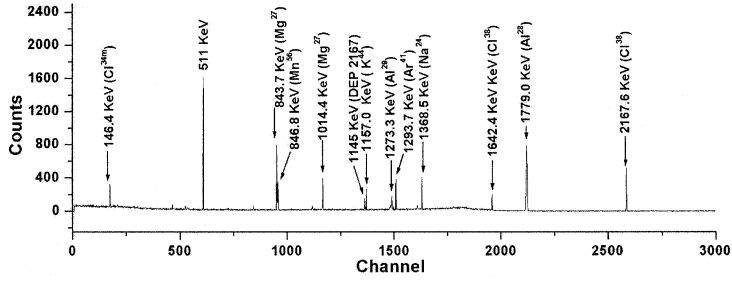

Fig.3 Gamma ray spectra of neutron activated sample of face powder (Sample 1) irradiation time = 300 s, cooling time = 500 s, counting time =1200 s.

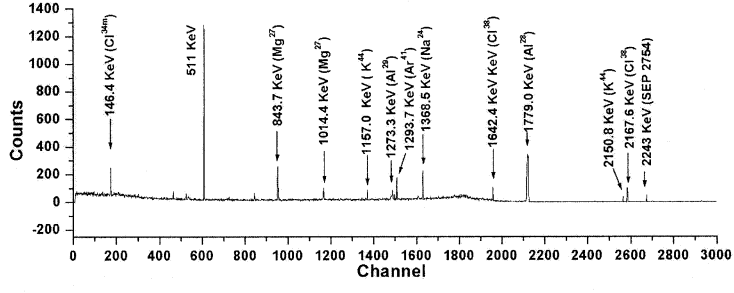

Fig.4 Gamma ray spectra of neutron activated sample of face powder (Sample 2) irradiation time = 300 s, cooling time = 500 s, counting time =1200 s.

CONCLUSION

In this study, it was given a description of a neutron generator model Mf-physics A-1054. This generator was applied for studying some Egyptian cosmetics (face powder). Most of elements found in these samples are light. The determination of their concentration was achieved by resolving the problem of interference. This facility is an essential complement to thermal neutron activation analysis because of its higher detection sensitivity for Na, Mg, Al, Si, K, Cl, Ca and Fe in cosmetic samples. The efficiency of this method will never replace instrumental neutron activation analysis for total elemental analysis.

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Мидхат М.Э., Али М.А., Фаиз Хассан М.
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Анализ элементов в некоторых египетских косметических образцах с помощью активационного анализа на быстрых нейтронах

Представлена схема используемого D–T-нейтронного генератора, который может быть использован для определения некоторых выбранных элементов, особенно легких, в различных материалах путем активации быстрыми нейтронами. В нашей работе при использовании нейтронов с энергией 14 МэВ определялись концентрации Na, Mg, Al, Si, K, Cl, Ca и Fe в двух египетских марках пудры.

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Medhat M.E., Ali M.A., Fayez Hassan M.
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Analysis of Some Egyptian Cosmetic Samples by Fast Neutron Activation Analysis

A description of D–T neutron generator (NG) is presented. This generator can be used for fast neutron activation analysis applied to determine some selected elements, especially light elements, in different materials. In our work, the concentration of the elements Na, Mg, Al, Si, K, Cl, Ca and Fe, were determined in two domestic brands of face powder by using 14 MeV neutron activation analysis.

The investigation has been performed at the Nuclear Research Centre (Cairo, Egypt) and at the Flerov Laboratory of Nuclear Reactions, JINR.

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