Jointly published by
Elsevier Science S. A., Lausanne and
Akadémiai Kiadó, Budapest

J.Radioanal.Nucl.Chem.,Letters
199 (4) 309-316 (1995)

INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS OF BLOOD SERUM

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Received 13 September 1994
Accepted 28 October 1994

Instrumental neutron activation analysis has been used to determine 15 trace elements in twelve blood serum samples taken from healthy students at Bilkent University in Ankara. The method allowed the determination of Sc, Cr, Mn, Fe, Co, Zn, Se, Rb, Cs, Ce, Eu, Tb, Hf, Ta and Hg, which occur at the $\mu g.ml^{-1}$ to $ng.ml^{-1}$ levels. There are no values reported for Tb, Hf, Ce, Eu and Ta before. The other results are compared with the values reported in the literature. Most are in the range of the reported values except for Fe, Zn, Se and Cs.

INTRODUCTION

The importance of trace elements in human health has been realized only in the last twenty years. The biological function of trace elements and the effect of their deficiency in human metabolism remain important questions. A great majority of the trace elements serve chiefly as key components in enzyme systems connected

0236-5731/95/US $ 9.50

TABLE 1

Biological importance of some trace elements

Element	Biological importance
Se	An integral component of the enzyme glutathione peroxidase which neutralizes active oxygen species such as H_2O_2 and O_2^-.
Cr	A cofactor of sugar metabolism. Essential for the effective metabolism of insulin in insulin sensitive organs.
Co	A component of vitamin B_{12}.
Hg	Toxic element. Causes severe health problems.
Zn	A constituent of over 200 metalloenzymes (cabonic anhydrase, alkaline phosphatase, etc.). Essential for many diverse functions including growth and development, normal reproduction, immune and sensory functions, anti-oxidant protection and stabilization of membranes.
Mn	Essential for growth. An activator of some enzymes such as Ribonucleotide reductase, Phosphoglycerate and Phosphomutase and L-threonine dehydrogenase.
Fe	Essential for growth. An integral component of hemoglobin, hemoproteins and protein B_2.

to vital protein synthesis. If the metal is removed the protein usually loses its functional capacity. Table 1 summarizes the biological importance of some trace elements. Blood serum is often considered a convenient sample material as it can be easily obtained from large groups of subjects.

Among the various analytical techniques, Instrumental Neutron Activation Analysis (INAA) is one of the most powerful for the simultaneous determination of several elements in human blood serum and other biological materials[1-7].

In this work concentrations of fifteen trace elements have been determined in human blood serum using INNA method. Five of these elements are reported for the first time.

EXPERIMENTAL

The blood samples were taken from a group of healthy students at Bilkent University in Ankara using stainless steel disposable needles. No anticoagulant was used. The serum was separated from the erythrocytes by centrifuging at 1000 g for 10 min and the serum part was decanted into precleaned polycarbonate tubes. The serum samples were then freeze-dried. They were introduced into quartz tubes which were cleaned and sterilized by immersing into a boiling solution of concentrated HNO_3 and H_2SO_4 acids and rinsing several times with doubly distilled, deionized water.

The serum samples were sealed and irradiated in the Reactor at the Nuclear Research Center in K. Çekmece (Istanbul) together with standard and blank samples, for 8 h at a flux of $4x10^{13}$ $n.cm^{-2}.s^{-1}$. After 17 d of cooling, activity measurements were done using a hyperpure coaxial Ge detector and a multichannel analyzer. The resolution (FWHM) of the detector was 0.790 keV for the 122 keV γ-line of ^{58}Co and 1.80 keV for the 1330 keV γ-line of ^{60}Co. Efficiency calibration was done using standard sources. The samples were systematically analyzed according to a counting program for about 9 months. The background contribution of the blank sample was subtracted from each measurement. All activities were corrected to the end of irradiation using standard growth and decay equations.

RESULTS AND DISCUSSION

Figure 1 shows two γ-ray spectra of blood serum irradiated for 8 h and counted for 2600 s. The top spectrum was taken 27 d after irradiation and the bottom spectrum 118 d later. All the peaks were well resolved except for the 279.2 keV γ-peak of ^{203}Hg which could not be separated from the 279.5 keV γ-peak of ^{75}Se. The net activity of ^{203}Hg was calculated by subtracting the contribution of ^{75}Se from its 264.7 keV γ-peak. Figure 2 illustrates the half-life determination of the radionuclides used in the analysis. The decay of the γ-peaks was followed by counting the samples several times. The half-lives obtained agree well with the literature values in all cases.

Table 2 gives the list of radioelements, their γ-peaks, absolute intensities and half-lives used in the analysis together with the concentrations of fifteen trace elements determined in each of the 12 blood serum samples. Experimental mean values of each element, their ranges and available literature ranges[8] are given. For the trace elements, Hf, Tb, Ta, Eu and Ce no literature values are available. The wide ranges reported reflect analytical difficulties in determining such low levels of elements. Our results for Cr, Hg, Co, Rb, Mn and Sc are within the ranges reported in the literature. Those of Zn and Se are somewhat lower. The low values of Zn and Se may be important as both of these are essential trace elements. The distribution of Zn and Se tend to show regional differences depending on environmental and agricultural conditions[9,10]. It may be worthwhile to pursue the reasons for low levels of Zn and Se by examining the subjects further. The levels of Fe and Cs are higher

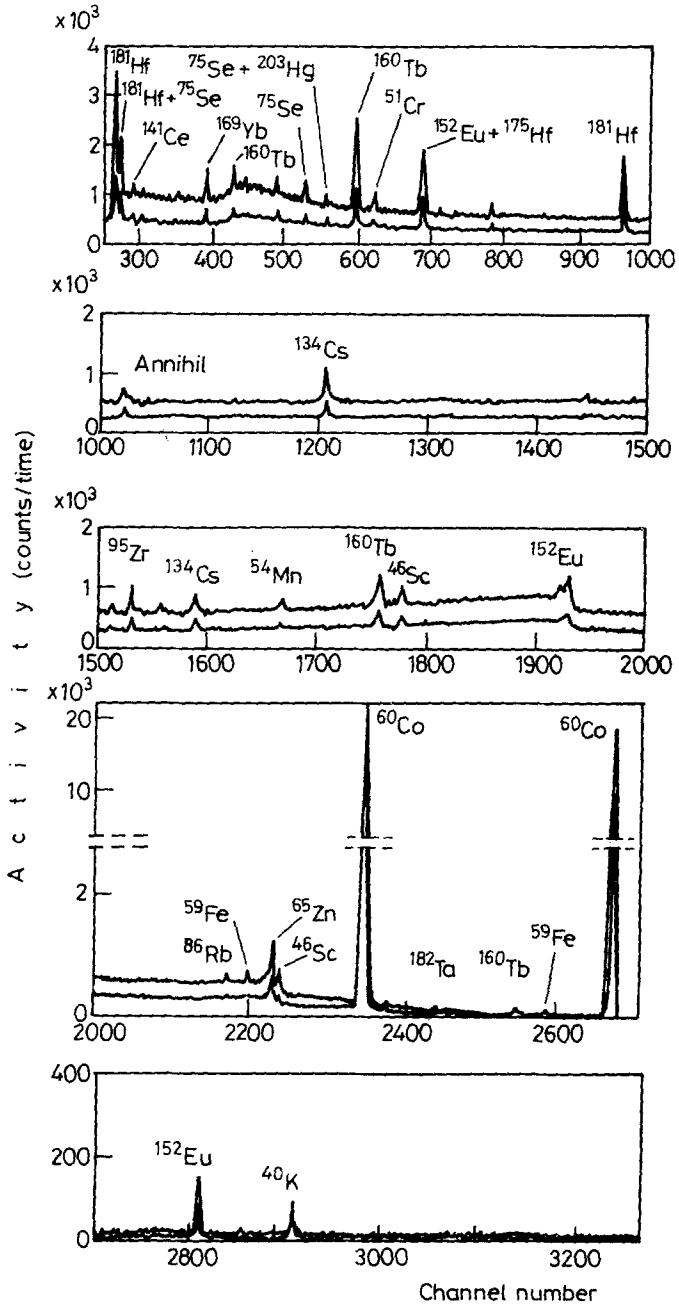

Fig. 1. Gamma-ray spectra of blood serum irradiated for 8 h and counted for 2600 s. The top spectrum was taken 27 d after irradiation and the bottom spectrum 118 d later. The gain was 0.5 keV/channel

TABLE 2

List of the radionuclides, their γ-peaks, intensities and half-lives used in the activation analysis of blood serum, together with the experimentally determined levels of trace elements from this work and available literature values. Mean values of 12 subjects and concentration ranges are given for each trace element. The minimum detectable mass, M_D and sensitivity factor, K values are also given

Element	Radio-nuclide	Half-life, day	γ-Energy, keV	Absolute intensity	Mean value, ng ml^{-1}	Range, ng ml^{-1}	Lit. range, ng ml^{-1}	M_D, ng	K count g^{-1} $x10^{-7}$
Sc	^{46}Sc	83.8	889.3	0.99	4.2±0.3	0.83-10.8	0.15-6	0.4	39.4
Cr	^{51}Cr	27.7	320.1	0.10	102±6	2.94-268	2-400	2.6	218
Mn	^{54}Mn	312.3	834.8	0.99	1.4±0.7	0.78-2.31	0.4-400	0.4	12.8
Fe	^{59}Fe	44.5	1099.3	0.56	3175±756	2424-3743	460-2000	-	-
Co	^{60}Co	$1.9x10^3$	1173.2	0.99	93±5	37.8-268	0.3-400	0.15	5.1
Zn	^{65}Zn	244.3	1115.5	0.51	654±33	261-1368	800-3500	8	0.21
Se	^{75}Se	119.6	264.7	0.59	46±14	21.3-113	60-150	1	1.52
Rb	^{86}Rb	18.7	1077	0.09	817±50	673-1061	40-2000	330	0.04
Cs	^{134}Cs	754.3	604.7	0.98	24±1	4.3-66	0.74-1.8	0.34	4.1
Ce	^{141}Ce	32.5	145.4	0.49	87±4	25.2-190	-	5	4.81
Eu	^{152}Eu	$3.1x10^3$	1408	0.21	1±0.6	0.15-3.1	-	0.1	62
Tb	^{160}Tb	72.3	879.4	0.30	10±3	3.0-26	-	0.34	4.1
Hf	^{181}Hf	42.4	482	0.86	29±1.2	23-36	-	4.9	15.6
Ta	^{182}Ta	114.4	1221.4	0.27	7±1	1.9-14	-	1	3.1
Hg	^{203}Hg	46.6	279.2	0.82	2±0.9	0.7-5.0	1.3-5	0.6	6.14

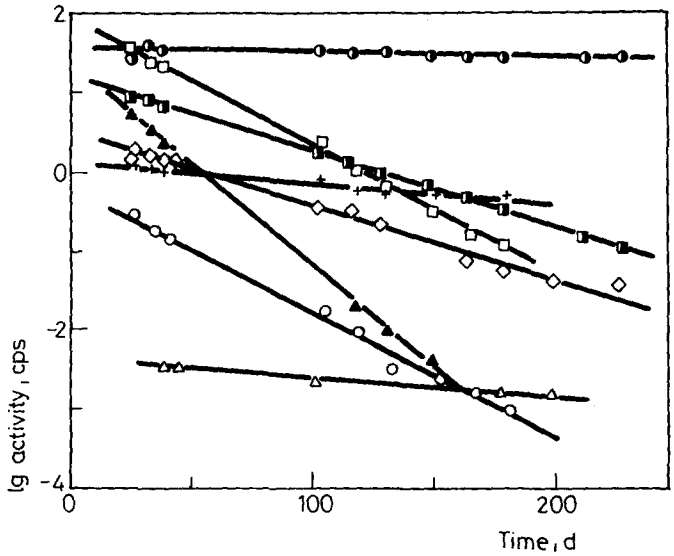

Fig. 2. Illustration of the half-life determination of some radionuclides used in the analysis.

		Exp. half-life, d
◨:	^{46}Sc	71.8±10
▲:	^{51}Cr	26.5±0.4
○:	^{59}Fe	43.4±0.03
◇:	^{160}Tb	72.5±0.9
□:	^{181}Hf	43.3±1.4
△:	^{54}Mn	274.5±35
◑:	^{60}Co	1.2×10^3±512
+:	^{65}Zn	255.6±13

than the reported ranges. In the case of Fe, erythrocyte contamination of some samples may cause a higher value.

The detection limit of a radionuclide is an important parameter in neutron activation analysis. It is usually defined as the smallest photo-peak that can be detected with certain confidence above the background continuum. Currie[11] showed that the limit of detection, L_D (counts), for a certain radioactivity is equal to 3.29 σ_B, where σ_B is the standard deviation of the peak of interest in the blank sample. The minimum detectable mass, M_D is given by $M_D = L_D/K$, where K is the sensitivity factor

(counts.g^{-1}). In this work, K was found from the slope of the radionuclide activity vs. weight (g) of trace element plot using 12 samples. The M_D values and the sensitivity factors K for each element analyzed are also listed in Table 2.

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We thank the Turkish Atomic Energy Commission for Reactor Irradiations and Z. Gökmenoğlu for her contributions in the initial phases of this work.

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