Key Stage 5 – Spectroscopy

Notes for teachers

At a glance

Scientists working on the QCUMbER project led by the University of Oxford have found ways to imprint quantum pulses of light with spectra. This would potentially allow us to send and receive more information, more securely, through fibre optic networks. A key part of the process of sending information uses spectroscopy. This is a tool used for a variety of different scientific research.

In this lesson students make their own spectroscope and find out more about how emission lines are formed.

Learning Outcomes

- Light from various sources can be split into its component parts using prisms or diffraction gratings.
- Heated elements produce a set of emission lines that are characteristic to that particular element.
- Light from stars, including our sun, has lines in characteristic places that correspond to the emission lines seen in its component elements.

Each student will need

- A spectroscope/diffraction grating (this can be one made with a CD – see below).
- Access to emission tubes or pictures of emission spectra for elements.
- Student sheets.

Possible Lesson Activities

1. **Starter activity**
    - Ask the students to watch the Oxford Sparks 'What are quantum rainbows?' animation (see weblinks).
    - Remind the students that the QCUMbER project relies on successfully imprinting photons with a spectrum, using that to send information and then being able to 'read' the spectrum at the other end.
    - In order to read spectra, a common tool used by scientists is spectrometry.

2. **Main activity: Making a CD spectroscope (optional) and using a spectroscope/diffraction grating**
    - Students can make their own spectrometer using the template from 'Toys from Trash' (see weblinks section) this can work well, but the spectra observed will depend on how well made the spectrometer is. You may wish to provide your own spectrometers or diffraction gratings for viewing light sources.
    - Tips for making the spectroscopes
        - Make the spectroscope yourself first. This will both give you an example for students to copy and also an idea of the various stages involved.
        - If your school has access to a laser cutter it might be possible to cut out the template on that.
        - It is difficult, but not impossible, to cut out the slits well with scissors and far easier to do this with a craft knife.
        - Students often fold the model the wrong way when making the spectroscope. In particular they tend to fold the bottom flaps in rather than out. Get them to check the pictures in the instructions often. Encourage them to look at your example if they get stuck.
        - CDs seem to work better than DVDs for this. They can be cut in advance into wedge shapes with sharp scissors/a guillotine blade although this will probably dull the blades.
        - Make sure students are looking through the right slit when they use it.
        - There's a bit of trial and error involved with finding the right angle to view spectra clearly. Encourage them to keep trying.
    - Ask the students to look at light from a variety of light sources including sunlight (through a window is fine) and fluorescent lighting.
    - If you have a set of emission tubes, it would be good to allow them to look at the light through this as well. Alternatively a set of pictures of emission lines from elements could be used (see weblinks).
    - They should see that sunlight appears as a continuous spectrum and that artificial lights are usually made up of bright bands or lines of colour. Similarly the emission tubes should show lines of colour too.

3. **Main activity: Emission Spectra**
   - Give the students the student sheets to read and get them to work through the calculations.

Answers: Wavelength emitted = 589nm ; Wavelength emitted = 413nm

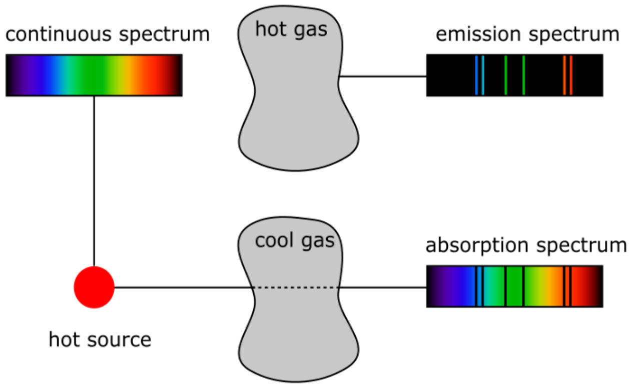
4. **Plenary**
   - Uses of spectroscopy

   Spectroscopy is a useful tool for scientists and can be used for a variety of purposes. One use is to look at the light from stars. Light from stars has characteristic lines in characteristic places (like the emission spectra) and so scientists can tell which elements are in the stars by looking at the light.

   - **OPTIONAL-** Absorption spectra

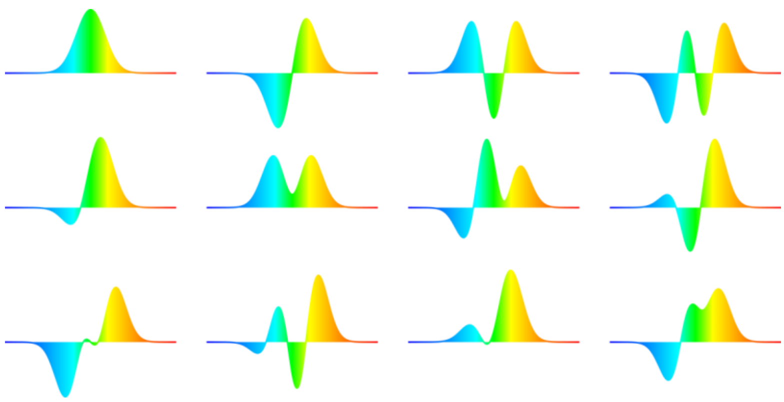
     In fact, the light from stars, such as out sun, does not appear the same as in emission spectra. Instead it appears as a continuous spectrum with dark lines crossing the spectrum corresponding to the coloured lines in the emission spectrum. These are absorption lines.

     We can think of the sun as a hot light source of dense gas producing a continuum of light that is surrounded by cooler gases. The cooler gases absorb energy at specific wavelengths and so we see a continuum of light with bits missing where the cooler gases have absorbed the light (Fraunhofer lines in the sun). The cooler outer gases reemit the light in all directions. If we could observe just the outer gases we would see emission lines from this reemitted light. Normally when looking at the sun these emissions are overwhelmed by the main source of light, but if we look at the cooler outer gases during an eclipse an emission spectrum can be seen. Similarly if we look at the light from nebulae (clouds of cooler gases) then they appear as emission, not absorption spectra.



   - Use of spectrometry for QCUMbER

     Let students know that for the QCUMbER project each quantum light pulse contains a continuous spectrum but the spectra they imprint can be different shapes (see below). So they need to look at the amplitude and phase of the light before they can be sure what type of light pulse they have received.



Weblinks

- Oxford Sparks 'What are quantum rainbows?' animation: https://www.oxfordsparks.ox.ac.uk/content/what-are-quantum-rainbows
- Spectroscope template and instructions: http://www.arvindguptatoys.com/toys/CDspectroscope0.html
- NASA page on using light to study planets (includes images of emission spectra): https://www.jpl.nasa.gov/edu/teach/activity/using-light-to-study-planets/