Diet drinks and Mentos™:

Figure 1 *- Geyser Tube arrangement with 3 Mentos™ in place. Removal of the pin (located just underneath the Mentos™) releases the Mentos™ into the bottle.*

Background

In a recent article in this Bulletin [1] we explored a number of possible ways in which fluorescence might be demonstrated in the classroom. We hinted in that article that we would continue to search for carbonated drinks so that we might produce a variant of the so-called Diet Coke™/Mentos™ eruption [2-4] in which different colours of fluorescence were produced; our intention at that time was to produce a rainbow of colours. Thus far, our search for commercially available fluorescent carbonated drinks has been disappointing in terms of results other than tonic water in which blue fluorescence arises from the quinine contained therein. The only other possible candidate for inclusion which we found, despite intensive researches in local supermarkets, was Red Bull™ although the level of fluorescence obtained under UV illumination was low compared to that obtained from tonic water. We did get quite excited after buying a bottle of Mountain Dew Energy® only to find that the yellow-green fluorescence we observed was from the container rather than the contents! Undeterred by our inability to locate suitable materials we decided to add fluorescent materials to diet lemonade to provide us with a range of colours of the rainbow. Lemonade was chosen because it is readily available, non-fluorescent and 'cheap'. We wish to present the results of our researches here.

Methods

The UV lamp (catalogue XX-40BLB) we used was from Ultra-Violet Products Ltd. (Trinity Hall Farm Estate, Nuffield Road, Cambridge CB4 1TG (see http://uvp.com) with a peak emission wavelength of 365 nm.

In all experiments reported here we used 'diet' carbonated drinks since the residues which we occasionally produced on benches, and in extreme cases ceilings, of the laboratory could be more easily removed. Proprietary brands of drinks were used without special preparations being made; so for example Schweppes Diet Tonic Water™ was used. In most of the experiments reported we used Premium Diet Lemonade from Tesco; this choice being based on 2 key factors *viz* (i) both container and lemonade were non-fluorescent when viewed under UV light, and (ii) the drink was on 'special offer' on the day of purchase.

Rhodamine B and Rhodamine 6G and were drawn from laboratory stock (both were from Aldrich - www.sigmaaldrich.com/) and used without further purification. Aqueous stock solutions of the dyes were prepared at a concentration of 5 x 10^{-4} mol dm^{-3} and appropriate aliquots (typically 30 – 40 cm^3) of these solutions were added to bottles (1 dm^3) of diet lemonade at room temperature. To produce green fluorescence we used Tesco Lemon All Purpose Cleaner*™* and in this case approximately 40 cm^3 of undiluted cleaner was added to a bottle (1 dm^3) of diet lemonade. Mentos™ were released into the carbonated drinks using a 'Geyser Tube' (available from a number of sources including Amazon [www.amazon.co.uk]). A typical set-up is shown in Figure 1.

A novel twist on an old favourite

Those familiar with the Diet Coke™/Mentos™ experiment and its variants will know that significant volumes of liquid can be released and typically this activity is not normally performed indoors. The experiments described here require the environment to be blacked out or, at the very least, lighting levels should be kept to a minimum and for this reason it is convenient to perform the experiment indoors. Consequently, you will need to consider how best to reduce the effects of spillages. We place our carbonated drinks bottles (1 dm^3) in the centre of a large paddling pool (Figure 2) and we find that of the 500 cm^3 of liquid typically released (the actual volume released depends on a number of factors including the number of Mentos™ used and temperature of the carbonated drink) some 90%+ of this volume falls back into the paddling pool. In line with good laboratory practice, we recommend that the demonstrator wears eye protection. Clearly it is important to avoid directing the liquid at any electrical (e.g. ceiling lights) or sensitive equipment and we recommend that the UV lamp should be kept at a minimum of 2 m from the drinks bottle.

Results

Our choice of fluorescent dye was based on a number of criteria:

- water solubility
- availability at (relatively) low cost
- high yield of fluorescence
- suitable absorption properties – our excitation source is a UV lamp emitting predominantly at 365 nm
- low toxicological concerns at the concentrations used.

In looking to produce the colours of the rainbow we immediately encountered a problem in that it has proved a challenge too far to identify a substance which meets the above selection criteria and emits violet fluorescence. We made reasonable progress with other parts of the spectrum and our results are shown in Figure 3.

The amount of fluorescence emitted by a sample is related to (i) the fluorescence efficiency, Φ_F, (i.e. the ratio of emitted photons to absorbed photons), and (ii) the extent to which excitation light (in this case 365 nm) is absorbed by the sample. The fact that the fluorescence fountains observed are not all of the same light intensity can be explained by consideration of these 2 factors. We would be keen to hear from anyone who can suggest dyes which display fluorescence in the violet or red portions of the spectrum and which additionally meet the criteria in the Methods section.

It had been our original intention to use fluorescein as one of our chosen dyes but the observed yield of fluorescence was quite low under the conditions used. In part the explanation for this is that Φ_F for fluorescein is pH dependent. At pH 3 (the approximate pH of the lemonade used) Φ_F is reduced by some 90% compared to that at pH 7 [5]. Tesco Lemon All Purpose Cleaner™ contains the trisodium salt of 8-hydroxypyrene-1,3,6-trisulfonic acid (also known as pyranine and Solvent Green 7) as the fluorophore (information taken from http://www.detergentinfo.com/) and the yield of fluorescence is appreciable and apparently not affected by changes in pH.

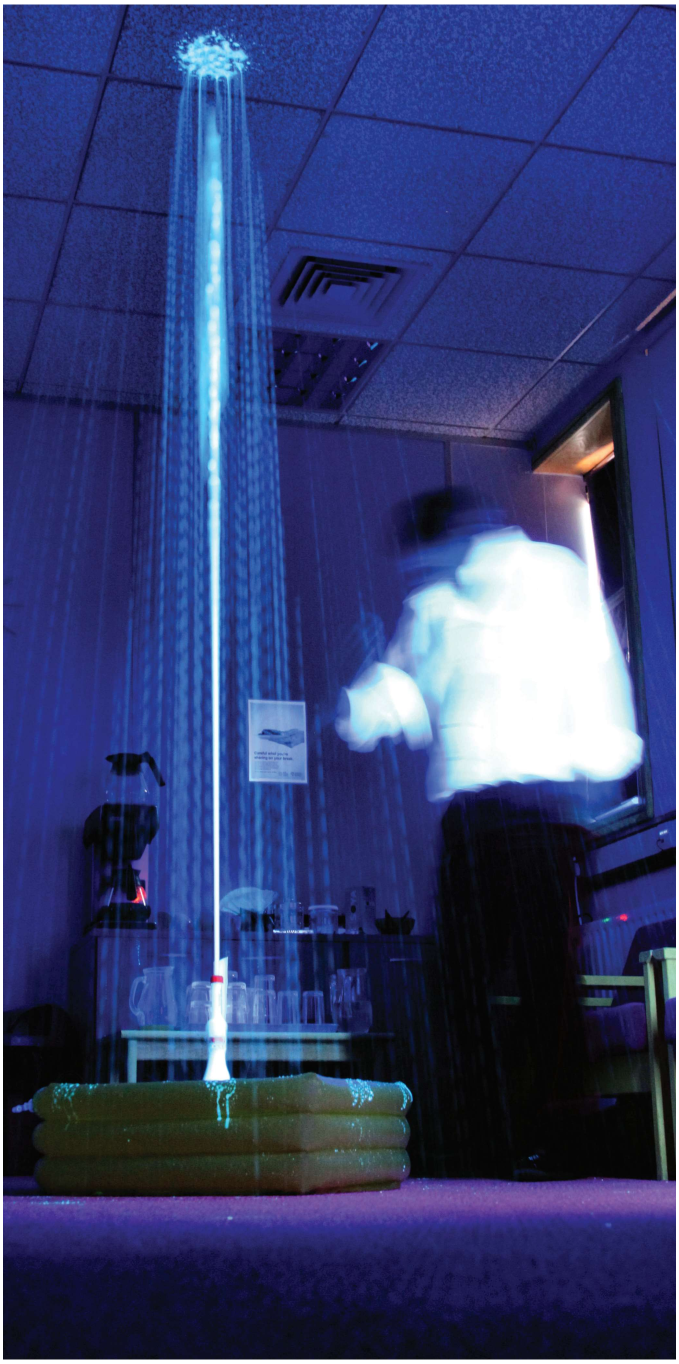

Figure 2 *- Diet tonic water + Mentos™ eruption. Illumination was from a 365 nm UV lamp located just out of camera shot.*

Diet drinks and Mentos™ cont.

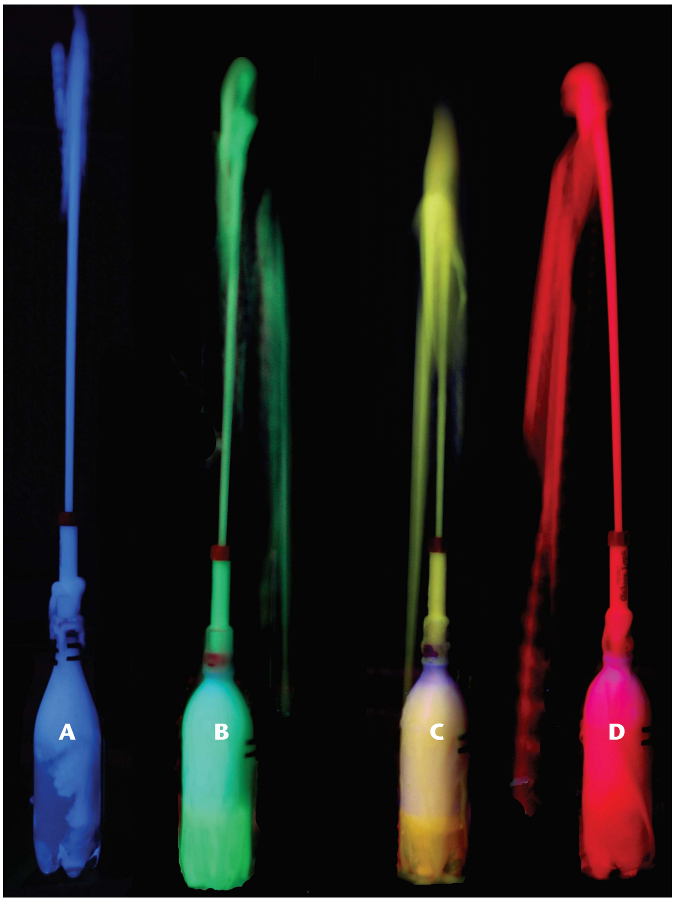

Figure 3 - The Mentos™ eruption in the presence of fluorescent dyes and illuminated with UV (365 nm) light. In each case 2 Mentos™ were added via a Geyser Tube.

A *Tonic water*
B *Lemonade + Tesco Lemon All Purpose Cleaner™ (40 cm^3 cleaner added to 1 dm^3 of lemonade)*
C *Lemonade + Rhodamine 6G (1.5 x 10^{-5} mol dm^{-3})*
D *Lemonade + Rhodamine B (1.5 x 10^{-5} mol dm^{-3})*

We recognise that the costs of the rhodamine dyes used in these experiments may be beyond the scope of many school budgets in the current economic climate but we anticipate that access to diet tonic water, diet lemonade and Tesco Lemon All Purpose Cleaner™ should not be too problematic. If you have a UV lamp and a room which can be blacked out we thoroughly recommend that you try one or more of the fluorescent combinations described here.

This article is based on a manuscript accepted for publication elsewhere [7].

Curriculum Links to *CFE* [6]

By exploring radiations beyond the visible, I can describe a selected application, discussing the advantages and limitations [SCN 3-11b].

By carrying out a comparison of the properties of parts of the electromagnetic spectrum beyond the visible, I can explain the use of radiation and discuss how this has impacted upon society and our quality of life [SCN 4-11b].

Safety

None of the experiments here present significant health and safety risks provided standard laboratory practices are observed. Eye protection to reduce exposure to UV light should be worn by those carrying out the experiment. We recommend that the experiments, as described, should not be carried out by students.

At the final concentrations used the fluorescent dyes do not pose significant health risks although care should be taken when handling pure rhodamine dyes and undiluted Tesco Lemon All Purpose Cleaner™. In preparing stock solutions of rhodamine dyes appropriate care should be taken to avoid skin and eye contact.

References

[1] Beaumont, P.C. (2011) Fun with fluorescence! *SSERC Bulletin*, **236**, 7-9. See also http://www.science318.org/sserc/images/Bulletins/ 236/Fun_with_Fluorescence.pdf

[2] Wikipedia (2011), Soda and candy eruption. Available at http://en.wikipedia.org/wiki/Soda_and_candy_eruption (accessed January 2012).

[3] Coffey, T.S. (2008a), Diet Coke and Mentos: What is really behind this physical reaction? *Am. J. Phys.* **76**, 551-557.

[4] Coffey, T.S. (2008b), Soda Pop Fizz-ics. *The Physics Teacher*, 46, 473-476.

[5] Haugland, R.P. (2002), *Handbook of Fluorescent Probes and Research Products,* (9th Edition), Molecular Probes, Eugene OR, USA.

[6] Curriculum for Excellence: Sciences - Experiences and outcomes – available at http://www.ltscotland.org.uk/learningteachingandassessment/ curriculumareas/sciences/eandos/index.asp (accessed January 2012).

[7] Beaumont, P.C., Boswell, A. and Lloyd, C. (2012) Diet drinks and Mentos™: A novel twist on an old favourite, *School Science Review*, in press.