SSERC Bulletin

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Ideas and inspiration supporting Science & Technology for all Local Authorities

Gamma sources & standard school expts.

Van de Graaff generator hazards

Heterocyst occurrence in Anabaena cylindrica

Goodbye to you my trusted friend

CfE - Science draft experiences & outcomes

Hydrogen/chlorine explosion

Disposable gas cylinders

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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]

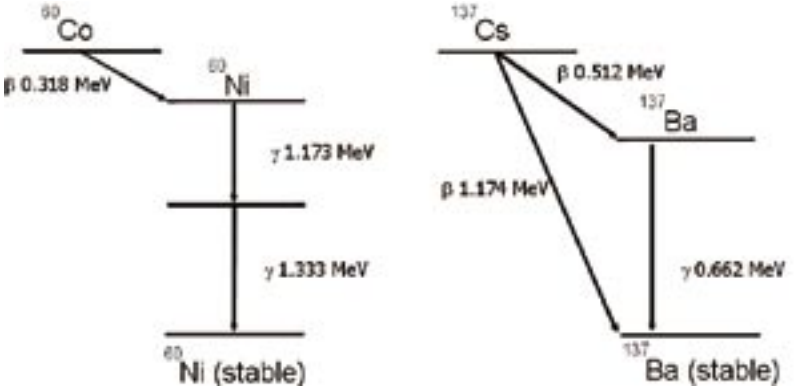


Figure 1 - Decay of caesium-137 & cobalt-60.

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

Van de Graaff generator hazards

We have had another look at the safety of the Van de Graaff (VDG) generator in light of new information in electrical standards and from measurements of dome voltage.

Our original risk assessment on the Van de Graaff generator [1] was done theoretically. Using $C = 4\pi\varepsilon_0 a$ to get the dome's capacitance and taking the maximum voltage on the dome to be $3a$ MV, where a is the dome radius, the maximum value for the stored electrical energy was derived from $E = {}^1/_2 CV^2$. Using the standard extant at the time [2], 1000 mJ of energy from a spark discharge was the limit set by us, it being the threshold at which everybody is affected severely from a spark. By calculation, a dome diameter of 25 cm can store, theoretically, 1000 mJ of energy. Therefore that became our limiting size. Any machine with a dome diameter bigger than 25 cm was declared dangerous.

There were several problems with this. Firstly it was based entirely on theory. Although it was probable that no machine would live up to scratch, we had no means of assessing by how much below par it would be. Secondly, there was concern that the limiting energy (1000 mJ) might be too big in that, in the words of the standard, it 'affects everybody severely'. Might not this limit be dangerously high? Thirdly, there is the knowledge that electrostatics is capricious. But what does that mean? Is it 'sometimes dud', in which case it fails to safety? Or is it 'sometimes unexpectedly lively', implying that it can overstep the mark?

With new VDGs appearing on the market, there was a need to assess them, adding pressure to revise our safety guidance. A complaint about one of these newcomers, the Edulab, had to be responded to. The complainant had written to say, "several members of staff have used it and felt quite uncomfortable – the 'shock' received has been quite unpleasant". With a diameter of 21 cm, well below our limit, might this be a VDG whose capriciousness was overstepping the mark?

Also a caution in an electrostatics' standard [3] issued after we had published our VDG guidance in 2002 had to be reckoned with. This said that discharges above 350 mJ "are considered to be a direct hazard to health".

The new approach we have taken has been to measure the voltage on the dome of a charged VDG by finding how far it will spark. There is a rule of thumb that the insulation of air breaks down at a potential gradient of 3 MV m^{-1}. From this, if the length of the longest spark gap were 10 cm, then the voltage would be 300 kV. This rule is refined in a new standard [4].

Figure 1 - Voltage measurement by means of standard air gaps. The dome on the right is being charged up. The dome on the left is connected to earth.

It has tables for voltage against length of spark gap for two adjacent conducting spheres, one charged, the other earthed, for different diameters[1]. Tabulated values range from between 10% to 25% lower than predicted by the rule of thumb at 3 MV m^{-1}.

We applied this method by setting up two VDGs side by side with their domes at the same height (Fig. 1). The dome of one machine was earthed. The other (the one under test) was allowed to charge up until sparking began. By repeating this procedure for lots of distances, we arrived at a value for the longest spark.

Four different VDG models were tested (Table 1). By comparing the ratios of the measured to theoretical voltages, a gauge of merit was found. The worst performance was 0.36; the best, 0.79. Indeed we reckoned that the best you would ever get from a VDG is 0.8 – resolving our fears on what to do about the capricious nature of electrostatics. 0.8 is as good or as bad as it gets, depending on how you look at it. We thereby derived hypothetical values for any machine at $2.4a$ MV, being the highest voltage that anyone could possibly reach from 'souping up' their machine.

Finding that all four of the VDGs can exceed 350 mJ hypothetically and that two of them do so in practice, the new safety limit we decided upon is 500 mJ (a compromise between 350 and 1000 mJ). Any machine discharging more than 500 mJ, or holding more that 5 μC of charge, would seem to be unsuitably hazardous.

In conclusion, any new type of VDG with a dome diameter exceeding 20 cm should be risk assessed by SSERC to find out whether it is safe for use.

[1] Strictly, the method applies best to ac voltage measurement. If used for dc, the uncertainties are not knowable.

Charging a person

We also reconsidered the risk of harm when a person – usually a pupil – is deliberately charged up and then discharged. During the time a machine is running the highest potential on the person making contact with the dome is limited to about 50 kV [2] by electrical leaking and sparking. The capacitance of the human body lies between 100 and 300 pF. Taking the top of this range (300 pF) to investigate the worst case, the energy to be discharged from the person would be 375 mJ and the charge stored on the person, 15 μC. A sudden discharge of this amount of energy and charge would certainly be disagreeable. It might be painful, but is unlikely to have any other direct effect.

The VDG does not charge up to its normal operating voltage when a person is touching the dome because the rate of leakage of charge from the person is too great. We tested this by charging up the author of this report and bringing up a second, earthed dome towards the charged one until there was a discharge across the air gap (Fig. 2). The voltage on the dome had about halved (Table 2).

Figure 2 - Determining the voltage on a dome when charging a person.

When several pupils link hands to form a chain from the person in contact with the dome, the capacitance of the system will become quite large. Nevertheless because of leakage and internal impedances [5] the voltage successive members of the chain reach will presumably fall from person to person. Therefore the system

Van de Graaff	Arco	EduLab	Frederiksen	Altay
Dome diameter (m)	0.215	0.210	0.220	0.278
Capacitance (pF)	12.0	11.7	12.2	15.5
Charge polarity	Negative	Positive	Negative	Positive
Spark gap (m)	0.042	0.075	0.120	0.104
Maximum voltage (by theory from dome diameter and 3 MV m^{-1} voltage breakdown) (kV)	323	315	330	417
Maximum voltage (by length of spark gap and 3 MV m^{-1} voltage breakdown) (kV)	126	225	360	312
Maximum voltage (by length of spark gap and reading off Table 2 in BS EN 60052:2002)	116	188	261	256
Ratio of voltages: Measured versus theoretical	0.36	0.60	0.79	0.61
Estimate from theoretical voltage				
Charge (μC)	3.9	3.7	4.0	6.5
Energy (mJ)	620	580	670	1,340
Derivation from actual voltage				
Charge (μC)	1.4	2.2	3.2	4.0
Energy (mJ)	80	210	420	510
Physiological effects	Slight discomfort	Disagreeable shock	Disagreeable or painful shock	Painful shock and risk of harm

Table 1 - Derivation of dome voltage by 3 methods.
Values of charge and energy as derived: (a) by a theoretical consideration of the dome diameter, and (b) from the BS EN air gap method.

is hardly likely to become dangerous unless everyone is well insulated from the floor by standing on plastic platforms. The fact that teachers have been doing this demonstration for years without harming anyone, so far as we are aware, bears this out.

Further details

The full report on VDG safety can be found on our website. It has test results on four different models of VDG, explaining how this comparative study helped establish our revised safety guidance. The differences between spark, corona and brush discharges are explained. By means of a corona discharge, anyone should be able to discharge a fully charged dome harmlessly by touching the dome with a pointed finger (Fig. 3).

Figure 3 - Corona discharge through a projecting finger.

The operational rules published in Bulletin 205 [1] have been revised. The new ones are on the website. Details on screening for heart conditions are given.

As for the report that the Edulab VDG is frighteningly energetic – so it is, and so it should be. Good for it! What is the point of running your VDG if it doesn't scare? A spark discharge needs just enough energy to be violent, but not too much to injure. How that judgement is made is what our research has found out.

Of the four machines tested (Table 3), the Arco was under par, the Edulab and Frederiksen were suitably scary, but the Altay was right on the edge of what we consider tolerable. The best performer of all was the machine from Frederiksen.

Don't zap your laptop

During spark discharges, electromagnetic energy is radiated from the spark gap. This radiated energy might be picked up by any nearby electrical leads, across which extra-high voltages can be induced. These voltages can destroy electronic apparatus (Fig. 4). Vulnerable equipment includes anything supplied from a plug-top power supply such as a laptop computer, digital balance or digital camera because the long supply lead can act as a pick-up aerial. Keep ICT equipment well away from a VDG.

References

1. *Van de Graaff generator hazards* Bulletin 205 SSERC 2002.
2. BS 5958: Part 1 : 1991 *Code of practice for control of undesirable static electricity Part 1 General considerations* BSI.
3. PD CLC/TR 50404:2003 *Electrostatics – Code of practice for avoidance of hazards due to static electricity* BSI.
4. BS EN 60052:2002 *Voltage measurement by means of standard air gaps* BSI.
5. DD IEC/TS 60479-1:2005 *Effects of current on human beings and livestock – Part 1: General aspects* BSI.

Figure 4 - Track-side view of a plug-top power supply damaged by a VDG spark.

Van de Graaff	EduLab	Frederiksen
Isolated dome:		
Spark gap to earth (m)	0.075	0.120
Voltage on dome (kV)	188	261
Dome with person attached:		
Spark gap to earth (m)	0.038	0.0475
Voltage on dome (kV)	106	130
Maximum voltage on person (kV)	50	50

Table 2 - Values of voltage on domes with and without person attached.

Maker	Model	Supplier	Product code	Price (£)	Other suppliers
Arco		Economatics	1080660/P	110.00	Timstar
Edulab		Economatics	P920	239.95	S&C
Frederiksen	3700.50	Timstar	EL62550	327.50	PASCO S&C
Altay	4623.20	IDS	withdrawn		

Table 3 - Details of the 4 VDGs reported on.

The effect of nitrogen deprivation on the frequency of heterocyst occurrence in *Anabaena cylindrica* (cover pic)

Introduction

Anabaena are cyanobacteria which are capable of nitrogen fixation. They grow in long filaments of vegetative cells (Fig. 1). Irregularly spaced between the normal photosynthetic cells are colourless cells called heterocysts (Fig. 2). These heterocysts are able to carry out nitrogen fixation. The functions of photosynthesis and nitrogen fixation have to be kept separate due to the instability of the nitrogen-fixing enzyme, nitrogenase, in the presence of oxygen (a photosynthetic product).

Figure 1 - *Anaebena cylindrica* filaments in normal medium (x400 magnification). Note the absence of heterocysts.

In times of low environmental nitrogen levels, approximately 10% of normal cells will differentiate into heterocysts and thus lose the ability to photosynthesise. These heterocysts then supply neighbouring cells with fixed nitrogen in return for carbohydrate which they themselves are no longer able to produce.

To prevent entry of oxygen into the heterocysts, they have the ability to build three additional layers around their cell wall, giving them the appearance of being enlarged and rounded. (Fig 2).

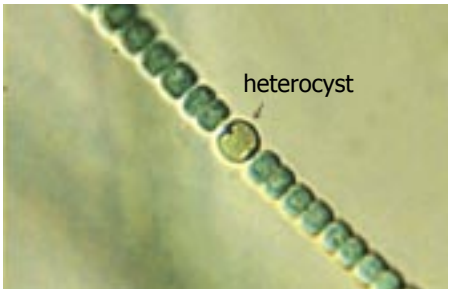


Figure 2 - *Anaebena* species. The arrow is pointing to a heterocyst. From: http://botit.botany.wisc.edu/images/130/Bacteria/Cyanobacteria/Anabaena/heterocysts_dic.html

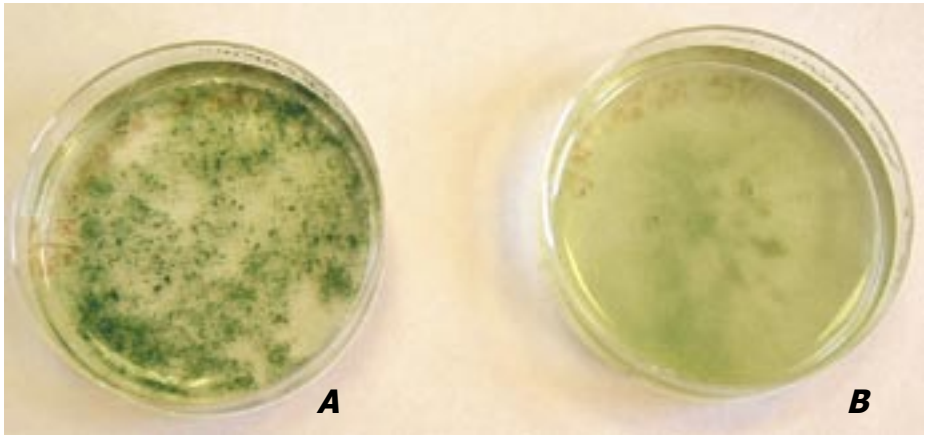


Figure 3a - Cultures of *Anaebena* left on a windowsill for three weeks.
A - Normal medium ***B*** - Nitrogen-deficient medium

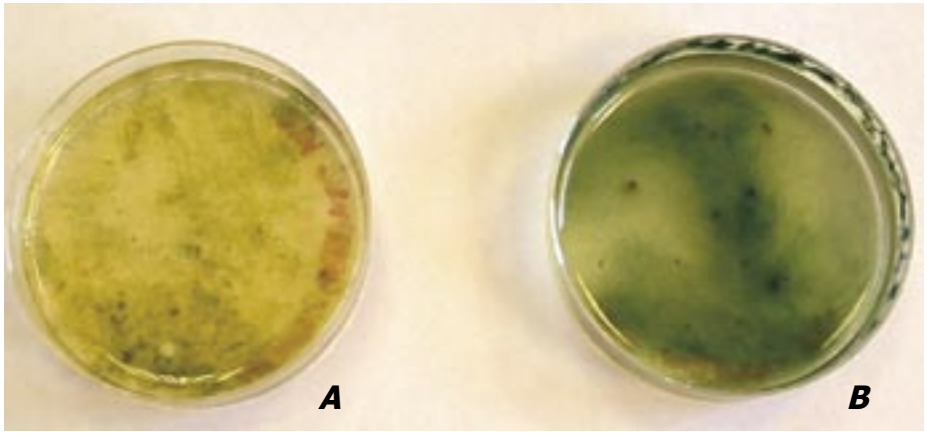


Figure 3b - Cultures of *Anaebena* left under a lightbank for three weeks.
A - Normal medium ***B*** - Nitrogen-deficient medium
Note that the *Anaebena* grown in normal culture medium (***A***) and left under the lightbank did not give particularly viable filaments after approximately three weeks growth.

The activity described below makes use of this easily observed difference between normal vegetative cells and heterocysts to compare heterocyst frequency in *Anaebena* grown in medium of normal nitrogen levels with that of *Anaebena* grown in nitrogen-deficient medium.

Preparing for the Activity

A culture of *Anabaena cylindrica* was obtained from Sciento[1]. The culture media were made up using Sach's tablets, one medium complete and one lacking nitrogen[2]. Ten cm^3 of each medium were made up, according to the accompanying instructions, and added to small plastic Petri dishes. Each dish was inoculated with 0.5 cm^3 of *Anaebena* using a sterile plastic pipette. These were than left either in direct sunlight on a windowsill or under a lightbank which was left on 24 hours a day[3]. Once a week, 1 cm^3 of the appropriate fresh medium was added to each culture (Figs. 3a & 3b). This ensured that the normal medium, in particular, did not become depleted of nitrogen.

Samples of the *Anaebena* from both cultures were observed at x400 magnification and the frequency of heterocysts per filament in normal and nitrogen-deficient medium was calculated.

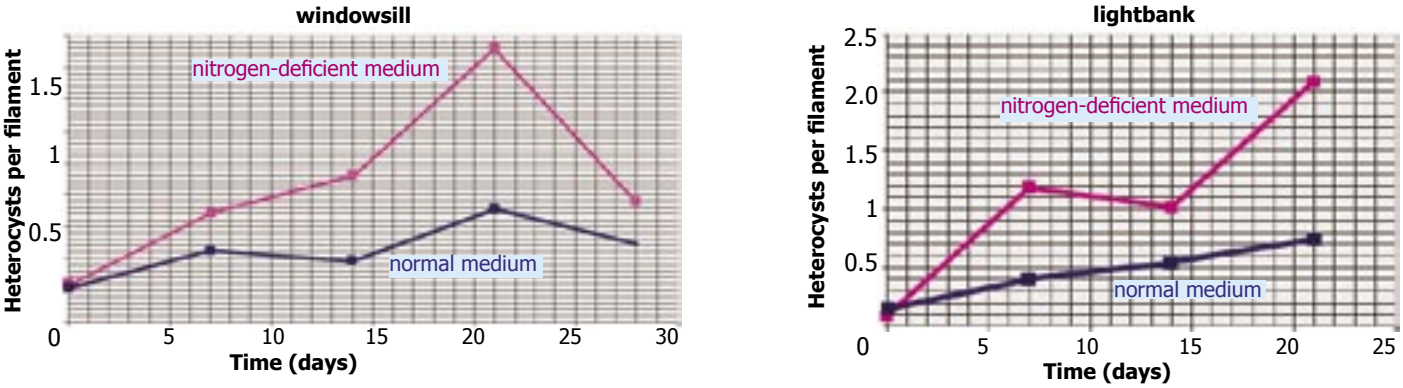
Results

As can be seen from the graphs in Figs. 4a and b the number of heterocysts per filament increased significantly in both normal medium and nitrogen-

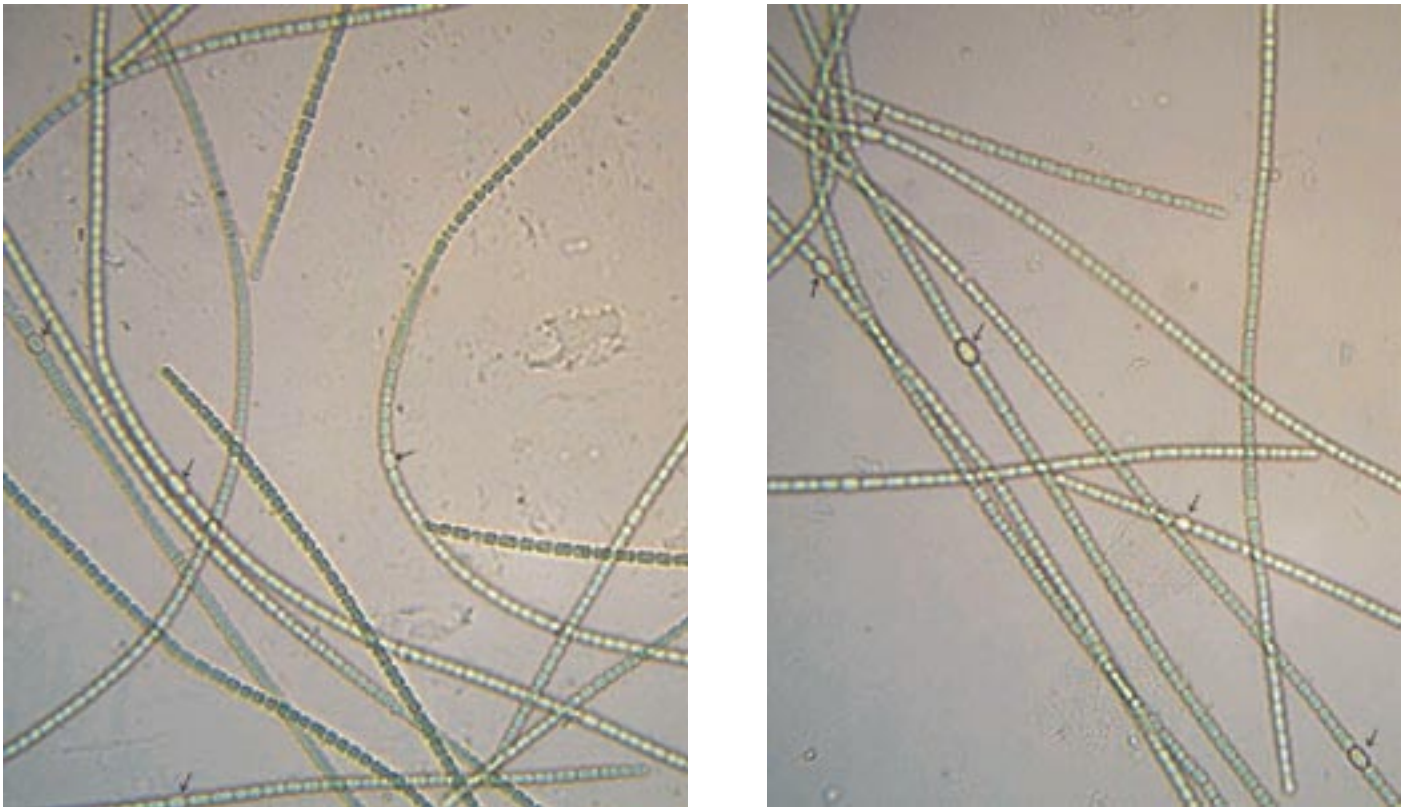
1 Sciento, 61 Bury Old Road, Whitefield, Manchester M45 6TB. Tel/Fax 01607736338 Email: sales@sciento.co.uk. Product No A490 £6.20

2 Supplied by Timstar Laboratory Suppliers Ltd, Timstar House, Marshfield Bank, Crewe, Cheshire CWL 8UY. Tel:01270 250459, Fax: 01270250601 Email: sales@timstar.co.uk. Product No PL3555, £19.50 per set

3 Light Bank versus windowsill? It was found that leaving the cultures on the windowsill provided viable cultures which lasted for longer (See Figs. 3a and 3b).



Figs 4a & b - Graphs showing the development of heterocysts in *Anaebena* cultured in Petri dishes kept on a windowsill (a) and a lightbank (b).



Figs. 5a & b - Anaebena filaments growing in normal medium from: (a) a one day old culture (left graphic) and (b) a 2 week old culture (right graphic). Arrows indicate heterocysts.

deficient medium, regardless of which light source was used. However, in both cases, *Anaebena* cultured in the nitrogen-deficient medium showed a far higher heterocyst to filament ratio than that in the normal medium after two to three weeks.

To make a one-off comparison of heterocyst frequencies in the two media, we would recommend the use of cultures which have undergone three weeks of incubation (Figs 5-6). After this time, the number of heterocysts per filament decreased in both types of media in the culture kept on the windowsill. As outlined earlier[3] the cultures kept under the light bank were not viable beyond the three-week incubation period and so no data was obtained for this time. When viewed under the microscope, the filaments often appeared very fragmented, and the heterocysts became difficult to identify.

A possible procedure for use in the classroom is as follows:

Pupil Procedures

Pupils could work individually on this activity if there are enough microscopes available.

Materials for each pupil/group

2 microscope slides
2 coverslips
2 sample Petri dishes containing cultures of *Anabaena*, labelled ***A*** and ***B*** (one has been cultured with nitrogen in the medium, the other has no nitrogen - omit to tell pupils which is which so that they can work it out)
2 plastic pipettes

microscope (any microscope which has a x40 lens would be suitable)

Method

1. Take a drop of *Anabaena* from culture ***A*** using a pipette and place on a microscope slide.
2. Place a coverslip on top and view with a microscope using x400 total magnification.
3. Draw and label a typical filament, making sure that you can tell the difference between a normal cell and a heterocyst.
4. Count the number of filaments in the field of view. Then count the number of heterocyst cells in the same field of view.
5. Do this for at least five fields of view, noting down your results for each one in a table (or combine class results).
6. Repeat steps 1-5 for culture ***B***.

Figs. 6a & b - *Anaebena* filaments growing in nitrogen-deficient medium from: (a) a one day old culture (top graphic) and (b) a 2 week old culture (bottom graphic). Arrows indicate heterocysts.

7. Calculate the number of heterocysts per filament for each culture. Repeat this for the combined class results.
8. Decide which of the two cultures has been kept in nitrogen-deficient medium.

Application

The development of heterocysts in *Anaebena* under different environmental conditions can be easily studied in the classroom and may be of use in supporting the following areas of the Advanced Higher Biology curriculum:

- Environmental Biology Unit - The nitrogen cycle
- Cell and Molecular Biology Unit - Differentiation of cells
- Biotechnology Unit|(optional) - Enhancing nitrogen fixing

It may also be used as an Advanced Higher investigation. Some suggestions for investigations are as follows:

- What is the time course for heterocyst development in nitrogen-rich compared with nitrogen-deficient media?
- Do deficiencies of other nutrients have similar effects?
- Is there a level of nitrogen which triggers off heterocyst production?

Use of this protocol may also stimulate class discussion on the following:

1. The mechanism by which the cells are differentiated into heterocysts (allowing revision of Higher work on cell differentiation and the switching on and off of genes)

2. How this ability may be of future potential use in agriculture (see references below).

References

http://www-biol.paisley.ac.uk/bioref/Eubacteria/Anabaena.html

http://microbewiki.kenyon.edu/index.php/Anaebena

Cover pic reproduced with kind permission of Mike Clayton, Department of Botany, University of Wisconsin - Madison

http://botit.botany.wisc.edu/images/130/Bacteria/Cyanobacteria/Anabaena/heterocysts_dic.html

Goodbye to you my trusted friend...

In a previous Bulletin [1] we wrote about "Going back to the Seventies with Ammeters and Voltmeters". Our *Bulletin Designer* found a rather fetching graphic to illustrate the piece, in the form of a chap with flared trousers and a particularly offensively-patterned shirt. Walk in to a classroom dressed like that today and you would deserve any of the dug's abuse that came your way. In some ways, and through no fault of our own, we do that every other day in science teaching when we present children with the sort of apparatus shown in Figure 1.

This particular counter still works but we have said goodbye to it at SSERC. Previously, we kept such items as we knew that some schools were still using them. Now we are of the opinion that if they are, they shouldn't be. What sort of a message is this sending out about science education if pupils meet decades-old technology in our subject, then find themselves in front of a state-of-the-art LCD monitor in business studies?

There is, of course, a finance issue here. The author, freshly out of the classroom, is currently evaluating a spectrophotometer designed for school use that costs more than he was given for his annual requisition. (The same company sells a model that costs more than he paid for his car). We have no qualms about the modern methodology advocated by CfE but hope that there is an appreciation that modern equipment is needed, and that the money is made available to bring science into the new millennium.

Figure 1 - Serviceable, but as up-to-date as the Hovis advert.

As ever, SSERC staff are able and willing to recommend equipment suitable for purchase by science departments.

Meanwhile, if you do have serviceable but outdated equipment that you can live without, it may be suitable for donation to the Third World. See www.labaid.org for details.

1. http://www.sserc.org.uk/members/SafetyNet/bulls/221/Physics_back_to_70s.htm

Curriculum for Excellence – draft Experiences and Outcomes for Science

What's new?

In September 2007 everyone had their first chance to have a look at the complete new draft experiences and outcomes in Science. Back in 2004 the Curriculum Review Group made a commitment to "update, simplify and prioritise the curriculum, starting with science". The new draft outcomes are the culmination of that promise.

The science component, along with that for numeracy, forms part of the initial engagement process which introduces the first curricular framework elements of a *Curriculum for Excellence (CfE)* [1]. It must be stressed that these draft outcomes simply don't replace the old attainment outcomes, strands and targets of the science component of Environmental Studies. Neither are they designed as assessment criteria. The new outcomes have been carefully worded to "encourage a range of learning and teaching styles as well as allowing for evaluation by looking at a child's evidence gathered during an investigation, whilst at the same time actively encouraging participation and the development of a range of skills."

Learning through the sciences enables children and young people to:

- investigate their environment by observing, exploring, investigating and recording
- demonstrate a secure understanding of the big ideas and concepts of science
- make sense of evidence collected and presented in a scientific manner
- recognise the impact science makes on their lives, on the lives of others, on the environment and on culture
- express opinions and make decisions on social, moral, ethical, economic and environmental issues informed by their knowledge and understanding of science
- establish the foundation where appropriate, for more advanced learning and future careers in the sciences and technologies.

Curriculum for Excellence has at its heart four purposes i.e to develop *Successful Learners, Confident Individuals, Responsible Citizens* and *Effective Contributors*.

Do teachers throw the baby out with the bath-water?

There's a whole new ball-game and other such stereotyped, hackneyed phrases that may be applied here. Well, it's the only game in town, and at the end of the day we've got to take each outcome as it com.... enough! Do we scrap everything that has gone before? Do we have to develop a whole new set of resources to suit CfE? No, is the answer.

What we do need is to reflect on what are the best resources and teaching methodologies and integrate them into teaching and learning strategies which support CfE. We should be looking for a balanced meal here rather than turkey twizzler worksheets with a few vitamin

supplement methodologies sprinkled on top. SSERC is here to support teachers by keeping the curriculum applications up-to-date through the delivery of a healthy exercise regime of researched practicals and relevant CPD. An important part of the *Engagement Process* are the questions for reflection and response which have been published alongside the new outcomes [2]. All schools, LA centres and other organisations can reflect on how this draft guidance may affect them and consider how the values, purposes and principles of a Curriculum for Excellence may be thereby upheld.

How can SSERC help?

In response to the emergence of the new draft outcomes in Science, SSERC has re-vamped the Home Page (Fig. 1) of the *Improving Science Education (ISE)* website [3]. To help ease the transition from Environmental Studies to CfE we've shown the science wheel diagram with the seven curricular areas and provided links to the relevant draft outcomes. Those who were familiar with the *Interactive Guidelines* with attainment levels A to F for the components of Environmental Studies will see a similar set-up for the Achievement Levels, Early (see Fig. 2) through to Fourth.

There will be new and evolving content produced and tested by SSERC where we cover such things as novel materials and their applications. SSERC will have a continuing role in updating teachers' knowledge and the development of suitable practical work.

We've articulated the new draft outcomes with the Framework for Planning and some of the old Science component of the Guidelines where there may be similarities in coverage. This is not to say that these are absolute

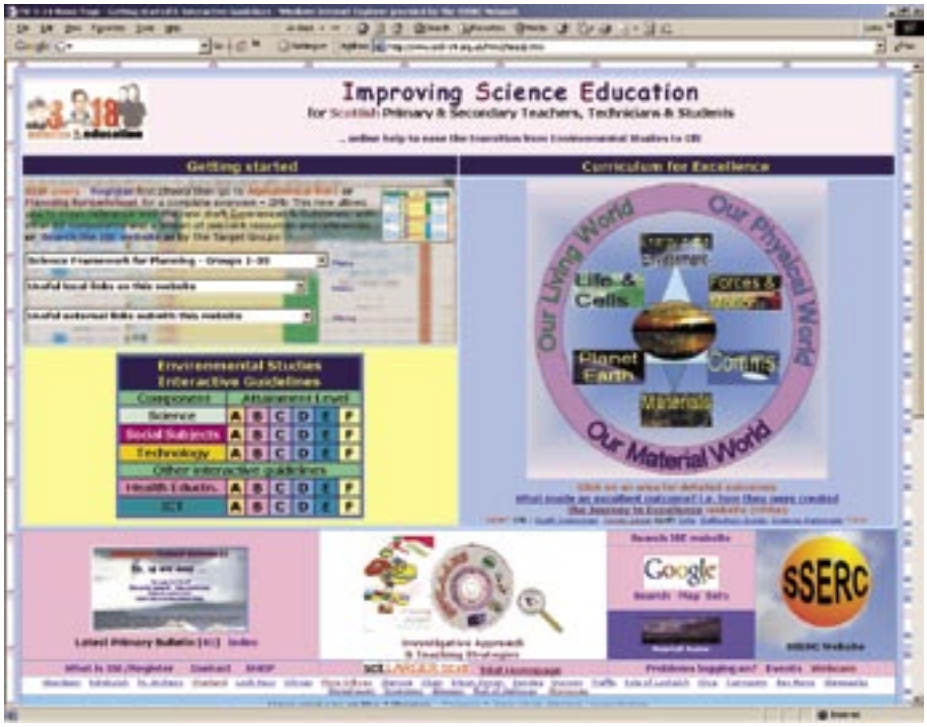


Figure 1 - The Improving Science Education Home Page

equivalents but they may serve to point towards existing resources that may be suitable or that can be adapted at some stage to suit the demands of CfE. We've completed this on the *Planning Spreadsheet* (Fig.3) and flagged up where appropriate on the *Target Groups* (Fig.4) within the *Framework for Planning*. To register with ISE send an email to ian.birrell@sserc.org.uk

As said earlier, CfE and the new outcomes encourage a "range of teaching and learning skills". To this end the Home Page of the ISE site also provides prominent links (Fig.5) to *An Investigative Approach to Science, Teaching Strategies, Thinking Skills & Formative Assessment*. Here you will find the excellent *Tayside Science Education Consortium (TSEC)* material where *Living Things and the Processes of Life* not only explains the `what' of good teaching practice but also the 'how'. There are many videos which highlight best practice in teaching strategies and methodologies as well as the resource material to go with them. Also in this section of the site is the *Glasgow and Lanarkshire Learning for Understanding in Science consortium (GALLUS) CPD* which details a comprehensive 5-day CPD course covering the *Thinking Classroom, Formative Assessment, Investigative Approach and Science with Attitude*. Finally there's a section on Thinking Skills which highlights the excellent work done in Fife by the *Cognitive Acceleration programme (CAP)* and superb videos from the new HMIe website, *The Journey to Excellence* [7]

Figure 2 - Forces & Motion (Early) new draft outcomes [4]

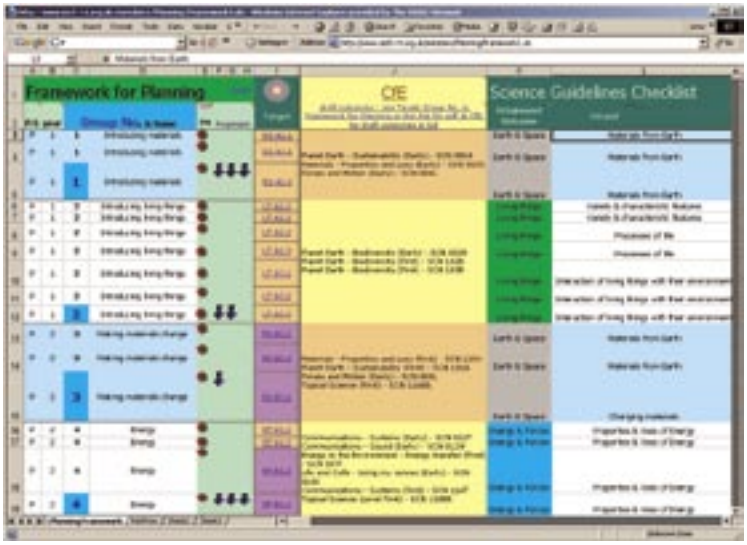


Figure 3 - Overlap with Framework for Planning and ES Guidelines [5]

Figure 4 - CfE outcomes flagged up where there may be possible overlap with ES Guidelines.

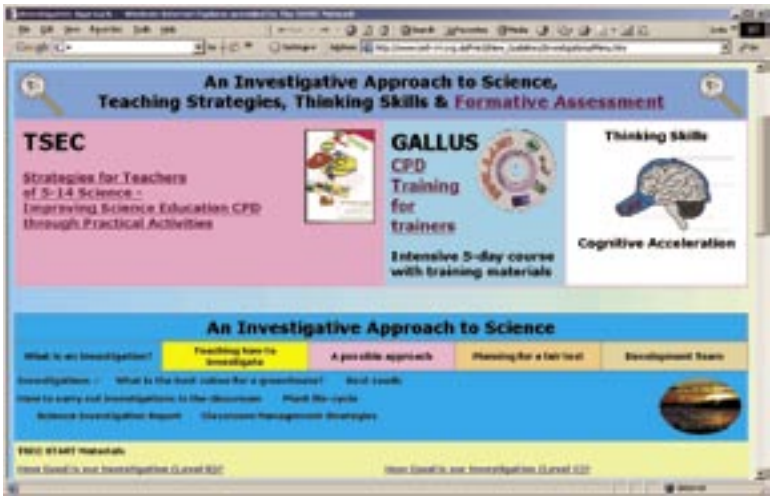


Figure 5 - An *Investigative Approach to Science, Teaching Strategies, Thinking Skills & Formative Assessment* [6]

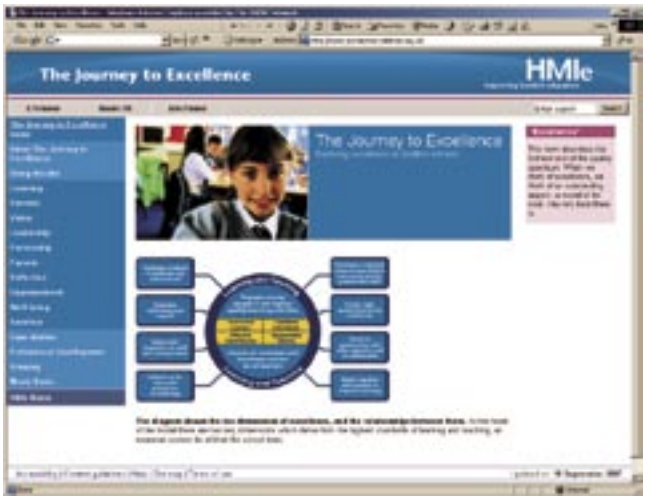


Figure 6 - Many videos showing best practice on the new *Journey to Excellence* HMIe website

References

[1] www.curriculumforexcellencescotland.gov.uk/outcomes/science/index.asp

[2] www.curriculumforexcellencescotland.gov.uk/images/science_outcomesv2_tcm4-443199.pdf

[3] www.ise5-14.org.uk/Prim3/head2.htm

[4] www.ise5-14.org.uk/Prim3/New_Levels/Forces_and_Motion_Early.HTM

[5] www.ise5-14.org.uk/members/Planning/Framework3.xls

[6] www.ise5-14.org.uk/Prim3/New_Guidelines/Investigations/Menu.htm

[7] www.journeytoexcellence.org.uk/

The photochemical reaction of hydrogen with chlorine

Introduction

The majority of chemical reactions are initiated by heat, but this is not the only source of activation energy. For example, light provides the energy for the chemical reactions which take place during photosynthesis and the exposure of photographic film. Another light-initiated process is the spectacular, explosive reaction between the gases, hydrogen and chlorine.

What you will need

Chemicals

hydrogen, cylinder (we used the new 20 l disposable cylinders obtainable from Scientific & Chemical - see p12) **or**

sulphuric acid, 2M
zinc, granular

copper(II) sulphate solution, 1M

hydrochloric acid (concentrated)

potassium manganate(VII), crystals

Equipment

chlorine generator, (Pyrex Büchner flask with dropping funnel and delivery tube running from side arm).

hydrogen generator, (Büchner flask with dropping funnel – all polypropylene).

trough of cold water.

aluminium foil or a UV-light absorbing brown plastic hood (e.g. the top section of a dark brown plastic cider bottle)

camera flash unit, old

stand, with boss-head and clamp

centrifuge tubes or similar, polycarbonate, 15 cm^3 capacity, 16 mm O.D.

fume cupboard

goggles, indirect vent

gloves, nitrile

ear protectors

safety screens, 2 (for front & back of experiment)

Generating the chlorine

Cylinders of chlorine gas are not recommended for school use. Chlorine gas (Toxic & Dangerous for the Environment) can be generated in a fume cupboard by dripping concentrated hydrochloric acid (Corrosive), from a dropping funnel, into a Büchner flask containing potassium manganate(VII) crystals (Oxidizing, Harmful & Dangerous for the Environment). As this can be a very vigorous reaction, ensure that either the acid is dripped in slowly, or that a little water has first been added to cover the potassium manganate(VII) crystals, before the acid is added.

Generating the hydrogen

If a cylinder is not available then hydrogen gas (Extremely Flammable) can be generated in a fume cupboard, or well-ventilated room, by the reaction between 2M sulphuric acid (Corrosive) and zinc granules. Polypropylene equipment should be used in the preparation as a safety precaution (see *Hazardous Chemicals* section of *SafetyNet* - website [1] and CD). Slowly add 2M sulphuric acid from a dropping funnel into a Büchner flask containing the granulated zinc, and maintain a steady stream of gas production. It is important to ensure that all of the air has been displaced from the flask before starting to collect the hydrogen. A dropping funnel is preferable to a thistle funnel as

the latter may allow air to be pushed into the flask upon the addition of more acid. To improve the reaction rate add some copper(II) sulphate solution to the flask.

Preparing the gas mixture

Draw a line on the outside of the polycarbonate centrifuge tube with a permanent marker just under the half-volume position. Fill the centrifuge tube to the mark with chlorine gas by the downward displacement of water in the trough. Ensure that the lighting level is dim, before filling the rest of the centrifuge tube with hydrogen by the same method. Having a slight excess of hydrogen gas will minimize the amount of chlorine gas remaining after the reaction. Stopper the tube and cover with aluminium foil or a UV-light absorbing plastic hood. Filling the tube with the gases in this order will start the mixing process, and leaving the stoppered tube for a further five minutes allows the gases to thoroughly mix by diffusion.

The demonstration

There are two methods for exploding the gaseous mixture. In both cases the container should be used only once:

Method 1: Using an immobilised plastic tube (Fig. 1)

Clamp the stoppered centrifuge tube between two safety screens with the mouth pointing in a safe direction, and at an angle to prevent damage or ricochets. A polycarbonate tube is safer than a glass tube, as it is less likely to shatter if undue force has been used to stopper the tube.

Place the flash unit directly behind the clamped tube. Make certain that the audience is at least three metres away, and warn them to cover their ears. Remove the cover from the tube and switch on the light source.

Method 2: Using an immobilised rubber stopper (Fig. 2)

This method uses a rubber stopper which is firmly screwed into a heavy wooden base, with a camera flash unit mounted next to the polycarbonate centrifuge tube.

Hold the covered polycarbonate centrifuge tube vertically. Quickly remove its stopper and push the mouth of the tube over the immobilized rubber stopper.

Arrange the safety screens on the audience and demonstrator sides of the apparatus, with the audience at least three metres away. Warn the audience to cover their ears before removing the cover from the centrifuge tube.

Trigger the flash unit, by remote control if possible, and the force of the explosion will project the centrifuge tube vertically into the air. This method should only be attempted indoors if the room has a high, solid, ceiling.

Chemicals & procedures	Main Hazard	Control Measures
sulphuric acid (2M)	Corrosive	Wear nitrile gloves & indirect vent goggles.
hydrogen gas	Extremely Flammable	Check that there are no sources of ignition.
hydrochloric acid (concentrated)	Corrosive	Wear nitrile gloves and indirect vent goggles.
potassium manganate(VII)	Oxidising agent, Harmful & Dangerous for the Environment	Wear nitrile gloves and indirect vent goggles.
chlorine gas	Toxic & Dangerous for the Environment	Carry out preparation in a fume cupboard
Mixing of hydrogen and chlorine gases	Explosion	Prepare in dimmed light. Cover filled container with aluminium foil or UV-light absorbing brown plastic hood before transporting it.
Reaction of hydrogen and chlorine	High velocity impact Noise	Use double safety screens and fire in a safe direction. Demonstrator should use ear plugs, and audience must be told to protect their ears.
hydrogen chloride (reaction product)	Toxic & Corrosive	Use a well ventilated room

Table 1 - Hazards and control measures

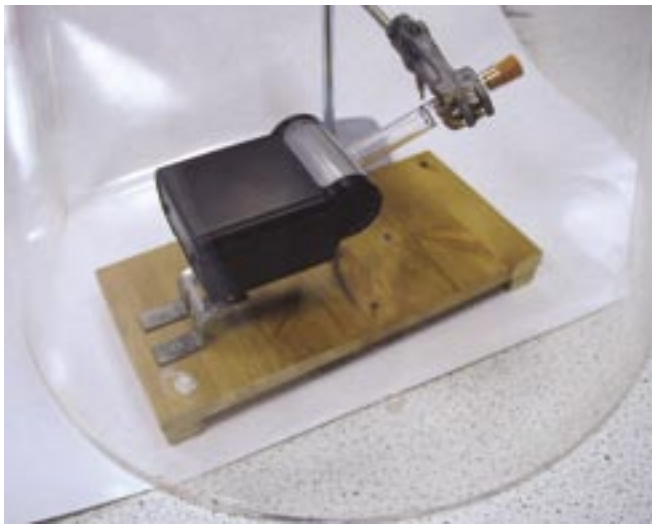


Figure 1 - Method 1 - Using an immobilised plastic tube.

The same apparatus could be used in the open air, with a wide exclusion zone, to explode larger volumes of the hydrogen – chlorine gas mixture using 100 cm^3 plastic bottles.

It has been found that some types of plastic mineral-water bottles are weakest at the base and will split or disintegrate, unless taped. (Figure 3).

For either method, if the gaseous mixture repeatedly fails to react, cover the tube and remove it to a safe place for later disposal in a darkened fume cupboard.

[1] - http://www.sserc.org.uk/members/SafetyNet/HazChem/NewHaz15/ETOL/CM/hydrogen.HTM

Figure 2 - Method 2 - Using an immobilised rubber stopper.

Figure 3 - Apparatus for larger-scale explosions of hydrogen & chlorine - only suitable for rooms with high ceilings or preferably in the open air.

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Contents

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Telephone: 01383 626070 Fax: 01383 842793 E-mail: sts@sserc.org.uk Web: www.sserc.org.uk
Managing Editor - Fred Young

Disposable gas cylinders – a lightweight and compact alternative to rented cylinders

Gases are used in science courses from S1 to S6. They can be generated using chemicals or bought in cylinders. Traditional cylinders from suppliers incur charges such as annual rental and delivery as well as the charge for the gas itself. Each cylinder also requires a regulator which is specific to the gas. These regulators require regular inspection and maintenance. For more information on all aspects of the Hazards, Handling, Testing, Storage and Disposal of gas cylinders see your *SafetyNet* disc or online at :-

http://www.sserc.org.uk/members/SafetyNet/HazChem/NewHaz15/ETOL/gas_cylinders.HTM

A range of gases (hydrogen, carbon dioxide, oxygen & nitrogen) in disposable, compact, non-refillable, aluminium cylinders is now produced by Cryoservice and available from Scientific and Chemical (Fig. 1). These gases are available in cylinders from 5 l to 110 l capacity. Once empty, these aluminium cylinders can be punctured with either a recycling tool or a hacksaw before disposal in an aluminium recycling bin.

A plastic carrying case is available to store the containers in. Whether this is used or not, the cylinders should still be stored in a cool, well ventilated and secure area.

Figure 1 - Disposable gas cylinders (20 l)

Suppliers

Scientific and Chemical Supplies
Unit 13, Airways Industrial Estate
Pitmedden Road, Dyce
Aberdeen
AB21 0DT
Tel: 01224 774 667
Fax: 01224 774 668

Scientific and Chemical Supplies
39 Back Sneddon Street
Paisley
PA3 2DE
Tel: 0141 887 3531
Fax: 0141 889 8706

Figure 2 - Reverse side of disposable gas cylinders (20 l) with mini flow valve

Item	Cost	Product code
Gas cylinder – 20 l (Fig. 1 - from left - oxygen, hydrogen & carbon doxide)	£35.00 (irrespective of type of gas)	Hydrogen: $020-14-11000 Oxygen: $020-22-10000 Carbon dioxide: $020-07010000 Nitrogen: $020-19-01000
Mini flow valve – fits 5/12/20 l cylinders	£35.00	$FCVTO/F1
Regulator (optional)	Not available	-
Gas cylinder – 110 L	£88.00 (irrespective of type of gas)	Hydrogen: $110-14-11000 Oxygen: $110-22-10000 Carbon dioxide: $110-07010000 Nitrogen: $110-19-01000
Mini flow valve – fits 34/58/110 L cylinders	£35.00	$FCVTO/F2
Regulator (optional – replaces need for a mini flow valve)	£85.00	$REG.XL-V
Recycling tool	£45.00	$RECYC
Carry/Storage case for 2 cylinders and one regulator	£55.00	$CCG
Carriage charge	£18.00	
Carriage charge is a single charge no matter how many cylinders are ordered. Unlike regulators for traditional cylinders the mini flow valves are not gas specific, thus saving money. Although these disposable gas cylinders may be an expensive way for a centre to supply gases for experiments, there are other factors which should be considered when deciding whether or not to use them. These will include for low rate of usage, a saving on annual rental charges, ease of transport, storage and handling (the 110 l cylinder is only 361 x 89 mm and 1.05 kg).		

Table 1 - Costs for hydrogen, oxygen, carbon dioxide and nitrogen gases – 20 l & 110 l cylinders