The Hot Balloon (Not Air)

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Students are usually fascinated and impressed by lab experiments that appeal directly to their sense of sight or hearing. Radioactivity experiments do not fall into this category. The clicking sound of a Geiger counter or the counting up of a digital display may cause a fleeting sense of wonder, but basic nuclear counting experiments can be considered as some of the most boring activities confronted by students. Nuclear physicists may appreciate that the real beauty and excitement of such experiments reside in the analysis of data, but the student is still left dumbfounded.

Even though the operation of radiation detectors and counting systems requires careful explanation, we believe that the radiation source itself is the major source of boredom and confusion for the student. Stating that a very tiny speck of radioactive material embedded in a plastic disk emits radioactive particles that are readily detected by a Geiger-counter/scaler system simply does not generate enthusiasm or understanding for the typical student.

The use of naturally occurring radioactive materials and radioactive consumer products[1] begins to overcome the problem of using commercial sources. However, these materials and products have been known for a very long time, albeit by a very small fraction of the general population (or even of science teachers). More recently a novel method[2–4] was described for extracting a radiation source from the atmosphere by the motion and collisions of a handball or racquetball. Although the underlying theory is explained in detail in Ref. 2, the basic idea is that after radon gas (^{222}Rn) diffuses out of the ground a majority of the daughter products become attached to positive charged aerosol particles.[5] These particles can then be readily attracted to a negative charged object, thereby building up a source with a compound half-life of about 45 minutes.

Filtering dust particles from the air has long been a standard and reliable procedure for obtaining a convenient radioactive source. We have been using this technique[6] for over 20 years by drawing air through eight layers of lens-cleaner tissue placed over the intake of a large-volume air blower (a simple ShopVac works fine) for anywhere from 45 minutes to 24 hours. (Decay of the thoron daughter products is governed mainly by the 10.6-hour half-life of ^{212}Pb.) Any filter that doesn't appreciably impede the air flow or load down the motor should work just as well.

However, the most impressive technique we've discovered for extracting a radioactive source from the atmosphere involves a simple balloon. A 9-inch round balloon was inflated, suspended in air, and rubbed for about one minute with an animal fur typically used for demonstrating electrostatics. After being left undisturbed for 45 minutes the balloon was deflated, compacted, and placed as close as possible to a thin-window Geiger counter. Even though the background radiation registered only 30 counts per minute with this system, the balloon provided a phenomenal total activity of 10,051 counts in five minutes!

Three other trials on different days resulted in initial five-minute total counts of 8919, 2639, and 1383, respectively (a dry atmosphere is an obvious requisite). This technique proves very exciting for students, since they become active participants in source fabrication and directly observe how easy it is to concentrate radioactivity from the atmosphere we breathe. Effective half-life measurements can then be made, which demonstrates that this particular source of radiation is being constantly replenished. Even more remarkable is the fact that the activity of 10,051 was obtained in a room in which the radon concentration during the experiment was measured to be 0.3 pCi/l (picocurie per liter) using a femto-TECH Model 510 Continuous Radon Monitor. This value is about the average outdoor radon concentration in the United States. It would be interesting to see what level of radioactive (hot) balloon can be obtained in a high-radon environment.

On another day seven groups of students performed this experiment at the same time in the room discussed above and obtained initial five-minute total counts of 6262, 5593, 4934, 3878, 3606, 2726, and 2200, respectively. There was no obvious pattern to these results, partly due to the different conditions employed by the individual groups for obtaining a source.

Figure 1 presents data for half-life measurements of a trial for which the initial net activity was 11,660 counts per five minutes (after subtracting a background value of 150 counts). The shape of the activity-vs-time data is very similar to that obtained for a filtered air sample.[7] This experiment can also be very instructive for advanced undergraduate physics (and related) majors if these students are asked to account for the exact shape of the decay curve from known radioactive decay schemes. This shape will depend on both the sample

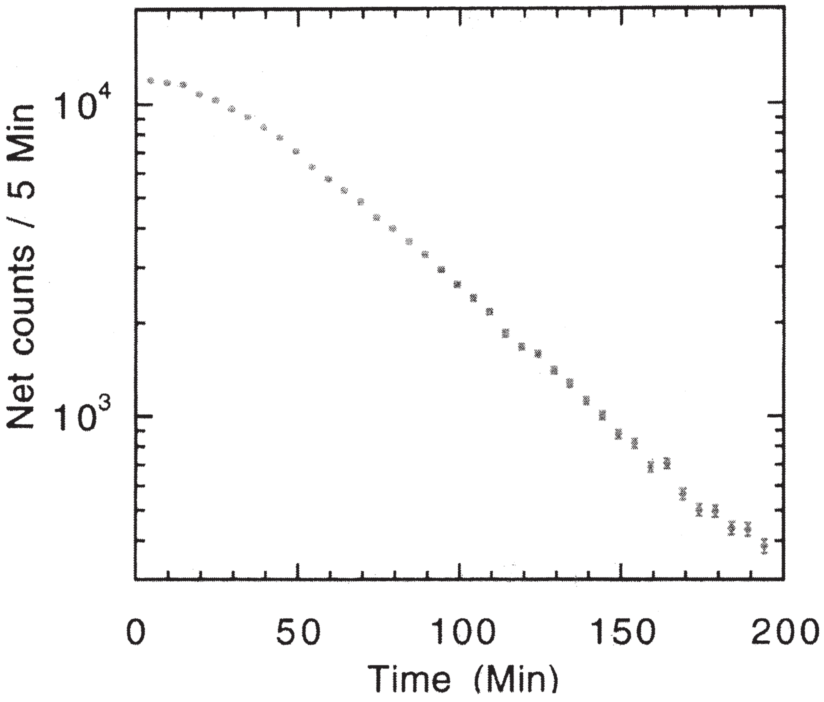

Fig. 1. Activity of radioactive balloon. Error bars indicate one standard deviation.

collection time and the waiting time before counting begins.[8]

Students feel more at ease in using commercial sources after they witness the balloon experiment, since the acquired activities can be significantly higher than some of the sources typically used in undergraduate counting experiments. These students also begin to appreciate the level of the natural radioactive environment in which we live.

Another assignment that physics students would find instructive is a calculation to account for the initial measured activity from the charged balloon exposed to a known radon concentration. This calculation would include efficiency and geometry properties of the counting system and knowledge of radioactive decay schemes of the radon daughter products. The commonly used unit of 1 pCi/l corresponds to an activity of about 2.2 disintegrations per minute per liter of air. This activity is the same as the SI value of 37 Bq/m^3 (becquerel per cubic meter). For our room dimensions of approximately 32 × 25 × 9.3 feet, we find that the measurement of 0.3 pCi/l corresponds to about 140,000 disintegrations of Radon-222 per minute in the room. No wonder the balloon can pick up an appreciable activity as recorded by a sensitive Geiger counter!

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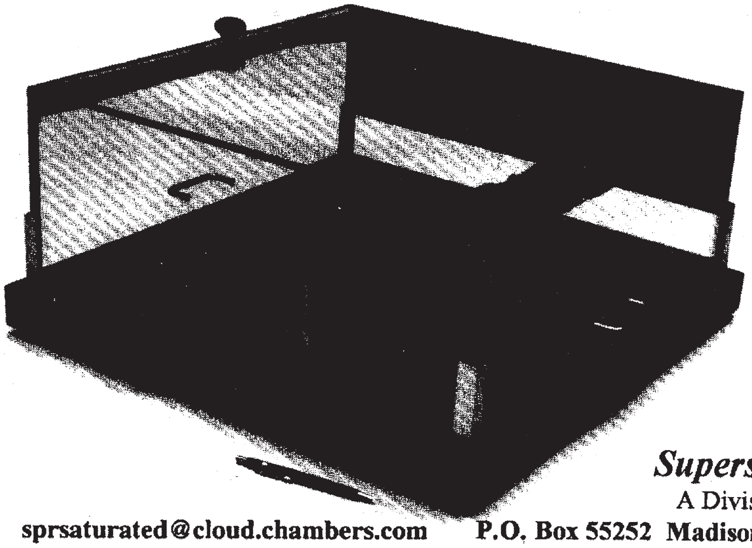

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