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Contents

- 1 News - Smoking machines in schools
 - Is science uncool?
- 2 ICT / Physics - Audacity - adopt an audacious approach to the study of sound
- 6 Supporting Scottish Science Education
 - CPD news
- 8 Physics - Half-life demonstrations

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Is science uncool?

The papers have been full of gloom-and-doom articles recently, about how the apparently stifling effects of risk aversion, boring teaching methods and exam-led education has resulted in a decline in the number of pupils taking Chemistry and Physics Highers. "Pupils are being denied the chance to carry out scientific experiments because teachers are being put off by health and safety regulations" [1], "SCIENCE AT SCHOOL IS UNCOOL" [2], "ACTIVITY BAN HAS MADE PUPILS SOFT AND SICKLY", [3]. Professor Anne Glover, the new Chief Scientific Adviser for Scotland, has called for a greater emphasis on practical activities to turn on youngsters to the excitement of the essentially investigative nature of science. Director-General of the CBI Richard Lambert recently said "We must smash the stereotypes that surround science and rebrand it as desirable and exciting; a gateway to some fantastic career opportunities" [4].

Whilst the premises put forward by Professor Glover may make a case for why kids are voting with their feet, we need to elicit other factors, which may affect the figures, as well as suggest reasons to be optimistic about the future.

We may be forgiven for being concerned that health and safety regulations are one of the main culprits since it is a major part of our raison d'être. Health and safety regulations need to be wisely applied and proportionate to the risks. Safety myths often suffocate the educational atmosphere like will-o'-the-wisps

The use of smoking machines in schools

SEED has advised that the use of smoking machines indoors, even in a fume cupboard and following the control measures resulting from a suitable risk assessment as outlined in *SSERC Bulletin 217*, is illegal. SSERC has been informed that teachers carrying out this demonstration in a laboratory are liable to be prosecuted. However, SEED states that it would be legal to demonstrate the smoking machine outdoors.

We believe that the use of the smoking machine in schools is effective, valuable and should be exempt from *The Smoking, Health and Social Care (Scotland) Act, 2005*.

For a full position statement see www.sserc.org.uk/public/smoking_generic.pdf

e.g. in the *Scotsman* [1] the bell in the bell jar experiment can no longer be practised because the restrictions on producing vacuums in classrooms are so strict that manufacturers don't sell them (sic) any more - just don't have any lit cigarettes around! In the majority of school experiments, the risks are trifling and teachers need not be afraid, given that the appropriate control measures are applied. There is seldom any good health and safety reason for not doing an experiment.

For too long the examination tail has wagged the curriculum dog. The powers that be and higher education have measured children's success in what are intrinsically practical, skills-laden, problem-solving subjects by a relentless analysis of their ability to recall thosands o' facts. Countless numbers of kids are turned off the subjects by being marginalised because they don't fit the academia profile or, even if they do, are bored out of their skulls by the relentless tedium of the courses. Those who jump on the trendy, online bandwagon by developing new, socially and technologically aware 'courses' should beware repeating the curricular mistakes of the past. Teachers should question whether they cover scientific methodology or are just another excuse to peddle yet more scientific facts in the guise of being aware of social, moral and technological gadgetry issues. The debate has "showed that people want a curriculum that will fully prepare today's children for adult life in the 21st century, be less crowded and better connected, and offer more choice and enjoyment." This was stated in *The Curriculum for Excellence* (CfE) [5], published by the Curriculum Review Group in 2004. Existing courses must take account of the implications for the 3-18 curriculum, which may result from the application of the aims of the CfE. At present there is a curriculum review in science based on implementing the principles of *Challenge and enjoyment, Breadth, Progression, Depth, Personalisation and choice, Coherence*

and Relevance

. We await the results of their deliberations with interest.

So is the assessment tail still wagging and is

there any room for optimism? *Assessment is*

for Learning (AfL) [6] is a national initiative,

which seeks to develop a streamlined and coheren system of assessment for schools that

will support learning. The trend is towards

the use of *Formative Assessment* [7], [8], [9],

[10] & 11 techniques rather than *Summative Assessment* which is inevitably the result of

reliance on the recall of facts.

Summing up, science is probably not cool

and never will be – so last-century descrip-

tion. Now 'wicked' or 'bad' – that's what we

should be aiming for! Many factors have led

to schools doing less practical work in science.

It should undoubtedly be better funded than

it is [12] and the present arrangements –

courses, examinations and teaching methods – need reforming.

[1] news.scotsman.com/scotland.cfm?id=1174302006

[2] *Science at School is Uncool* by Thomas Smith, Sunday Mirror, August 13th 2006

[3] *Activity Ban has made Pupils Soft and*

Sickly by Ron Moore, Daily Mirror, Aug., 2006

[4] [news.bbc.co.uk/2/hi/uk_news/educa-](http://news.bbc.co.uk/2/hi/uk_news/education/4780017.stm)

tion/4780017.stm

[5] www.acurriculumforexcellencescotland.gov.uk/about/index.asp

[6] www.ltscotland.org.uk/assess/

[7] www.learningcurve.info/fais/overview.htm

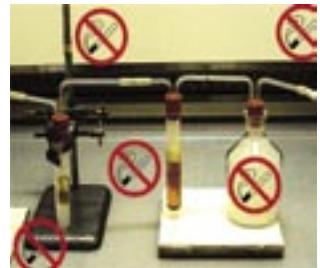
[8] www.ise5-14.org.uk/members/Exemplar_Materials/Overview.htm

[9] www.ise5-14.org.uk/members/Gallus_News_and_Background.htm

[10] www.ise5-14.org.uk/members/TSEC_DVD/News_and_Background.htm

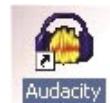
[11] www.ise5-14.org.uk/members/Exemplar_Materials/Overview.htm

[12] *Funding surveys in Physics Departments* by Stuart Farmer, SSERC Bulletins 203 & 210



Audacity – adopt an audacious approach to the study of sound

Audacity is open source software for recording and editing sounds and is available for Mac OS X, Microsoft Windows, GNU/Linux, and other operating systems. It may be downloaded from the SourceForge.net website, the world's largest Open Source software development web site. Open source promotes collaboration between developers and end-users to produce enduring, high quality software.



Introduction

For the last couple of years my younger son has been using various incarnations of this wonderful application to realise his musical creations by the use of multi-track recording and editing. It is extremely easy to use and files can be saved out as Audacity files (for future editing/mixing), *WAV* (the type of files you get on music Cds), *Ogg Vorbis* (a type of compressed audio file) and *MP3* (a compressed audio file format that most folk under the age of 25 will be very familiar with!). One of our SSERC staff recently attended a one-day course run by Tom Dickson (Tom.Dickson@smtp5.fife.gov.uk). Audacity was used to provide edited commentaries for video and PowerPoint files. The program must definitely have arrived since we hear that there was a talk about '*Audacity and Music*' at the *2006 Physics Summer School* in Glasgow.

After looking at the Science component of *Environmental Studies (5-14)* and the various *S3-S6 Physics syllabuses* (see *Curricular References*), it is apparent that Audacity can serve as an excellent tool for investigative work in the study of sound ... and the best bit ... it's free!

Equipment requirements

The first and most obvious requirement is that your computer should have a sound facilities fitted. On many inexpensive machines and laptops these are often integrated with the motherboard i.e. the main circuit board at the heart of the computer. Those who are interested in gaming and the like may have a separate soundcard fitted to cope with all the bangs and explosions. As for the speed of processor which you require, we've managed to get Audacity to run on computers running at 333 MHz, and right up to 3.1 GHz. You'll also need a microphone (mic). We used a perfectly



Figure 1 - Simple desk microphone & stand

satisfactory one, Cat. No. CS13516, priced at only £1.82 incl. vat, from CPC (Fig. 1). The final add-on for your sound experiments is a pair of speakers or, for a little extra cash, a pair with a sub-woofer (Cat. No. CS1283205) to give you these extra-low frequencies (Fig. 2).



Figure 2 - Speakers & subwoofer system

Getting the software

Simply go to the download address (<http://audacity.sourceforge.net>) and then to the University of Kent mirror site link. You can save this executable file to your hard disc for installation on the computer you're on or to a pen-drive for set-up later on another desktop computer or laptop. This file is only 2.21 Mb so you'll not wait for hours downloading or installing it.

Setting up the computer

Before starting to record any sounds the computer settings need to be configured to receive them via the microphone. Plug the jackplug end of the mic into the pink colour-coded socket. This is often found to the rear of the computer (Fig. 3b) but newer machines can have a panel conveniently situated on the front (Fig. 3a). The sound output (green socket) should be connected to the speakers via the green jackplug as shown.



Figures 3a & 3b - Mic inputs (front & rear)

Go to *Start – Settings – Control Panel* then double click on *Sounds and Multimedia*. Choose the *Audio* tag at the top and then the *Volume* button within

Sound Recording. A window (Fig.4) will appear on screen entitled *Recording Control*. Make sure the *Microphone slider control* is there and the *Select* box is ticked.

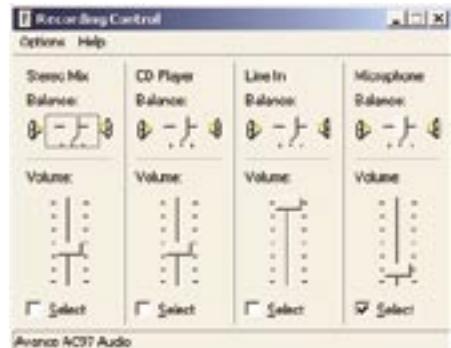


Figure 4 - Recording Control window

If there is no microphone area click on *Options – Properties*, select *Recording* and make sure the *Microphone* tick-box in the scrolling area at the bottom of the window is ticked. The *Microphone slider* should then appear in the *Recording Control window*. Click on the *Advanced* button and tick the *1 Mic Boost* tick-box. This boosts the signal from the microphone and effectively makes it more sensitive to any sounds (Fig. 5).

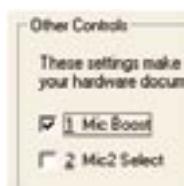


Figure 5

You may also need to adjust the *Volume Control*. This is accessible directly via a right-click on the wee speaker icon on the toolbar at the bottom of the desktop. Click on *Open Volume Controls* and the window appears on screen (Fig.6). This window is also accessible via the *Sounds and Multimedia* section of the *Control Panel*.

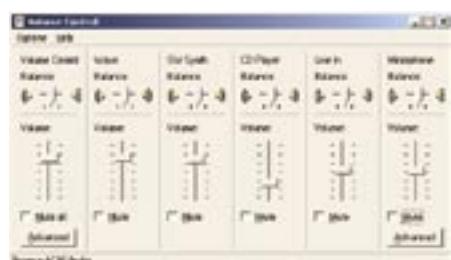


Figure 6 - Volume Control window

Make sure that the *Microphone* tick box is not *Muted*. If all is OK with the Recording and Volume Controls then you should be able to hear your voice being amplified when you speak into the microphone.

You are now ready to start up Audacity and use it as a tool to make and study sounds. This article will take you through the basics of :-

- recording & analysing sound waves
- using Audacity to generate sounds
- threshold of hearing
- vibrating air columns
- speed of sound experiment
- capture of sound pollution
- interference

Recording & analysing

When Audacity is installed on a computer it will put the application icon on the Desktop. Double click on this and the Audacity application starts (Fig. 7).



Figure 7 - Recording Control window

The six circular buttons control, from left to right, *Start of Recorded file*, *Play*, *Record*, *Pause*, *Stop* and *End of Recorded file*. Below these are two slider controls for *Playback Level* (speaker symbol) and *Recording Level* (mic symbol). Make sure the microphone is connected, set the *Recording Level* to about halfway and try a recording by pressing the *Red button* in the centre. A scrolling trace will appear in the grey area below – try making a few sounds – the recording will continue until the *Stop* or *Pause* buttons are pressed.

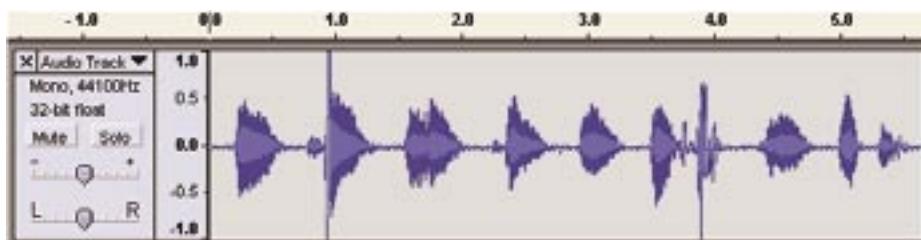


Figure 8 - Sample sounds recorded

Fig. 8 shows speech patterns of the letters of the alphabet from A to H. The *Recording Level slider control* can be adjusted so that the trace uses the full height +1 to -1. If the trace overshoots this scale then the recorded sound will be over-recorded and playback will be distorted. If the height of the trace is very small then the recorded sound will be under-recorded and weak.

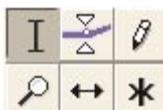


Figure 9 - Selection Toolbar

The sounds can be analysed in closer detail by clicking on the *Selection Tool* (Fig. 9, 'I' symbol), selecting and highlighting an interesting area on the trace, then clicking on the *Zoom In* icon (wee magnifying glass with a + inside) on the *Edit Toolbar* (Fig. 10). The display zooms in to show high detail.

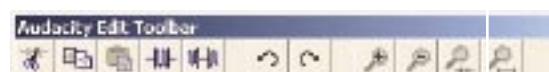


Figure 10 - Edit Toolbar

Threshold of hearing

We can put the sound-generating ability of Audacity to good use by generating a number of tone bursts of steadily increasing frequency to examine the threshold of hearing. Interspersing these tone bursts we have slots of generated silence (Fig. 14). The task can be made more akin to hearing tests by not increasing the frequency by steady increments, randomising the sound bursts, blindfolding the subjects and using high quality headphones. It should also be noted that these tests are as much a test of the loudspeaker/headphone equipment you use as it is of what frequencies can be heard. If you use a sub-woofer then the low frequency bursts are pretty impressive.



Figure 14 - Tones of increasing frequency

You can also test the ability of your microphone to pick up pure tone sounds by playing the tone-bursts and recording simultaneously on another track. For this to happen select *Edit - Preferences...* then put a tick in the *Play other tracks while recording new one* tick-box.

On Fig. 15 it can be seen that the combination of the loudspeaker used to make the sound and the frequency-response of the microphone results in an uneven reproduction of sounds across the frequency spectrum. This is quite normal and one of the reasons why graphic equalisers are a good idea.

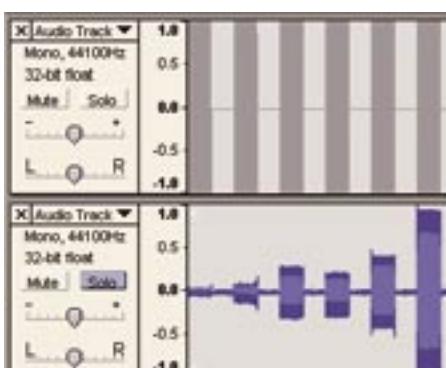


Figure 15 - Microphone frequency response

Generating sounds

As well as recording sounds Audacity can be used as a sound generator. Click on *Generate - Tone...* then a *Sine*, *Square* or *Sawtooth* waveform can be selected and the *Frequency* (in Hz), *Amplitude* (0-1) and *duration* (in seconds) specified. Fig. 11 shows a tone which is Sine, 400 Hz and Amplitude 1 (full scale) for 5 s. These particular settings produce a virtually solid blue trace (Fig. 12) because the frequency chosen and the screen resolution cannot show individual waves. Click on the *Zoom In* icon 6 times and the sinusoidal trace can be seen (Fig. 13).

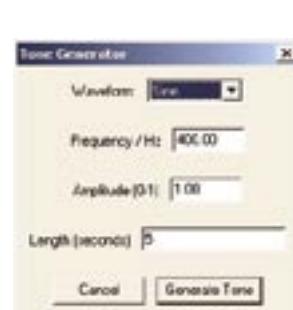


Figure 11 - Tone Generator window

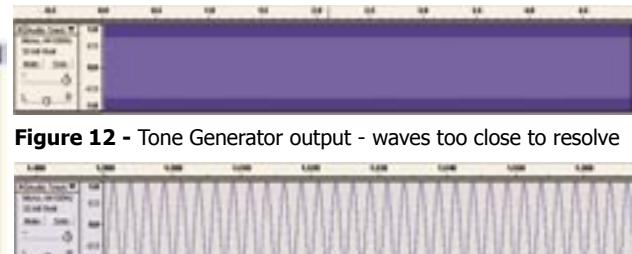


Figure 12 - Tone Generator output - waves too close to resolve

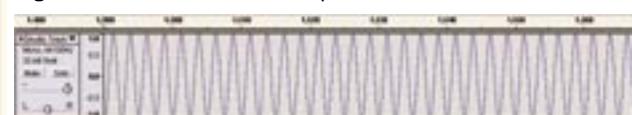


Figure 13 - Zoomed-in view shows individual sound waves

Vibrating air columns

Here we look at the sounds produced by blowing air (Fig. 1) over the neck of two sizes of glass medical-flats bottles (19 cm and 15.5 cm tall). The top trace is the larger bottle. The *Audacity* software can be used to analyse the frequencies produced by the two bottles. Ten wavelengths (10λ) on the top trace are highlighted and the times for the start, end and duration of the selection are displayed (Fig. 16).

Figure 16 - Time for 10λ

Selection: 0:00.493861 - 0:00.535171 (0:00.041310 min:sec)

Big bottle - 10 wavelengths correspond to a time period = 0.04131 s (Fig. 18, top)

Therefore 1 wavelength has a period (T) = 0.004131 s

$$\text{Frequency } (f) = 1 / T = 1 / 0.004131 = 242 \text{ Hz}$$

Small bottle - 10 wavelengths correspond to a time period = 0.032591 s

Therefore 1 wavelength has a period (T) = 0.0032591 s

$$\text{Frequency } (f) = 1 / T = 1 / 0.0032591 = 307 \text{ Hz}$$

The calculated frequencies can be checked (Fig. 19) by generating a short burst of each frequency and see if it sounds the same as the recorded one. This experiment is just one of many which can be done in this vein. Look also at pukka instruments and resonant frequencies in tubes which can be varied in length with the use of a plunger.

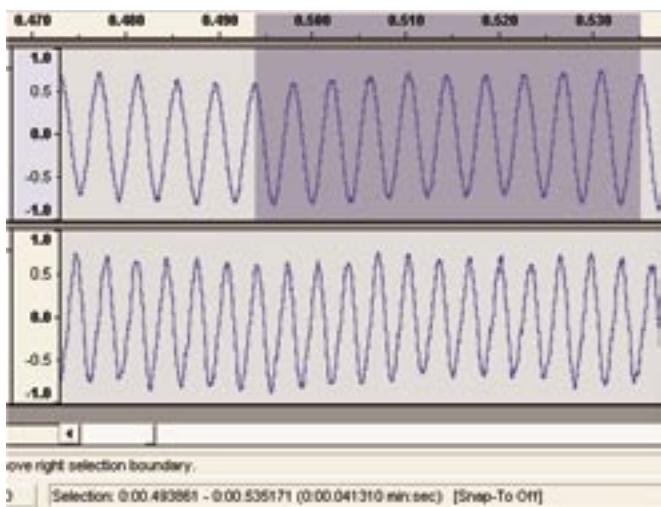


Figure 18 - Big bottle (top, 242 Hz), small bottle (bottom, 307 Hz)

Speed of sound experiment

Ok, so this has all been done before with hammers, contacts, oscilloscopes or digital stopclocks and the like. We were interested, however, to see if this could be done within the confines of the desktop (the real one that is!) and the wall opposite (39 cm away from the computer screen).

Another beauty of this set-up is that you don't have any triggering to worry about and you can be quite relaxed about when the sound measurement is taken and that you'll not miss anything with readings being taken about every 0.00002 s. At that rate Audacity says that the hard disc can take over 100 hours of recording!

The microphone was blu-takked to the monitor, 0.39 m from the wall (inset Fig. 20). Recording was started with the red button and a sharp clap carried out about the same distance in front of the screen. This distance is not important. However, the loudness of the clap and recording level should be set in order to achieve full scale.

The short duration of the clap being recorded as well as the echo from the wall can be highlighted and zoomed-in on until a trace, similar to Fig. 21, is obtained. The time between initial sound and the echo was measured (grey area) as 0.002313 s (t). Therefore the sound had taken this time to travel 0.78 m (d).

The **speed of sound (v)** is therefore calculated to be $d / t = 0.78 / 0.002313 = 337 \text{ ms}^{-1}$

Try varying the distance between the microphone and wall. A large sheet of dense material could replace the wall as reflector of the sound if one is not nearby.



Figure 17 - Blow gently over the bottle

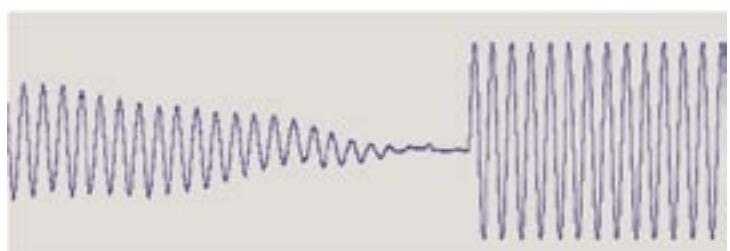


Figure 19 - Recorded waveform & generated tone of predicted frequency

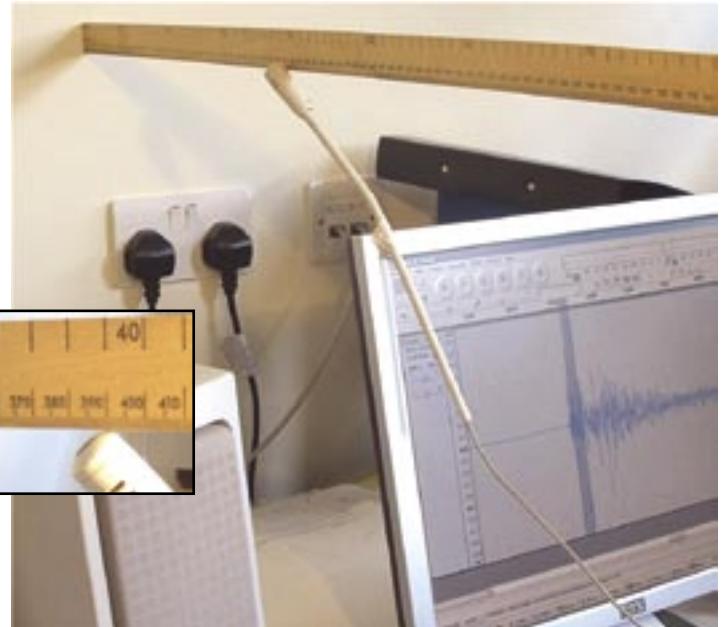


Figure 20 - Measuring distance from the microphone to the wall

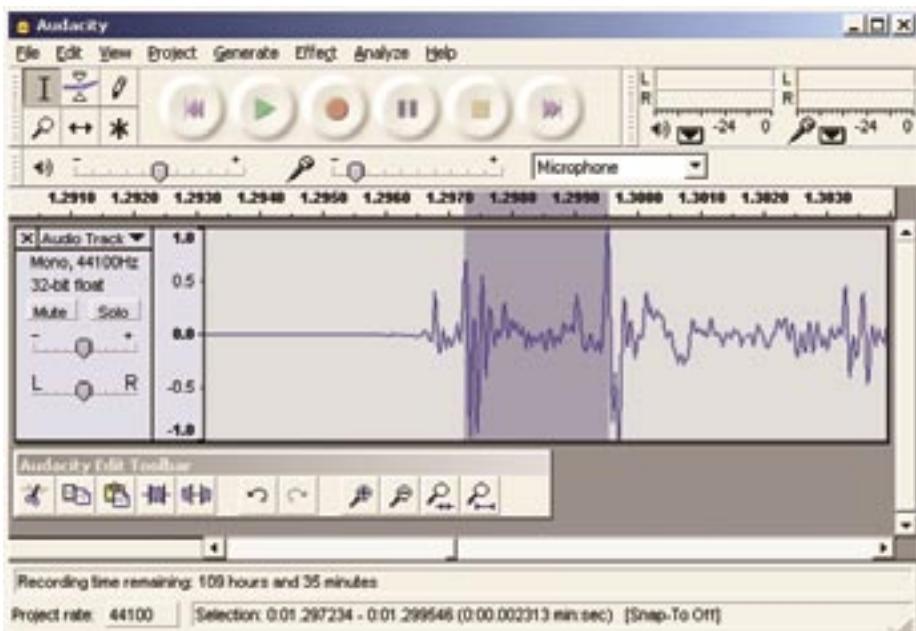


Figure 21 - Speed of sound experiment. Time between clap and echo is highlighted.

Noise pollution

There are many activities worth exploring with regard to noise pollution. In our ever-increasingly noisy environment we need to find ways of measuring sound levels which do not rely on our subjective perceptions. This is because the irritation factor of some noises e.g. babies crying, dogs barking, cats wailing etc., are more difficult to measure than the 'powered' noises emanating from the engines of cars and aircraft or sound systems blaring out from houses and cars.

We went with a microphone and laptop running Audacity to a busy road (Fig. 22).



Figure 22 - Noise pollution trace from a busy road.

The areas of dense blue correspond to particularly busy traffic flow – the greater amplitude corresponds to greater noise. The tall peaks which are wide equate to something like an articulated lorry passing by. How could we use information like this to better design screening for busy roads? Try and design experiments to test the efficiency of sound-absorbing material e.g why do workers require ear-defenders?

Interference

Here we go back to generating tone-bursts of increasing frequencies with Audacity's in-built tone generator. The same tone comes out of the two speakers as we simultaneously record with the microphone panning across between them. You can see that the pattern of high and low volume, corresponding to constructive and destructive interference, changes as the frequency increases from left to right.

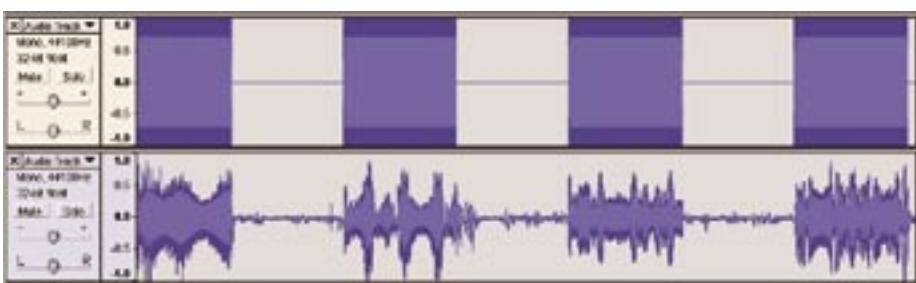


Figure 23 - Interference patterns produced as microphone pans between two speakers

Concluding remarks

We hope that this wee article has given you the spur to go on and explore the world of sound with Audacity. Other applications we've tried are transmission of sound in wood, Doppler Effect, spectrum analysis of animal sounds and damped oscillation. We hope to feature these in future issues of the Bulletin

Let us know how you get on, make it fun and give us your ideas for further experiments.

Curricular References

ISE 5-14 learning outcomes

EF-C1.3 - link sound to sources of vibration, Science Framework for Planning – Group 10 (Light & Sound)

(http://www.ise5-14.org.uk/Prim3/New_Guidelines/Levels/topics-c.htm#2-1-3)

EF-D1.4 - use the terms 'pitch' and 'volume' to describe sound

(http://www.ise5-14.org.uk/Prim3/New_Guidelines/Levels/topics-d.htm#2-1-4)

EF-D1.5 - explain what happens when sound passes through different materials

(http://www.ise5-14.org.uk/Prim3/New_Guidelines/Levels/topics-e.htm#2-1-5)

EF-F1.3 - describe the relationship between pitch and frequency and between loudness and amplitude

(http://www.ise5-14.org.uk/Prim3/New_Guidelines/Levels/TOPICS-F.HTM#2-1-3)

Standard Grade Physics

Unit 3, Section 2, Health Physics, Using Sound - The stethoscope, Investigate range of hearing experiment with signal generator and loudspeaker, Noise pollution.

Unit 3, Section 6, Health Physics, Practical Investigation – noise level measurement / pollution/ absorption.

Physics (Access 3 & Intermediate 1)

Unit (Sound and Music), Section 4.1 – Sound waves, *Section 4.2 – Speed of sound, Section 4.3 – Using sound, Section 4.4 – Amplified sound*

Physics (Intermediate 2, Higher and Advanced Higher)

Unit (Waves and Optics), Section 3.1 – Waves

Addresses

SourceForge.net -

<http://sourceforge.net/docs/about>

Download address for Audacity app.

- <http://audacity.sourceforge.net>

Great site for browsing and listening to music and sound effects files – snippets can be recorded by Audacity :-

<http://www.audiolicense.net/>

Mic & speakers - <http://www.cpc.co.uk>

Supporting Scottish Science Education - CPD news



Figure 1 - Practical session at the Biotechnology Summer School
- Plant Biodiversity through DNA fingerprinting

Introduction

As reported previous Bulletin articles [1] & CPD News [2 & 3], SSERC is engaged in a number of Scottish Executive funded projects that involve Continuing Professional Development for school science educators in Scotland. Here, we provide an update on a range of CPD activities provided through the partners in the 'Supporting Scottish Science Education through CPD' and 'CPD for School Science and Technology Support Staff' initiatives.

Leadership course for new and aspiring Heads of Faculty

Thirty Heads of Faculty and Principal Teachers Curriculum took part in this five-day residential course on 'Improving Achievement in Science'. The course offered opportunities for participants to develop their skills, knowledge and understanding of how to lead others as well as how to strategically manage their faculty or department. This was always done with a view to the creation of an ethos where the main goal was the inspirational teaching of science. A major, successful feature of the course was an action research project carried out by the delegates, either individually or in groups, between the initial, demanding 3 day session of the course held in November, 2005 and the 2 intensive recall days held in May, 2006. During a 'show and tell' session, delegates had opportunity to exchange their ideas and experiences.

All of the projects were impressive and many delegates commented on how valuable they had found this and other aspects of the course, a typical comment being :-

"An enjoyable, informative and beneficial course over five days."

The course was supported by the National Science Learning Centre (NSLC) [4] at York as part of its support for provision of CPD for Scottish science teachers.

Residential school for trainee postgraduate science teachers in Scotland

On June 6th and 7th, 2006, one hundred and eighty Post Graduate Diploma

in Education (PGDE) students came together and worked and played hard at an action-packed, two-day, residential, professional development conference held at the University of Edinburgh's Pollock Halls. These Biology, Chemistry and Physics students, who came from the six Initial Teacher Education Institutes across Scotland, will start teaching in August 2006. As teachers, these students will be key to the successful implementation of the Science 3-18 Review and *A Curriculum for Excellence (ACE)* [5]. The theme of 'Sustainable Development', which ran throughout the conference, afforded an excellent channel for students to explore learning and teaching methodologies including cross-disciplinary collaborative-working that support the implementation of *ACE* within the context of science education. This unique conference also provided these new entrants to the profession with their first taste of high quality Continuing Professional Development (CPD) and encouraged them to establish networks with other teachers of science on a Scotland-wide basis. Feedback from participants was very positive with comments e.g.:-

"Great introduction to CPD" and
"This event should continue and grow each year."

The conference was organised by university tutors and supported by SSERC and its partners in the *Support for Science Education through CPD* initiative. The conference was underwritten by SSERC with contribution from ITEIs and the students themselves.

Summer schools

The last week in June has become a recognised date in the calendar for the Biotechnology and Biosciences, Chemistry and Physics summer schools. This year, around seventy-five teachers, from schools across Scotland, attended with many sacrificing part of their summer holiday to be there. In addition to the established offering of opportunities for participants to raise levels of knowledge and confidence in the teaching of their subject, the 2006 summer schools



Figure 2 - Dr. Tony Miller of the Royal Botanic Garden, Edinburgh talked to the Biotechnology Summer School about biodiversity and the remote island of Socotra in the Indian Ocean.

let delegates explore activities and pedagogy that support the purposes and principles of *A Curriculum for Excellence*. The programmes for each of the three summer schools comprised an interactive approach that incorporated a mix of practical activities, group tasks, discussions, lectures and visits.

Biotechnology and Biosciences Summer School

Visits to the Roslin Institute (RI), the Scottish Agricultural Science Agency (SASA) and the Royal Botanic Garden, Edinburgh (RBGE) provided some of the highlights. The Summer School was held at the University of Edinburgh and organised by Science and Plants for Schools (SAPS) and SSERC. Participants visited either the Roslin Institute or SASA, both of whom were wonderful hosts. Each organisation treated delegates to an inside view of their work and demonstrated superbly science at the frontiers of both research and application. Scientists from RI and SASA departed from their normal day jobs to work closely with small groups of participants to produce a PowerPoint presentation, on an aspect of the work of the organisation relevant to the curriculum, which can be used in the classroom. Another visit, on a glorious day, to RBGE provided a wealth of information and ideas in a day entitled, 'Biodiversity – why should we bother?'

Chemistry Summer School

Delegates enjoyed a wide range of activities designed to compliment and enhance their classroom teaching. These included lectures on 'The Elements of Life and Medicines: a Web of Health?' and presentations by the exuberant Paul Murray on 'Chemistry of the Stars' and 'Colourful Chemistry'. Laboratory work included spectroscopic sample preparation & analysis and a chance to preview some new Forensics and Investigations teaching materials for use in S1/S2.

A visit to the National Museum of Scotland's minerals section in Granton proved a great success with delegates gaining valuable insight into the formation of gemstones and they themselves chemically removing impurities from mineral samples. The Chemistry Summer School was organised by the Development to Update School Chemistry (DUSC), SSERC and the University of Edinburgh where the event took place.

Physics Summer School

This was supported by the Institute of Physics, SSERC, University of Edinburgh and the University of Glasgow, where the Summer School was held.



Figure 3 - Practical session at the Physics Summer School - Spark Counter experiments & Radioactivity

Lectures included an eclectic mix of subject matter that ranged from nanotechnology, through the 'Physics of Music', to 'Irn Bru from the Stars'. There was even a visit from two astronauts. Throughout the week, attendees worked together in small groups to produce an excellent CD that they will be able to use a resource in the classroom to support the learning and teaching of a variety of topics that include: Electric circuits – thinking and modelling; Momentum and impulse – banging and crashing explained; Radioactivity - what Joe Public makes of it; and Light, waves and polarisation – understanding and explaining.

CPD & related activities for school support staff - progress

This project, managed through SSERC and the Scottish Technicians' Advisory Group (STAG), was reported on in some

detail in Bulletin 215 [6]. Plans are underway to publish the *National Survey 2005 Interim Report*. This baseline survey report describes the current national position and the variety of extant support arrangements within Local Authorities. Good progress is being made in developing a suitable Scottish qualifications and CPD framework for science and technology support staff. It is hoped that four units will be credit rated and levelled through the SQA's Scottish Credit and Qualifications Framework (SCQF) within the timescale of the project. Two of these learning programmes have been successfully trialled: Safety in Microbiology for Schools and Safe Use of Fixed Workshop Machinery. Following the success of last year's event, the Technicians' Consultative Conference 2006 will be held from 1st – 3rd November in Crieff Hydro. Brian Richmond, Project Manager has written to all Local Authorities seeking nominations for delegates to attend.

References & addresses



Figure 4 - Lecture session at the Physics Summer School - Irn Bru from the Stars by Dr. Lyndsay Fletcher of the University of Glasgow

For further information on any of these activities contact kath.crawford@sserc.org.uk

- [1] www.sserc.org.uk/members/SafetyNet/bulls/214/editorial.htm
- [2] [www.sserc.org.uk/members/SafetyNet/bulls/215/CPDNews1_OnScreen\[1\].pdf](http://www.sserc.org.uk/members/SafetyNet/bulls/215/CPDNews1_OnScreen[1].pdf)
- [3] www.ise5-14.org.uk/prim3/CPD_Project_News/On%20screenISE5-14%20News%20e.pdf
- [4] www.sciencelearningcentres.org.uk/WebPortal.aspx?page=1
- [5] www.acurriculumforexcellence-scotland.gov.uk/about/index.asp
- [6] www.sserc.org.uk/members/SafetyNet/bulls/215/newscomment_4.htm

Half-life demonstrations

Radioactive decay and the half-life concept can be shown by three methods, each of which presents a negligible risk of harm: (1) by the evolution of Radon-220 from thoriated gas mantles; (2) by the elution of Barium-137m from Cesium-137; and (3) by the electrodeposition of daughter products of Radon-222 on a charged rubber balloon.

Open source work

An *open source* is one where the radioactive material can be dispersed. A *sealed* or *closed* source is one where, by engineering design, the radioactive material is effectively enclosed and cannot contaminate the workplace.

On a point of principle, schools should never work with open radioactive materials unless there is a justifiable reason and the risk is trivial. As a general rule, radioactive materials should be in the form of sealed sources. An exception is the source used for showing radioactive decay and the half-life concept because this practice requires a short-lived radionuclide to be extracted from the parent nuclide and isolated for monitoring elsewhere.

Any open source work must comply with the *Ionising Radiations Regulations* (IRR). The conditions for working with open sources are stiff, putting almost any open-source operation outside the scope of what schools can do. However the new 1999 version of IRR allows for relaxations where the amount of open radioactive material is very low, applying the legal principle of *de minimis non curat lex*, which translates as 'the law does not concern itself with trifles'. In the three demonstration experiments written about here, the amount of material is very low and the risks are almost trifling¹.

Radioactive decay of ^{220}Rn with a Cooknell ionisation chamber

The original radon (or thoron) generator was banned in the 1980s because the source, a compound of thorium, was a fine dust that could be dispersed very easily causing widespread, random contamination. A new version has been devised by Ralph Whitcher² which uses four thoriated gas mantles as the source (Fig. 1). Radon gas ^{220}Rn (gas of this isotope is also known as *thoron*) emanating from the thorium is collected from the source and transferred to an ionisation chamber. The tiny current flowing between the electrodes in the chamber is indicative of the concentration of ^{220}Rn .

¹ In any work with radioactive material, whether the risks are trifling or not, the operator is morally and legally bound to protect him- or herself and any others who may be affected.

² Private correspondence.



Figure 1 - Thoriated gas-lamp mantle.



Figure 2 - The Cooknell Ionisation Chamber. The bottle, chamber and balloon form a closed system; when the bottle is squeezed, air is displaced to inflate the balloon, enriching air in the ionisation chamber with thoron gas (^{220}Rn).

As the radon decays, so does the current, which is amplified by an extra-high impedance amplifier and read on either a voltmeter or datalogger. The half-life of ^{220}Rn is 54 s.

The apparatus is made by Cooknell Electronics (Email: enquiries@cooknell-electronics.co.uk) and costs £200 including the source (Fig. 2). A sample has been tested for performance and assessed for safety. The source is easy to dispose of at the end of its working life by putting it out with normal refuse.

Method

Connect either a digital voltmeter set to its 2 V DC range or a datalogger set to monitor voltage at 10 s intervals across the output electrical terminals of the ionization chamber. Open the Mhor clip and squeeze the bottle once, displacing radon-rich air from the bottle. This floods into the ionization chamber and temporarily inflates the balloon. When the hand squeezing the bottle is relaxed, the balloon deflates and air returns to the bottle. The end result is that the air in the ionization chamber is enriched with ^{220}Rn .

The apparatus is easy to operate and, with a computer and datalogger, will quickly provide a set of readings, six a minute, which, when graphed, shows the exponential decay of count-rate against time (Fig. 3). There is negligible background. The first three or so readings should be omitted from the analysis. The half-life value from the results at 58 ± 3 s is a little above the accepted value (54 s).

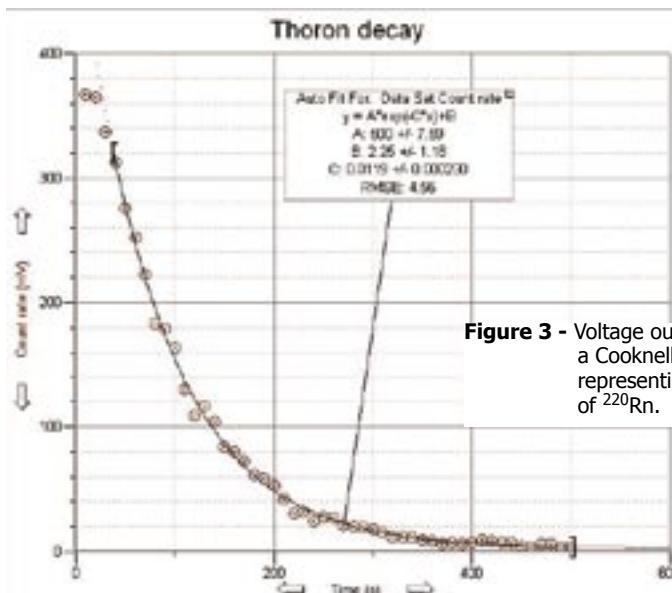


Figure 3 - Voltage output versus time from a Cooknell ionisation chamber representing the radioactive decay of ^{220}Rn .

Thorium sources and gas mantles

The mantle is woven with a cotton or silk thread impregnated with a thorium and cerium compound mixture (helping prevent a lit mantle clogging up with soot). (Mixture: 99% thorium(IV) oxide and 1% cerium oxide.) The mass of thorium is about 12.5% of the mantle's total mass. Some makes of gas mantle do not contain thorium.

The activity of a single mantle is roughly about 1 kBq. With a new mantle with freshly refined thorium, the activities of ^{228}Th and other progeny below this isotope are nearly equal to the parent of the series, ^{232}Th (Table 1). Thereafter the activity of the part of the series from ^{228}Th onwards drops to a minimum at 4 y then builds up to secular equilibrium at 40 y. The emanation of radon ^{220}Rn is a minimum at 4 y, being 40% of what it had been when the mantle was new, or what it will again become when the mantle is old.

About 25% of the radon ^{220}Rn generated by nuclear decay within the mantle is evolved as gas. An unused (in the sense of unburnt) thoriated mantle is unlikely to cause much contamination. However after use in a paraffin flame the mantle becomes very fragile and can disintegrate into a fine, thoriated ash. The main hazard is the inhalation of ^{232}Th and ^{228}Th dust.

Radioactive decay of ^{137m}Ba from an AEA Isotope Generator

Key words:

Elution - The process of removing an absorbed material from an absorbent by washing it in a liquid.

Eluant or eluent - The liquor used in the elution before the eluting begins.

Eluate - The solution consisting of the material washed out from the absorbent by the eluant.

Elute, to elute - Transitive verb describing the process.

Eluting - Adj. describing the process.

How it works

The Isotope Generator is an eluting source i.e. a small quantity of liquor (or eluant) is injected into the inlet at the top of the source holder, dribbles through the parent source (^{137}Cs) and chemically extracts the short-lived daughter (^{137m}Ba). The liquor (or eluate) drains from the outlet in the bottom of the source holder and is collected in a small glass vessel.

^{137}Cs has a 94.6% probability of decaying by beta emission to ^{137m}Ba , an

Nuclide	Half-life	Alpha	Beta	Gamma
energy (MeV)				
Thorium-232	1.41×10^{10} years	4.0	-	0.06
Radium-228	6.7 years	-	0.04	-
Actinium-228	6.1 h	-	2.1	1.6
Thorium-228	1.9 years	5.4	-	0.08
Radium-224	3.6 days	5.7	-	0.24
Radon-220	54 s	6.3	-	-
Polonium-216	0.158 s	6.8	-	-
Lead-212	10.6 h	-	0.57	0.3
Bismuth-212	60.5 min	6.1	2.3	1.6
Polonium-212	3×10^{-7} s	8.8	-	-
Thallium-208	3.1 min	-	1.8	2.6
Lead-208	Stable	-	-	-

Table 1 - Thorium-232 decay series.

isomeric nuclear state of barium (Fig. 4). The half-life of this decay is 30.1 y. The barium isomer, ^{137m}Ba , makes an isomeric transition to a lower energy state accompanied by the emission of gamma rays. The half-life of this decay is 2.6 min. The thick-walled plastic enclosure of the source stops beta radiation, but not gamma. The source is therefore effectively a gamma emitter and can be used in demonstration experiments to show the properties of gamma radiation.

Because the half-life of ^{137m}Ba is very much shorter than the half-life of the parent, ^{137}Cs , parent and daughter will be in stable equilibrium except for a period of about 30 minutes after an elution. If the activity of ^{137}Cs is 33 kBq and the eluant is completely efficient at washing ^{137m}Ba out of the Generator, then the activity of ^{137m}Ba in the eluate immediately after elution can be presumed to be around 33 kBq.

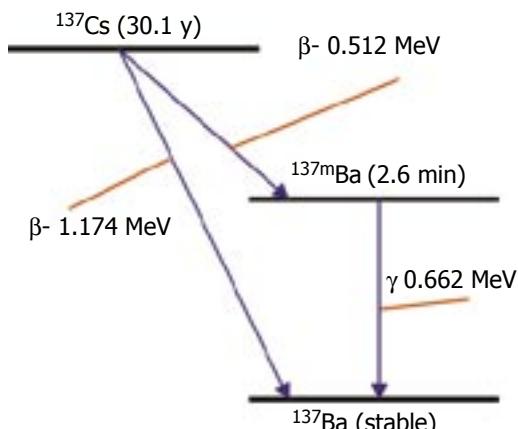


Figure 4 - Energy state diagram of ^{137}Cs and daughters showing the radioactive emissions associated with changes of state. There is a 94.6% probability of the decay transitions going via the ^{137m}Ba isomer.

The source

During manufacture, the radioactive material ^{137}Cs is incorporated within ion-exchange beads placed within a glued cylindrical plastic enclosure (diameter about 40 mm, height about 30 mm) between two membrane filters with a sub-micron pore size. A pre-stage filter has been added. The glued plastic enclosure has two openings through one of which ^{137m}Ba , the short-lived radioactive daughter product of ^{137}Cs , can be eluted by using 0.9% NaCl solution in 0.04 M HCl. When not in use, the openings on the Isotope Generator are sealed by caps (Fig. 5).



Figure 5 - Isotope Generator in storage box with syringe and tubing. The eluant is in the bottle alongside.

There may be a small amount of bleedthrough of ^{137}Cs with the eluate. AEA have reported that the ^{137}Cs content of the eluate was assayed 45 minutes after elution with 2 ml of solution in a batch of 14 generators. One generator showed 200 Bq of ^{137}Cs in the eluate; all the other generators had less than 50 Bq. The

measurements were repeated over a period of 3 months and the bleedthrough did not deteriorate.

Procedure

The demonstration is carried out over two drip trays one metre apart. The elution is done over the first tray and the counting over the second one. Beginning with the elution, a receiving bottle with a capacity of 10 ml is stood in a flat glass dish on one of the trays, lined with absorbent paper. The end caps of the source are removed. 2 ml of eluant is drawn into the syringe through plastic tubing dipped in the eluant stock bottle. The tubing is removed from the syringe and the syringe is screwed into the top aperture of the Isotope Generator, which is held in one hand over the receiving bottle while the other hand depresses the plunger transferring the eluant into the source (Fig. 6). Almost immediately liquor (now called the elu-



Figure 6 - Isotope Generator during an elution. (The source should be gripped in the operator's other hand for greater stability.)

ate) drips from the outlet in the base of the source into the receiving bottle. The whole elution is over in a time of about 15 s. The receiving bottle must then be transferred immediately without delay to the other tray and placed in front of the GM tube already set up waiting (Fig. 7). Counting from the source is then begun. The recommended counting period is 60 s and counting should continue for at least 15 min, but preferably 30, so that the decay is seen to have run its course (Fig. 8). The half-life value derived from

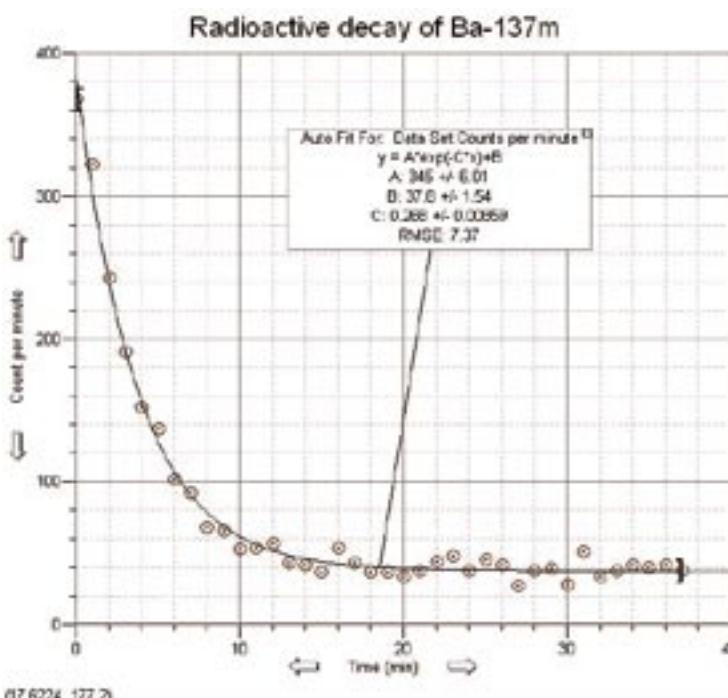


Figure 8 - Typical set of results from an Isotope Generator. The count was detected with a small-window GM tube.

the results worked out at 2.6 ± 0.2 min, matching the accepted value. The counting of background should have begun before the elution and if using a computer datalogger you should time the beginning of the elution so that it ends for the eluate to be in position just before a fresh minute's count is about to begin.

Risk assessment

The Isotope Generator is an open source and during an elution radioactive material is extracted from the source in liquid form and collected in a beaker. The amount of radioactive material is tiny and is such that from any likely accident the risk of harm would be negligible. Comparing the radioactivity of a freshly prepared eluate with a charged rubber balloon (next demonstration), the balloon can be much more radioactive. A risk assessment can be downloaded from the SSERC website.

What can go wrong?

It is foreseeable that the eluate might spill (but having done about fifty elutions without spillage, this is unlikely).



Figure 7 - Monitoring count rate from eluate.

Because the volume is limited to 2 ml, the contaminated area will be small. Any spilt ^{137}mBa will be self-cleaning. After a period of 45 min, it will have almost completely run-out, its activity being effectively zero. Nevertheless there is a possibility that a small amount of ^{137}Cs will also have bled through with the eluate. The amount is unlikely to exceed 50 Bq. Therefore you would have to treat a spillage as though you were cleaning up a spill of 50 Bq of ^{137}Cs . This is done by placing absorbent paper towels on the spilt liquor, which will gather up virtually all the spillage, and putting the wet paper directly on a drip-tray where it should be left for 45 min letting the ^{137}mBa decay away and the paper dry. The paper can then be disposed of in a polythene bag with normal refuse.

Disposal and acquisition

After an elution, the eluate should be left for half an hour for most of its radioactivity to decay. Then it should be poured into a laboratory drain and the drain flushed with water for several minutes. Schools are legally permitted to make this sort of disposal for the small amount of radioactive material being handled. They are also allowed to dispose of an open ^{137}Cs source with normal refuse provided that the activity does not exceed 40 kBq.

There are two types of Isotope Generator. There is one of low activity at 33 kBq and another of high activity at 370 kBq. Only the low-activity generator should be obtained because it can be disposed of easily at no cost at the end of its working life. The high-activity one must not

be purchased. Different legal constraints would make it costly to dispose of and incur you in much paperwork and an amazingly large fee to SEPA.

The UK agent for the Isotope Generator is Nicholl Education (Email: sales@nicholl.co.uk). A 33 kBq generator (order code CDRB5215) costs £495. A letter of approval to buy the source is needed from the Scottish Office Education Department (Tel: 0131 244 0956). The eluting solution (NQB1948) costs a further £45, but can be made in school from stock chemicals.

Electrodeposition of radon daughters on a charged rubber balloon

There are two purposes to this demonstration. The first is that by showing that a charged rubber balloon left hanging becomes radioactive, a reasonable inference would be that the radioactivity had originated in the air. The second is that by monitoring the count rate from the balloon fragments over a period of about 3 hours, the count rate is seen to drop by a sort of exponential decay, being the compound decay of more than one short-lived radionuclide.

Method

Inflate a rubber balloon, tie it at the neck, attach a nylon thread, rub the balloon on your head until you hear the crackling that you get with static electricity and you feel your hair standing out, then suspend the charged balloon from a support so that it touches nothing. Next start logging background radiation with a count period of one minute. After 30 minutes, burst the balloon, place the rubber fragments on a sheet of paper under the GM tube window (Fig. 9) and note that the count rate has increased many times over. Keep watching and the rate decays with a sort of exponential decay with a half-life of about 50 mins (Fig. 10). Presumably the activity is that of ^{214}Pb (26.8 min) and ^{214}Bi (19.9 min) - progeny of ^{222}Rn . The demonstration nicely shows that the natural world is quite radioactive. While it also shows radioactive decay, the decay curve is not analysable with school-level maths.

From the simplified list of emissions in the Uranium/Radium (4n+2) series (Table 2), energies of beta and gamma emissions from ^{214}Pb are moderately high and those from ^{214}Bi are very high. These would be readily detectable by a GM tube sited a few centimetres from the rubber fragments. The count is mainly caused by emissions from these two nuclides.

Nuclide	Half-life	Alpha	Beta	Gamma
energy (MeV)				
Radium-226	1620 years	4.8	-	0.19
Radon-222	3.8 days	5.5	-	-
Polonium-218	3.1 min	6.0	-	-
Lead-214	26.8 min	-	0.65	0.35
Bismuth-214	19.9 min	-	3.3	2.4
Polonium-214	1.6×10^{-4} s	7.7	-	-
Lead-210	22.3 years	-	0.06	0.05

Table 2 - Uranium-238 decay series from ^{226}Ra onwards.

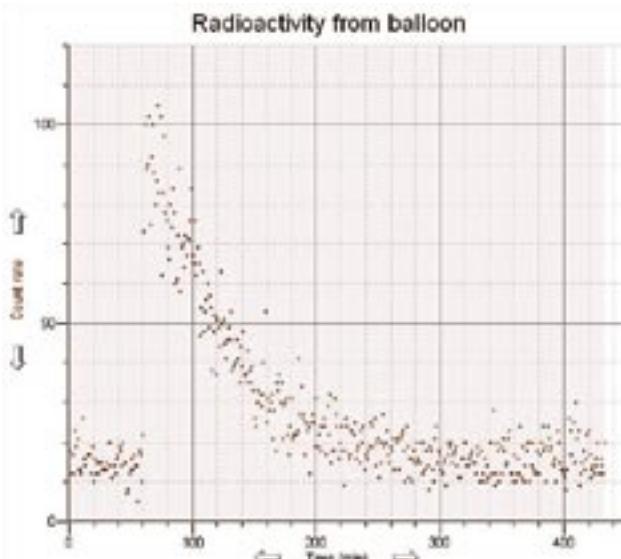


Figure 10 - The count rate from the balloon is typically about five times background. The decay curve is a compound effect of ^{214}Pb decaying into ^{214}Bi , which decays into ^{214}Po .

There may also be a minor contribution from the daughters of thoron (^{220}Rn), whose relative abundance is very much lower than radon (^{222}Rn).

Electrostatic puzzle

According to the triboelectric series, when rubber is rubbed with fur, the rubber gets negatively charged. This has been confirmed by checking with a coulombmeter. Since radon decays by alpha emission, its daughter, ^{218}Po , would be negatively charged also. Why then does ^{218}Po deposit on a negatively-charged rubber balloon?



Figure 9 - Monitoring the count rate from balloon fragments.

The answer is that the ^{222}Rn atom decays with the emission of an alpha-particle having an energy of 5.49 MeV. The resulting ^{218}Po atom has a recoil energy of 101 keV, sufficient to produce a recoil range of 72 μm in air. The freshly generated radionuclide interacts with the air molecules during its recoil path (the duration of which is of the order of nanoseconds), loses its charge and tends to be positively ionised with a single positive charge after thermalisation.

Educational significance

I wish to comment on the educational significance of this demonstration by relating a personal experience at an EU conference in Holland in 1993. My talk, "a lesson to demonstrate the presence of radon in air" differed from other contributions. Whereas they were grand statements of policy, mine was on a single lesson. Before standing up to speak, I had become concerned that I had misjudged the nature of this contribution, thinking it was too lightweight and narrow. In fact I hadn't. The first person on his feet was the chief inspector of schools of the UK's Health and Safety Executive saying that this was exactly the sort of science lesson that should be taught by schools. It showed incontrovertibly that the world is naturally radioactive. No one can lead a risk-free life. Whilst one can oppose applications of nuclear technology, one cannot be against radioactivity in principle. It is of the very best of science lessons because it opens up minds to facts that cannot be avoided and demolishes minds closed to reality.

Risk assessment

A comparison can be made between the radiological risk of harm from the contaminated balloon and the radioactive

Physics

eluate with ^{137m}Ba . The count rate N at time t for a radionuclide with a half-life τ and decay constant λ is given by :-

$$N = N_0 \exp(-\lambda t) + B$$

where N_0 is the initial count rate from the source and B is the count rate from background. The half-life and decay constant are related by

$$\tau = (\ln 2)/\lambda = 0.693/\lambda$$

The total count from a short-lived radioactive material can be found by integrating the function $N = N_0 \exp(-\lambda t) + B$ with respect to time for values between zero and infinity. This yields N_0/λ omitting background.

For a typical elution of ^{137m}Ba , $N_0 = 300 \text{ (1 min)}^{-1}$ and $\lambda = 0.267$, giving a total count of about 1,000.

For a typical charged balloon, $N_0 = 90 \text{ (1 min)}^{-1}$ and $\lambda = 0.0139$ (approx.), giving a total count of about 6,500.

Knowing forbye that the energy spectrum from the balloon's emissions is

higher than that from the eluate's, which of these two sources presents the greater radiological risk? The main point is that the risk from both sources is trivial.

Conclusion

Following the withdrawal of the protactinium generator because of the old age of that source there has been no way of showing radioactive decay and obtaining the half-life of a source. This has been a serious omission in the set of practical experiments that underpin the science curriculum.

Here then are three ways of meeting this task. Of the two radiation generators, the revised thoron generator with Cooknell ionisation chamber is the easier to use and costs rather much less than the Isotope Generator. A clear winner? Well no. The Isotope Generator scores tops on the educational ground that the short-lived daughter is plainly seen to be extracted from the parent and taken off elsewhere to be monitored with a GM detector whereas it is less clear what is

happening with the squeezy bottle and ionisation chamber. Also an elution is an interesting bit of theatre. Radioactive decay is an important demonstration. Both of these radiation generators are worth getting. Ask your employer for funding to get both and pay for balloons from your own budget.

Acknowledgements

I am grateful to Ralph Whitcher, RPA for West Sussex Council and Chairman of the ASE Safeguards Committee, for the prior risk assessment and discussions on the new thoron generator, and Cooknell Electronics for the loan of apparatus for testing; to Steven Judge, then of AEA Technology, for technical information on the Isotope Generator, arranging for assays of ^{137}Cs bleedthrough and the loan of apparatus; and to Marion Milton (NRPB, now HPA) for suggestions on the elution risk assessment, and to specialist radiation inspectors of the HSE, Jo Nettleton and Lindsey Cairns, for their checks and comments. The balloon experiment has been written about in several articles, the first I saw being that by Walkiewicz (*The Physics Teacher*, Vol. 33, Sept. 1995, 344-5). And my thanks go to Ciara Walsh of Nuclear Technologies for solving the electrodeposition puzzle.

Annual Conference & AGM of SSERC Limited

Friday 8th of December 2006 at BLCC, Dunfermline

Draft Programme & Application Form

9:15-10:00	Registration, exhibitions open and coffee.
10:00-10:05	Welcome and introduction:
10:05-10:30	Keynote Address: To be confirmed
10:30-11:00	Supporting Science Education through CPD Project Overview by Kath Crawford, Depute Chief Executive Officer, Projects Primary CPD by Aileen Gray, Development & Educational Support Officer
11:00-11:30	Coffee and exhibitions
11:30-11:50	CPD & related activities for School Science Support Staff Training Packages under Development – by the Project Team
11:50-12:00	SafetyNet CD News by Ian Birrell, Network Designer, SSERC
12:00-12:20	Radioactive Sources in Schools by Jim Jamieson, Radiation Protection Adviser, SSERC
12:20-13:00	Health & Safety – HSE Inspector - School visits and what they throw up!
Closing remarks – Bristow Muldoon MSP	
13:00-14:00	Lunch and Exhibitions
14:00 ->	Annual Report and General Meeting Board Meeting of SSERC Ltd. (Directors & Officers of the Company)
14:00-14:30	Exhibitions
15:00-16:30	Open afternoon in SSERC facilities at Pitreavie, Dunfermline

I wish to reserve a place at the 41st Annual SSERC Science, Technology & Safety Conference:

Name : _____ Position _____ Date _____

Address _____

I shall / shall not attend the SSERC Open Afternoon at the SSERC facilities in Pitreavie, Dunfermline in the afternoon. I enclose my cheque/official order* in payment of the delegate fee(s) of £60 + VAT (£70-50) for members*/£80 + VAT (£94) for non members* [delete if inapplicable]. I would like*/do not require* a receipt.

Return to: Catherine Russell, 2 Pitreavie Court, South Pitreavie Business Park, Dunfermline, KY11 8UB