Gamma sources and standard school experiments

We set out to evaluate three gamma ray sources - caesium-137 (74 kBq), caesium-137 (370 kBq) and cobalt-60 (74 kBq), with a view to determining which would be the most suitable for a school to buy. The standard experiments we used were the half value thickness of lead and the inverse square law.

Introduction

In evaluating the sources, we had three main considerations:

- Safety;
- Working life;
- Effectiveness for standard expts.

Safety

We used Isotrak sources from AEA technology [1]. All were of identical construction. The cobalt-60 source decays by emitting a beta particle (β) of energy 0.318 MeV, followed by two successive gamma (γ) photons of energies 1.173 MeV and 1.333 MeV. Caesium-137 emits a beta particle of energy 0.512 MeV, followed by a gamma photon of energy 0.662 MeV. Around 5% of caesium decays are through the emission of a beta particle of energy 1.174 MeV, with no subsequent gamma radiation.

The dose from each source received during a typical experiment can be calculated. It is assumed that the dose comes solely from gamma radiation. As mentioned, both caesium and cobalt also emit beta radiation but the design is such that there should be no dose from this radiation unless a person is directly in front of the radiation window. The manufacturers claim that the beta radiation is absorbed by the radiation window of the source container which is made of aluminium of thickness 0.1 mm. In calculating the dose rate, we assumed that a teacher spent 2 minutes carrying the source to and from the classroom in a standard lab tray. A total of 4 min. was spent manipulating the source with the fingers around 8 cm from the radioactive material and 30 minutes was spent at a distance of 1 m from the source while readings were taken.

Source (Activity)	Dose (μSv)	
	Hand	Whole body
Co-60 (74 kBq)	0.3	0.05
Cs-137 (74 kBq)	0.1	0.01
Cs-137 (370 kBq)	0.4	0.06

Table 1 - Dose during a typical experiment.

Note that the dose from the more active caesium-137 source is only around 30% greater than that from the cobalt-60 source. To put these doses in to perspective, the annual average dose to the UK population from all sources of ionising radiation is 2.7 mSv and the average hourly dose from natural radiation is 0.26 μSv. We also measured the dose rate from the 370 kBq caesium-137 source at a distance of 100 mm. It was 2.8 μSv h^{-1} - comfortably below the International Commission on Radiological Protection (ICRP) limit of 10 μSv h^{-1} for working in schools with gamma sources [2]

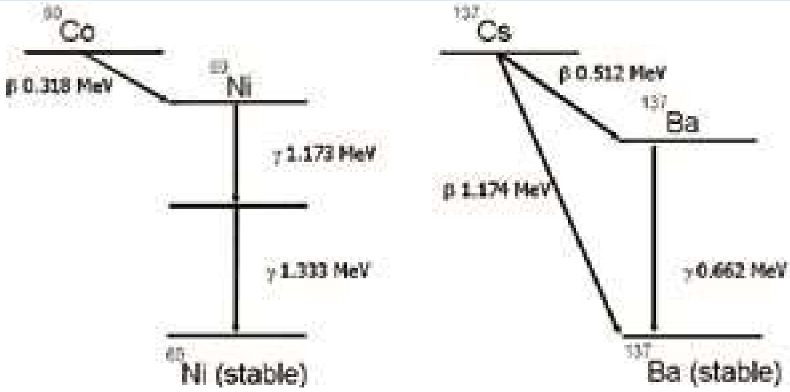

Figure 1 - Decay of caesium-137 & cobalt-60.

Working life

Caesium-137 has a half life of 30.1 years. Cobalt-60's half life is 5.3 years. Thus, after 30 years, a caesium-137 source whose activity was 74 kBq when bought will have an activity of 37 kBq. A cobalt-60 source with the same initial activity will have an activity of little over 1 kBq after 30 years. Indeed, after 15 years a cobalt-60 source will be effectively spent. There are many sources in schools just now that were purchased around 30 years ago.

Standard experiments

The two quantitative experiments, for which gamma sources are currently used, are *half value thickness of lead* and the *inverse square law*. In carrying out the comparison of sources, we were also able to draw up advice as to the best way to carry out these investigations. Details are available on the SSERC website [3].

Conclusions

The dose from the 74 kBq caesium-137 source is notably less than those from the 74 kBq cobalt-60 source and the 370 kBq caesium-137 source. When comparing the latter two, it should be noted that not only are the doses comparable, many schools using cobalt-60 sources use ones with initial activities of 185 kBq. Due to the cobalt-60 emitting two photons, each with a greater energy than the single photon emitted when caesium-137 decays, such a source would give an operator a larger dose than that from a 370 kBq caesium-137 source. In each case, the doses received by teachers and observers during standard experiments are well within safe limits.

Caesium-137 370 kBq performed best when standard experiments were carried out under classroom conditions. The larger count rate leads to relatively smaller uncertainties. The relationships are much clearer. Better results could be obtained using the 74 kBq source if counts were taken over longer periods of time, but the experiment would take around four or five times as long to perform and the dose would then be the same as that from using the more active source.

We believe that some beta radiation may be emitted by the sources but the amounts are not enough to affect significantly the results of standard experiments.

Historically, schools have kept radioactive sources for decades. The thirty-year half life of caesium-137 compared with 5 years for cobalt-60 means that after thirty years, a caesium-137 source would still be active enough to be useable whereas a cobalt-60 source with the same initial activity would be spent.

For these reasons, we recommend that schools purchase a sealed caesium-137 source of activity 370 kBq with which to study gamma radiation.

References

1. www.isotrak.de

2. *Protection against Ionizing Radiation in the Teaching of Science*, ICRP Publication 36

3. www.sserc.org.uk/members/SafetyNet/bulls/223/Gamma_sources_download.doc

Figure 2 - Caesium-137 370 kBq source