DETERMINATION OF ACTIVITY OF ^{40}K IN CHEMICAL SAMPLE

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ABSTRACT

In this research work, determination of ^{40}K activity in Chemical sample using gamma ray spectrometry. The NaI (Tl) scintillation detector was used for all of the measurements. The reference Whey Powder (IAEA-154) was first measured. The full energy peak efficiencies of NaI (Tl) scintillation detector was determined for ^{137}Cs (661.66keV) and ^{40}K (1460.75keV). The activity of ^{40}K is (1548.60 $\pm$122.02 Bq/kg) and the activity of ^{137}Cs is (2336.78$\pm$136 Bq/kg) in the Whey Powder sample. And also the unknown activity of Chemical Sample (Potassium Nitrate sample) was measured. The activity of ^{40}K in Chemical sample (Potassium Nitrate sample) is (8217.53 $\pm$503.69 Bq/kg).

Introduction

We live in a naturally radioactive world. Radioactive polonium and radium are present in our bones, our muscles contain radioactive carbon and potassium and there are radioactive noble gases and tritium in our lungs. We are bombarded by cosmic radiation from space and irradiation from within by the natural and artificial substances we eat and drink each day. Potassium is a soft, silver-white metal. An important constituent of soil is present in all plant and animal tissues. Potassium-40 is a naturally occurring radioactive isotope of potassium. Two stable (non radioactive) isotopes of potassium exist, potassium-39 and potassium-41. Potassium-39 comprises most (about 93%) of naturally occurring potassium, and potassium-41 accounts for essentially all the rest. Radioactive postassium-40 comprises a very small fraction (about 0.012%) of naturally occurring potassium.

The half-life of potassium-40 is 1.3 billion years, and it decays to calcium-40 by emitting a beta particle with no attendant gamma radiation (89% of the time) and to the gas argon-40 by electron capture with emission of an energetic gamma ray (11% of the time). Potassium-40 is an important radionuclide in terms of the dose associated with naturally occurring radionuclides. Potassium is present in the earth's crust, oceans, and all organic material. Since potassium is found in the intercellular fluids, about 98% of the potassium in the body is within cells. Thus, at least 98% of these disintegrations take place within body cells, and are potentially capable of altering the cell's DNA

Sample Collection

In this research work, two kinds of sample were measured. These are Whey Powder sample that was produced from cow's milk, Potassium Nitrate (KNO_3**)** sample was chemical products.

Sample Collection and Preparation

The Whey Powder samples were obtained from **IAEA** Laboratories at Seibersdorf, Vienna, Austria. It was produced from cow's milk obtained from animals that had grazed on land contaminated with radioactive fallout resulting from the Chernobyl incident in 1986. The milk powder was donated to the IAEA by a milk processing facility in the former USSR. A bulk sample of approximately 500kg of milk powder prepared in a single batch was received by the Agency's Laboratories at Seibersdorf. In this sample ^{40}K, ^{90}Sr, ^{134}Cs and ^{137}Cs are contained. The Potassium Nitrate (KNO_3) sample was collected from local market. These samples contain 38.66% of potassium.

Experimental setup

Gamma ray spectrometry is used to measure the energy, intensity and to determine the energy spectrum of the incident gamma radiation and the element in unknown sample. The gamma ray spectrometry is an important technique not only in basic nuclear physics but also in applied nuclear physics. Gamma spectrometry is extremely important measurement. The instrumentation used in present work consists of a Scintillation detector, associated with electrons, and a computer based, multichannel analyzer (MCA).

NaI (Tl) Scintillation Detector

A typical NaI(Tl) detector based gamma spectroscopy system. NaI (Tl) detector consists of a scintillator coupled optically to a photomultiplier tube. The scintillator used in the present work is a thallium activated sodium iodide crystal [NaI(Tl)]. The size of the crystal used in this work is 3"x 3". NaI (Tl) are high efficiency for the detection of gamma radiation even more so than solid state conductivity detectors. However the crystal will absorb moisture from the atmosphere and irradiate very rapidly. It is therefore 'canned' in an air-tight container. The NaI (Tl) detector is easier to use in the work

environmental than a solid state conductivity detector because it does not need to be cooled. It also a much better measuring efficiency, particularly at higher energies.

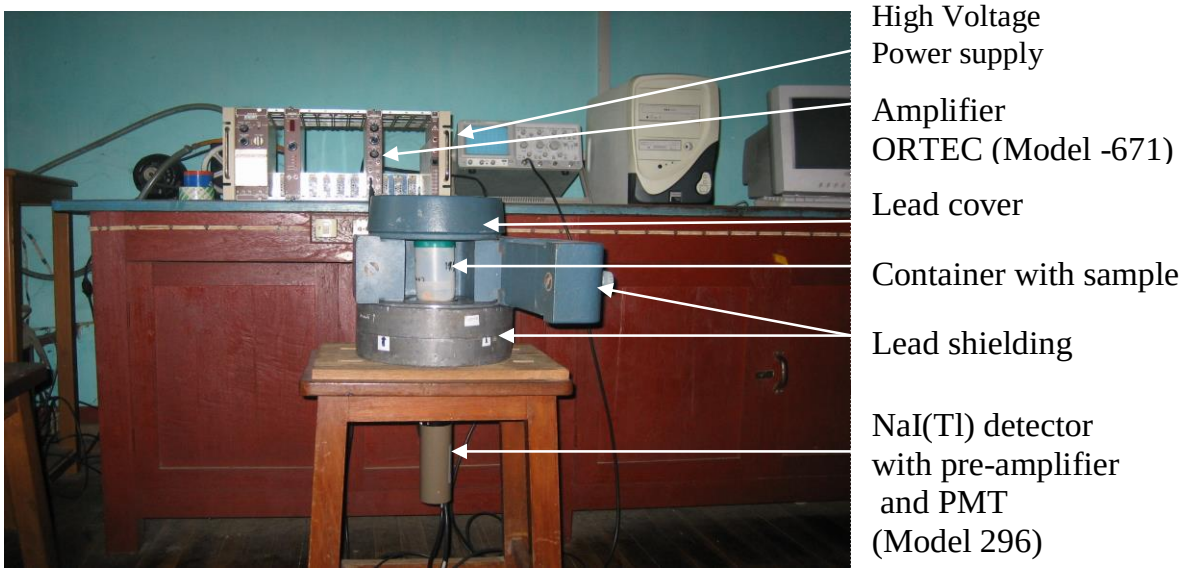

Fig.4.1 (a) Arrangement of experimental set up for detection system

Fig.4.1 (b) Arrangement of experimental set up for detection system

Experimental Detail procedure

Before assembly sample preparation, the weight of the plastic container was first recorded by using digital balance (Model – PW 254). And then, sample was placed in the container. The weight of the container with sample was recorded again. The net weight (0.21 kg) of the each sample was used in this measurement. The Whey Powder sample (ρ = 0.591gcm^{-3}), Potassium Nitrate sample (ρ = 0.656gcm^{-3}) sample was used for this measurement.

In gamma ray spectrometry system, the following equipments are included. They are NaI (Tl) scintillation detector associated with ORTEC (Model 296) photo multiplier tube, preamplifier, fast spectroscopy amplifier (ORTEC Model 671), a pulse stored multi-channel analyzer (MCA) together with Gamma Vision 32 software installed in PC, high voltage power supply and laser printer.The high voltage power supply was used for the detector. The operating voltage for NaI (Tl) scintillation detector is +1000V. The 3"x 3" NaI (Tl) scintillation detector was used to detect the gamma radiation intensity before and after passing through the absorbing material. These informations (electronic pulses) were amplified and stored in MCA based on personal computer. This experimental setting was fixed throughout the whole research laboratory measurement.

Present activity of the measured sample can be calculated by using the following equation

$$A(t) = A_0 e^{-\lambda t} \qquad (1)$$

where, $A(t)$ = the present activity of the source

$A(0)$ = the activity of the source at the manufactured time

λ = disintegration constant

t = the period between sampling date and measuring date

For measurements of the samples, plastic polythene container is used. By putting empty polythene container on NaI (Tl) scintillation detector, the background was measured for 18000 seconds. And then, the powder sample (0.21 kg) was placed in the container and was measured for 10800 seconds. The two samples were measured under same conditions (i.e. same setting, same geometry). At the end of a counting period, the

spectra stored in MCA were analyzed by using the Gamma Vision 32 application Software.

The activity concentrations of K-40 and Cs-137 present of the samples were calculated. And then the activity concentrations of ^{40}K in Whey Powder sample, and Potassium Nitrate sample were calculated.

The activity concentration A of a gamma-emitting radionuclide in the sample can be calculated by using equation (2).

$$A = \frac{N}{\varepsilon \gamma t_s m K_1 K_2 K_3} \qquad (2)$$

where,

ε = the efficiency at photopeak energy,

γ = the emission probability of the gamma line corresponding to the peak energy,

m = the mass [kg] of the measured sample,

K_1= the correction factor for the nuclide decay from the time the sample was collected to the start of the measurement,

K_2 = the correction factor for the nuclide decay during counting period,

K_3 = the correction factor for a self-attenuation

N = the corrected net peak area of the corresponding photopeak

Results

The detection limit (DL) and minimum detectable activity (MDA) values were calculated from the measurement data of Whey Powder sample, Potassium Nitrate sample. The comparison of net counts rate from the measured spectra, minimum detectable activity (MDA) and detection limit of ^{40}K and ^{137}Cs in Whey Powder sample are shown in Table (1). The value of detection limit (DL) and the minimum detectable activity (MDA) values of ^{40}K in Potassium Nitrate sample are shown in Table (2). Recommended Values and Present Activity of the Whey Powder sample (IAEA-154) are shown in Table (3).

Activity concentration results of ^{40}K and ^{137}Cs in samples were obtained by using activity equations (2). The comparison of Whey Powder sample and background spectrum is

shown in Fig .2 In this spectrum 661.66 keV of ^{137}Cs peak and 1460.75 keV of ^{40}K peak can be seen. From this spectrum, activities concentration of ^{137}Cs and ^{40}K were calculated.

Comparison of Potassium Nitrate sample and background spectrum are as shown in Fig.3. The ^{40}K – background subtracted spectrums are as shown in Fig.4. In these spectra, 1460.75keV of ^{40}K peak can be seen clearly.

Table (1) Comparison of Net Counts rate and Minimum Detectable Activity (MDA) with Detection Limit (DL) (Whey Powder sample, IAEA-154)

Element	Net Counts rate (cps)	MDA (cps)	Detection Limit (DL)(cps)	Remark
^{40}K	1.2227	2.7580	0.0240	N > DL MDA >DL
^{137}Cs	12.4800	2.8224	0.0562	N >DL MDA >DL

Table (2) Comparison of net counts rate and Minimum Detectable Activity (MDA) with Detection limit (DL) (Potassium Nitrate sample

Sample Name	Element	Net Counts (cps)	Minimum Detectable Activity (MDA) (cps)	Detection Limit (DL) (cps)	Remark
Potassium Nitrate	^{40}K	6.8337	3.0546	0.0273	N>DL MDA>DL

Table (3) Recommended Values and Present Activity of the Whey Powder sample (IAEA-154)

Element	Recommended Value (Bq/kg)	95% Confidence Interval (Bq/kg)	Present Activity (Bq/kg)	Half-life (yrs) $T_{1/2}$
^{40}K	1575	1484-1645	1575.00	$1.28x10^{9}$
^{137}Cs	3749	2267 - 2512	2387	30.1
^{134}Cs	1355	7.26 – 7.93	7.59	2.62
^{90}Sr	6.9	4.13 – 4.51	4.32	29.00

This table is taken from reference [20]

Discussion

According to Table (1) and (2), the net counts rates of the elements are greater than the detection limit. It is sensitive on measured samples by using NaI (Tl) detector. According to the Table (3), the Whey Powder sample consists of ^{40}K, ^{90}Sr, ^{134}Cs and ^{137}Cs. In the Whey Powder sample spectrum, (661.66 keV) of ^{137}Cs peak and (1460.75keV) ^{40}K peak can be seen. The first peak of gamma energy (604.66keV) in ^{134}Cs and that of ^{137}Cs (661.66keV) are superimposed and it's difficult to distinguish because of poor resolution of NaI (Tl) detector. This Whey Powder sample was produced since 1987.

At the (661.66 keV) photon energy of ^{137}Cs in Whey Powder spectrum the ROI reported a net peak area of N = 141647 counts [U_N/N = 0.20 %] and a fitted full-energy peak efficiency of ε = 0.05 [$U_ε$/ ε = 2%]. The result of activity concentration was A = 2342.75 Bq/kg with a standard uncertainty of A = 147.06 Bq/kg [U_c (A)/A = 3.13 %].

At the (1460.75 keV) photon energy of ^{40}K in Whey Powder spectrum the ROI reported a net peak area of N = 14037 counts [U_N/N = 1.1%] and a fitted full-energy peak efficiency of ε = 0.04 [$U_ε$/ ε = 2.5%]. The result of activity

concentration was A = 1562.99 Bq/kg with a standard uncertainty of A=90.93Bq/kg [U_c (A)/A = 2.90 %].

At the (1460.75 keV) photon energy of ^{40}K in Potassium Nitrate spectrum the ROI reported a net peak area of N = 73804 counts [U_N/N = 0.5%] and a fitted full-energy peak efficiency of ε = 0.04 [U_ε/ ε = 2.5%]. The result of activity concentration was A = 8217.53 Bq/kg with a standard uncertainty of A = 503.69 Bq/kg[U_c(A)/A=2.91%]

Conclusion

According to Table (1) and (2), the net count rate is greater than the detection limit in Whey Powder sample. These samples are contaminated. That means they have a 95% confidence limit.The activity concentrations of ^{40}K in Potassium Nitrate was obtained (8217.53 Bq/kg) by using equation (2).

The results of a measurement are only an approximation or estimate of the value of the specific quantity subject to measurement, that is, the measured value, and thus the result is complete only when accompanied by a quantitative statement of its uncertainty.

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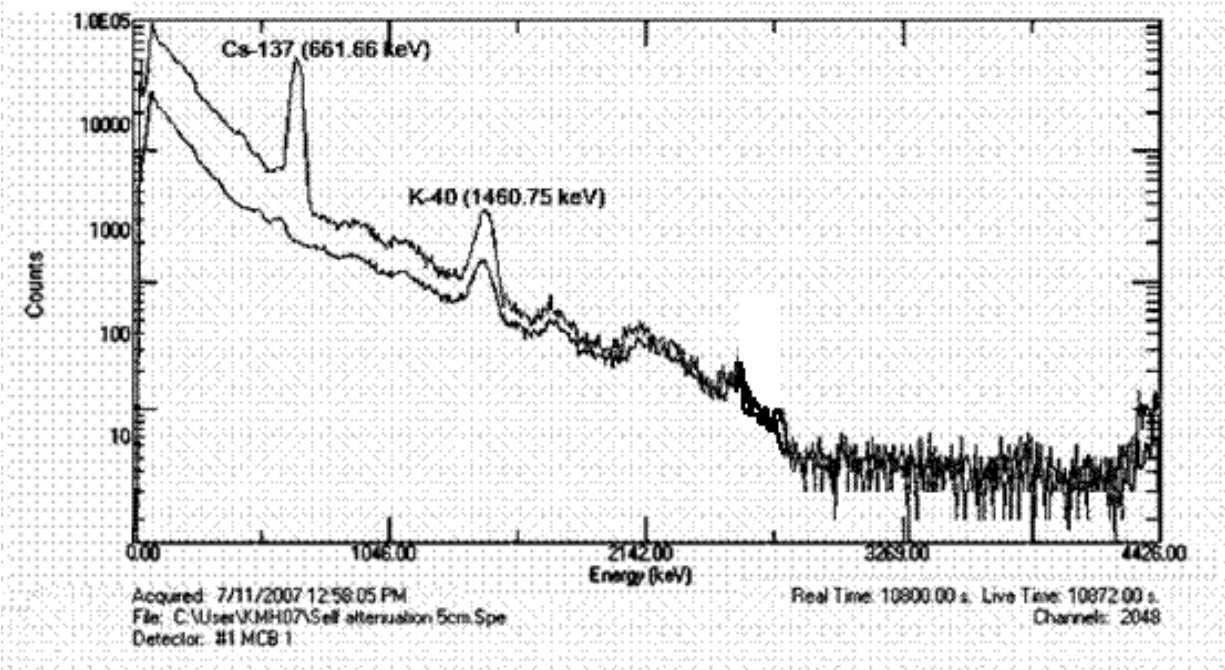

Fig.2 Comparison of Whey Powder sample and background spectrum.

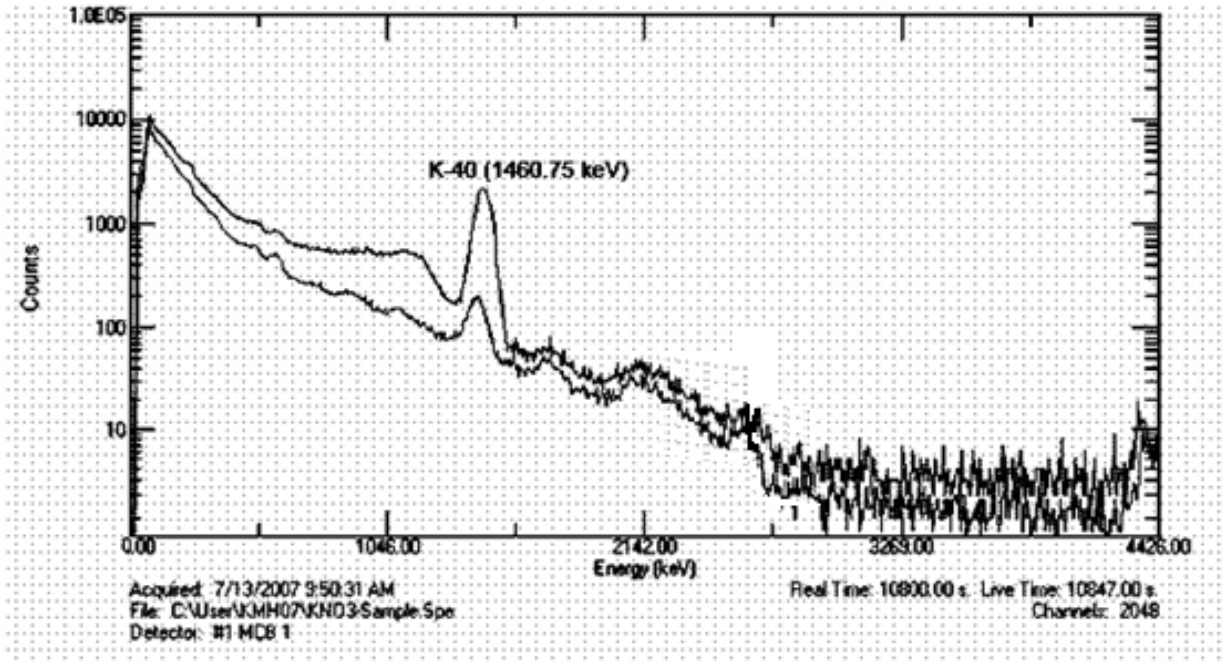

Fig.3 Comparison of Potassium Nitrate sample and background spectrum.