Thomas Walkiewicz's Hot Balloon – A Delightful Teaching Tool

««« By Bryan White

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Curriculum Connection: Units related to radiation in SCH3U, SCH4U; SPH3U, SPH4U; General Science, and Earth Sciences.

Cognitive Disequilibrium

The inflated party balloon is an icon for enjoyment by children of all ages, the world over. A balloon brings a smile to every face. Balloons feature rich colours and have pleasing symmetry. They "pop" when pricked with a pin. When inflated and then released, they rocket about in an unpredictable manner making a rude noise. They are almost as light as air itself and once rubbed on hair or a sweater will stick to a wall. What's not to love about a balloon?

Using such a familiar object for which students have an established positive association, to present a surprising result, provides a memorable learning experience. In this instance, by placing an electrostatic charge on a balloon and suspending it in the classroom it will collect from the ambient air radioactive atoms that arise from the decay of radon nuclei. Radon gas is present in most indoor environments at concentrations below those considered hazardous. In about 30 minutes the balloon accumulates sufficient radionuclides that, when it is placed atop a sensitive Geiger-Müeller detector, the count rate increases in a spectacular manner.

The students experience *cognitive disequilibrium* – the innocent beloved balloon has become radioactive! Moreover the radioactivity came from the air they breathe in their classrooms! Most students have the perception that radioactivity and ionising radiation are uniquely hazardous, and that man-made radiation is especially so. But they love their balloons. This simple experiment offers the opportunity to explore background radiation, naturally-occurring radioactive materials, decay series, and types of ionising radiation.

The Experiment

Recently the author was given a reference to a 1997 paper by Austen and Brouwer[1] that describes their experience at the University of Alberta with this simple experiment. Their paper references the 1995 paper by Walkiewicz entitled "The Hot Balloon (Not Air)."[2]

1 Austen, D. and Brower, W., "Radioactive balloons: experiments on radon concentration in schools or homes", Institute of Physics, Phys. Educ. 32, 97-100, 1997. http://www.iopscience.org

2 Walkiewicz, Thomas A., "The Hot Balloon (Not Air)", The Physics Teacher, 33, 344-345 (1995) *(available by interlibrary loan)*

The CNS provides workshops on radiation physics for teachers at various venues, such as the STAO annual conference – *and in 2011 we have added the balloon experiment!* If you weren't able to attend the CNS Ionising Radiation Workshop at the STAO 2011 Annual Conference in Toronto on Thursday, November 10th, please consider including our workshop in your planning for a Conference or Board PD Day. Alternatively please visit the CNS website. *The workshop presentation slides and notes are freely available for download at* www.cns-snc.ca → Education → Information for Teachers and Students.

If you don't have a sensitive Geiger-Müeller instrument in your school, check out the CNS Geiger Kit Program donations on the website. We'd be pleased to add your school to our list.

The Procedure

Our recommended procedure is to inflate the balloon at the beginning of the class and seal the stem with a metal document clamp. The clamp is fixed to a string tied to a magnet. The balloon may be suspended by attaching the magnet to a lighting fixture or other convenient steel structure. The balloon is charged by rubbing thoroughly with a microfiber cloth (or a piece of fur). After 20 or 30 minutes, the balloon is recovered and deflated quickly by removing the clamp. The limp balloon is placed on the window of a Geiger-Müeller detector and held flat with a piece of plastic.

Inflated balloon, clamp, string

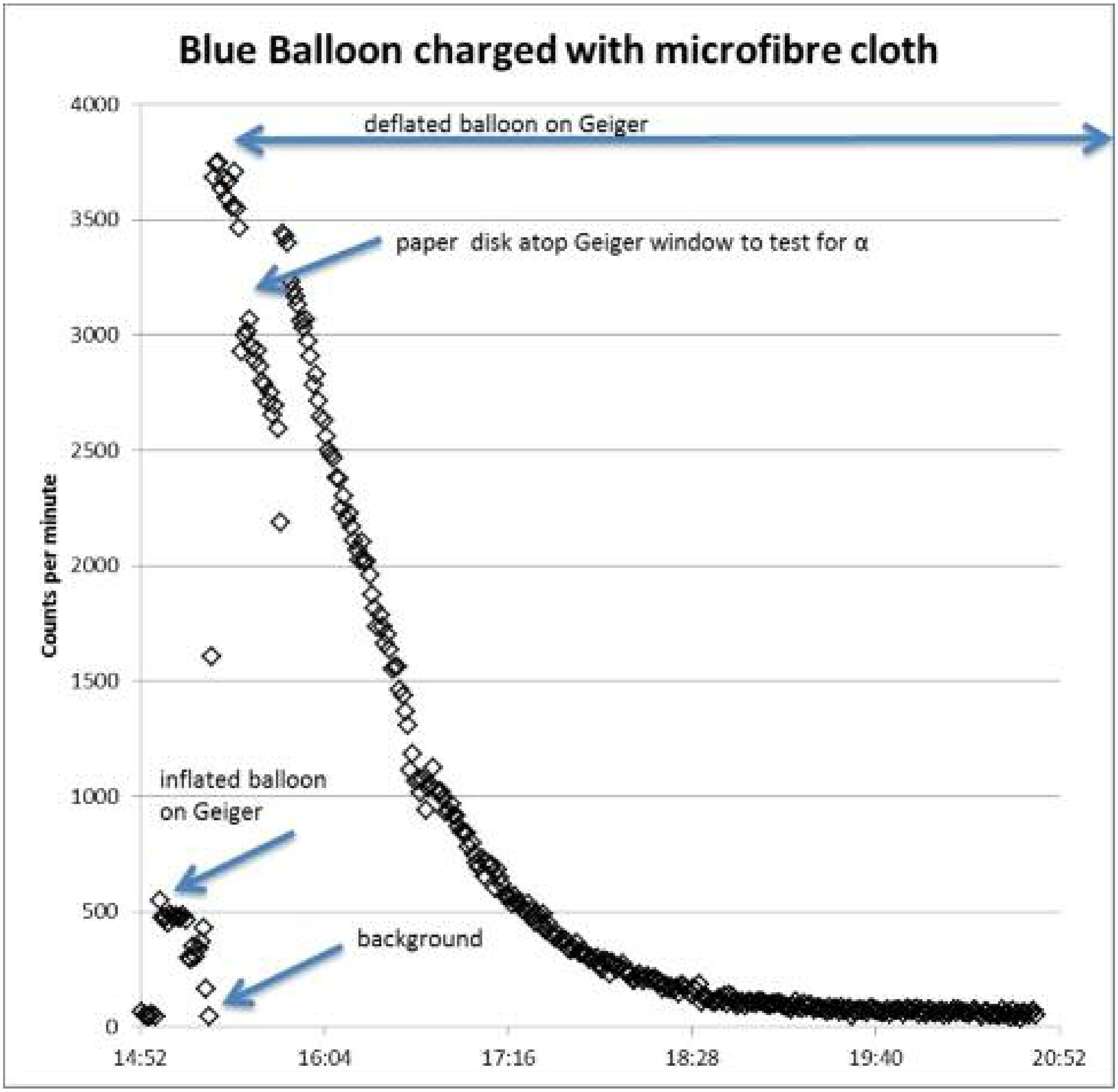
Deflated balloon on Geiger

Observations

The Geiger instrument we use in the workshop routinely provides a count rate of 40 to 50 counts per minute for background radiation conditions in most locations, and this increases to over 4000 counts per minute with the freshly loaded balloon: ~100 times background. It's a delightful surprise every time! This simple balloon demonstration delivers a lasting impression that enriches academic understanding, in 30 minutes. The balloon costs ~$0.04.

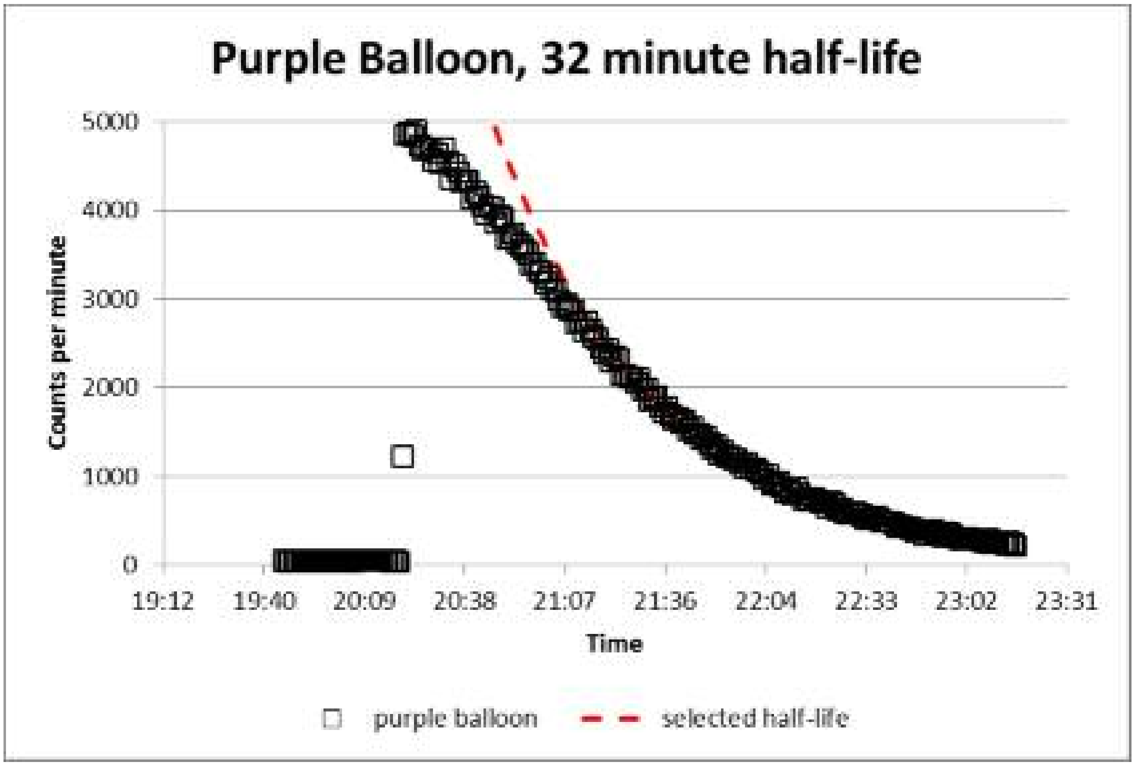
Placing the inflated balloon on the Geiger produces an increased count rate – about 10 times background in the case above. As the balloon will roll off the Geiger due to moving air, measures are required to keep it perched on the Geiger. Deflating the balloon concentrates the radioactive nuclides collected on surface of the balloon to produce a much higher count rate. (The area of the sphere is collapsed to the two sides of a disk with a reduction in area by a factor ~40. Your students may calculate this and test it by drawing a figure on an inflated balloon.)

If one removes the balloon from the Geiger window and covers the window with a paper disk before replacing the balloon, the count rate drops significantly. Moreover, if the paper disk is in place for the full time, the shape of the decay curve is different with the paper absorber present than without. In the workshop we discuss the radionuclides involved: Rn-222, Po-218, Pb-214, Bi-214, Po-214. Bacon provides an analysis of the collection process.[3]



3 Bacon, M.E., "A comparison of electrostatic and filtered air collection of radon progeny", Institute of Physics, Eur. J. Phys. 25, 239-248 (2004) http://www.df.uba.ar/users/sgil/physics_paper_doc/papers_phys/modern/radon2k4.pdf

During the collection period, one must avoid suspending the balloon near a fresh air supply duct diffuser. (We had a disappointing result in one science classroom at Mark Garneau Collegiate Institute in Toronto this past February – the fans were on. However, we were successful in a second similar room – the fans were off – later the same day. It has worked every time in my den so far. It worked well in Fellowes High School in Pembroke, in April 2011. It is difficult to charge the balloon in humid weather, and count rates will be lower with open windows.



Analysis of the Data

By deflating the purple balloon quickly and immediately placing atop the Geiger window, we obtained a higher initial count rate. Analysis of the data collected with the purple balloon shows that the long tail of the decay corresponds to an apparent half-life of about 32 minutes. **The decay back to background levels requires more than 3 hours.** This simple characterisation does not fit the overall shape. Within the class time it is possible to see the initial shape of the decay.

Summary

This experiment demonstrates:

i. An electrostatically charged balloon collects radionuclides present in the air;
ii. In 20 to 30 minutes the activity of the radionuclides collected on the balloon is sufficient to generate elevated count rates;
iii. The decrease in the count rate with the paper disk absorber present indicates a significant contribution from alpha particles;
iv. The activity decays to background levels in 6 to 7 hours.

Radioactive Balloons – who'd have thought? A teachable moment… thanks Thomas!

If you're interested in more of the physics, see the Workshop Notes (available on the CNS website).