# Measuring gaseous carbon dioxide

## Background

The Biology Team in SSERC is responding to the publication of the Arrangements Documents [1, 2] for the Revised Highers in Biology and Human Biology through the publication of a series of protocols to support practical work. In due course, these protocols will appear on the Science 3-18 website [3] or in this Bulletin (for example [4]).

In Unit 2 (Metabolism and Survival), part 2 (Maintaining Metabolism) of the Revised Higher in Biology [1] one of the suggested learning activities and approaches is to '*Investigate metabolic rate using oxygen, carbon dioxide and temperature probes'*. The aims of this article are twofold *viz* (i) to show how gaseous $CO_2$ can be measured in experimental systems, and (ii) to highlight the availability from SSERC, via a loan system, of a set of carbon dioxide sensors.

## Equipment

A number of sensors are available which can measure gaseous carbon dioxide concentrations. We have opted to use the $CO_2$ gas sensor (Figure 1) manufactured by Vernier and marketed in the UK by Instruments Direct Services Ltd (www.inds.co.uk).

At the time of writing (January 2012) the sensor and Go!™ Link interface have a combined price, to include VAT and postage, of just under £400. The $CO_2$ gas sensor is designed to measure gaseous levels of $CO_2$ only and will not function in liquid systems. Useful User and Technical Guides are available on-line from Vernier [5].

## Interface / software

To connect the $CO_2$ gas sensors to our computers, we use the Vernier Go!Link interface and Logger Lite software package (PC and MAC versions are available) which comes with the interface (shown in Figure 2).

## How does the sensor work?

The basic structure of the sensor is shown schematically in Figure 3. Infra-red radiation is produced from a light emitting diode at one end of the sensor and is detected at the opposite end. $CO_2$ absorbs infra-red radiation and so at increased $CO_2$ concentrations less radiation will be detected. $CO_2$ moves in and out of the sensor by diffusion through one of the vent holes. The sensor is calibrated assuming an atmospheric $CO_2$ concentration of 380 ppm. Care should be taken if a re-calibration is deemed necessary since it is advisable to use 'fresh' air from outside rather than using air from a laboratory which will probably have a higher $CO_2$ level.


***Figure 1*** *- $CO_2$ gas sensor (Product code VR105512) from Instruments Direct Services Ltd.*


***Figure 2*** *- Go!™ Link interface and Logger Lite Software*

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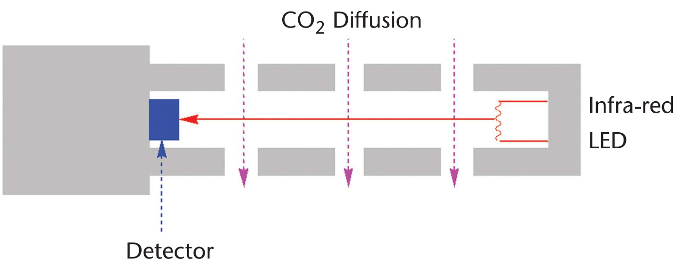


***Figure 3*** *- Schematic representation of the Vernier $CO_2$ gas sensor.*

## Experiments

For those looking for ideas for experiments involving measurement of gaseous $CO_2$, the article by Delpech [6] is highly recommended. In an unpublished experiment, Roger Delpech suggests measuring the carbon dioxide levels in the air space above UHT and pasteurised milk samples to show the presence or absence of viable microorganisms in samples – very impressive!

With the recent introduction of the Revised Higher Biology programme, some support materials which include an 'Experimental procedure for investigating respiration rates in germinating peas' based on the use of the Vernier $CO_2$ gas sensor have been published by LTScotland (now Education Scotland) [7]. In SSERC we have used the sensor with a variety of different protocols, all of which have been based on experiments published by Redding and Masterman [8].

In our view an experiment which shows carbon dioxide uptake and release by plants is a particularly interesting and valuable exercise. The basic experimental set-up is shown in Figure 4 and in this case we have taken 6 leaves from a basil plant. However, we have successfully used a variety of plants for this purpose. A tissue culture flask filled with water (to act as a heat sink) is placed in front of the experimental chamber into which the $CO_2$ sensor is placed. The light source is a small desk lamp although a range of lamps could be used. The detailed protocol is available elsewhere [3] but briefly:


***Figure 4*** *- Experimental set-up for measuring respiration and photosynthesis rates in plants.*

- Leaves are placed into the respiration chamber which is wrapped in aluminium foil so as to exclude light.
- The $CO_2$ sensor is placed into the chamber and data collected for about 10 min.
- The aluminium foil is removed and the lamp switched on and data collected for a further 10 min.

Figure 5 shows the results obtained using the experimental set-up in Figure 4. The experimental chamber was initially covered for about 800 seconds. During this period $CO_2$ levels are seen to rise as the process of respiration takes place. The lamp is then switched on. This shows a leveling off of $CO_2$ concentration and shortly thereafter (at about 960 s) $CO_2$ concentration starts to fall as photosynthesis dominates. The software package allows for linear regression analysis of sections chosen by the user. For the data in Figure 5 it is sufficient to record that the rate of respiration and the apparent rate of photosynthesis can be readily determined

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(note that the apparent rate of photosynthesis is lower than the true photosynthetic rate since we can assume that respiration continues while photosynthesis takes place).

It is entirely possible to investigate factors which affect the rate of photosynthesis. So for example the experimental chamber can be wrapped in filters of different colour (such filters can be readily obtained [9]) and protocols available on the SAPS website [10] can be adapted for this purpose). Judicious use of neutral density filters (also available from Lee Filters [9]) can lead to estimation of the compensation point in an extension to a previous experiment suggested by Rodger McAndrew [11].

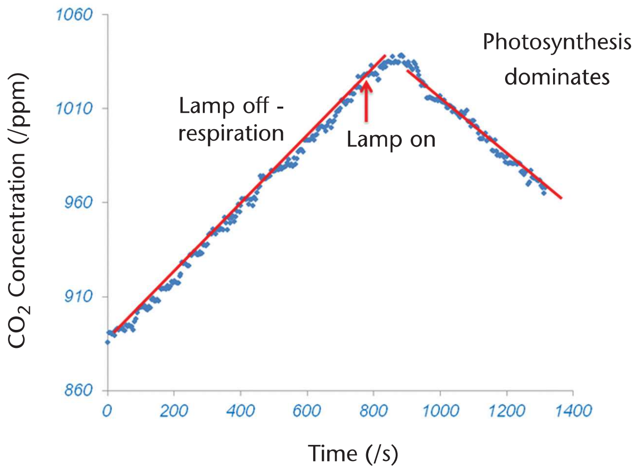


***Figure 5*** *- Carbon dioxide levels in the absence and presence of light (see text for detailed explanation)*

## SSERC Support

We recognise that the costs of purchasing $CO_2$ sensors may be prohibitive, given the current financial constraints under which most science departments are operating. We are able to offer, through a loan system, six $CO_2$ sensors together with associated software and interfaces. We anticipate high demand for such a service and so we would recommend contacting us as soon as possible if you or your colleagues wish to take up this offer. Anyone wishing to borrow the $CO_2$ sensors from SSERC should, in the first instance, contact sts@sserc.org.uk.

## References

[1] SQA (2010) Biology (revised) Higher – the Arrangements Document can be downloaded at http://www.sqa.org.uk/sqa/files_ccc/HigherBiologyCourseSpec.pdf (accessed 30th January 2012).

[2] SQA (2010) Human Biology (revised) Higher – the Arrangements Document can be downloaded at http://www.sqa.org.uk/sqa/files_ccc/HigherHumanBiologyCourseSpec.pdf (accessed 30th January 2012).

[3] The Science 3-18 website is available at www.science3-18.org. Please note that to access all resources on the website you will need to register and be provided with a log-on ID and password.

[4] Beaumont, P.C., Moore, G. and Crawford, K. (2010) Polymerase Chain Reaction - don't assume what it says in the text books –prove it! *SSERC Bulletin* **233**, *4-5*.

[5] User and Technical Guides are available at http://www2.vernier.com/booklets/co2-bta.pdf and http://www.vernier.com/til/1366.html respectively (accessed 30th January 2012).

[6] Delpech, R. (2006), Making the invisible visible: monitoring levels of gaseous carbon dioxide in the field and classroom, School Science Review, **87** (320), *41-51*. The full article can be downloaded at http://www.saps.org.uk/attachments/article/287/Making_the_invisible_visible.pdf (accessed 30th January 2012).

[7] Learning and Teaching Scotland (2011) Biology: Skills of Scientific Experimentation, Investigation and Enquiry – available at http://www.ltscotland.org.uk/nationalqualifications/resources/b/nqresource_tcm4649410.asp (accessed 30th January 2012).

[8] Redding, K. & Masterman, D. (2007), Biology with Vernier, Vernier Software & Technology, Beaverton, OR 97005-2886, USA. Aspects of this publication can be downloaded at http://www.vernier.com/cmat/bwv.html (accessed 30th January 2012).

[9] Lee Filters - see http://www.leefilters.com (accessed 30th January 2012).

[10] Anon (2011) The effect of light colour and intensity on the rate of photosynthesis – available at http://www.saps.org.uk/attachments/article/130/SAPS%20-%20the%20effect%20of%20light%20colour%20on%20photosynthesis.pdf (accessed July 30th January 2012).

[11] McAndrew, R. (2008) Investigating the Compensation Point of Algae. *SSERC Bulletin* **225**, *6-7*.