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Appearance of Chance Coincidence in Attenuation Measurements Carried out by using Coincidence Technique

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ABSTRACT

The appearance of chance coincidence in attenuation measurements using coincidence technique is investigated. A two 3"*3" NaI(Tl) detector coincidence spectrometer with 0.5 µ Ci Na-22 source were used. Two different materials with different forms, namely mixed metallic powders and Fe-sheets are used. The ratio of chance counts to total real coincidences in annihilation peak had ranged between (0.007-0.013) and (0.011-0.036) for the different thicknesses of the two materials mentioned respectively. The coincidence linear attenuation coefficients due to the chance coincidence at 1274keV were 0.1 and 0.38 cm^{-1} for the two materials assuring the proportionality with energy. When the chance coincidence counts were treated as being "lost" from real coincidences and added again to the latter, no change were observed in attenuation coefficient at annihilation peak from that calculated before taking accidental counts into consideration.

1- Introduction

Coincidence circuits is a category of electronic circuits that have many applications where it is required to measure an event in one detector that occurs in the same time as an event in another detector, or to obtain the time delay between two events. The oldest type of coincidence circuits was the so-called Rossi circuits [1].

In physics and particularly the spectrometry studies in many fields (i.e. nuclear, atomic, molecular) coincidence technique had acquired a special interest. of course, the knowledge of decay schemes, life times of levels and time relations between different emitted particles, were principally based on information from coincidence circuits used [2]. The applications of these circuits were also extended for useful applied tests, such as positron annihilation in materials.

The events that are registered by the detectors used in coincidence circuits are generally subdivided into true and accidental coincidences. Accidental coincidence events are always treated to be made as little as possible through precise adjustment of the systems [3].

Recently, several investigations were carried out that used coincidence technique in attenuation studies of different materials. The efforts aimed at reducing background events to have better quality spectra. Good results were obtained in measuring attenuation coefficients, and build-up factor [4-6]. In the present work we investigate the appearance of chance coincidence in an attenuation measurement carried out by a coincidence spectrometer.

2-Theoretical

In theory, a true coincidence is the result of the arrival of two pulses at exactly the same time. In practice this "exact coincidence" seldom occurs, and for this reason a coincidence unit is designed to register a coincident event arriving a finite but short time interval τ. The interval τ is called the resolving time or the width of the coincidence and is set by the observer [3].

Two or more events are coincident if they occur within the time period τ. Since the pulses from a two-detector system arrive randomly, a certain number of accidental (or chance) coincidences will always be recorded and is given as [3]:

$N_{ac} = 2N_1N_2\tau$ …(1)

where N_1 and N_2 are the counting rates in the two detectors. The best way to reduce accidental coincidence is to make the resolving time as small as possible. However, the resolving time can't be reduced below the amount of time jitter in the detector pulses without losing true coincidences. So the type of detector determines the minimum resolving time. The chance coincidence can also be reduced through adjusting a moderate counting rate and suitable choice of the angle between the detectors [3,7].

Na-22 source is a suitable choice for a two-detector coincidence spectrometer. It emits positrons that are annihilated in source cover producing two gamma quanta each with 511keV energy that enter the two detectors in time. Positron emission populates the Ne-22 excited level that decays by emitting the 1274keV line. Fig. (1) shows the gamma spectrum by using Na-22 source and Na I (Tl) detector. The coincidence spectrometer is normally adjusted to allow only the 511keV peak to appear, but there still a possible appearance of chance coincidence to occur at the 1274keV location [7].

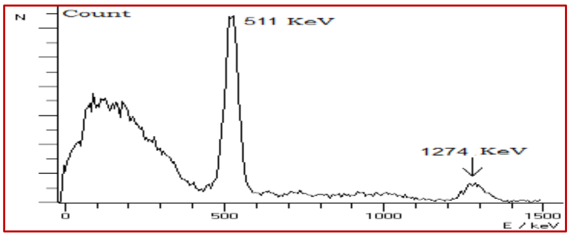

Fig 1: Typical gamma spectrum for Na-22 source obtained with NaI (Tl) detector [7].

In attenuation measurements the so -called Lambert equation

I=I$_o$ $e^{-\mu t}$ ….(2)

is used. Where **I$_o$** and **I** are the beam intensities initially and at thickness t respectively, and μ the attenuation coefficient.

3- Experimental

The measurements were carried out at the physics department / college of education for pure science/ university of Baghdad. A coincidence spectrometer was installed consisting of two 3”*3” Na I (TI) detectors with the related electronics as shown in Fig. (2).

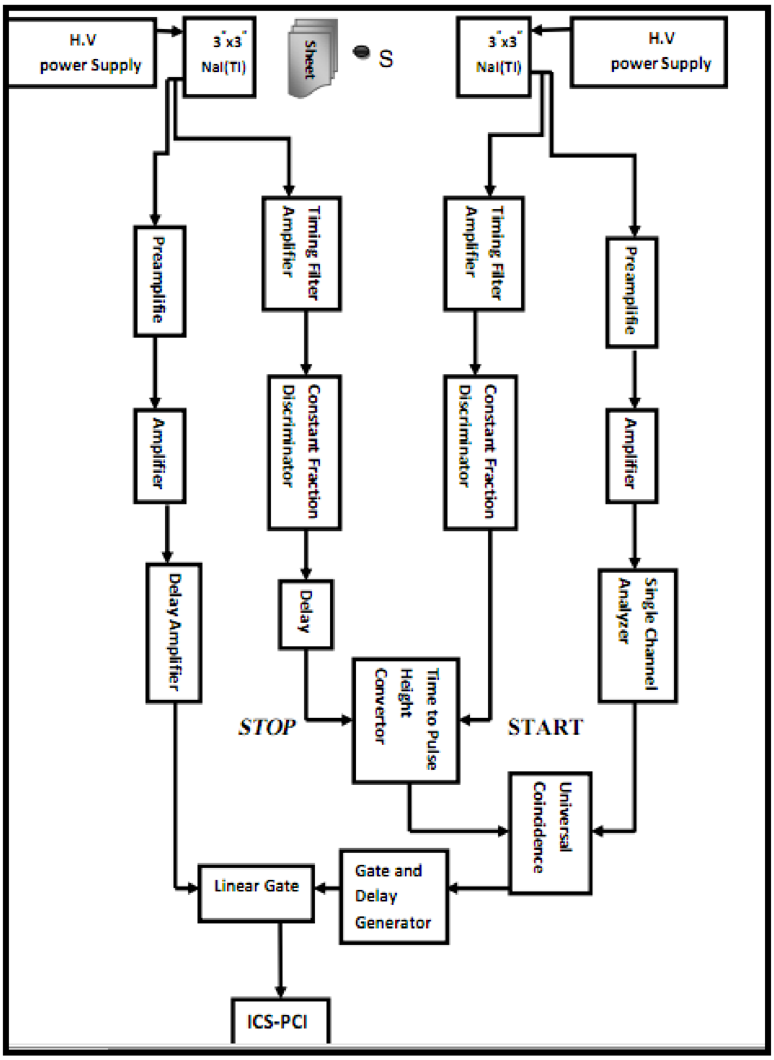

Fig. 2: Block diagram of the gamma-gamma coincidence spectrometer

A 0.5 μ Ci Na-22 radioactive source is used. The detectors are kept at l80° angle facing each other and the source is located between. An energy gate of 511keV is adjusted in one detector branch that registers the gammas in air. The other second detector registers the gammas that are in coincidence with the first one after penetrating a thickness of the material being studied.

Two materials are studied in this work, the first is a mixed metallic powder (composed of Fe, Mg, Si and Al) and the second is Fe sheets.

4- Results and discussion

For each of the two materials studied in the present work, the information from the coincidence spectra are tabulated. These include gross peak area GA and net peak area NA of the 511keV peak in addition to the chance coincidence area CC appearing in the 1274keV location. The ratios CC/GA and CC/NA and GA+CC are calculated and tabulated. For obtaining the attenuation coefficient the natural logs of CC and GA+CC are also calculated for the different thicknesses.

4-1: The mixed metallic powders

This material is in the form of metallic powder with grain size in the micron range. The coincidence spectra for the different thicknesses are registered for a certain time suitable to obtain good statistics. Table (1) shows the data of these measurements.

Table 1: Data of gamma-ray attenuation in the mixed metallic powders using coincidence spectrometer

Thickness (cm)	GA	NA	CC	CC/GA	CC/NA	GA+CC	ln(CC)	ln(GA+CC)
1	29548	28147	210	0.0071	0.0074	29758	5.3471	10.3008
2	23644	22273	193	0.0081	0.0086	23837	5.2626	10.0789
3	19888	18448	183	0.0092	0.0099	20071	5.2094	9.9070
4	16002	14758	163	0.0101	0.0110	16165	5.0937	9.6906
5	12881	11636	125	0.0097	0.0107	13006	4.8283	9.4731
6	10811	9536	123	0.0113	0.0128	10934	4.8121	9.2996
7	9109	7786	119	0.0130	0.0152	9228	4.7791	9.1299

From the above table it is seen that while the chance coincidence count decreases with increasing thickness, it's ratios CC/GA and CC/NA increase. These ratios although seem too low, but they may affect the μ calculations. It may be interesting to investigate the attenuation coefficient for the appearing chance coincidence. A plot of in (CC) against thickness t is presented in Fig. (3). The slope gives the μ value as about 0.1 cm^{-1}. A comparison of this value with the coincidence μ value using the same material and spectrometer [4], which was about 0.198 cm^{-1} at 511kev, shows that μ values also behave as inversely proportional with energy.

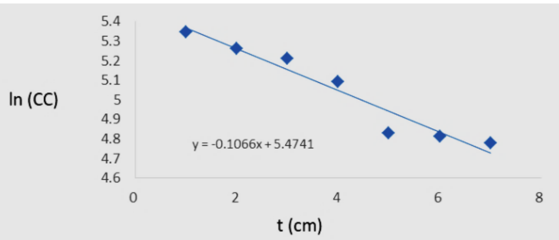

Fig. 3: Relation between in (CC) and thickness for the mixed metallic powders material

If the chance coincidence counts are treated as being "lost" from the actual or true coincidences, then when adding them to GA and plotting In(GA+ CC) vs thickness we obtained the plot shown in Fig.(4).The new μ value at 511keV is about 0.196 cm^{-1} , and is nearly the same as that in ref [4] meaning that the chance coincidence here has no significant effect on μ calculations. It should be mentioned that the time resolution of the spectrometer was about 6 n sec. Also, when we tested the spectrometer without a radioactive source, no background counts were registered during the accumulation time being set.

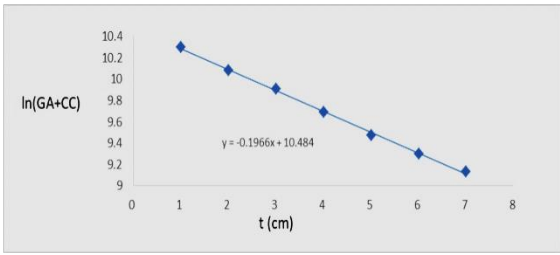

Fig. 4: Relation between in (GA+CC) and thickness for the mixed metallic powders material

4-2: Fe sheets

As for the previous metallic powder material, the coincidence spectra are obtained using Fe sheets. The data of the measurement are shown in Table (2).

Here also the CC/GA and CC/NA ratios increase with increasing thickness, but with relatively higher rate. The attenuation coefficient calculated by taking in(CC) against thickness t was 0.389 cm^{-1}, Fig. (5). Again, this assures the inverse proportionality with energy as when compared with that at annihilation peak (μ=0.526 cm^{-1}, ref. [4]). Also, when the chance coincidence counts were added to the real coincidences at annihilation peak, the re-calculation of μ here gave the same value (0.523), Fig. (6). The chance coincidence counts registered by the present spectrometer adjustment had no significant effect on the μ value at the annihilation peak.

Table 2: Data of gamma-ray attenuation in Fe sheets using coincidence spectrometer

Thickness (cm)	GA	NA	CC	CC/GA	CC/NA	GA+CC	Ln(CC)	Ln(GA+CC)
1	22732	21178	266	0.0117	0.0125	22998	5.5834	10.0431
2	13147	11971	206	0.0156	0.0172	13353	5.3278	9.4994
3	8158	7093	148	0.0181	0.0208	8306	4.9972	9.0247
4	4686	3918	104	0.0221	0.0265	4790	4.6443	8.4742
5	2722	1961	47	0.0172	0.0239	2769	3.8501	7.9262
6	1934	1417	44	0.0227	0.0310	1978	3.7841	7.5898
7	980	630	29	0.0295	0.0460	1009	3.3672	6.9167
8	526	233	19	0.0361	0.0815	545	2.9444	6.3007

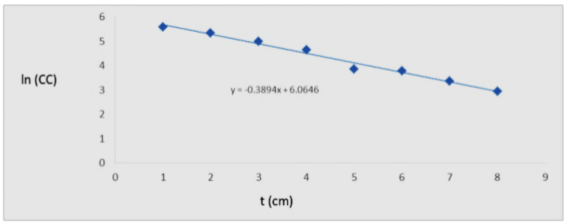

Fig. 5: Relation between In (CC) and thickness for Fe sheets

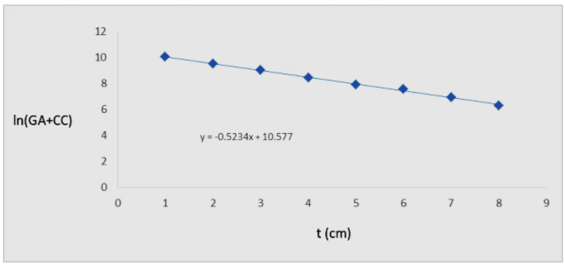

Fig. 6: Relation between In (GA+CC) and thickness for Fe sheets

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ظهور التطابق التصادفي في قياسات التوهين المجراة باستخدام تقنية التطابق

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الملخص

درس ظهور التطابق التصادفي في قياسات التوهين باستخدام تقنية التطابق. استخدم مطياف تطابقي من كاشفين NaI(Tl) "3*"3 مع مصدر Na-22 بفعالية 0.5 μCi. استخدمت مادتان مختلفتان وبهيئتين مختلفتين هما خليط مساحيق معدنية والواح حديد. ان نسبة العد التصادفي الى التطابقات الحقيقية الكلية عند قمة الفناء تراوحت ما بين (0.007 -0.013) و (0.011 -0.036) للأسماك المختلفة للمادتين المذكورتين على التوالي. ان معاملات التوهين التطابقية للتطابق التصادفي عند الطاقة 1274keV كانت 0.1 و $0.38\ cm^{-1}$ للمادتين مؤكدة التناسب مع الطاقة. وعند اعتبار عدات التطابق التصادفي كأنها "فقدت" من التطابقات الحقيقية واضافتها ثانية الى الاخيرة، لم يلاحظ تغير في معامل التوهين عند قمة الفناء عن ذلك المحسوب قبل اخذ العدات التصادفية بنظر الاعتبار.

كلمات مفتاحية: تقنية التطابق، التطابق التصادفي، توهين اشعة كاما.