Project 1

Observation and inference

Emission competition

- Themed lesson guide for teachers
- Teacher's project guide
- Class project instructions
- Student project portfolio

This project is extracted from Analytical Chemistry in Ireland
More projects and resources available from https://rsc.li/3P00Lfl

THEMED LESSON GUIDE FOR TEACHERS

Emission competition

Focus: **observation and inference.** Two–three lesson plan

1

This is a collection of lesson ideas to support students as they explore and develop their thoughts and skills in analytical chemistry. Through a flame test experiment and building a DIY spectrometer, students will get to consider the actual observation of scientific phenomena and compare it with the scientific skill of drawing conclusions based on data.

This project contains:
- a teacher-led practical;
- a student introduction to spectroscopy via a DIY spectroscope activity;
- a competitive student project based on carrying out flame tests which finishes with a photography competition to further enhance the 'observation' theme.

The first lesson opens with the inspiring story of an Irish teenager who won the Google Science Fair prize, which involved building his own spectrometer.

The section is fully supported by a PowerPoint presentation which guides the discussion to focus on the collection of data, asking the questions: 'What are the different ways in which scientists achieve this?' and 'What is the best way to present it?' Both questions feed into the photography competition.

Learning objectives

On completion of the project students will:
- be able to recall why scientists collect data, explain what an experimental observation is, and discuss the difference between observation and inference;
- have constructed a model spectroscope which will generate observable phenomenon;
- be able to carry out flame tests and have participated in a photography competition based on what they observed while carrying out their tests.

Pre-planning

- Collect some prizes for the winning photographs.
- Consider how you would like to receive the photographs – students could submit photos by email, or produce poster presentations.
- Consider printing and framing the winning entries to encourage future and current students.

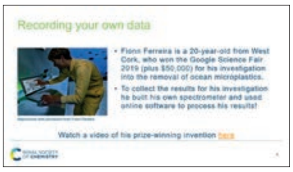
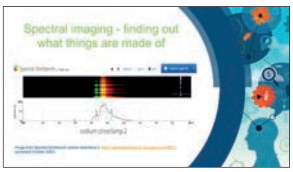
General equipment

- Black A4 card (alternatively colour white card black with permanent marker)
- Print-outs of the spectroscope template (found in the student explanation section)
- Craft equipment, a selection of coloured paper, cardboard and cellotape
- Flame test salts and equipment – Li, Na, K, Ba, Sr, $CuCl_2$

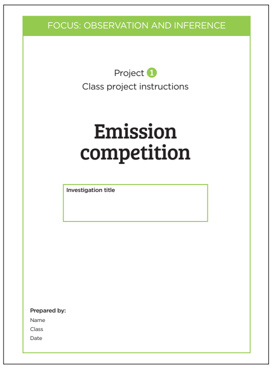
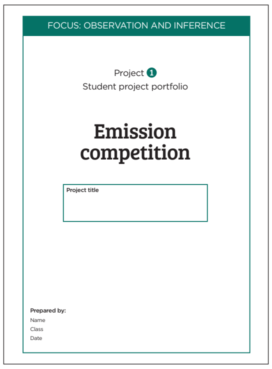
Additional resources

- For use with the suggested lesson plan PowerPoints, the **teacher's project guide**, the **class project instructions** and the **student project portfolio**.
- Visit **rsc.org/resources/analysis** for information and resources for teaching about spectroscopy **edu.rsc.org/resources/make-your-own-spectroscope/1289.article** and **edu.rsc.org/resources/flame-tests-using-metal-salts/1875.article**
- *The Nature of Science: Black Box*, or **edu.rsc.org/practical/identifying-ions-practical-videos-14-16-students/4011491.article**, **edu.rsc.org/resources/black-box/1275.article**

EMISSION COMPETITION: LESSON ONE
Recording results

STAGE/PURPOSE	RUNNING NOTES
Engage Get students interested in the idea of recording information.	 Display slide 2 shows the question, which introduces the themes of data collection and instrumentation.  Display slide 3 – students could discuss in pairs or as a group the answers to the questions on the board.
Scientific method This activity allows teachers to introduce key concepts for undertaking the scientific method. Including the focus for this project: observation and inference.	**Slide 3 – suggested activity** One of the most basic skills in scientific inquiry is the ability to make observations during experimental work. Students will often say what they think is happening rather than what they observe, eg stating that hydrogen gas is given off is not an observation in the true sense, because the student cannot see that it is hydrogen gas, and a further test would need to be carried out to verify this. A true observation would be 'a gas is given off'. **1** Students can be put into groups of two. **2** One student is given a picture, but they are not allowed to say what it is, only to describe it. **3** The partner tries to recreate the image by sketching it onto a piece of paper. **4** Students can then compare the picture with the sketch. **5** This will allow students to recognise their strengths in making observations and also communicating these observations, as well as improvements they would need to make in order to allow their partner to produce more accurate sketches. **6** The roles could then be reversed using a different picture, to allow the second student to make and communicate their observations.
Real world and careers link Get students interested in how this links to their career aspirations and industry in Ireland.	  Display slide 4 and 5 show how this is relevant to the real and global world. The link below outlines Finn's experiment, including details of his spectrometer (after several prototypes). Note: he makes a spectrometer and this project asks for a spectroscope – the former being quantitative and the latter qualitative. See **blog.google/outreach-initiatives/education/2019-google-science-fair-winners** for more details.  Display slide 6 shows condensed personalised versions of two careers stories (the full versions of which can be found in the **careers and industry** section).
Project and homework instructions	 Display slide 7 – discuss the photograph competition as a way to collect and present results. Give students the **class project instructions** sheets, and instruct them to follow along in their student **project portfolio** – shown overleaf. Give class time to make a basic spectrometer, and set as a homework to improve their model so that they can take the best picture.

EMISSION COMPETITION: LESSON TWO
Carrying out the investigation and write-up

STAGE/PURPOSE	RUNNING NOTES
Flame test Giving students the opportunity to conduct the experiment with their equipment.	Encourage the students to use the vocabulary of observation and inference and allow them to write up the results in the **student project portfolio**. They should be encouraged to finish the write-up at home and to submit photos for the photo competition – perhaps sharing the categories with the students in advance. 

EMISSION COMPETITION: LESSON THREE
Presentation and prizes

STAGE/PURPOSE	RUNNING NOTES
Presentation	Discussing with the students the merit of the pictures encourages a culture of evaluation.

Suggested photo categories

1 Best picture
2 Most original (source of light)
3 Best instrument
4 Best explanation of emission spectrum
5 Best variety of photos

Useful links

1 **solar-center.stanford.edu/activities/cots.html**
2 **livescience.com/41548-spectroscopy-science-fair-project.html**
3 **exploratorium.edu/snacks/cd-spectroscope**

Project 1

Teacher's project guide

Emission competition

Finding out what things are made of

Prepared by:

Name

Class

Date

Planning sheet

Why are you doing this investigation?

What do you want to find out? This could be some type of hypothesis or idea you want to prove or disprove, or a way to explain a complex process.

Include any inspiration for undertaking the project. This could be some type of hypothesis or idea you want to prove or disprove, or a way to explain a complex process.

What do you think you might discover or find? This could be some type of hypothesis or idea you want to prove or disprove, or a way to explain a complex process.

Flame test variables

Students should identify that the salt will be the independent variable, the flame colour the dependent and that the 'results' will be the thing they have determined, or inferred. To support this, students should be given a copy of the metal ions and their corresponding colours, or alternatively research them. Here is a useful resource using the wooden splint method **edu.rsc.org/resources/flame-tests-the-wooden-splint-method/759.article**

Deciding on your method and instrument

It is good to encourage the students to focus on how they will record the evidence. This will allow students to imagine which version of the spectroscope they are most interested in creating – a high-tech or low-tech one. They need to think about how they will attach the camera, as the quality of recording materials will affect the quality of the observations.

Suggestion for attaching a phone

You can find detailed guidance on how to build a smartphone spectrometer and record emission spectra in this resource **edu.rsc.org/download?ac=15353**

This design from Public Lab gives also advice on how to analyse the spectra using Spectralworkbench **spectralworkbench.org**

Discussion

A discussion could be started about how the camera might provide less biased answers than relying on humans. However, it should also be pointed out at some stage that cameras tend to have filters and also that pictures can be altered before and after printing. Which is more reliable? People or cameras? Or both?

EMISSION COMPETITION
Results

When recording results scientists normally collect quantitative data, which is usually in the form of numerical values, like concentration or wavelength. Then they use this to carry out calculations or present the values in a graph to establish a relationship between independent and dependent variables.

For qualitative data, observational data is usually collected and inferences made based on the work of previous scientists.

Table of results

OBSERVATIONS		
Salt to be tested	**Colour of flame**	**Corresponding metal ion**
A	Magenta	Li
B	Yellow	Na
C	Lilac	K
D	Yellow-green	Ba
E	Crimson-red	Sr
F	Blue or green	Cu

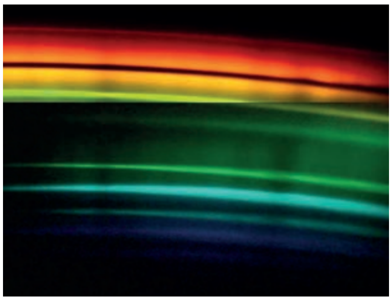
Students should be clear these are qualitative and that to make it quantative they would need to add numbers, eg wavelength.

Supportive results

This would include photographic evidence of your results.

Suggested categories

1 Best picture
2 Most original (source of light)
3 Best instrument
4 Best explanation of emission spectrum
5 Best variety of photos



High-pressure sodium light and its spectrum

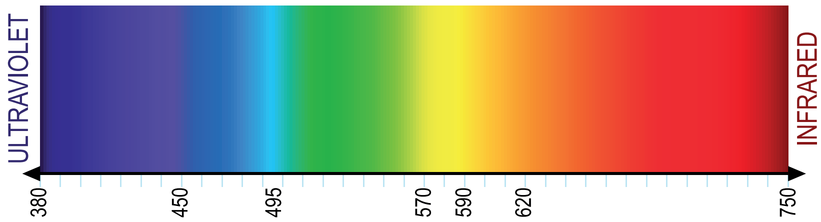
EMISSION COMPETITION
Analysis and conclusion

In this section they should describe which salt is which and explain using their observations, eg I believe salt one is a sodium salt because it produced a bright orange flame.

Inference **Observation**

They should support this inference or deduction by referring to well-known scientific facts, eg that sodium produces a bright orange light when heated.

Some will go further and use the wavelength as a quantitative reference, if they had a calibrated spectrometer, eg 'I believe the salt was sodium based on the peak at 590 nm'.



The emission spectra with corresponding wavelengths

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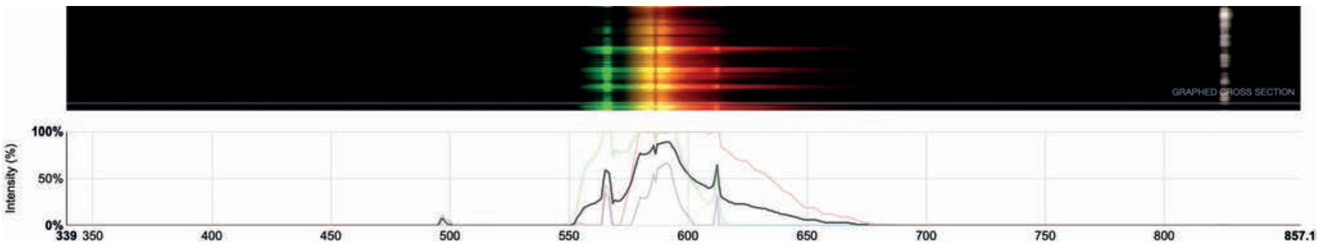
An example is included below, taken from Spectral Workbench **spectralworkbench.org**

This document explains how to analyse these spectra **edu.rsc.org/download?ac=15350**



Emission spectrum from a sodium street lamp

Project 1

Class project instructions

Emission competition

Investigation title

Prepared by:

Name

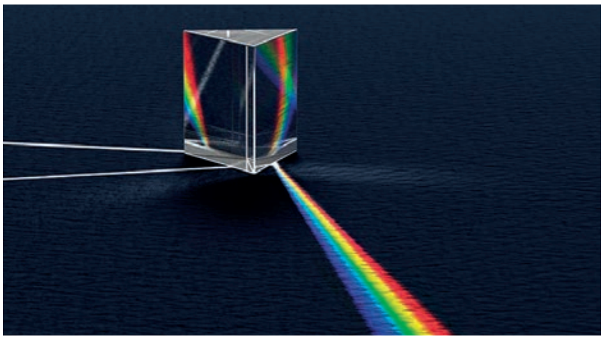
Class

Date

Finding out what things are made of

Background

The first spectroscopes were prisms with graduations credited to Gustav Robert Kirchoff and Robert Wilhem Bunsen. They evolved to include a slit for the light and a lens to narrow the beam. The spectroscope quickly became valued for its ability to measure the wavelength and the intensity of light.[1]



Using prisms as early spectroscopes

Kirchhoff, like many other scientists at the time, was beginning to unravel the secrets of light. He discovered that the bright lines he saw in his spectroscope were the same pattern of dark lines he found when he looked at the sun, and he realised this was absorption and emission of some kind, concluding that this could only mean one thing – that the sun and the stars were made of the same things as here on Earth.

The pattern seen in the spectroscope[2]

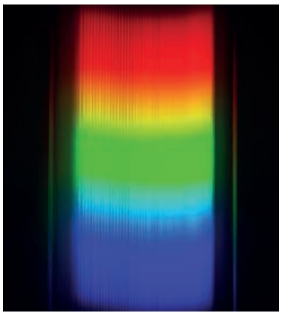
So he and Bunsen began, like many students do, putting whatever 'elements' they thought they had into the Bunsen flame and watching the different spectra lines. They concluded – as you will too – that each pattern represents a different substance. In this method Kirchhoff had discovered an exquisite analytical method, capable of identifying elements.

Different light sources

Many light sources exhibit different forms of the spectra. Look at the two below.

The sun and many torches emit all the colours of the rainbow and a continuous spectrum of all the colours can be seen.[3]

If you look at a TV screen or a fluorescent light you will see separate lines of different colours.[4]



The spectra seen when looking at the sun[4]

The spectra seen when looking at the TV[4]

Missing or extra light tells us that certain elements have been affected. Astronomers and chemists study these spectra because they contain information about the light source.

This is particularly useful when working out the composition of distant stars and indeed was used to discover the composition of our own sun.

Some spectra of individual elements[2]

Hydrogen absorption spectrum

Helium emission

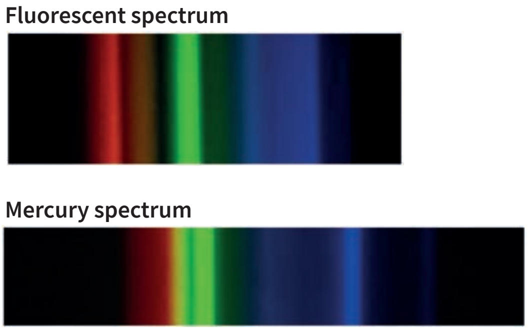
Hydrogen emission spectrum

References
1 sciencehistory.org/historical-profile/robert-bunsen-and-gustav-kirchhoff
2 Free resources available at **solar-center.stanford.edu/activities/cots.html**.
3 chemistryworld.com/opinion/kirchhoffs-spectroscope/6547.article
4 edu.rsc.org/resources/make-your-own-spectroscope/1289.article

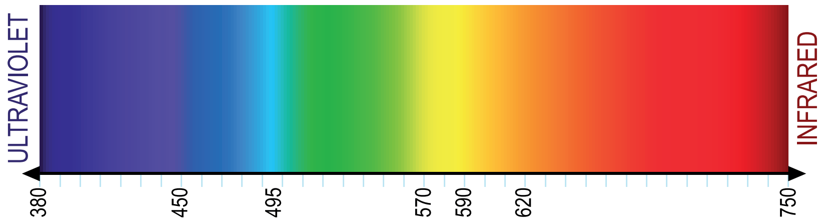
Comparing a pure sample and a mixture

Composition can also be determined by comparing a sample with pure spectra. This is shown on the right, where the lines in the photo of fluorescent light correspond to the lines shown in pure elemental mercury, proving that fluorescent light contains mercury.

Another more accurate way to describe this overlap is to describe the light in terms of its wavelength and often its intensity, shown below.



Comparing a sample with pure spectra[2]



The emission spectra with corresponding wavelengths

Scientists use instruments all the time and through this project you will build your own. This will give you a keen insight into why instruments are so important, what you should be looking for and also the best ways to record and interpret your results.

Your task

Your task is to find out what metals are present in the salts using a combination of flame tests and emission spectroscopy and to record and present your results. You can take photo's of each metal's emission spectrum. But first you will need to build your instrument!

Making your spectroscope

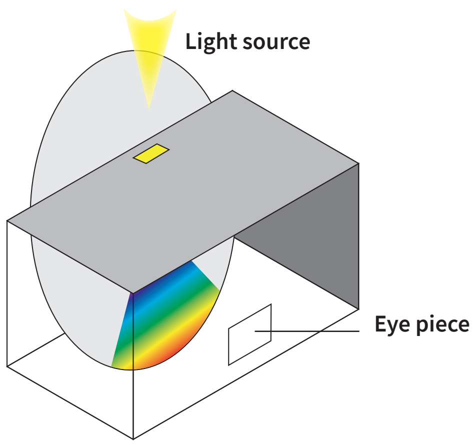
The simplest spectroscope can be created using the template provided and a CD.

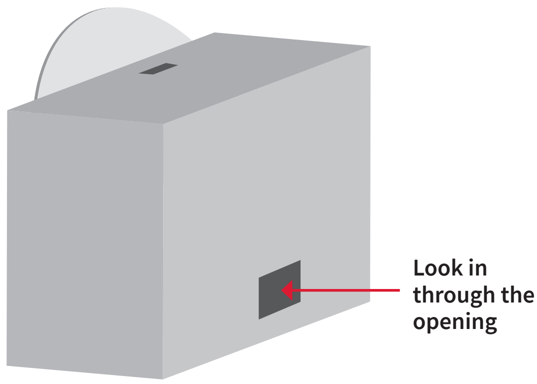
The end product is shown in the image – it is advisable to tape down the CD so it doesn't wobble, while you look through the eye piece.

However, there are a number of different types and designs, so choose wisely!

Hint! There are many YouTube videos demonstrating how you can make a simple spectrometer and take pictures using a phone camera. Here is one from MIT OpenCourseWare **youtube.com/watch?v=fl42pnUbCCA**

How it works





The completed spectroscope – see template provided overleaf

1

2

Make your own spectroscope

1 Glue this template onto an A4 piece of card.

2 Cut along all the solid black lines with scissors, including line **a**, and cut out the rectangles **b** and **c** (it's a bit tricky!).

3 Fold along all the dotted black lines.

4 Make the template into a box by joining the same numbered flaps together, eg **1** joins to **1**.

3

a

b

5 Put a CD into the box through the slot you made at line **a** with the bottom 'rainbowy' side of the CD facing upwards.

6 Look into the box through the square hole and you should be able to see light split into a rainbow.

7 Try looking at different types and colours of light and see what changes in your spectroscope.

2

3

c

1

EMISSION COMPETITION
Planning sheet

Why are you doing this investigation?

What do you want to find out? This could be some type of hypothesis or idea you want to prove or disprove, or a way to explain a complex process.

Include any inspiration for undertaking the project. The work of other scientists (particularly anything from the careers stories), or things in the media that might have motivated your interest in this topic.

What do you think you might discover or find? This should link to the focus of research and analysis – how your results will prove or disprove your hypothesis or idea.

Flame test variables

You will test six different salts, make an observation and from these you will determine their identity. In your group identify which variable is which:

Corresponding salt	**Independent variable** – the thing you change each time.
The colour of the flame	**Dependent variable** – the thing you measure, which changes depending on the independent variable.
Salt to be tested	**Results** – the thing you have determined.

Deciding your method and instrument

To record your observations, you should first be clear on what an observation can be, ie something you can: see; feel (heating up or cooling down); hear; smell.

These are things you cannot easily determine, for example, 'things fall because of gravity'. This is something you have understood to be true but did not determine in the experiment. The correct observation could be 'unsupported things fall to the ground'. This is the difference between observation and inference.

Once you have built your own spectrometer, you can use it and your smart phone to take photo's of the emission spectrum of the flame produced by each metal salt. You could use any free light meter app available on your smartphone to make a measurement.

1

Include a description of how you will collect your observations.
Hint! diagrams are helpful

Results

When recording results scientists normally collect quantitative data, which is usually in the form of numerical values, like concentration or wavelength. Then they use this to carry out calculations or present the values in a graph to establish a relationship between independent and dependent variables.

For qualitative data, observational data is usually collected and inferences made based on the work of previous scientists.

Table of results

OBSERVATIONS		
Independent variable	**Dependent variable**	**Results**

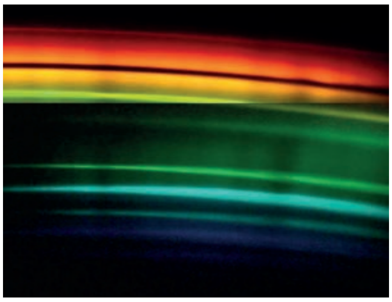
Do you think these results are qualitative or quantative?

1

Supportive results

This would include photographic evidence of your results for the emission competition.

Your work should be presented with a photo of the light and a picture of its spectrum, eg see the sodium streetlight photos below.



High-pressure sodium light and its spectrum

This will be a competition to see who can produce the best photos – the emission competition.

Include a link or print out of your photos.

Analysis and conclusion

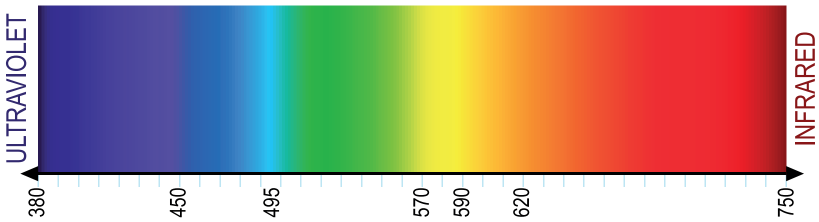
In this section they should describe which salt is which and explain using their observations, eg I believe salt one is a sodium salt because it produced a bright orange flame.

Inference — I believe salt one is a sodium salt

Observation — produced a bright orange flame

They should support this inference or deduction by referring to well-known scientific facts, eg that sodium produces a bright orange light when heated.

Some will go further and use the wavelength as a quantitative reference, if they had a calibrated spectrometer, eg 'I believe the salt was sodium based on the peak at 590 nm'.



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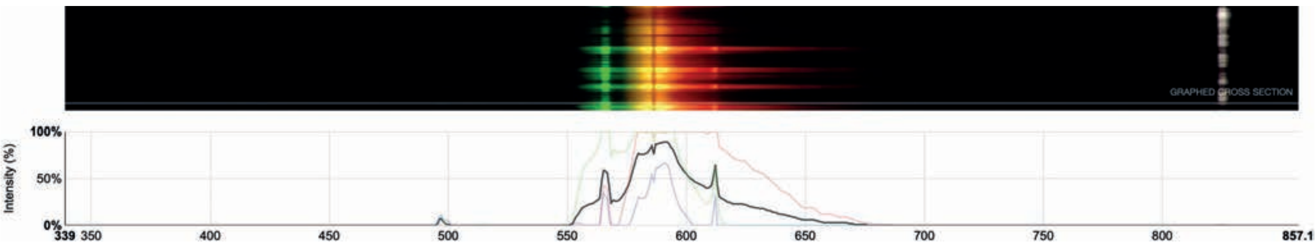

Emission spectrum from a sodium street lamp

Project 1

Student project portfolio

Emission competition

Project title

Prepared by:

Name

Class

Date

EMISSION COMPETITION
Planning sheet

Why are you doing this investigation?

Variables

Deciding your method and instrument

Spectroscope diagram

1

Results

Table of results

Emission competition

1

Analysis and conclusion

Explain your observations

1