Fun with Fluorescence!

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We are all probably familiar with materials which fluoresce. In this article we discuss some examples of fluorescence and how these can be explored in a classroom context. It is useful to consider what we mean by the term fluorescence and a useful starting definition is '*The emission of light by a substance that has absorbed light or other electromagnetic radiation of a different wavelength'* [1]. With very few exceptions, the fluorescence emitted by a substance is at a longer wavelength than the light which has been absorbed (shown schematically in Figure 1).

In general, the colour of the incident light does not affect the colour of the emitted light provided the light is actually absorbed by the substance. So in the system shown in Figure 1 the blue light could be replaced with ultraviolet light and if this were absorbed it would still give rise to green fluorescence. An example of this phenomenon is shown in Figure 2 where we have placed a solution of fluorescein under UV, blue and red light. The fluorescence from the fluorescein solution is only observed with incident UV and blue light. Since both UV and blue light have greater energy than the colour of the emitted light [green/yellow]), fluorescence is produced. On the other hand red light, being of lower energy than the wavelengths of light emitted by the fluorescein, is not absorbed and so fails to produce fluorescence although some scattering of the red light can be observed.

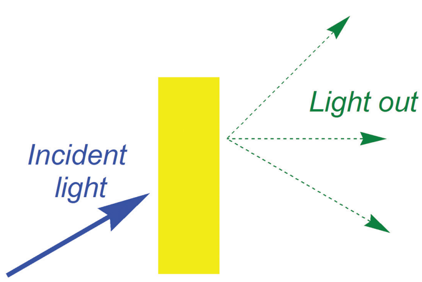

Figure 1 - Schematic representation of fluorescence. Incident, blue light is absorbed by a substance/object (shown in yellow) and fluorescence is shown as emitted green light.

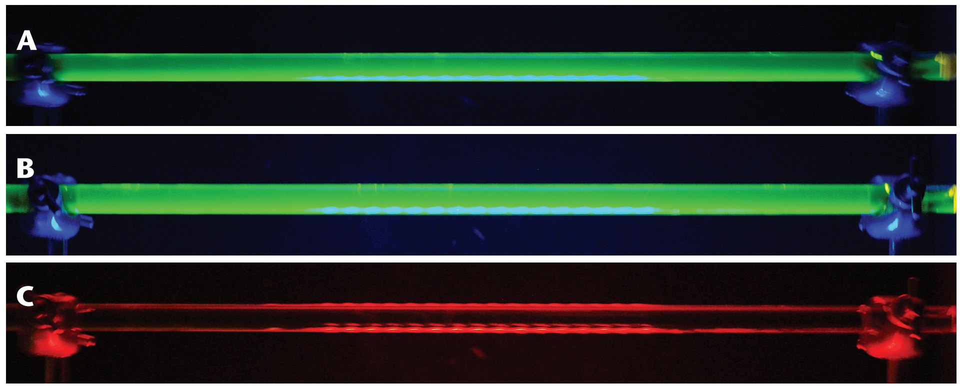

Figure 2 - Aqueous solution of fluorescein contained in a glass tube. (A) light source UV (365 nm); (B) light source blue (450 nm) (C) light source red (620 nm).

Fluorescence in the green-yellow part of the spectrum is often utilised in high-visibility materials. Fluorescence in this part of the visible spectrum is used because these colours are those most readily seen by eye although other colours (oranges and pinks) are also used in specialised cases (there is some interesting background information on high visibility clothing, and why certain colours are used, on the *Brightkidz* website [2]).

Figure 3 - High visibility jacket – image taken from [2].

The observation [3] that bananas display different fluorescent properties according to their ripeness (see Figure 4) was first noted in the literature as recently as 2008 and the phenomenon has been more widely explored by MacCormac *et al*. [4] who showed that a number of foodstuffs fluoresce when illuminated under UV light. The suggestion [5] of using welding equipment to observe fluorescence from bananas does, however, seem somewhat extreme. The blue fluorescence in bananas is thought [3] to arise from abundant "fluorescent" catabolites which are intermediates of chlorophyll breakdown. As the banana ripens further these intermediate catabolites are broken down into non-fluorescent products.

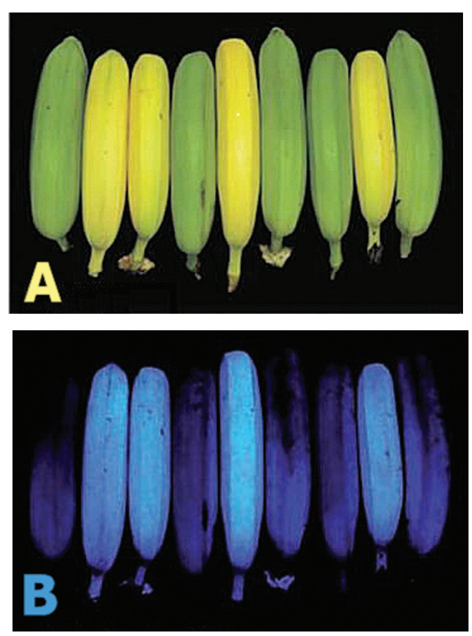

Figure 4 - Yellow bananas are blue luminescent. Yellow (ripe) and green (unripe) bananas under white light (A) and under UV light at a wavelength of 366 nm (B). Images taken from [3].

Encouraged by the relative ease with which fluorescence from foodstuffs can be seen, we decided to look at a range of samples in our local supermarket to see what might be available. So, for example in Figure 5 we show samples of split yellow peas (Tesco *Whole Foods*), soup

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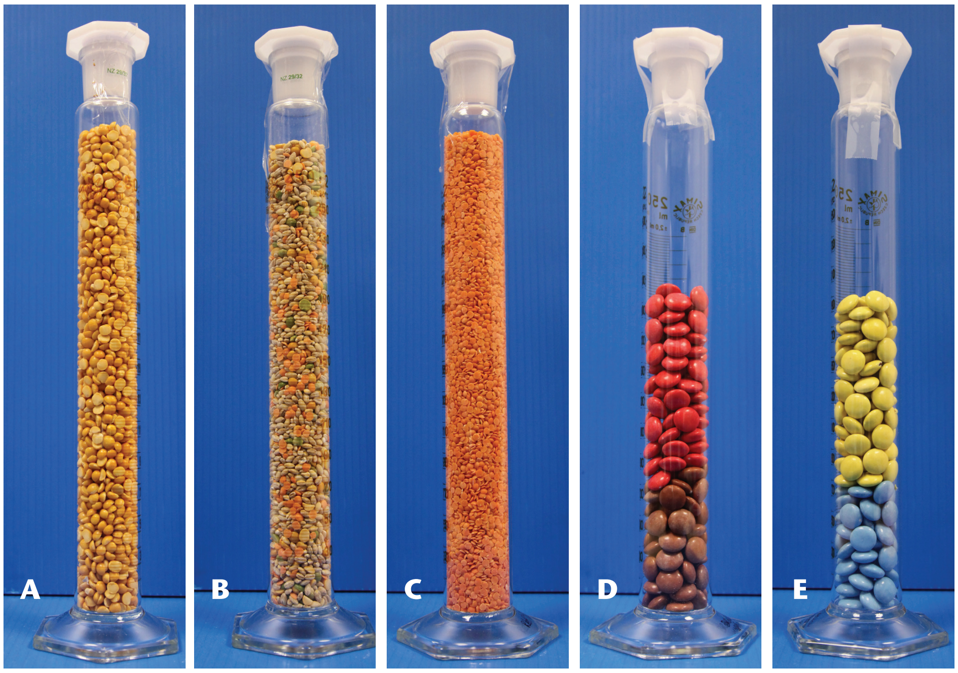

Figure 5 - Samples of (A) split yellow peas (Tesco 'Whole Foods'), (B) soup and broth mix (Tesco 'Whole Foods'), (C) red split lentils (Great Scot), (D) red and brown Smarties®, (E) yellow and blue Smarties®. All samples photographed under 'normal' laboratory lighting conditions.

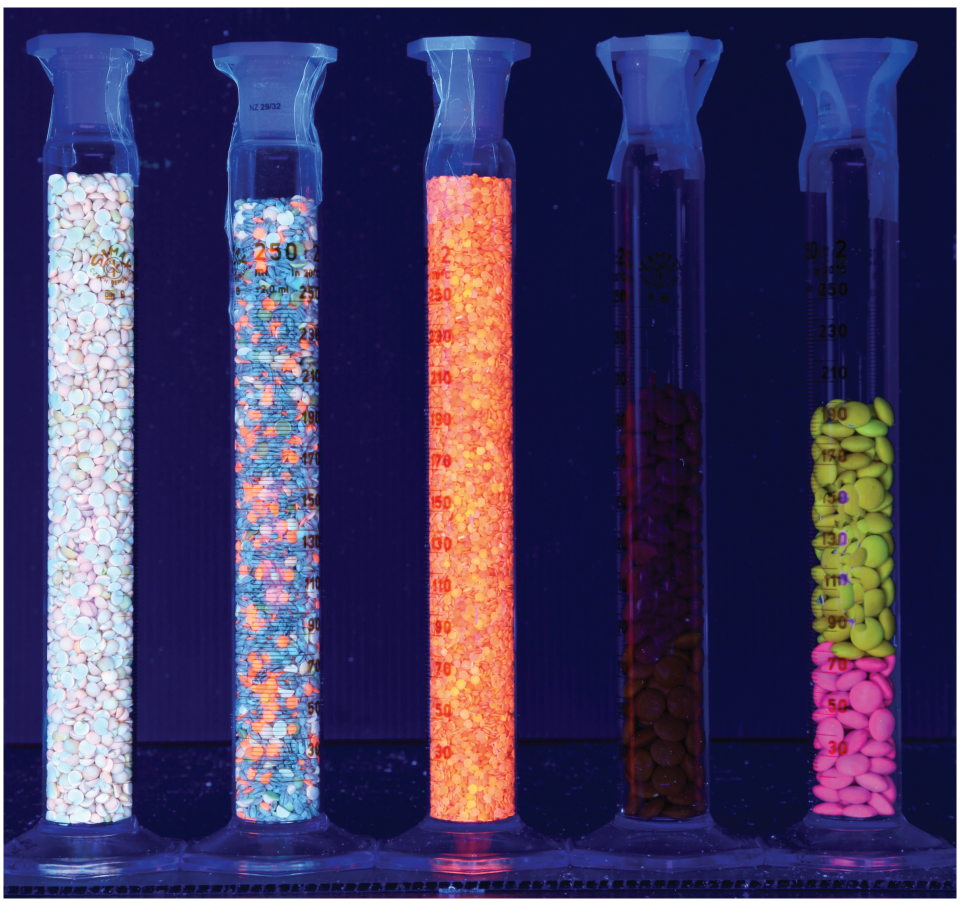

Figure 6 - The effect of UV light (365 nm) on (from left) of split yellow peas, soup and broth mix, red split lentils, red and brown Smarties®, yellow and blue Smarties®.

and broth mix (Tesco *Whole Foods*), and red split lentils (*Great Scot*). In each case we show samples illuminated under laboratory conditions. Under UV light (Figure 6) it can be seen that red lentils emit bright orange/red fluorescence under these conditions. Some, but not all, of the fluorescence in the soup and broth mix arises from the red split lentils present (the composition on the packet is given as pearl barley 55%, yellow split peas 18%, green split peas 9%, marrowfat peas 9%, and red split lentils 9%). It seems unlikely in these cases that food additives are the cause of the observed fluorescence. Chlorophyll in red split lentils is reported [4] to be the molecule which gives rise to the red fluorescence.

Of course visiting your supermarket opens up all sorts of possibilities for exciting field trips and investigations in the confectionary aisle(s) (see images 5D and 5E). It should be pointed out that the rationale behind selecting a given product was based on personal choice rather than an attempt to make a comprehensive survey (sweets that turn out to be non-fluorescent are of course potentially available for consumption!). So, for example, it is definitely worth looking at Haribo® Tangfastics® under a UV lamp! A particularly interesting observation is that red and brown Smarties® are, to all intents and purposes, non–fluorescent when illuminated with UV light. By contrast, however, yellow and blue Smarties® are highly fluorescent and whilst yellow Smarties® fluoresce in the yellow part of the spectrum we were surprised to observe that blue Smarties® are pink when observed under UV illumination. Much has been written about the various colours of Smarties® (see for example [6, 7]) and in particular the history associated with blue Smarties®. It appears that the dye used to colour blue Smarties® is extracted from *Spirulina* –a possible investigation in the making?

Extending our researches into the drinks arena has been relatively disappointing with the exception of tonic water which when illuminated with UV light emits a blue fluorescence (Figure 7 and front cover); the molecule responsible for the

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blue fluorescence being quinine. 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 plastic bottle rather than the drink itself!

The observation of fluorescence in tonic water allows us to adapt one of the most popular demonstrations - the so-called Diet Coke®/Mentos® eruption [8].

Explanations of the reactions which bring about the eruption have been well described in the literature [9, 10]. Briefly, nucleation sites on the surface of the Mentos® allow dissolved CO_2 to form bubbles and these are then rapidly released from solution.

A number of video clips of the demonstration exist but one of our favourites is the 'The Extreme Diet Coke & Mentos Experiments' [11]. Virtually any carbonated drink can be substituted for the Diet Coke® including tonic water [10].

So the tonic water/Mentos™ eruption is the basis for a beautiful demonstration in a room darkened except for a UV lamp (see Figure 7).

Our search for alternative carbonated drinks with different fluorescent properties continues; who knows one day we may be able to report on a fluorescent rainbow…

***Figure 7** - Diet tonic water + Mentos®. Just visible at the top right hand corner of the photograph is the UV light source used as an illumination source.*

What next?

In a future issue of the Bulletin we will report on how observation and measurement of fluorescence is providing new insights into structure and function in biological systems.

Curriculum links to CFE [12]

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 electro-magnetic 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*].

Equipment

Many of the experiments / activities described in this short article can be undertaken using portable UV lamps. If your budgets permit we would recommend the purchase of a large lamp such as an XX-40BLB manufactured by UVP (see www.uvp.com).

This lamp is available from a number of UK suppliers and the current catalogue price is of the order of £230. Such a lamp has many practical applications across the sciences.

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