

# STEM bulletin

supporting STEM for all Local Authorities through advice, ideas and inspiration

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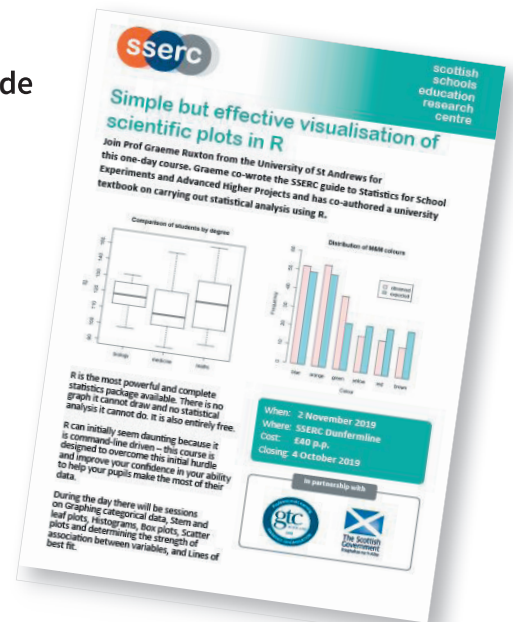


# Graphing and statistical analysis **with R**

Graphing is a really important skill in the sciences. Graphs provide an excellent way to organise data but, more importantly, such visual aids can be really useful when it comes to interpreting data and looking for patterns. One relatively easy way to get professional-looking graphs is through using the software package known as R.

Statistical analysis can provide more information about data beyond that derived from visual representation in graphs. If you skimp on statistics, you are missing a trick in getting the maximum information from your hard-won data. In addition, thinking about ways to present data graphically and to statistically analyse data leads you to thinking about the best experimental design to collect that data. The software package R carries out the sometimes complex and repetitive statistical calculations for you, freeing up your time to think about the science.

R is entirely free to download and use without any restriction. You can download it onto any computer and as many computers as you want, you never need to enter any credit card details, you will never be charged, and it will never stop working. There is no catch. It is also a very powerful and well-designed package that more and more professional scientists use. If your students go on to university, the most commonly used package for statistical analysis that they encounter will be R. Don't be fooled by the fact that it is free: R is the Rolls-Royce option for statistical analysis. Once you download it and open it, you will see a large window with a ">" cursor, just type in commands here (and press return after each) and it will do all your calculations for you. As well as being the most comprehensive and reliable statistics package in the known universe, it is also the most flexible graph-drawing package. Another bonus is that it is completely free to anyone and works on both PC and Mac, regardless of operating system. You can also save the code you use to produce any graph and come back to edit or reproduce it whenever you like.

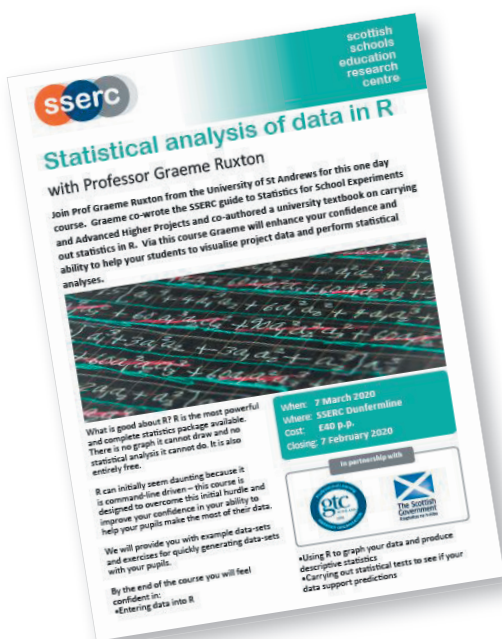


We are fortunate in SSERC to have teamed up with Professor Graeme Ruxton from the University of St Andrews. Graeme co-authored our Statistics for School Biology Experiments [1]. We are delighted to be able to report that Graeme has offered to deliver two courses at SSERC during the coming academic year - one on graphing using R (2 November 2019), and the other on statistical analysis of data using R (7 March 2020).

We do hope that you will be able to join us. Further details at plotting data and statistical analysis. <<

## References

- [1] Ruxton, G.D. and Stafford, J. (2015) Statistics for School Biology Experiments and Advanced Higher Projects. Available at <https://www.sserc.org.uk/wp-content/uploads/2018/06/Statistics-book-final.pdf> (accessed 5 August 2019).



# Using model houses to investigate the effect of different types of house insulation

Model houses are used to investigate which type of insulation has the most effect on the ambient temperature of the house. This is very relevant for the level 3 course as the bench mark for *Energy sources and sustainability - SCN 3-04a* requires pupils “to explain how materials can be used in building design to reduce heat loss, for example double glazing.” Wooden model houses for this investigation are now difficult to source from science equipment suppliers. Here we show how model houses can be made from old cardboard boxes. The houses are simple to make and robust.

## Requirements

PVA glue, a pencil, Sellotape, double sided sticky tape, cardboard, stiff transparent plastic from packaging, a metal ruler, a Stanley knife, a cutting board, templates for the model house [1], bulldog clips, a 12 volt 24 watt filament bulb in a

socket with two 4 mm connectors, a 12 volt power supply, a -10°C to 110°C thermometer, bubble wrap and A3 sheets of card, a thermal imaging camera (In 2014, SSERC gave every local authority a thermal imaging camera to lend to schools. These are available on loan from your local authority). The thermal imaging camera is not essential but does enable visual displays that highlight where the heat loss has been reduced when the house is insulated.

## Constructing the house

Place the template [1] on the sheet of cardboard from which the house is being made (Figure 1). Draw round the template using a pencil. Fold in

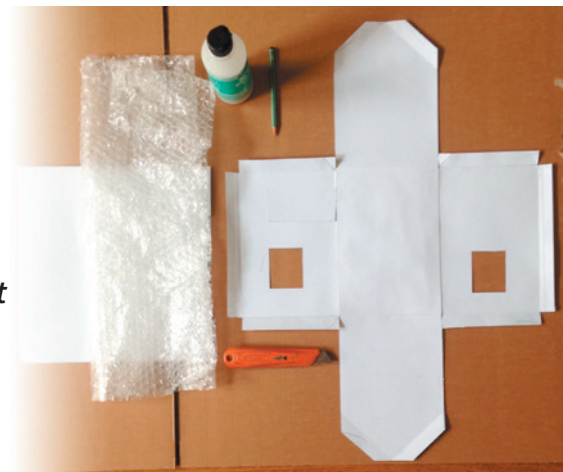


Figure 1

the flaps on the template along the dashed lines and draw dashed lines along the new edge of the template; this gives the lines the house needs to be folded along when constructing it. Place a cutting board beneath the cardboard. Cut round the outline of the house on the cardboard using a Stanley knife. Score along the dashed lines using a ruler and the Stanley knife, as this makes folding the cardboard much easier (Figure 2). Cut out the windows and cut round three sides of the door and cut round along the dashed line as that forms the door hinge.

Put glue along the folding line of cardboard on the gable ends (Figure 3). Fold the cardboard >>



Figure 2



Figure 3



Figure 4

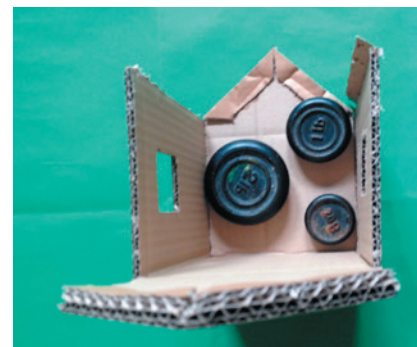


Figure 5



Figure 6

over and hold it in place with a clip (Figure 3). This strengthens the gable ends.

Put glue along the flaps on the side of one end of the house (Figure 4). Fold the flaps behind the gable end. Hold the flaps in place using weights (Figure 5).

Do the same with the gable on the other end of the house. The base of the house is complete (Figure 6). The house needs windows which are made from the stiff transparent plastic. Cut four 8 cm x 8 cm rectangles of the transparent plastic. This enables single and double glazing to be compared.

Place sticky tape round the edges of the plastic window (Figure 7), and stick it to the inside of the house so the plastic covers the window opening and the sticky tape seals the opening. This ensures no air can escape through the window (Figure 8).

Repeat for the second window. Sticking the window to the inside



Figure 7

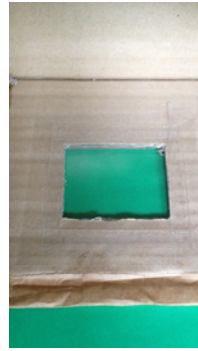


Figure 8

enables the double glazed house to be easily identified as the second pane is stuck to the outside of the house. Make the ceiling from a piece of card by drawing round the base of the house and adding 1 cm flaps along each side. No flaps are needed at the gable ends. Position the ceiling on top of the side walls (Figure 9).

In the gable end furthest from the door, make a hole in the centre of the gable end about 5 cm from the base of the house so the thermometer is held firmly by it (Figure 11). Draw round the roof template and cut out the roof. Score along the centre roof line to enable the roof to be bent in half so it sits on the two gable ends (Figure 10). To increase the strength of the roof tear a strip of brown paper from the cardboard and using PVA glue stick the paper over where the cardboard has been scored and bent. Doing this also holds the roof in the correct shape.

### The investigation

Open the door of the house and place the 12 volt, 24 watt light bulb in its holder inside the house (Figure 11).



Figure 9

Insert the thermometer through the hole in the gable end so the  $-10^{\circ}\text{C}$  mark is at the hole. This ensures the thermometer can be kept in the same position throughout the experiment (Figure 11). The same heat source, a light bulb, is used throughout the experiment.

Make sure the bulb is at least 5 cm from the walls of the house. Set the power supply to 12 volts and connect the light bulb to it. Replace the ceiling and the roof of the house (Figure 12). Switch on the light bulb and wait till the temperature on the thermometer becomes stable, typically 20 minutes. This gives the equilibrium temperature for the house. Take a photo of the house with a thermal imaging camera (Figure 13).

Loft insulation, cavity wall insulation and double glazing can be investigated. The effect on the final equilibrium temperature reached by the house for each type on insulation can be found. Finally, the equilibrium temperature of the house which >>



Figure 10

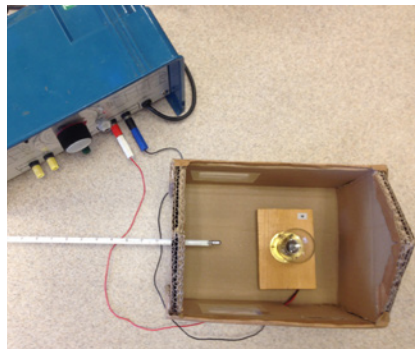


Figure 11

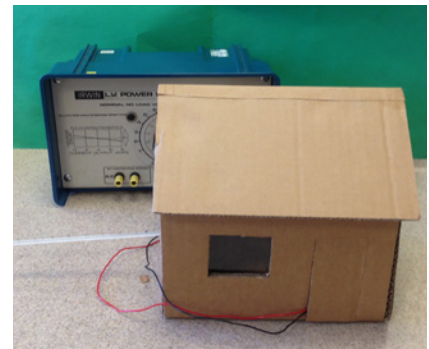
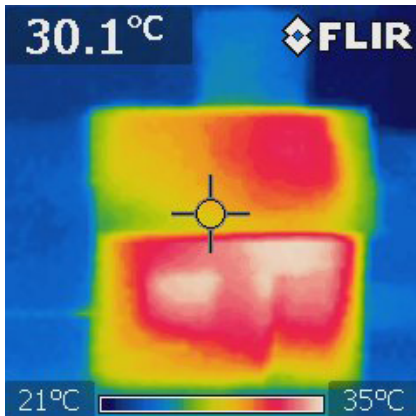


Figure 12 - House with no insulation.



**Figure 13** - Thermal image of the house with no insulation.

is fully insulated can be found. Pupils could simply be given bubble-wrap and extra glazing and instructed to insulate the house appropriately. To have more control over the experiment the different types of insulation can be made so they are easily slotted into place and can be reused when required.

Loft insulation is made from bubble wrap. Draw round the base of the house and cut out two pieces of card the same dimensions as the base of the house. Cut a piece of bubble wrap the same size as the two pieces of card. Stick double sided sticky tape down around the edge of each of the card rectangles and stick them either side of the bubble wrap, (Figure 14). This deters pupils from popping the bubble wrap. Adjust the size so the loft insulation sits on top of the ceiling and the roof fits snugly over the gable ends (Figure 15). Replace the roof, switch on the light bulb and wait till the temperature of the house is steady. Record the final temperature. Take a photo with a thermal imaging camera (Figure 16).

This thermal imaging photo when compared with the reference photo (Figure 13) clearly shows that heat loss through the ceiling has been reduced as the roof is not as hot. Remove the loft insulation.



**Figure 14**

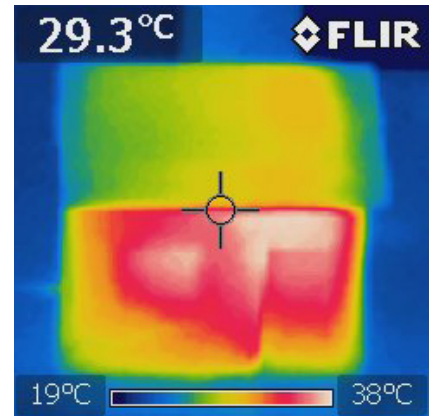


**Figure 15**

Cavity wall insulation can be made using bubble wrap. Draw round the house template for the sides of the model house alone on a piece of card, the other parts of the house can be folded out of the way (Figure 17). Cut out the door and the windows. Apart from one corner join the pieces of card together using sticky tape. Place double sided sticky tape round the sides of the rectangle. Place bubble wrap on top so the bubble wrap sticks to it and cut the bubble wrap to size. Cut the windows and door out. Position the insulation inside the house with the card next to the house walls. Place card on the inside of the walls coated with bubble-wrap so the card fits snugly against the bubble wrap and mark where the folds need to be made in the card. Remove the card and fold it along the marked lines. Replace the card and draw round the openings for the windows and



**Figure 17**



**Figure 16** - Thermal image of the house with loft insulation.

door. Remove from the card again and cut out the windows and door. Stick double sided tape around the side of the bubble wrap closest to the ceiling. Replace the card and stick it to the other side of the bubble wrap (Figure 18). Make a hole in the cavity wall insulation for the thermometer. Replace the ceiling and the roof. Switch on the light bulb and wait till the temperature of the house remains steady. Record the temperature and take a photo with the thermal imaging camera (Figure 19).

This thermal imaging photo when compared with the reference photo, (see Figure 13) clearly shows that heat loss through the walls has been reduced as the outside of the walls are not as hot. Remove the cavity wall insulation.

The house can be double glazed. Put sticky tape around all four sides of two 8 cm x 8 cm pieces of rigid plastic (Figure 20). Stick the window onto the outside of the house to form a sealed cavity between the >>



**Figure 18**

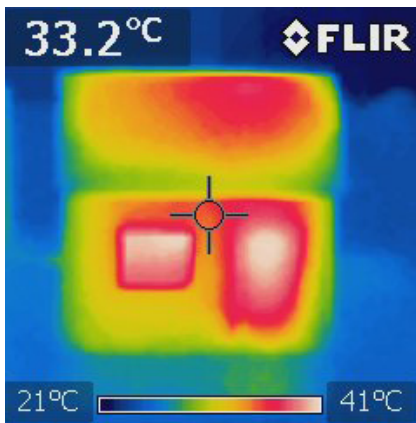


Figure 19 - Thermal image of the house with cavity wall insulation.

two windows (see Figure 21). Replace the ceiling and the roof. Switch on the light bulb and wait until a steady temperature is reached. Take a photo of the house with the thermal imaging camera (Figure 22). Record the final temperature. Comparing the thermal imaging photo with the reference photo (Figure 13), it is clear that double glazing has reduced the heat loss from the window as the window is no longer white so must be at a lower temperature.

Finally have the house fully insulated and see what effect insulation has on the final temperature. Place the light bulb inside the house which has loft insulation, cavity wall insulation and double glazing. Switch on the light bulb and wait until the temperature is steady. Record the final temperature and take a photo with thermal imaging camera (Figure 23).

This thermal imaging photo when compared with the reference photo (Figure 13), clearly shows that heat loss through the ceiling, walls and windows has been reduced.

### Results

Type of insulation	Final temperature (°C)
None	47
Loft	51
Cavity wall	55
Double glazing	50
Loft, cavity wall and double glazing	60

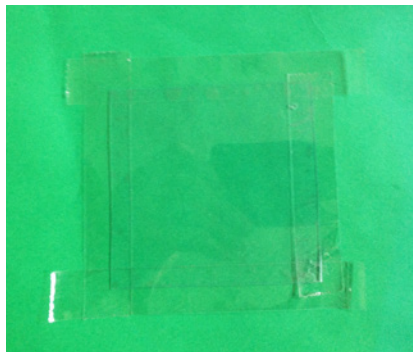


Figure 20

### Summary

The thermal images show clearly the effect the insulation of a house has on heat loss from the house. This should help pupils appreciate the need for insulation to improve the energy efficiency of buildings. The same heat source is used throughout the experiment, yet the well-insulated house had a final temperature of 60°C and the un-insulated house had a final temperature of 47°C. Using bubble wrap as the insulating material helps reinforce the fact that trapped air is a good insulator. To see the effect temperature difference has the model house could be placed in a cool room so the temperature difference across the walls is greater. Having completed the investigation pupils should be able to satisfy **SCN3-04a** - *I can use my knowledge of the different ways in which heat is transferred between hot and cold objects and the thermal conductivity of materials to improve the energy efficiency of buildings.*

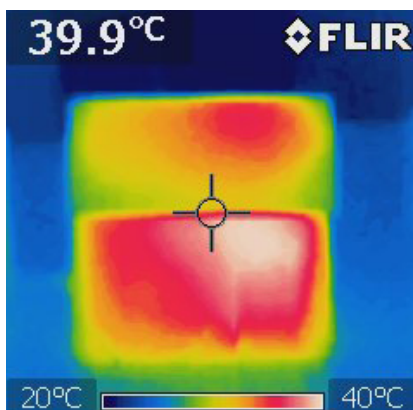


Figure 22 - Thermal image of the house with double glazing.

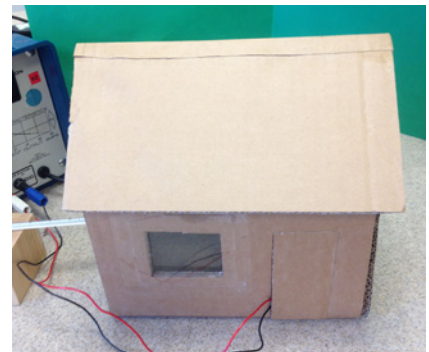


Figure 21 - Double glazing.

This activity also helps with the Level 3 skills. It lends itself to relating findings to scientific knowledge and understanding and drawing conclusions based on the results gathered in relation to an aim.

### Safety notes

There is no need to use a mercury-in-glass thermometer for this investigation. An alcohol thermometer is suitable and, if it does break, a spill will be much easier to clean up.

If the model house is built and used as described in this article, the cardboard will never become hot enough to present a fire risk. <<

### Reference

- [1] Templates can be downloaded from [www.sserc.org.uk/subject-areas/physics/physics-other-resources/model-houses/](http://www.sserc.org.uk/subject-areas/physics/physics-other-resources/model-houses/) (accessed August 2019).

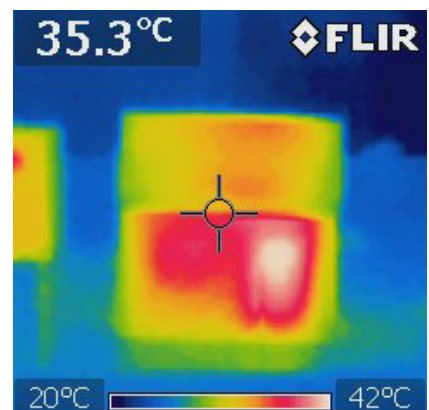


Figure 23 - Thermal image of the house with loft insulation, cavity wall insulation and double glazing.

# The Young STEM Leader (YSL) Programme: Inspiring and developing young people through STEM

**Excitement, interest and positivity around the YSL Programme continues to grow across Scotland.**

The pilot phase is now underway with hundreds of young people all over the country preparing to create and lead inspirational STEM activities, events and interactions in their schools, community and youth groups.

The YSL Project Team at SSERC have completed the development of the CfE Second Level and SCQF Level 6 versions of the programme. These two levels will now be piloted across Scotland with 59 centres taking part. Of the centres involved, 19 are primary schools, 32 are secondary and 8 are from community groups or existing STEM initiatives. Being able to pilot the programme across such a broad range of young people and centres is certain to yield excellent results, case study material and valuable feedback.

YSL Project Manager, Graeme Rough said “We are delighted to have reached this stage, piloting with two levels so soon after the team has been formed. We’d like to thank our project partners, the working group and of course the many young people who have helped shape this incredibly exciting STEM programme - this has the potential to make a huge impact in STEM engagement on a national scale”.

Many pilot centres have already shared their plans on how young people will towards their digital badges or certificates (CfE Second Level) or their formal accredited award (SCQF Level 6). With such a wide and unusual range of ideas, it is expected that participants will realise that STEM is everywhere and can be appreciated by anyone.

There are many supporting documents now available to centres such as support notes, activity

packs, YSL logs and a handbook which serves as an informative guide for both Young Stem Leaders and centres. A training programme is being rolled out across the country to support the centres in delivering the programme.

More details can be found on the YSL website [www.yslpilot.scot](http://www.yslpilot.scot). <<



# Photosynthesis using seaweed - opportunities for quantitative studies

## Background

In a previous article [1] we suggested that seaweeds might offer opportunities for studying a range of parameters in relation to the rate of photosynthesis. We described how one might measure absorbance changes in hydrogencarbonate indicator solutions in the presence of knotted wrack (*Ascophyllum nodosum*) as a measure of photosynthesis activity. We have described other uses of this technique on previous occasions [2-3].

We describe here an updated version of our previous work [1] and offer suggestions for how the technique might be extended to offer opportunities for quantitative studies.

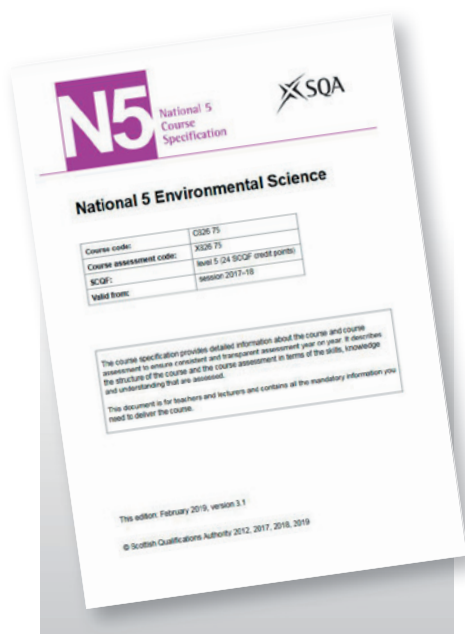
Whilst we anticipate that the methods shown here will be applicable for National 5 Environmental Science, we anticipate that investigations in National 5 Biology using the techniques outlined would also be possible.



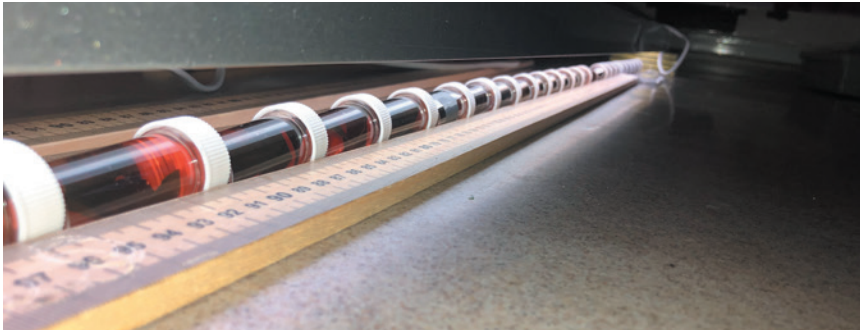
Figure 1 - Image of knotted wrack [5].

## Method

- 1) Knotted wrack (Figure 1) was collected from a local beach and stored in sea water until use; the experiments described here were performed on the day of sample collection although our previous observations [1] suggest that samples, kept moist, can be used for at least a week after collection.
- 2) Hydrogencarbonate indicator can be prepared [4] or purchased commercially.
- 3) Twenty-five samples of knotted wrack (approximately rectangular in shape, avoiding the air bladders and fruiting bodies) were cut and the mass of each sample adjusted to be  $0.3 \pm 0.02$  g.  
  
Because there is a slight time delay (20-30 min) between taking the samples and using them in the experiments which follow they were stored in seawater in the dark until use.
- 4) A sample of knotted wrack was placed into an empty Bijou bottle and the bottle was filled with hydrogencarbonate indicator (approximately  $7 \text{ cm}^3$ , pH = 7.2).
- 5) To test the effect of light intensity on the rate of photosynthesis the Bijou bottles were treated as follows:
  - Five bottles were exposed to the full lamp output.
  - Five bottles were covered in black paper to exclude all light.
  - Neutral density filters that allowed 71% or 50% or 25% of light to be transmitted [7] were used to cover the remaining 15 bottles (5 bottles for each light intensity).
- 6) All 25 bottles were laid on their side and placed under a standard fluorescent tube (Figure 2) and illuminated for a period of 60 min.
- 7) After illumination the samples of knotted wrack were removed from the Bijou bottles and the absorbances of the solutions were measured using a Mystrica colorimeter [6] using the green diode (distilled water was used as the blank in these colorimetric readings). Measured absorbance data are shown in Table 1. >>>







**Figure 2** - An experimental set-up allowing for measurement of the effects of light intensity on the rate of photosynthesis. Bijou bottles containing samples of knotted wrack are exposed to light from a fluorescent tube; light intensity is altered by the addition of a suitable filter.

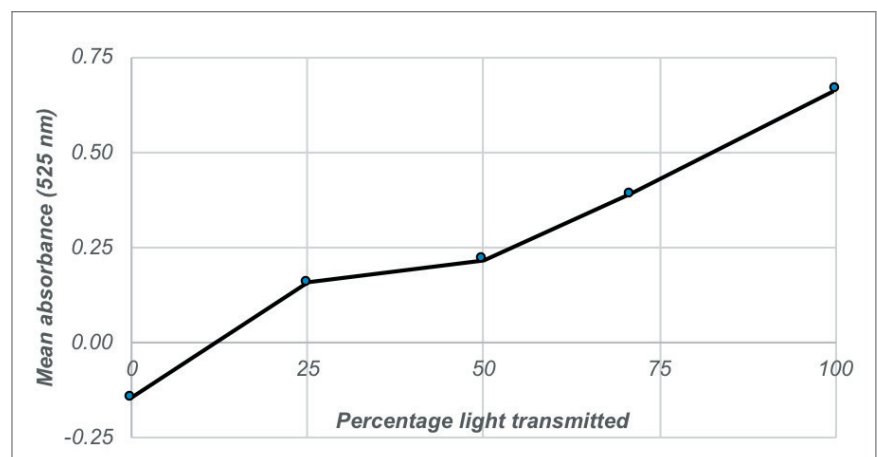
### Results and discussion

The data from Table 1 are shown graphically in Figure 3. It is important to recognise that an increase in absorbance represents a decrease in the concentration of CO<sub>2</sub> present in solution; the converse is also true. So, as light intensity is increased, we see that photosynthesis is the dominant process. One of the samples that had been irradiated with no filter (i.e. 100% value in Table 1) was returned to a Bijou bottle together with the hydrogencarbonate indicator in which it had been irradiated and left in the dark at room temperature. After a period of 1.5 hours the absorbance of the indicator had returned to a value of 0.40 (from a starting value of 1.08) indicating that respiration had taken place (we might assume that absorbance would continue to fall if samples were left for longer periods although we have not tested this hypothesis). The sample

was once again illuminated and an increase in absorbance from 0.40 to 0.90 noted after 45 min. Whilst the observation that respiration in the dark dominates is not surprising, the fact that photosynthesis can be 're-started' makes a useful demonstration.

The observed relationship as light intensity increases is interesting and offers scope for further investigative work for example a detailed analysis of the compensation point, and the effect of temperature on photosynthetic rates could both be studied.

With one exception (Run 1, 100% light transmission, A = 0.8), the consistency of results, as shown in Table 1, implies that the system should allow for quantitative studies to be undertaken. To firm up our thoughts on this we repeated the experiment but used fresh samples of knotted wrack collected some two weeks later. The corrected mean absorbance data for this second batch of knotted wrack are shown in Table 2. For comparison we have copied the corrected mean absorbance data from Table 1. >>



**Figure 3** - Effect of light intensity on the absorbance (525 nm, mean of 5 measurements) of hydrogencarbonate indicator solution. Samples of knotted wrack were immersed in hydrogencarbonate indicator solution and neutral density filters used to reduce the intensity of light incident on the sample. Further experimental details are in the text and the legend to Table 1.

Light Intensity (%)	Absorbance (525 nm) of hydrogencarbonate indicator					Mean of runs 1-5	Corrected mean absorbance
	Run 1	Run 2	Run 3	Run 4	Run 5		
0.0	0.28	0.28	0.29	0.29	0.29	0.29	-0.14
25	0.59	0.57	0.58	0.60	0.59	0.59	0.16
50	0.63	0.65	0.64	0.65	0.66	0.65	0.22
71	0.82	0.85	0.85	0.83	0.87	0.84	0.39
100	0.8*	1.13	1.06	1.08	1.11	1.10	0.67

**Table 1** - The effect of light intensity on the rate of photosynthesis in samples of knotted wrack. Data shown are the absorbance (wavelength of observation ~ 525 nm) values of hydrogencarbonate indicator solutions after illumination (standard fluorescent tube) for a period of 60 min. Other experimental details are in the text. The absorbance of a sample of hydrogencarbonate indicator in the absence of added knotted wrack was measured to be 0.43 and this value has been subtracted from the mean values to yield the absorbance value in the column named 'Corrected mean absorbance'. The data point marked\*, deemed to be an 'outlier,' has been excluded from the calculation of mean absorbance.

The mean absorbance values for the data in Table 2 are shown in Figure 4. We conclude that comparisons of photosynthetic rates between samples collected on separate days are entirely feasible.

### Acknowledgements

Several years ago, Liz McMillan (formerly Head of Science at Stromness Academy, Orkney) flagged up the possibility of using seaweeds for experiments with the 'hydrogencarbonate indicator system'. It has taken us some time to act on Liz's suggestion...

Much of the experimental data reported here was generated by Thomas Beaumont from Linlithgow Academy during a period of work experience in SSERC in July/August 2019. <<

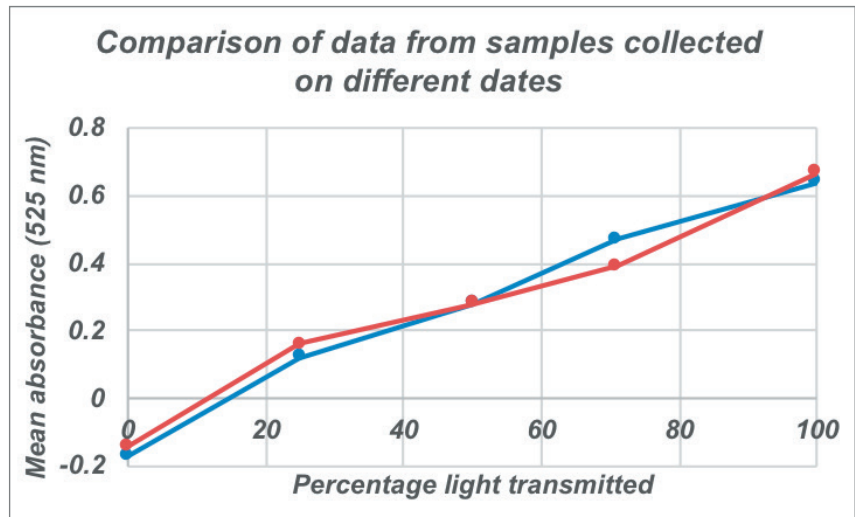


Figure 4 - Mean absorbance data for samples of knotted wrack collected on 25<sup>th</sup> July 2019 (●) and 7<sup>th</sup> August 2019 (●). Further experimental details in the text and the legend to Table 2.

Light Intensity (%)	Absorbance (525 nm) of hydrogencarbonate indicator					Mean of runs 1-5	Corrected mean absorbance	Corrected mean absorbance (from Table 1)
	Run 1	Run 2	Run 3	Run 4	Run 5			
0.0	0.23	0.25	0.21	0.21	0.28	0.24	-0.17	-0.14
25	0.55	0.53	0.51	0.54	0.52	0.53	0.12	0.16
50	0.72	0.69	0.68	0.67	n.d.	0.69	0.28	0.28
71	0.91	0.87	0.93	0.80	0.90	0.88	0.47	0.39
100	1.04	1.06	n.d.	1.08	1.03	1.05	0.64	0.67

Table 2 - The effect of light intensity on the rate of photosynthesis in samples of knotted wrack. Data shown are the absorbance (wavelength of observation ~ 525 nm) values of hydrogencarbonate indicator solutions after illumination (standard fluorescent tube) for a period of 60 min. Other experimental details in the text. The absorbance of a sample of hydrogencarbonate indicator in the absence of added knotted wrack was measured to be 0.41 and this value has been subtracted from the mean values to yield the absorbance value in the column named 'Corrected mean absorbance'.

### References

- [1] SSERC (2018), Photosynthesis using seaweed - opportunities for investigative work in Environmental Science? *SSERC Bulletin*, **263**, 4-5.
- [2] Andrews, K., Beaumont, P.C. and Crawford, K. (2015), Measurement of limiting factors in photosynthesis. *School Science Review*, **96** (356) 31-35.
- [3] Andrews, K. and Beaumont P.C. (2017) National 5 Biology assignment packs. *SSERC Bulletin*, **261**, 10-12.
- [4] To make a concentrated stock of indicator (10 times the concentration required for the experiments) use the following protocol:
  - dissolve cresol red (0.1 g) and thymol blue (0.2 g) in ethanol (IDA, 20 cm<sup>3</sup>).
  - dissolve sodium hydrogencarbonate (0.85 g) in freshly boiled distilled water (200 cm<sup>3</sup>).
  - add the solution of cresol red and thymol to the hydrogencarbonate solution and make to 1 dm<sup>3</sup> with freshly boiled distilled water.
  - for use in experiments dilute the stock indicator prepared above and adjust the pH to approximately 7.4.
  - aerate this diluted indicator prior to use.
- [5] Field Studies Council (2008), Knotted or Egg Wrack (*Ascophyllum nodosum*). Image taken from <https://www.theseashore.org.uk/theseashore/SpeciesPages/Knotted%20or%20Egg%20Wrack.jpg.html> (accessed 29<sup>th</sup> July 2019).
- [6] Lee Filters (2019), Neutral density (filters). Information available at <http://www.leefilters.com/lighting/technical-list.html> (accessed 21<sup>st</sup> July 2019).
- [7] Mystrica: Practical solutions (2019). Information available at <http://www.mystrica.com/Colorimeter> (accessed 21<sup>st</sup> July 2019).

# SSERC professional learning courses



Our professional development courses range from twilight events, day-courses through to residential meetings lasting up to 6 days in total. Our curriculum coverage spans both primary and secondary sectors and we offer events for teachers as part of their career long professional learning, newly qualified teachers and technicians. Many of our events receive funding from the ENTHUSE Bursary scheme or the Scottish Government.

Courses available for online booking include:

COURSE NAME	RESIDENTIAL?	DATES	CLOSING DATE	SECTOR
<b>Movie Making and Photography with iPad</b>	No	24 September 2019	17 September 2019	Primary
<b>Assignments for Environmental Science</b>	No	27 September 2019	3 September 2019	Secondary (Environmental Science)
<b>Engineering Bench Skills for Probationers</b>	Yes	24-25 October 2019	27 September 2019	Secondary (Technology)
<b>Games Design at Second Level</b>	No	7 October 2019	17 September 2019	Primary
<b>Safe Use of Workshop Machinery (Refresher)</b>	No	2 October 2019	31 August 2019	Secondary Technicians
<b>Advanced Higher Biology Day</b>	No	26 October 2019	28 September 2019	Secondary (Biology)
<b>Creativity</b>	Yes	28-29 October 2019	13 September 2019	Primary & Secondary
<b>Discovering Micro:Bits across the BGE</b>	No	30 October 2019	23 October 2019	Secondary
<b>Safe Use of Workshop Machinery</b>	No	30-31 October 2019	2 September 2019	Secondary Technicians
<b>Safety in Microbiology</b>	Yes	30 Oct - 1 Nov 2019	27 September 2019	Secondary Technicians
<b>Simple but effective visualisation of scientific plots in R</b>	No	2 November 2019	4 October 2019	Secondary
<b>Enhancing creativity with iPad</b>	No	7 November 2019	31 October 2019	Primary
<b>Demonstrations for Recently Qualified Chemists</b>	Yes 8 November 2019	8-9 November 2019 & 6 March 2020	4 October 2019	Secondary (Chemistry)
<b>Leading for Excellence in STEM</b>	Yes	10-13 November 2019 & 15-16 March 2020	20 September 2019	Secondary (Science and Technology)
<b>SSERC_Meet Pneumatics &amp; Hydraulics</b>	No	12 November 2019	18 October 2019	Primary
<b>Introduction to Micro:bit</b>	No	13 November 2019	6 November 2019	Primary & Secondary
<b>Super Science &amp; Terrific Technology</b>	Yes	15-16 November 2019 & 20-21 March 2020	1 October 2019	Primary
<b>SSERC_Meet Further Fun with Forensics</b>	No	18 November 2019	18 October 2019	Primary
<b>Online Health and Safety Update (3 sessions each of 1 hour)</b>	No	6, 13 & 20 November 2019	11 October 2019	Secondary
<b>Health &amp; Safety Update (1-day course at SSERC)</b>	No	19 November 2019	21 October 2019	Secondary
<b>Hot and Cold Metal Forming</b>	Yes	20-21 November 2019	4 October 2019	Secondary (Technology)
<b>Using Green Screen to Support Literacy</b>	No	21 November 2019	14 November 2019	Primary



CLPL courses continued:

COURSE NAME	RESIDENTIAL?	DATES	CLOSING DATE	SECTOR
<b>STEM CLPL for Early Level</b>	No	22 November 2019	8 November 2019	Primary
<b>Working with Radioactive Sources</b>	No	26 November 2019	4 November 2019	Secondary
<b>Safe Use of Workshop Machinery</b>	No	28-29 November 2019	31 October 2019	Secondary Technicians
<b>Introductory Physics</b>	No	28-29 November 2019	24 October 2019	Secondary Technicians
<b>Supporting All Learners using Digital Tools</b>	No	29 November 2019	22 November 2019	Primary & Secondary
<b>Introduction to Garageband</b>	No	5 December 2019	28 November 2019	Primary
<b>SSERC Conference</b>	No	6 December 2019	8 November 2019	Primary & Secondary
<b>Risk Assessment</b>	No	13 January 2020	16 December 2020	Secondary
<b>Safe Use of Workshop Machinery (Refresher)</b>	No	17 January 2020	15 December 2019	Secondary Technicians
<b>Safe Use of Workshop Machinery</b>	No	23-24 January 2019	15 December 2019	Secondary Technicians
<b>Technology Makerspace</b>	Yes	28-29 January 2020	29 November 2019	Secondary Technology
<b>Science for Probationers</b>	Yes	5-6 February & 3-4 June 2020	29 November 2019	Secondary
<b>Intermediate Physics</b>	No	11-12 February 2020	9 January 2020	Secondary Technicians
<b>Safe Use of Other Fixed Workshop Machinery</b>	No	11-12 February 2020	9 January 2020	Secondary Technicians
<b>Chemical Handling</b>	No	18-19 February 2020	21 January 2020	Secondary Technicians
<b>Fabrication Skills</b>	Yes	18-19 February 2020	10 January 2020	Secondary Technology
<b>Safe Use of Workshop Machinery</b>	No	25-26 February	28 January 2020	Secondary Technicians
<b>SSERC_Meet Teddy in the Park</b>	No	26 February 2020	31 January 2020	Primary
<b>Statistical analysis of data in R</b>	No	7 March 2020	7 February 2020	Secondary
<b>SSERC_Meet Science Inquiry: Observing, Exploring &amp; Classifying</b>	No	4 March 2020	7 February 2020	Primary
<b>Electrical Safety and PAT</b>	No	10-11 March	6 February 2020	Secondary Technicians
<b>Safe Use of Workshop Machinery</b>	No	18-19 March 2020	13 February 2020	Secondary Technicians
<b>Maintenance of Fixed Workshop Machinery</b>	No	25-27 March 2020	18 February 2020	Secondary Technicians
<b>Welding Skills</b>	Yes	6-7 May 2020	27 March 2020	Secondary Technology
<b>Welding Skills</b>	Yes	21-22 May 2020	3 April 2020	Secondary Technology

Please check our website pages at <https://www.sserc.org.uk/professional-learning/calendar/> for the most up-to-date details on our career long professional learning calendar.

# The green, green chemistry of home

The concept of 'green chemistry' appeared on the scene in the mid to late 1990s. The name certainly gives an indication but it is an approach to chemistry which aims to minimise the use and generation of hazardous substances. Green chemistry focuses on the environmental impact of chemistry, including technological approaches to preventing pollution and reducing consumption of non-renewable resources [2].

Of the 12 principles of Green Chemistry, most are quite understandably focussed on the chemical industry and relate to reducing the damage of industrial processes. There are some, however, that have wider relevance, particularly:

- **Prevention.** Preventing waste is better than treating or cleaning up waste after it is created.
- **Inherently safer chemistry for accident prevention.** Whenever possible, the substances in a process, and the forms of those substances, should be chosen to minimise risks such as explosions, fires, and accidental release.

School chemistry has never been as big an offender as industry for two main reasons: it takes place on a much smaller scale and schools are, quite reasonably, averse to using many of the more harmful substances. There are still many areas of school chemistry though where a greener approach would



Figure 1 - Green chemistry [1].

be beneficial. The environmental benefit is obvious but there are also safety advantages and significant cost savings to be had by reducing the amount of waste that has to be disposed of by costly contractors.

There are various things schools can do to develop a greener approach to their chemistry. In a series of upcoming articles, we will offer a few approaches to deal with particular issues. In the meantime, here are a few more general ideas.

## 1) Reduce the scale

For example, the making of a precipitate of lead iodide is still quite a common activity in many schools. We are the first to admit that this is a gorgeous, yellow precipitate but it does involve the preparation and use of lead nitrate solution as well as the production of the solid lead iodide itself. Lead compounds are reproductive toxins as well as being damaging to the environment and so, like all lead compounds, these must be disposed of as special waste. If the sole objective is to demonstrate

precipitation, there are plenty of alternatives that are not harmful to the environment.

If there is a particular desire to show lead iodide then your pupils can use a microscale approach (see the activity 'Diffusing Precipitates' [3]) where they will literally only use a grain or two of lead nitrate. The amount of lead used and produced is so small that the waste from the experiment can simply be wiped up on a paper towel and put in the bin.

Another way of reducing scale is to carry out an experiment as a demonstration – the students could experiment with less harmful precipitates and the teacher could show one example of the lead iodide precipitate.

## 2) Reuse and recycle

A common school practical is the preparation of copper sulphate crystals. Assuming that it really is desirable to make the attractive blue crystals, then there is little alternative to using copper oxide >>

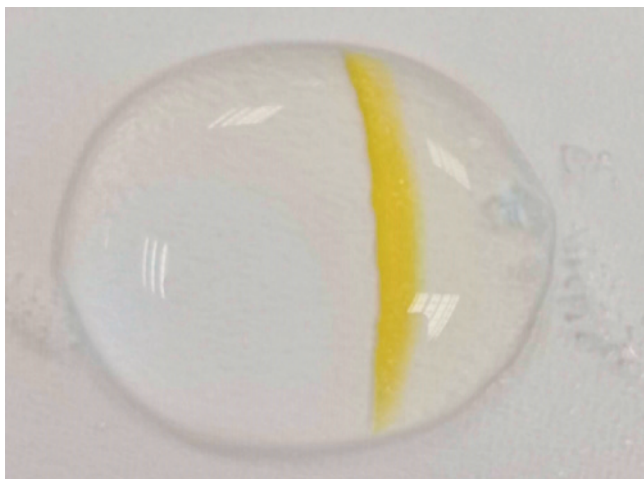


Figure 2 - A microscale precipitate of lead iodide.

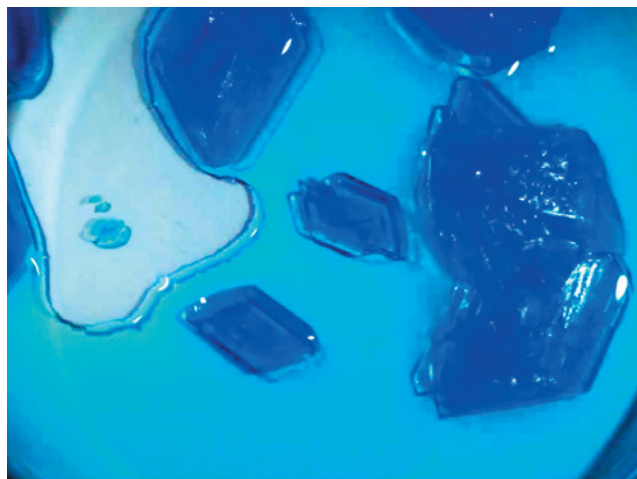


Figure 3 - Copper sulphate crystals.

meaning you can end up with an awful lot of copper sulphate solution. This is often just stored for disposal but why? Rather than paying for disposal and then buying in more copper sulphate to make up solutions, the sensible thing to do is simply to keep what has been made and to use it instead. The purity may not be perfect but unless it is needed for an advanced higher project then it is unlikely to make much, if any, difference. It will certainly be quite suitable for use for displacement reactions, exothermic reaction with zinc, analysis of water of hydration, producing precipitates of insoluble salts, complex formation and much more.

Similarly, many solutions of zinc and silver in particular can be treated and re-used.

### 3) Use something less environmentally harmful

We are all now quite wary of using lead and mercury compounds in part at least due to their environmental harm. But there are other elements that are deeply problematic for the environment.

**Copper** we have already touched on. In many cases iron salts can be used as a substitute and these are much less harmful.

**Cobalt and nickel** - these compounds are carcinogenic as well as being damaging for the environment. Where possible an alternative should be found.

**Zinc** - rather like copper, due to the fact that zinc compounds are so widely used we tend to overlook the environmental damage they can do. It is far from insignificant, however, and so where possible zinc compounds should be avoided.

**Chromium VI compounds** - these are dangerous for the environment and also are carcinogenic, toxic and have numerous other health hazards. In short, they are best avoided. Two common uses for these compounds

are oxidation tests for alcohols and as indicators in silver nitrate titrations of chlorides. These two procedures are addressed in the second part of this article. <<

#### Please note

SSERC is definitely **not** suggesting that these substances are banned (or are likely to be in the near future). We are merely suggesting a responsible approach. Where there is no suitable alternative, by all means go ahead and use dichromates or nickel compounds but do what you can to reduce the impact: have a demonstration rather than a class practical, use a microscale approach etc.

#### References

- [1] Image from Flavio~ on Flickr <https://www.flickr.com/photos/37873897@N06/8277000022/>.
- [2] [https://en.wikipedia.org/wiki/Green\\_chemistry](https://en.wikipedia.org/wiki/Green_chemistry).
- [3] <https://www.sserc.org.uk/subject-areas/chemistry/chemistry-resources/microscale-chemistry/diffusing-precipitates-microscale/>.

# Analysis of chloride in water

We all know that seawater is salty. We also know that this is due, in the main, to the presence of sodium chloride. (To be more precise, there is not actual sodium chloride present, merely sodium ions and chloride ions along with a host of other anions and cations in smaller quantities but it is convenient to talk in terms of sodium chloride). There are also chloride ions in far smaller concentrations in many 'fresh' water sources. A glance at the compositions of mineral waters will show chloride as a significant component.

Salinity is important as many water dwelling organisms will only thrive within a particular salinity range and also, in agriculture, increasing salinity of soils has implications for loss of production.

The average concentration in seawater worldwide is 3.5% (usually given as 35 ppt - parts per thousand) but the figure will vary depending on a variety of factors.

## Argentometry

The analysis of chloride is done by argentometry - titrating with silver salts.

## Mohr's method

The most common method, familiar in schools, is Mohr's method.

This involved titration with silver nitrate solution using potassium chromate as an indicator.

As you slowly add silver nitrate solution, a white precipitate of silver chloride forms (although it is coloured yellow by the chromate ions).



The end point occurs when all the chloride ions are precipitated. Then additional silver ions react with the chromate ions of the indicator, potassium chromate, to form a red-brown precipitate of silver chromate.

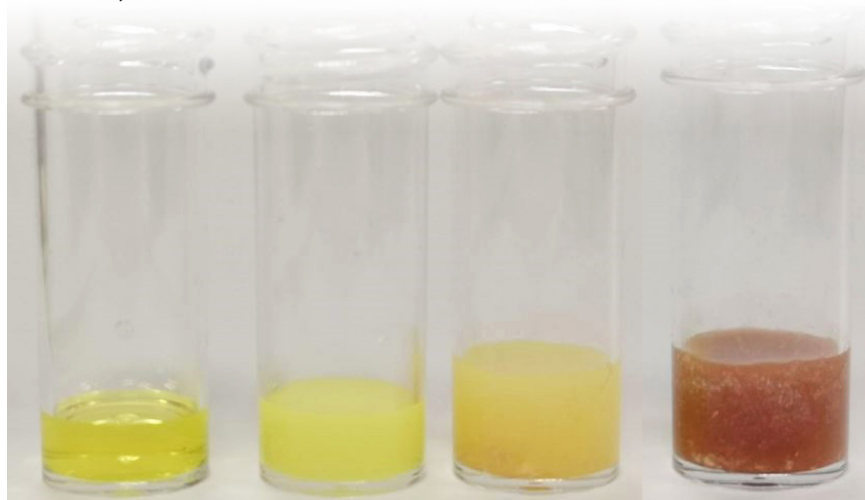


Figure 1 - Chromate. L-R Starting solution, silver chloride precipitate, end-point colour change, going further.

While this method works well, it has the problem of using chromate which is toxic and dangerous for the environment. But there are alternatives.

In both of these cases, the actual titration is carried out in exactly the same way as normal just using different indicators (and in the second one doing some preparation to the water sample).

## Fajan's method

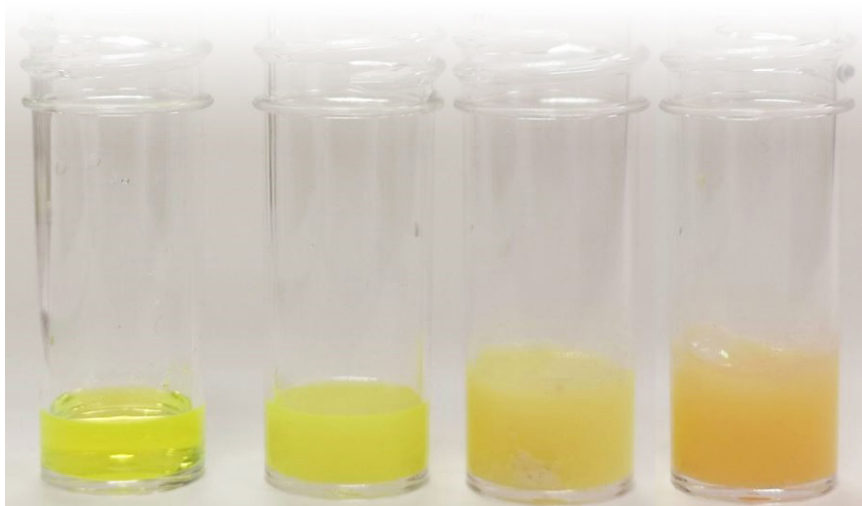
This alternative uses an adsorption indicator such as fluorescein. The indicator adsorbs onto the surface of the silver salt precipitate at the endpoint. This adsorption process causes a change in the colour of the indicator.

Common Fajan's adsorption indicators are weakly acidic organic compounds and in alkaline conditions will exist as the conjugate base, In<sup>-</sup>. It is this form of the indicator which interacts with the precipitate.

When AgNO<sub>3</sub> is added to a dilute solution of NaCl, the solution becomes turbid and coagulation does not usually occur immediately. The colloidal sized AgCl particles adsorb Cl<sup>-</sup> and these attract sodium ions. Colloidal particles are electrically charged and repel each other preventing coagulation.

As titration continues, the amount of chloride decreases but there is still some surface charge which acts to repel the negatively charged indicator ion. Immediately after the endpoint there is an excess of silver ions which will adsorb onto the surface of the precipitate.

The charged surface has now changed polarity and attracts the negative indicator ion causing an observable colour change. >>



**Figure 2** - Fluorescein. L-R Starting solution, silver chloride precipitate, end-point colour change, going further.

There is a variety of indicators that can be used. The most likely to be found in school are fluorescein and eosin. Fluorescein works from pH 7. Dichlorofluorescein is OK for more acidic solution (pH 4 and up) and eosin is fine above pH 1 BUT is unsuitable for chloride, though fine for bromide and iodide, as it binds too strongly.

There is, however, a new method.

### The Hong-Kim-Czae method [1]

It utilizes a mediator, a weak acid that can form an insoluble salt with the titrant. The mediator triggers a sudden change in pH at an equivalence point in a titration. This change can then trigger a colour change in an indicator. The version here uses phenolphthalein [2] as an indicator but it does rely on mixing the sample with a phosphate solution to mediate the reaction.

A weak acid (HA) whose conjugate base ( $A^-$ ) can form a slightly soluble salt ( $AgA$ ) with the titrant ( $Ag^+$ ) is added in place of the (chromate) above. The result is that at the equivalence point,  $H^+$  ions are produced leading to a sharp drop in pH which allows the equivalence point to be detected with an acid-base indicator.

The water sample first has a small amount of phosphate added to it and then a few drops of sodium hydroxide to make it alkaline. This makes it purple when phenolphthalein is added.

At the equivalence point, the drop in pH turns the indicator from purple to a reddish brown (there is notable clumping shortly before the end). Theoretically, the end should be colourless but it seems not to be - the reasons are obscure at present - there is, however, a clear colour change.

**Volhard's method** is another alternative that is not discussed here due to cost factors.



**Figure 3** - Phenolphthalein. L-R Starting solution, silver chloride precipitate, end-point colour change, going further.

It involves adding excess silver nitrate and then carrying out a back titration with an iron solution using thiocyanate as the indicator.

It is effective but has no real advantage over the previous methods and uses more silver nitrate.

**Gravimetric method** - this has also been discounted in this discussion as it needs significantly more silver nitrate to get an accurate result and there are also problems with the co-precipitation of other silver compounds such as sulphates.

### In conclusion

Silver nitrate, like all silver compounds, is expensive. In order to minimise cost, where possible it is a good idea to use microscale titrations as they will use a small fraction of the amount that a full-scale titration will.

The lack of chromate contamination in these methods, though, will mean that of recycling the silver, while not simple, is more likely to be possible. We will follow this up in a future article. <<

### References

- [1] The method has no name but these are the names of the authors of the paper.
- [2] <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3065052/pdf/IJAC2010-602939.pdf>.



# Permanganate oxidation of alcohols

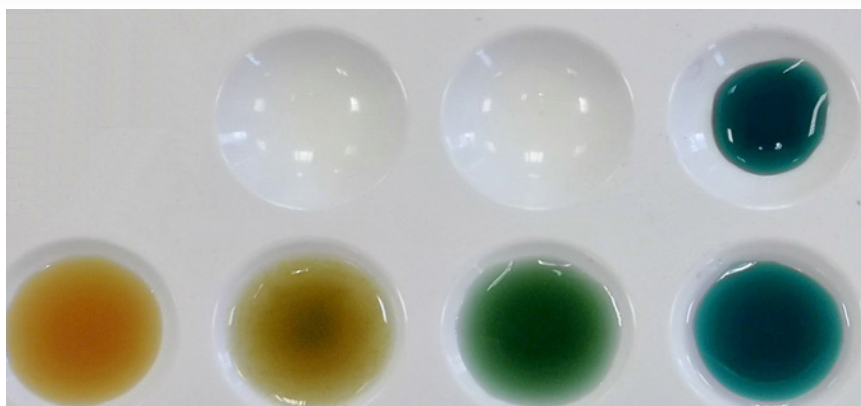
The oxidation of alcohols is commonly carried out on a test-tube (or spotting tile) scale to demonstrate to pupils the different properties of primary, secondary and tertiary alcohols.

It is normally carried out using acidified potassium dichromate. This reagent is an effective oxidant and has the advantage of an inherent colour change (from yellow to green) that allows the progress of the reaction to be easily observed.

However, chromium(VI) compounds, such as dichromates, are toxic, corrosive, carcinogenic, mutagenic, sensitisers and extremely hazardous to the environment. Where possible they are best avoided.

Other methods have been suggested, most notably by using a solution of acidified permanganate in which the primary, secondary and tertiary alcohols can be distinguished by the rate of change of the colour from purple to yellowish brown as the manganese VII is reduced to manganese IV. The colour changes are not all that clear, though, and the experiment takes some time.

As an alternative, we have developed an improved method which uses an **alkaline** permanganate solution. This gives an initial colour change (where oxidation happens) to the bright green manganese VI followed (in some cases) by a slow change to yellow/brown manganese IV. (The blue V state is very unstable and rapidly decomposes).



**Figure 1** - Top row: control. Bottom row (left to right): Ethanol, propan-1-ol, propan-2-ol and 2-methyl-propan-2-ol.

Alkaline permanganate is not as stable as the acidified solution and so will be reduced in air to the blue/green colour (possibly a mix of Mn VI and VII) but it is significantly different from the green produced if there is any reaction.

As can be seen in Figure 1 above, the colour changes are clear and this method has the great advantage of not being hazardous (for technicians either).

The permanganate solution is very dilute ( $0.006 \text{ mol l}^{-1}$ ) and so the solution can, after either neutralisation or further dilution simply be washed to waste. (The hazard of this solution is solely from the sodium hydroxide)

## The experiment

You will need:

- **Alkaline manganate VII solution**  
Dissolve 0.1 g of potassium manganate VII in  $100 \text{ cm}^3$  of  $0.4 \text{ mol l}^{-1}$  sodium hydroxide.
- **Spotting tile**
- **Alcohols to test**  
A good selection would be ethanol, propan-1-ol, propan-2-ol and 2-methyl-propan-2-ol but others can be tried.

## • Pasteur pipettes

It may be preferable to have the alcohols in dropping bottles. In either case, the alcohols have a tendency to flood out of the pipette/bottle rather more rapidly than water so students should take care and preferably have some practice at handling them

## Method

- 1) Take your spotting tile and add 10 drops of your alkaline manganate VII solution to each of 5 wells (4 alcohols and a control)
- 2) Use Pasteur pipettes or dropping bottles to add 2 drops of ethanol to the first well, propan-1-ol to the second, propan-2-ol to the third and 2-methyl-propan-2-ol to the fourth.
- 3) Observe the changes over the next few minutes.

## Results

The figure below shows the colours obtained from some common alcohols after leaving for about 5-6 minutes. >>

**Ethanol** - an immediate green colour which then slowly (over 5 minutes or more becomes yellower).

**Propan-1-ol** - the same as ethanol but it is very slightly slower.

**Propan-2-ol** - A slightly slower green colour (a couple of seconds) followed by a slower yellowing. It will end up green rather than yellow.

**2-methyl-propan-2-ol** - the solution rapidly goes a dark, slightly bluish green but then stays that colour.

**Control** - this slowly changes colour to end up the same dark bluish green as the tertiary alcohol.

### Extensions

**1) Ketones** - The only ketone we tested here was **propanone**. This goes the same colour as the primary alcohols only faster. Within about 1 minute the solution is yellow.

To be certain, test the propanone with an acidic permanganate solution - there will be no reaction and the solution will remain purple.

**2) Methanol** - This undergoes the same changes as ethanol but is a little slower

**3) Butan-1-ol** - again the same changes as ethanol but it needs stirring a little at the start to encourage mixing. The reaction is also noticeably slower.

**4) Aromatic alcohols** - we tested **phenylmethanol** and **cyclohexanol**. Both needed some stirring to encourage the reaction to start but they turned green after about 15 seconds and began to show a yellowish tinge after about 3 minutes.

**5) Diols and triols** - we tried **ethane-1,2-diol**, **propane-1,2-diol** and **propane-1,2,3-triol**. All three (after a little stirring to mix) rapidly went orange. <<

## Guide to practical physics

'Send the teachers on this!' commented a technician who attended our Introductory Physics course. It got us thinking about our own experiences as newly-qualified teachers and the guidance available when it came to setting up equipment. We decided to take the notes we had created for both Introductory and Intermediate Physics and put together a document we hope will be of use to technicians, science teachers who are not physicists but who teach physics at BGE, and to early-career physics teachers.

The result is the *Guide to practical physics*. This can be downloaded from our website [1] but you will need to log in to do so as it has a substantial amount of health and safety content. Such material is password protected. SSERC Bulletin 265 [2] tells you all you need to know about getting a password.

Guidance ranges from the very basic - which sockets to use when measuring current with a multimeter - to more complicated issues such as using the correct UV light source to demonstrate the photoelectric effect and indeed doing so safely. We have made videos to support some of the content [3].

When we first ran the Introductory Physics for Technicians course, we asked delegates for their ideas regarding content of an Intermediate course. We took these ideas onboard. In a similar spirit, we would like to hear your ideas for the content of the *Guide to*

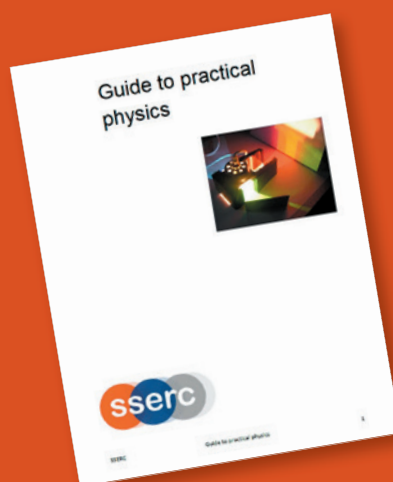


Figure 1 - The guide.

*practical physics*. We hope that it will be an ever-evolving document. Comments, please, to [gregor@sserc.scot](mailto:gregor@sserc.scot).

### References]

- [1] [www.sserc.org.uk/subject-areas/physics/physics-other-resources/guide-to-practical-physics/](http://www.sserc.org.uk/subject-areas/physics/physics-other-resources/guide-to-practical-physics/) (accessed August 2019).
- [2] [www.sserc.org.uk/wp-content/uploads/Publications/Bulletins/265/SSERC-bulletin-265-p7\\_8.pdf](http://www.sserc.org.uk/wp-content/uploads/Publications/Bulletins/265/SSERC-bulletin-265-p7_8.pdf) (accessed August 2019).
- [3] [www.sserc.org.uk/subject-areas/physics/physics-other-resources/how-to-videos/](http://www.sserc.org.uk/subject-areas/physics/physics-other-resources/how-to-videos/) (accessed August 2019).

# Leading for Excellence in STEM

Graham Donaldson, in his review of teacher education in Scotland [1], noted that international evidence ‘...suggests, perhaps unsurprisingly, that the foundations of successful education lie in the quality of teachers and their leadership. High quality people achieve high quality outcomes for children.’

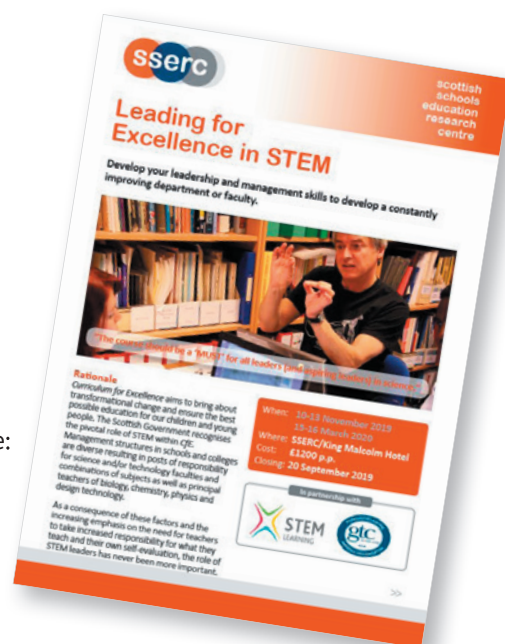
In SSERC we have for many years run a 2-part residential programme, *Leading for Excellence in Science*, aimed at all of those who have, or aspire to have, responsibility for leading secondary science education in their establishments. Additional support for leadership in Science is provided in the leadership pages on the SSERC web site [2].

Partly in response to the Government’s recently introduced *Science, Technology, Engineering and Mathematics - Education and Training Strategy for Scotland* [3], and in recognition of increased demand we are adapting the programme to accommodate teachers of Design and Technology as well as teachers of Science and this is reflected in the change of title to *Leading for Excellence in STEM*.

The course is coordinated and organised by staff from SSERC and delivered by experts nationally recognised in their field. External contributors in 2019/2020 will include:

- Ken Muir [Chief Executive, GTCS]
- Chris Baker [Freelance Consultant]
- Graham Donaldson CB [former HM Senior Chief Inspector of Education]
- Carol McDonald HMI [Lead Officer Secondary Inspections]
- Jack Jackson OBE [Professor of Curriculum Studies, University of Strathclyde]

Although some leadership skills are generic, there are aspects of STEM education which require specific leadership skills and have particular management responsibilities.



These particular responsibilities, as well as wider leadership issues, will be considered in STEM specific contexts.

ENTHUSE Bursaries are available to teachers/tutors from Local Authority schools/FE Colleges. The Bursary will offset 80% of the course fees.

Further details on the programme, together with details on how to apply for a place, can be found [here](#). The first closing date for applications is 20<sup>th</sup> September 2020. <<

## Reference

- [1] Donaldson, G. (2010), *Teaching Scotland’s Future-Report of a review of teacher education in Scotland*. Scottish Government. Available at <http://www.scotland.gov.uk/Resource/Doc/337626/0110852.pdf> (accessed 4<sup>th</sup> August 2019).

## Aged protactinium generators

- Protactinium generators 8 years old or older will need to be disposed of;
- Disposal will require a specialist contractor.

If you attend a SSERC course on working with radioactive materials, we will show you all the sources you are allowed to buy to study radioactive decay and half life. Two years ago, we made a short video on the subject for SQA [1]. We always stress that, although it is relatively cheap to buy, getting a protactinium generator may be a false economy.

A protactinium generator (figure 1) contains uranyl nitrate (toxic and radioactive), very strong hydrochloric acid (corrosive) and hexyl ethanoate (flammable). If there was a competition for a piece of school science apparatus with the most hazard symbols affixed to it, the protactinium generator would probably win.

Protactinium generators were quite commonplace in schools in the nineteen eighties. The Surplus Source Disposal initiative that took place around 12 years ago removed most of them. At that time, there was no replacement on the market. This changed in late 2011, meaning that the oldest protactinium generators are now around eight years old, an age that, as we shall see, is significant.

Any time you buy a radioactive source, the manufacturer will inform you of its recommended working life (RWL). Sealed sources used to demonstrate absorption of radiation, inverse square law and so on have RWLs of between 5 to 10 years. However, experience has shown that leakage is very rare even after 3 or 4 RWLs. If a sealed source appears in good condition (check using a mirror) and continues to pass its leak test, its RWL can be extended. We cannot do the same with a protactinium generator. The risk of leakage is too great. Its RWL is 8 years. Disposal will involve a specialist contractor. Although it is its chemical toxicity rather than the fact that it is radioactive that necessitates this, most hazardous chemical disposal companies do not handle radioactive material.



Figure 1 - Protactinium generator.

### What to do if you have a protactinium generator

- Check your inventory to find out how old it is.
- If it is 8 years old or older contact SSERC on [rpa@sserc.scot](mailto:rpa@sserc.scot) for advice on getting a contractor to dispose of it.
- If you don't know how old it is and can't find out by contacting former staff members, assume it requires disposal.

Make sure that what you have is actually a protactinium generator. Some schools who went on to buy barium isotope generators (eluting sources) continued to refer to them as 'protactinium generators'.

Unfortunately, disposal costs are likely to run well into three figures, hence the comment about 'false economy'. Please note that hanging on to radioactive material that you cannot use is not an option. <<

### Reference

- [1] [https://www.youtube.com/watch?v=hCVaLQ\\_bJ1g&t=5s](https://www.youtube.com/watch?v=hCVaLQ_bJ1g&t=5s) (accessed August 2019).