OCTOBER 2023

Bulletin 279
Activities & Professional Learning

Educational value of practical work

The reintroduction of Practical Assignments as an assessment component for N5 and Higher Sciences and Projects for Advanced Higher Sciences has some positive benefits – particularly in highlighting the critical role of practical work in introducing learners to scientific ideas and theories.

SSERC recognises the educational value of practical work and believes it should constitute a significant proportion of a learner's time when undertaking a STEM-based curriculum.

We believe that practical work serves the following purposes:

- to motivate and engage learners
- to teach the principles of STEM inquiry
- to develop specialist skills, e.g. measurement, observation
- to underpin the theory through practical skills
- to further develop critical skills and attributes such as communication, teamwork, and creative thinking
- to engage learners to continue the study of science (and STEM).

Teachers and technicians are the cornerstones of good quality practical activity in STEM subjects that take place in schools. Technicians, in particular, provide a potential untapped pool of knowledge and skills that can and should be further utilised and developed to support practical work to benefit teachers and learners linked to the practical assignment assessment component.

We are aware that this reintroduction has caused some anxiety at a time when some teachers who are new to the profession may not have had much experience in teaching practical skills. More experienced teachers will not have delivered the practical assignment component for some time, and despite reassurances that the assessment specification has not changed, may still be anxious. So, how can we help?

SSERC is a proactive organisation; however, our professional learning calendar is planned approximately a year in advance, so the (late) announcement of the reintroduction of this assessment component and the general anxiety expressed by the profession meant that we had to react to the situation. Across the sciences, we have scheduled various professional learning opportunities to provide support relating to suitable practical assignment contexts. These opportunities will be delivered in a variety of ways:

- Online live webinars
- Self-study courses
- Face-to-face professional learning opportunities at SSERC HQ or other appropriate locations.

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Other topics

For more information, visit our professional learning pages at Secondary PL - SSERC.

It is important to remember that SSERC is not responsible for setting the practical assignment specifications, developing (or interpreting) the marking instructions or responding to any questions linked to these areas. SQA will deal with these aspects at their Understanding Standards events planned for November/December 2023.

We hope that the support from SSERC, combined with the planned SQA Understanding Standards events, will not only provide reassurance to those who have delivered the practical assignment component in the past but also

confidence for those where 2023/2024 will be the first delivery occasion.

We are already recalibrating our professional learning calendar for the next academic year to ensure that we provide planned, appropriately timed and new practical assignment ideas to support practitioners (teachers and technicians) for the 2025 practical assignments and project assessment components. <<

Alastair MacGregor

Alastair MacGregor - Chief Executive Officer

Using a LED as a single photon detector

We came across a very interesting article here that we thought warranted further investigation. A fuller explanation of the semiconductor physics behind this experiment where the LED is operating in 'Geiger-mode', just beyond its breakdown voltage, is given in the article.

The up-front caveat is that this experiment only works with certain LEDs. From a small drawer of about twenty red LEDs we found one that worked.

The circuit is very easy to set up consisting of a single reverse biased LED in series with two resistors. You will also need a CRO and a 0-25V, continuously variable, smooth DC power supply.

The circuit is shown in Figure 1.

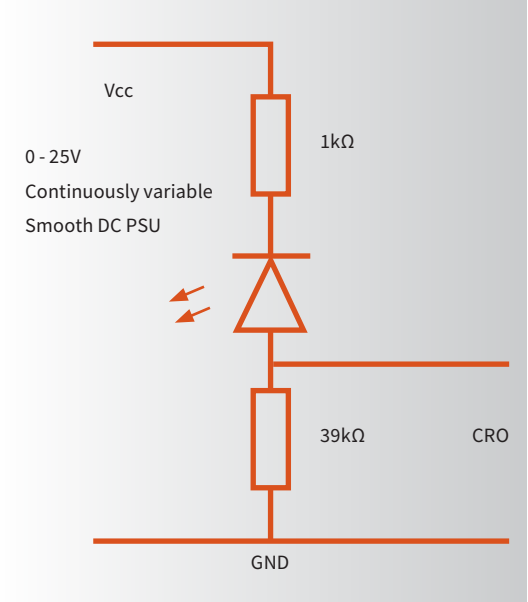

Figure 1 - Circuit diagram.

Set up the circuit as shown then slowly increase the supply voltage. If you have a suitable LED at some point you will see a trace with 'spikes' as shown in Figure 2.

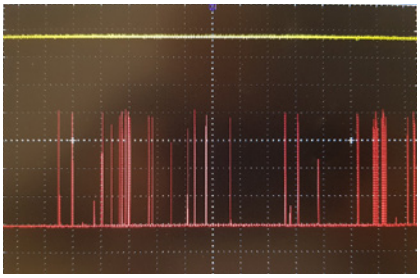

Figure 2 - Initial trace.

At this point it is worth confirming that there are more 'spikes' when it is brighter and fewer when it is darker. Using the CRO we can get a more detailed look at these 'spikes'. Adjusting the timebase we get an image as shown in Figure 3.

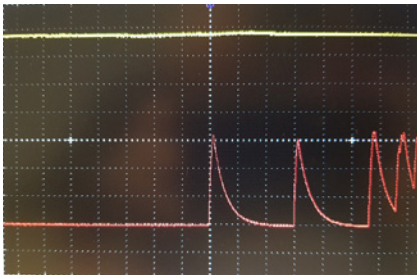

Figure 3 - A more detailed look at the 'spikes'.

In this image we can see the exponential decay nature on the falling edge of the pulse and 'after-pulsing' (where a charge produced during an avalanche is 'delayed' and later triggers a second avalanche) at the right of the image.

An even closer look at the pulse is shown in Figure 4. Here we can also see an initial rounding as the leading edge approaches its maximum value.

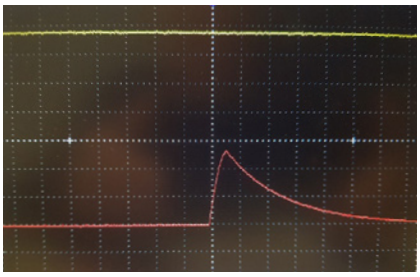

Figure 4 - Rounding of the rising edge.

In Figure 5 we can see that it takes approximately six divisions, each division being 2 µs, for the trailing edge to decay from max to near zero.

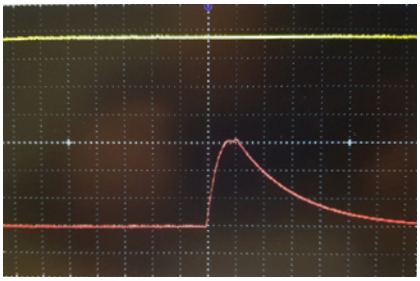

Figure 5 - The decay time.

A bit of a simplification, but we can consider the circuit to be that of a capacitor, the capacitance of the LED pn junction, and a series resistor (40 kΩ). Assuming that it takes 5 CR seconds to decay from max to near zero then 5CR = 12 µs.
CR = 12/ 5 µs = 2.4 µs. Taking R as 40 kΩ (1 kΩ + 39 kΩ) gives us an estimated value of 60 pF for the capacitance of the LED pn junction.

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Developing this idea further.

Another excellent article on using LEDs as a single photon detector can be found here.

In this article a simple discriminator circuit is added to produce square pulses which are then counted by a microcontroller. Two programs for a Teensy 3.2 microcontroller are provided in the article, one acts as a simple counter (with programmable gate time) and the other records the time interval between successive pulses. Datasets are written to the serial monitor of a computer. Statistical analysis is described for both datasets the latter being analogous to the work done by Rutherford, Geiger and Marsden. <<

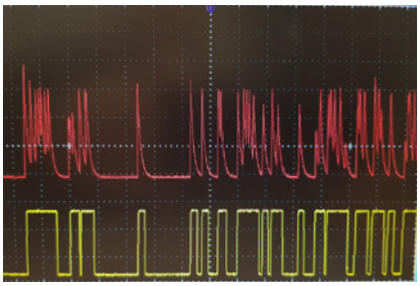

Figure 6 - Yellow trace shows discriminator output (experiment 3 in link above).

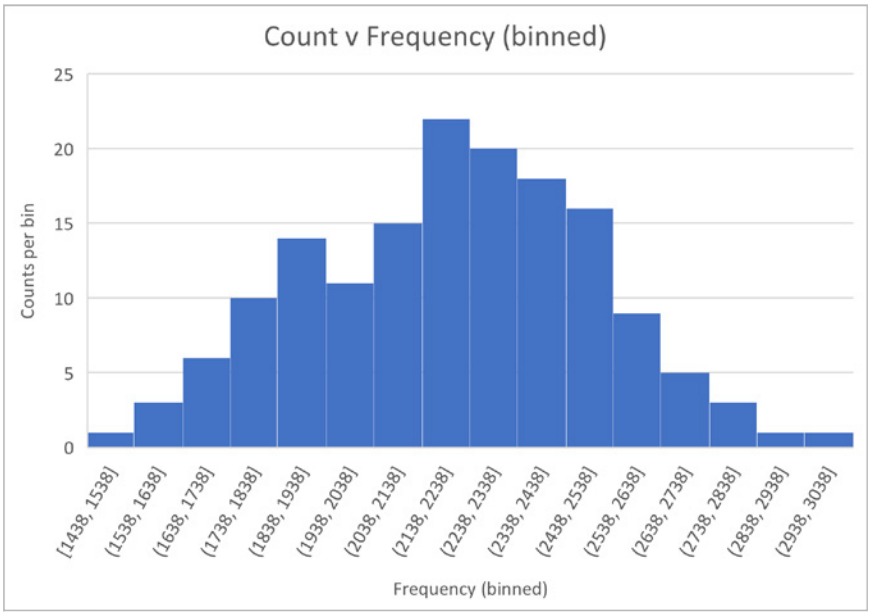

Figure 7 - Histogram showing 155 data values, mean = 2199.4 (experiment 4 in link above)

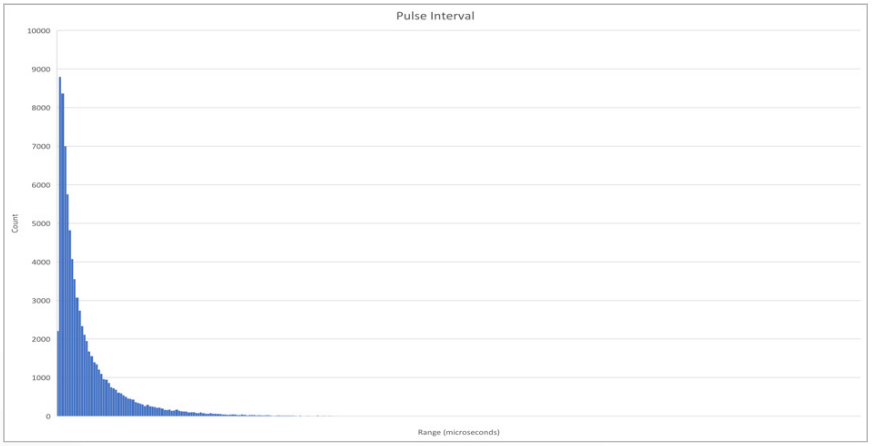

Figure 8 - Histogram of pulse interval data collected over 10 s (> 80 000 values, experiment 5 in link above).

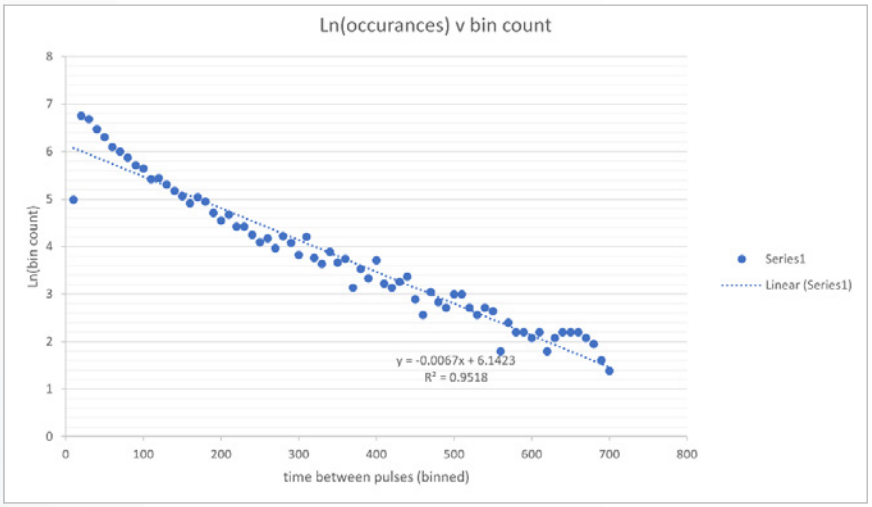

Figure 9 - Graph of Ln(occurrences) v binned inter pulse time.

Critical damping demonstration

This article was prompted by a post on Sputnik expressing a desire to demonstrate critical damping.

The work that follows was inspired by the excellent YouTube video demonstration here.

We have recreated the demonstration and then taken it a step further by using the first-rate, free, video analysis software, 'Tracker'. Find it here.

To book a place on our Tracker self-study course please go here.

Click here to find our tracker support material.

Figure 1 - Experimental set up.

Whilst not necessary we 3D printed a 'pivot' to mount on an 8 mm clamp rod. A simpler arrangement as shown in the original YouTube video would also work well.

The two, large neodymium magnets were placed either side of a half metre stick.

Please be mindful of the pitfalls and health and safety considerations of working with Neodymium magnets; avoid getting them stuck together as it is not easy getting them apart, risk of pinching, risk of fast moving fragments should the magnets be allowed to collide at speed, take care that the magnets do not interfere with other electrical/electronic devices such as pacemakers, hearing aids and mobile phones etc.

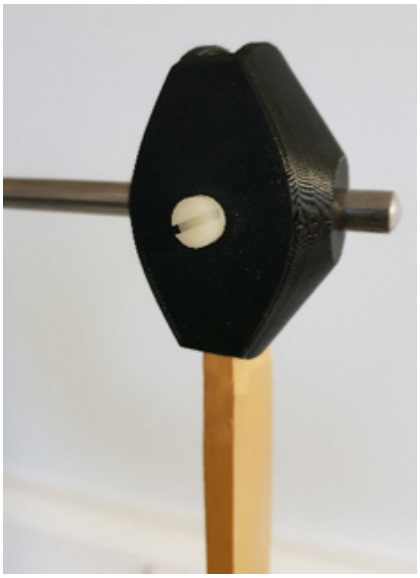

Figure 2 - Pivot details.

Figure 3 - Magnets attached to ½ m stick.

Using a smart phone, videos were taken of the pendulum at various magnet – aluminium separations. When the aluminium is exposed to a changing magnetic field a current is induced in the aluminium. Like any current in a conductor the eddy current will produce its own magnetic field. Lenz's Law states that the direction of the induced current will be such that it will oppose the change that caused it. These opposing magnetic fields are exploited to produce a braking force. The braking force is dependent on several factors including the magnetic field strength. The closer the magnet to the aluminium the greater the eddy current and the greater the braking force. Where damping is small the pendulum will oscillate about its equilibrium position. At 'critical' damping >>

the pendulum will approach the equilibrium position in the shortest time without oscillation. Where the damping is large the pendulum will approach the equilibrium position in a much longer time period. The videos were then transferred to a PC and analysed in Tracker.

The data from three runs (2 mm, 8 mm, 30 mm) was then exported from Tracker and imported into Excel where the start times were made to coincide and the data plotted on one graph. This yielded the following results:

The grey (30 mm) trace in Figure 5 was produced with a magnet – aluminium spacing of 30 mm. Here the distance is large and so the induced eddy current and therefore damping force is small. The system is under-damped. The orange trace (8 mm separation) shows the damping force is (near) critical and the pendulum settles to its equilibrium position, without oscillation, in the shortest time interval. The blue trace (2 mm separation) shows over-damping and that the pendulum takes much longer to settle to its equilibrium position.

Our attempt to recreate the excellent video montage at the end of the YouTube video linked to above can be found here. <<

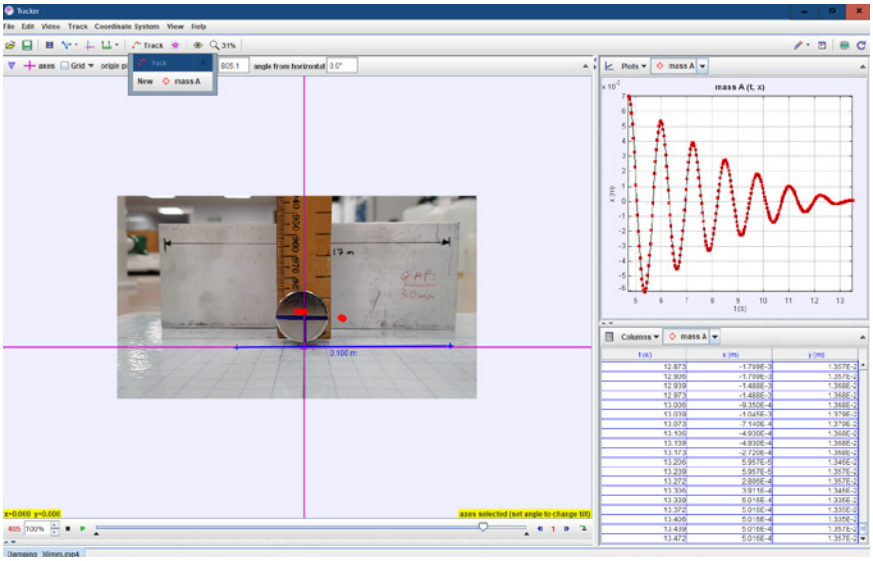

Figure 4 - Tracker screen showing a plot of x position against time.

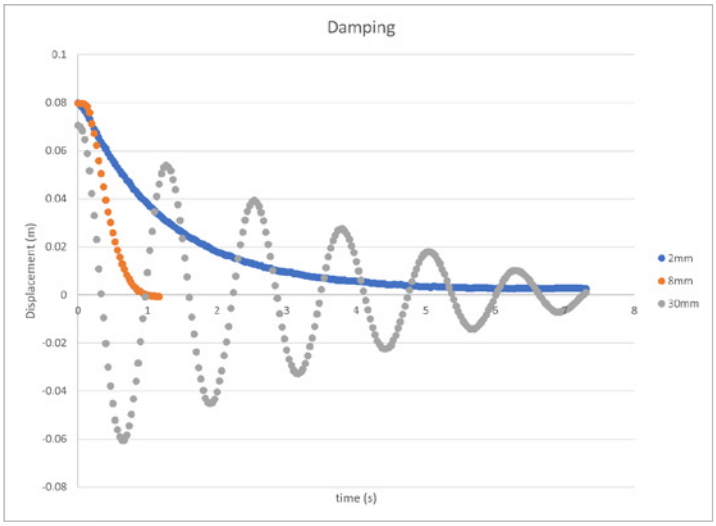

Figure 5 - Combined graph showing under, (near) critical and over damping.

SSERC professional learning courses

We offer professional learning (PL) courses and events for teachers in both primary and secondary settings, school technicians, and other educators. Many of our PL offers are financially supported via ENTHUSE funding from STEM Learning or from the Scottish Government. Such funding for our courses helps towards covering course costs and allows us to provide delegates with resources to support learning and teaching back in their schools.

Courses available for online booking include:

COURSE NAME	RESIDENTIAL?	DATES	CLOSING DATE	SECTOR
*Technology Probationers	Face-to-face	9-10 November 2023	2 October 2023	Secondary Technology
*Safety in Microbiology for Schools	Face-to-face	14-16 November 2023	2 October 2023	Secondary Technicians
*Hot and Cold Metal	Face-to-face	16-17 November 2023	2 October 2023	Secondary Technology***
Safe Use of Fixed Workshop Machinery	Face-to-face	21-22 November 2023	20 October 2023	Secondary Technicians**
Intermediate Physics	Face-to-face	22-23 November 2023	20 October 2023	Secondary Technicians
*Laboratory Science Nat 5	Face-to-face	5-7 December 2023	4 November 2023	Secondary Science
Safe Use of Fixed Workshop Machinery (Refresher)	Face-to-face	12 December 2023	10 November 2023	Secondary Technicians**
Biology SSERC Meet	Online	14 December 2023	8 December 2023	Secondary Biology***
Science Probationers Residential	Face-to-face	19-20 December 23	11 November 2023	Secondary Science
Science Probationers Residential	Face-to-face	17-18 January 2023	30 November 2023	Secondary Science
Safe Use of Fixed Workshop Machinery	Face-to-face	17-18 January 2023	30 November 2023	Secondary Technicians**
Science Probationers Residential	Face-to-face	24-25 January 2023	8 December 2023	Secondary Science
Safe Use of Fixed Classroom Machinery	Face-to-face	24-25 January 2023	8 December 2023	Secondary Technology
*Chemistry for Advanced Higher	Face-to-face	22-23 February 2023	5 January 2023	Secondary Chemistry
*Wood Turning	Face-to-face	22-23 February 2023	5 January 2023	Secondary Technology***
Safe Use of Fixed Classroom Machinery	Face-to-face	28-29 February 2023	12 January 2023	Secondary Technology
Chemical Handling	Face-to-face	5-6 March 2023	2 February 2023	Secondary Technicians
Electrical Safety and PAT	Face-to-face	7-8 March 2023	2 February 2023	Secondary Technicians
*Techniques for Senior Phase Biology	Face-to-Face	12-13 March 2023	26 January 2023	Secondary Biology
Biology SSERC Meet	Online	20 March 2023	13 March 2023	Secondary Biology***
*Centre Lathe Turning	Face-to-face	26-27 March 2023	24 February 2023	Secondary Technology***
Self-Study online courses	Self-study	29 March 2023	29 February 2023	Secondary Science***

* This course attracts ENTHUSE funding which offsets the course fee.
** May also be suitable for secondary teachers.
*** May also be suitable for secondary technician.

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

Phosphorylase - moving from N5 to AH

Phosphorylase, extracted from potatoes, is an enzyme that has been used in many classrooms to exemplify a synthesis reaction. The enzyme, found in several higher plants, catalyses the reversible transfer of glucosyl units from glucose-1-phosphate (substrate) to the non-reducing end of α-1,4-D-glucan chains with the release of phosphate, forming starch (Figure 1). The production of starch can be monitored by the addition of iodine, forming a blue-black complex.

This practical activity is particularly relevant at National 5 Biology level, with the SQA course specifications outlining a requirement for learners to understand that "enzymes can be involved in degradation and synthesis reactions" (Figure 2).

In this bulletin, we provide progression for learners working at Advanced Higher level through the inclusion of colorimetry and the production of a standard curve to estimate the concentration of starch synthesised during the reaction, supporting Key Area 1b of Cells and Proteins (Figure 2).

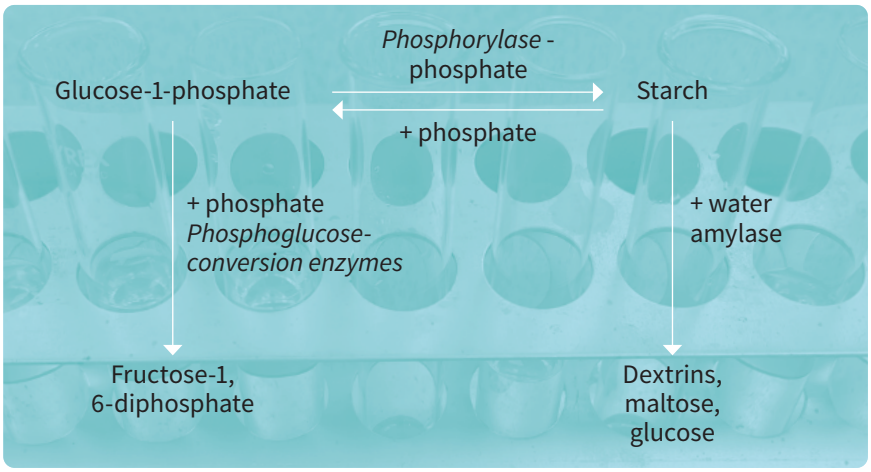

Figure 1 - An overview of the role of phosphorylase in metabolism. Image adapted from (1).

National 5 Biology

Candidates must become familiar with the techniques to measure enzyme activity.

Key area 4b: Required knowledge includes "enzymes can be involved in degradation and synthesis reactions".

A suggested learning activity is to "investigate the action of potato phosphorylase".

Advanced Higher Biology

In the course specification, Key Area 1b states that the learner must understand:

★ the method and uses of a colorimeter

★ know how to produce a standard curve to determine an unknown.

SQA

Figure 2 - Curriculum links relevant to this investigation.

Aim

The aim of this investigation is to extract an enzyme from biological material and investigate the enzymatic synthesis of starch.

Materials and method

In the first part of this investigation, phosphorylase must be extracted from potatoes. This requires the materials outlined in Figure 3.

Approximately 50 g chopped and peeled potato must be blended with sufficient water to form a slurry. After passing through muslin, the filtrate must be centrifuged (> 3000 rpm for 5 minutes) and the supernatant collected (contains the enzyme). Centrifugation separates the enzyme from starch granules; this should be confirmed by taking a drop of supernatant and combining

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Materials

- potato
- knife, chopping board, vegetable peeler
- blender
- muslin
- beaker
- centrifuge
- centrifuge tubes & rack
- container to store extract
- 3 cm^3 plastic pipettes
- 0.01 M iodine solution
- dimple tile

Figure 3 - Materials required for part 1.

it with a drop of iodine on a dimple tile. If there is a blue/black colour, centrifuge the sample for longer. The supernatant will discolour over 24 hours so should be prepared fresh.

The next part of the investigation focuses on the phosphorylase assay. The following steps are required:

1) Set up 7 cuvettes. To cuvette 1, add 3 cm^3 water (to zero the colorimeter). To cuvette 2-7, add 1 cm^3 water and 1 cm^3 iodine.
2) Collect 2 test tubes. To test tube 1 (colorimetric blank), add 1 cm^3 enzyme and 1 cm^3 water. To test tube 2, add 5 cm^3 enzyme and 5 cm^3 1% glucose-1-phosphate. Immediately start the stopwatch and incubate reactions at room temperature.
3) After 2 minutes, transfer 1 cm^3 from test tube 2 to cuvette [3].
4) After 60 s, transfer 1 cm^3 from test tube 2 to cuvette 4.
5) Repeat step 4 every 60 s.
6) Measure the absorbance of the samples. Using the red diode (or approximately 600 nm), zero the absorbance reading using the cuvette of water. To cuvette 2, add 1 cm^3 of the colorimetric blank (test tube 1). This should be recorded as 0 s time point.
7) Measure the absorbance of each sample.

Sample results for this investigation are shown in Figure 6. The assay was carried out in triplicate and mean values calculated. The mean absorbance value obtained at 0 s was subtracted from remaining absorbance values since this reflected the absorbance of the enzyme alone, not the production of starch, and would be present in all samples.

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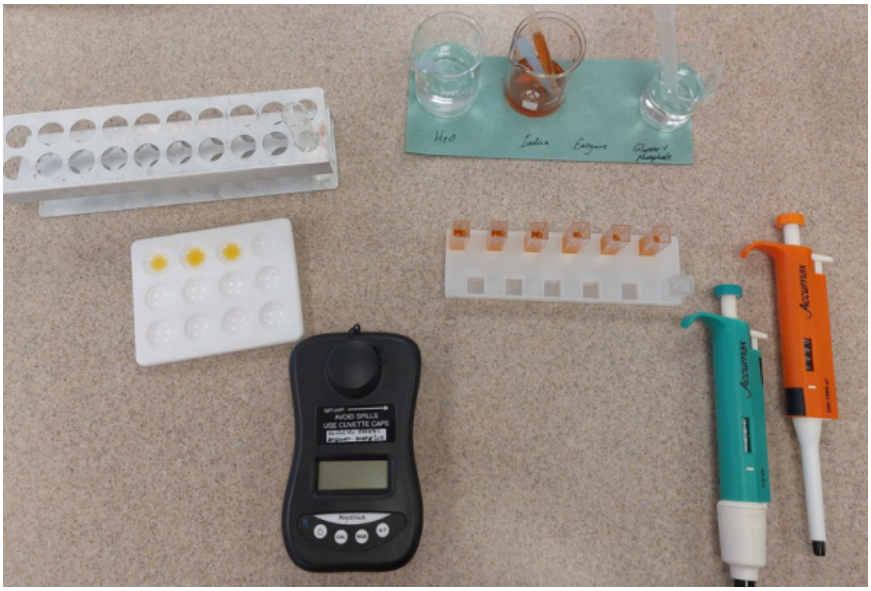

Figure 4 - Materials required for Part 2 of the investigation.

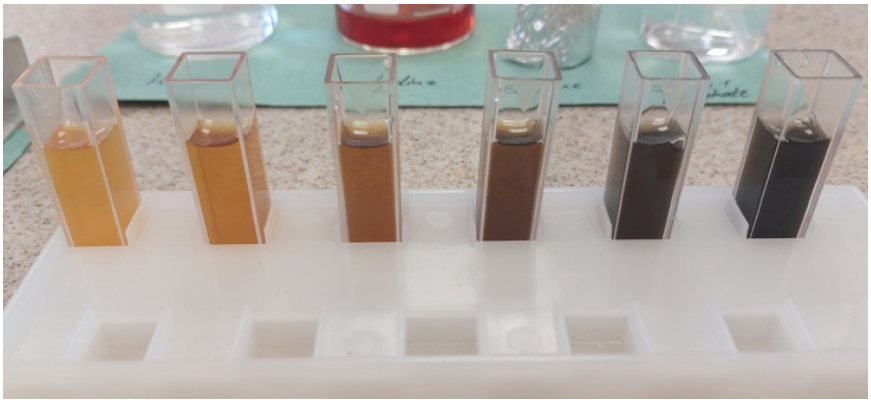

Figure 5 - Synthesis of starch from glucose-1-phosphate by phosphorylase over 5 minutes.

Time (s)	Absorbance				
	Trial 1	Trial 2	Trial3	Mean	Corrected mean
0	0.206	0.203	0.207	0.207	0.000
120	0.229	0.232	0.240	0.240	0.033
180	0.327	0.334	0.336	0.336	0.129
240	0.567	0.514	0.533	0.538	0.331
300	0.769	0.769	0.783	0.780	0.573
360	1.082	1.065	1.032	1.060	0.853

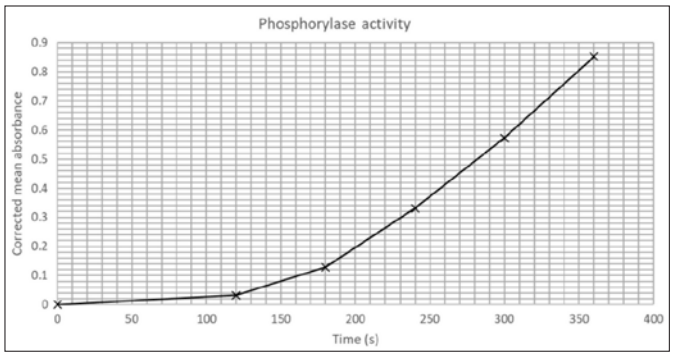

Figure 6 - Results obtained from the phosphorylase assay.

Materials

- 0.01 M iodine
- colorimeter (red diode)
- 9x cuvettes and rack
- 8x test tubes and rack
- 0.1 mg/ml starch suspension
- 0.2 mg/ml starch suspension
- 0.3 mg/ml starch suspension
- beaker of distilled water
- 1 cm³ automatic pipette and tips
- 10 cm³ measuring cylinder
- 3 cm³ plastic pipettes

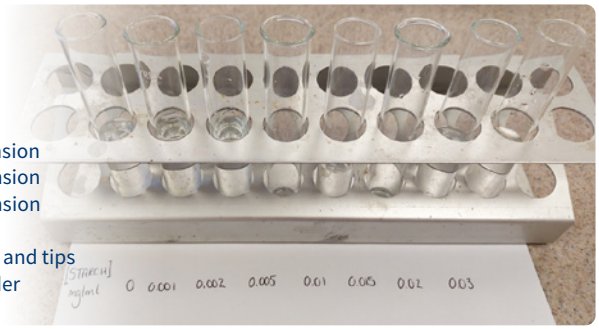

Figure 7 - Materials required to produce a starch standard curve.

Production of a standard curve

To extend this investigation for learners working at Advanced Higher level, a standard curve of starch can be plotted from which estimates of starch concentration synthesised during the phosphorylase assay can be made. Learners can develop their skills using measuring instruments to accurately prepare a dilution series of starch. These are then combined with iodine and the absorbance measured (Figure 7).

Learners should prepare a dilution series of starch to include concentrations of 0.001, 0.002, 0.005, 0.01, 0.015, 0.02 and 0.03 mg/ml starch. Once prepared, the following steps should be taken:

1) Collect 8 cuvettes: to cuvette 1, add 3 cm³ water (to zero the colorimeter); to cuvette 2-8, add 1 cm³ water and 1 cm³ iodine.
2) To cuvettes 2-7: add 1 cm³ appropriate starch suspension, working from the most dilute to the most concentrated.
3) Set the colorimeter to the red diode (or approximately 600 nm). Zero the colorimeter using the cuvette of water and then measure the absorbance of each solution.

Plot the results on graph paper or using a suitable graphing program, such as Excel. Add a line of best fit (hand-drawn graphs) or trendline (Excel). See Figure 9.

The data collected during the phosphorylase assay can be processed to estimate the starch concentration in each sample, as a result of phosphorylase action on the substrate glucose-1-phosphate. This can be done using the equation of the trendline of the standard curve.

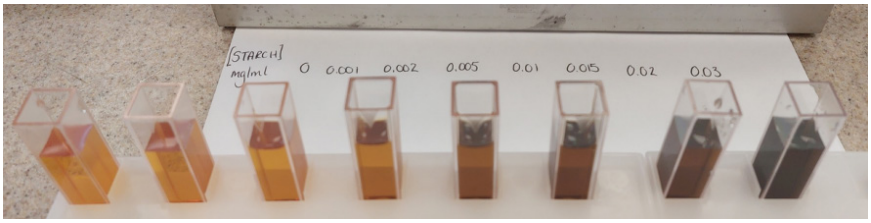

Figure 8 - A standard curve for starch can be produced from a suitable dilution series.

Starch Concentration (mg/ml)	Absorbance
0	
0.001	
0.002	
0.005	
0.01	
0.015	
0.02	
0.03	

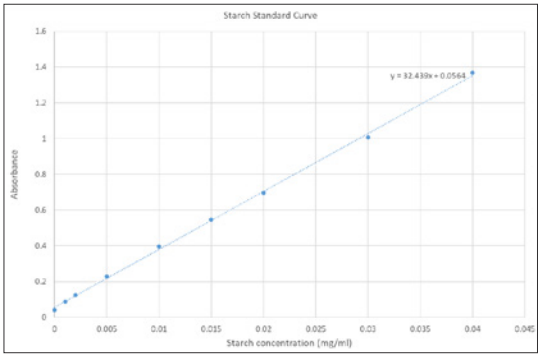

Figure 9 - Standard curve for starch.

Figure 10 provides sample results obtained at SSERC.

This protocol is available via the SSERC website, providing a breakdown of relevant calculations, support with the dilution series and technical support [2]. <<

Time (s)	Starch concentration (mg/ml)	Starch concentration (µg/ml)
0	0	0
120	0	0
180	0.002	2.2
240	0.008	8.5
300	0.016	15.9
360	0.025	24.5

Figure 10 - Concentration of starch synthesised by phosphorylase from glucose-1-phoshate over 6 minutes.

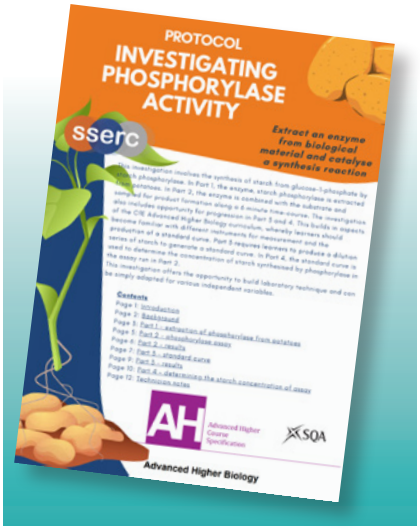

Figure 11 - SSERC's latest phosphorylase assay resource.

References

[1] Hanes, C.S. (1940), The reversible formation of starch from glucose-1-phosphate catalysed by potato phosphorylase, The Royal Society Publishing, available at https://royalsocietypublishing.org/doi/pdf/10.1098/rspb.1940.0035.

[2] SSERC (2023), Investigating phosphorylase activity, available at https://www.sserc.org.uk/wp-content/uploads/2023/08/Protocol-Phosphorylase-Activity.pdf.

Indicators

One of the most interesting and appealing topics in the whole of science is that of colour. While the fundamentals of colour are more usually covered in physics, once we get to the colours of materials – paints, dyes and the like, we are firmly in the realms of chemistry.

One group of coloured substances that is widely used from Early Years and Primary up to Advanced Higher and beyond is indicators, which have the benefit of being useful as well as aesthetically pleasing. This article sets out to give an overview of some of the more common types of indicators and their uses in chemistry.

Acid-base titrations

The most common type of chemical indicator is the acid-base indicator. These have a long history: the Spanish physician Arnaldus de Villa Nova began using litmus to study acids and bases in around 1300 and litmus, a dye extracted from certain species of lichen, has entered the language in general terms to refer to a diagnostic test.

Litmus in acid & alkali.

Litmus is an example of a 'natural' pH indicator and these are more common that might be imagined. Most learners are familiar with the impressive range of colours that can be generated from red cabbage.

However, there are many more natural compounds that change colour in different pH solutions. The largest group of these is the anthocyanins. These are all variations on the same basic structure (see Figure 1) with different groupings present.

Colours of red cabbage acid (l) to alkali (r).

These are the main compounds responsible for the colour of flowers - so many flower petals can be used as indicators. They are also widely found in fruits, particularly the darker ones such as brambles and elderberries.

Other plant materials that can be used as indicators are turmeric (cucurmin), tea (theoflavins), beetroot (betanin) and many more.

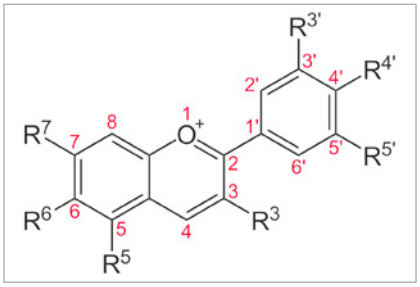

Figure 1 - Generic anthocyanin structure.

Commercial pH indicators

The pH indicators we use in the laboratory are not extracted from plants though. They are synthesized in a range of ways. Quite a lot of them are types of azo-dyes, though not all.

There are dozens of different indicators and they vary in both their colour changes and the pH at which these take place. Some of the ones that are most commonly encountered in schools are:

- Methyl orange which changes from red in acid to yellow in neutral/ alkali at around pH 4.
- Bromothymol blue which changes from yellow in acid to blue in alkali at about pH 7.
- Phenolphthalein which changes from colourless in acid/neutral to bright pink at around pH 9.

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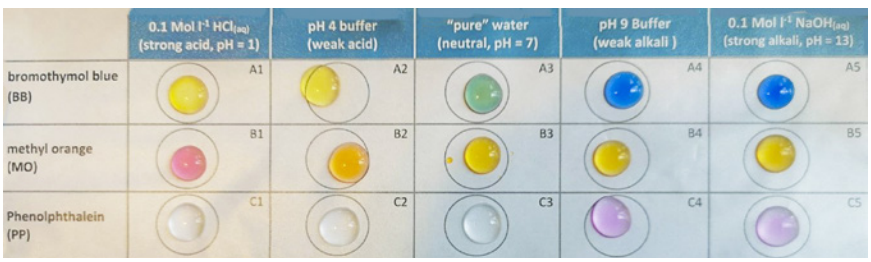

Colours of some common indicators.

Choosing a pH indicator

Indicators are widely used in acid-base titrations to show the end-point of the reaction. Depending on the nature of the acid and base involved, the pH of the end-point will be different and so different indicators are used.

Looking at these two titration curves (see Figure 2), the one at the top has a mod-point of about pH 7 so Bromothymol blue would be a suitable choice, while the one below it has a mid-point of a lower pH, around pH 5 so methyl red would be a better choice.

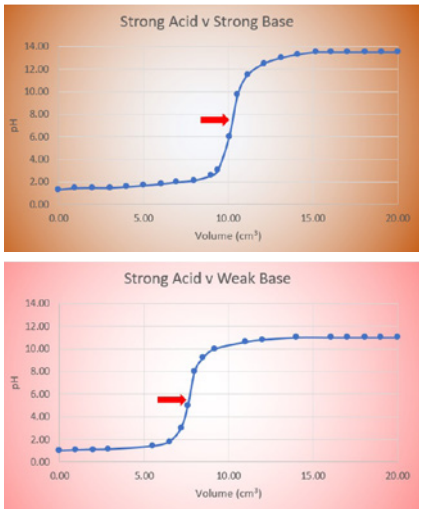

Figure 2 - Titration curves showing different mid-pointse.

How do pH indicators work?

pH indicators are weak acids. More than that, they have a different colour when protonated than when not. As a weak acid, the indicator will dissociate in solution as shown in this equation. (In = indicator molecule, HIn = protonated indicator)

$$HIn + H_2O \rightleftharpoons H_3O^+ + In^-$$

This dissociation of the weak acid indicator causes the solution to change colour.

The key point here is that this equation describes an equilibrium and as such it is subject to Le Chatelier's principle. So, if you add acid, you increase the concentration of H_3O^+ (H^+) the equilibrium is shifted to the right and as you remove H_3O^+ it shifts to the left.

Different indicators have their equivalence points (the 'balance' point of the equilibrium) at different pH values so with change colour at different points.

Redox titrations

Another main type of indicator is one used for finding the end point of redox reactions. In this case the different coloured forms are the oxidised and reduced form of the substance. Again, like with pH indicators, these two forms are in equilibrium (Figure 3).

Figure 3 - Iodine (l) and starch-iodine complex (r).

In this case, the indicators change colour at a specific electrode potential rather than pH, although some are pH dependent as well. Many redox titration, however, especially those carried out in schools and colleges, do not use separate indicators. They rely on colour changes inherent in the reaction.

For instance, titrating a reducing agent with a solution of iodine (yellow/brown) to produce iodide (colourless). Starch is usually used as an indicator to assist in the visualisation of a clear end-point though this is not actually a redox indicator.

Another example is titrating with potassium manganate VII, using the inherent purple colour of the permanganate ion as the indicator.

Complexiметric titrations

The third class of indicators include the starch mentioned above. In this class, the end point of the titration is indicated by the formation or dissolution of a sudden complex. The most common type of titration uses EDTA (ethylenediaminetetraacetic acid) as a titrant to determine a variety of metal cations: calcium and magnesium concentrations in water is a common experiment.

The reaction depends on the relative stability of different complexes. The indicator is added to the solution. For calcium or magnesium, murexide is a common one (Figure 4). This forms a red complex. The solution is >>

Figure 4 - Colour changes of murexide/magnesium complex (l) and uncomplexed murexide (r).

then titrated with EDTA. EDTA forms a more stable complex with the metal ions and so abstracts the metal leaving the non-complexed form of the indicator, which is blue.

$$MgIn^{-} + HY^{3-} \rightleftharpoons MgY^{2-} + HIn^{2-}$$
(Y = EDTA)

By varying the indicator and the pH at which the titration takes place, it is possible to vary the relative stability of the metal-indicator and metal-EDTA complexes.

Precipitation titrations

In this case, the titration involves the formation of a precipitate during the experiment. The titration is continued until the last of the precipitate is formed. At that point any excess titrant reacts with an indicator causing a colour change. The best-known example of this sort of titration is an argentometric titration, which is used to investigate the concentration of chloride (or other halides) by titration with silver nitrate (Figure 5). As the reaction proceeds, a precipitate of the silver halide is formed. Mohr's method uses potassium chromate as an indicator which forms red silver chromate at the end point. Farjan's method is similar but uses fluorescein dye that changes from yellow to pink at the endpoint.

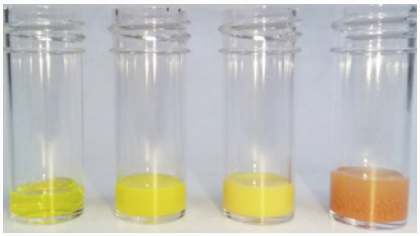

Figure 5 - Silver-chloride titration using fluorescein (Farjan's method).

Indicators and Art

It is possible to use the lovely colours generated by indicators for artistic purposes – a sort of pH related painting by numbers. There are some lovely examples, including the one here, in an article by Isobel Everest in Chem 13 News from a few years ago (Figure 6).

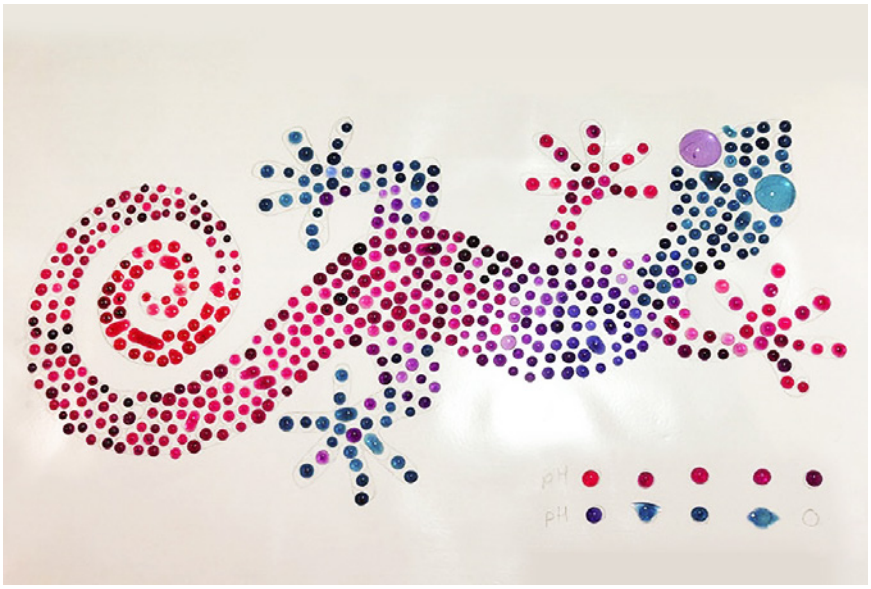

Figure 6 - PH Lizard made from drops of red cabbage indicator.

In conclusion

We have barely scratched the surface of this topic and as you can see there is a plethora of indicators that can be chosen from for a wide variety of purposes. Details of many, can be found on the SSERC website and if you need details of ones we don't list, just get in touch. <<

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