



Key Stage 4 – Fingerprinting Mars Mud

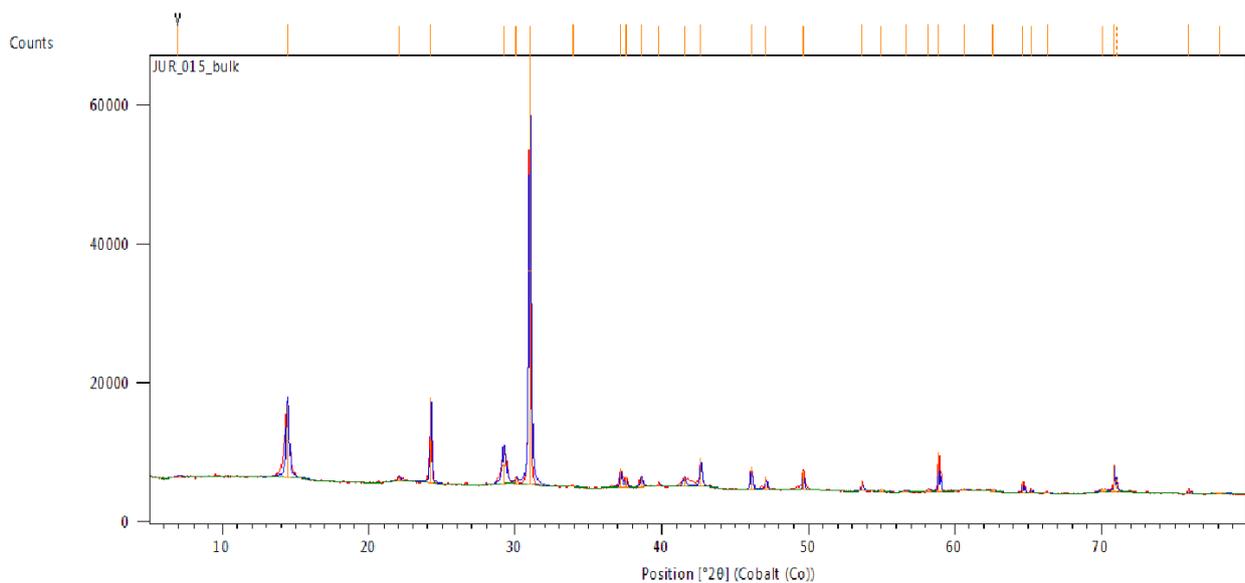
Notes for teachers

At a glance

This lesson is inspired by research at Oxford University into Australian mudstone fifteen times older than the dinosaurs. Traces of oxygen, nutrients, and early life in the mudstone have helped entirely reshape our picture of evolution, how the Earth developed and could help us identify traces of early life on Mars.

In this lesson, students will be exploring x-ray diffraction, the analytical technique used by scientists to explore the underlying structures of muds and comparing them to their own observations. Their detective skills will come in useful when samples gathered by rovers on Mars are compared to samples from Earth's history. Astrobiologists hope to detect traces of minerals that could be "fingerprints" of early life.

This lesson is better suited to higher ability classes.

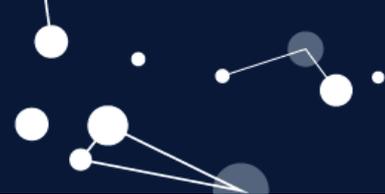


Learning Outcomes

- Students will link structure and bonding covered in the chemistry specifications to the physical shapes of crystal structures, and enhance microscope skills.
- Students will learn about diffraction through a grating or slit, constructive and destructive interference of waves.
- Students will develop an understanding of how chemistry, biology, geology and physics are linked in practical scientific investigations.

Each student will need

- A copy of the student worksheet
- Access to a microscope
- Access to a range of minerals in crystal form (suggestions: quartz, pyrite, selenite, pyroxene, micas, calcite)
- A piece of gauzy fabric, e.g., chiffon
- Access to a monochromatic laser pen



Possible Lesson Activities

1. Starter activity

- Write the key words below up on the board and ask the class to guess their meanings, write down their guesses, then research them to compare. They will need to use the internet to do research.

Key words: astrobiology, biogeochemistry, biomineralisation

- Watch the animation 'Ancient Mysteries in Marvellous Mud' (see weblinks).
- Discussion: What are the challenges of looking for life on Mars?

2. Main activity: Through the Lens

- Ask the class to read through **Structures and Bonding** on the provided worksheet.
- Ask the class to use a microscope or magnifying lens to examine the structures of at least three minerals.
- Students fill in a table of observations for three crystals. Encourage them to sketch the morphologies they can see.

3. Main activity: X-ray Supermicroscope

- Ask the class to read through **X-ray Supermicroscope** on the provided worksheet, complete **Add up the Waves** and read **Diffraction Gratings**.
- Provide the class with laser pens and safety briefing (see [appendix 1](#)). Allow them to explore diffraction patterns made by shining the light through a piece of gauzy fabric. If available, they may like to explore how different colours of light give slightly different patterns.

4. Main activity: Fingerprinting Mars Mud

- Ask the class to read through **Fingerprinting Mars Mud** on the provided worksheet.
- Provide the class with the reference spectra and sample spectra from the Mars Rover and challenge them to identify evidence of early life. They may wish to work in groups.

The reference spectra show the patterns you would expect to see if that mineral is present.

*The real spectra show a mixture of minerals in Mars mudstone samples. By comparing where the peaks are in the Mars spectra and sample spectra, the students can decide which they think may be present. The intensities of peaks can vary because of **moisture** and the amounts of some minerals present may be **higher** than others. There may also be non-crystalline (amorphous) things present, which do not give peaks but can raise the baseline of the spectra. If the students think hydroxyapatite mineral is present, this could indicate evidence of early life. A good way to see whether the patterns match is to hold up a Mars spectrum overlaid with a reference spectrum against the window to let the light shine through.*

5. Plenary

- Return the class' attention to the key words on the board and the concept of interdisciplinary science.
- Ask the class to discuss in groups why living things might make minerals in certain morphologies. Include:

How are bacteria that lay down minerals like spiders weaving a long trail of silk?



What can Mars mud tell us about the possibility of alien life?

Web links

Oxford Sparks: 'Ancient Mysteries in Marvellous Mud' animation:

<https://www.oxfordsparks.ox.ac.uk/content/ancient-mysteries-marvellous-mud>

Iron-respiring bacteria:

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC123774/> (open source)

<https://pubs.acs.org/doi/abs/10.1021/es990021x> (not open source)

Laser pens (see [appendix 1](#) for safety guidelines):

Here is a trusted site: <http://skylineselect.co.uk/>

And here are some others that are <1 mW and a little cheaper

https://www.aliexpress.com/item/Powerful-Red-Purple-Light-Laser-Pointer-Pen-5mW-650NM-Burning-Match-Visible-Beam/32853138519.html?ws_ab_test=searchweb0_0,searchweb201602_5_10152_10065_5722813_10151_10344_10068_10130_10324_10342_5722613_10547_10325_10343_5722913_10340_10548_10341_10696_10192_10190_10084_10083_5722713_10618_10307_10820_10301_10821_10303_10059_100031_10103_10624_10623_10622_10621_10620_5722513,searchweb201603_25,ppcSwitch_5&algo_expid=650d75ca-22b1-461f-bec9-3a3f55fffc2-11&algo_pvid=650d75ca-22b1-461f-bec9-3a3f55fffc2&transAbTest=ae803_2&priceBeautifyAB=0

https://www.aliexpress.com/item/Powerful-SD-Laser303-Adjustable-Focus-532nm-Green-Laser-Pointer-Light-Output-power-less-than-1mw-no/32828030238.html?ws_ab_test=searchweb0_0,searchweb201602_5_10152_10065_5722813_10151_10344_10068_10130_10324_10342_5722613_10547_10325_10343_5722913_10340_10548_10341_10696_10192_10190_10084_10083_5722713_10618_10307_10820_10301_10821_10303_10059_100031_10103_10624_10623_10622_10621_10620_5722513,searchweb201603_25,ppcSwitch_5&algo_expid=650d75ca-22b1-461f-bec9-3a3f55fffc2-20&algo_pvid=650d75ca-22b1-461f-bec9-3a3f55fffc2&transAbTest=ae803_2&priceBeautifyAB=0

and

<http://www.alibaba.com/product-detail/3-in-1-Universal-Clip-on-magnifying-lens-60285076619.html>

Cheap, clip-on-phone magnifying lenses can be used if microscopes are unavailable:

<http://www.alibaba.com/product-detail/3-in-1-Universal-Clip-on-magnifying-lens-60285076619.html>



Appendix 1. Laser pen safety

Laser Pen Health and Safety – according to Public Health England (PHE) guidelines

- Laser pointers in the UK have special requirements to be legal under Health and Safety legislation, for a General public presentation use type laser, the requirements are Class 2, less than one Milliwatt (1 mW) in Power and must have a "momentary switch". The laser classification

<https://www.oxfordsparks.ox.ac.uk/content/ancient-mysteries-marvellous-mud>

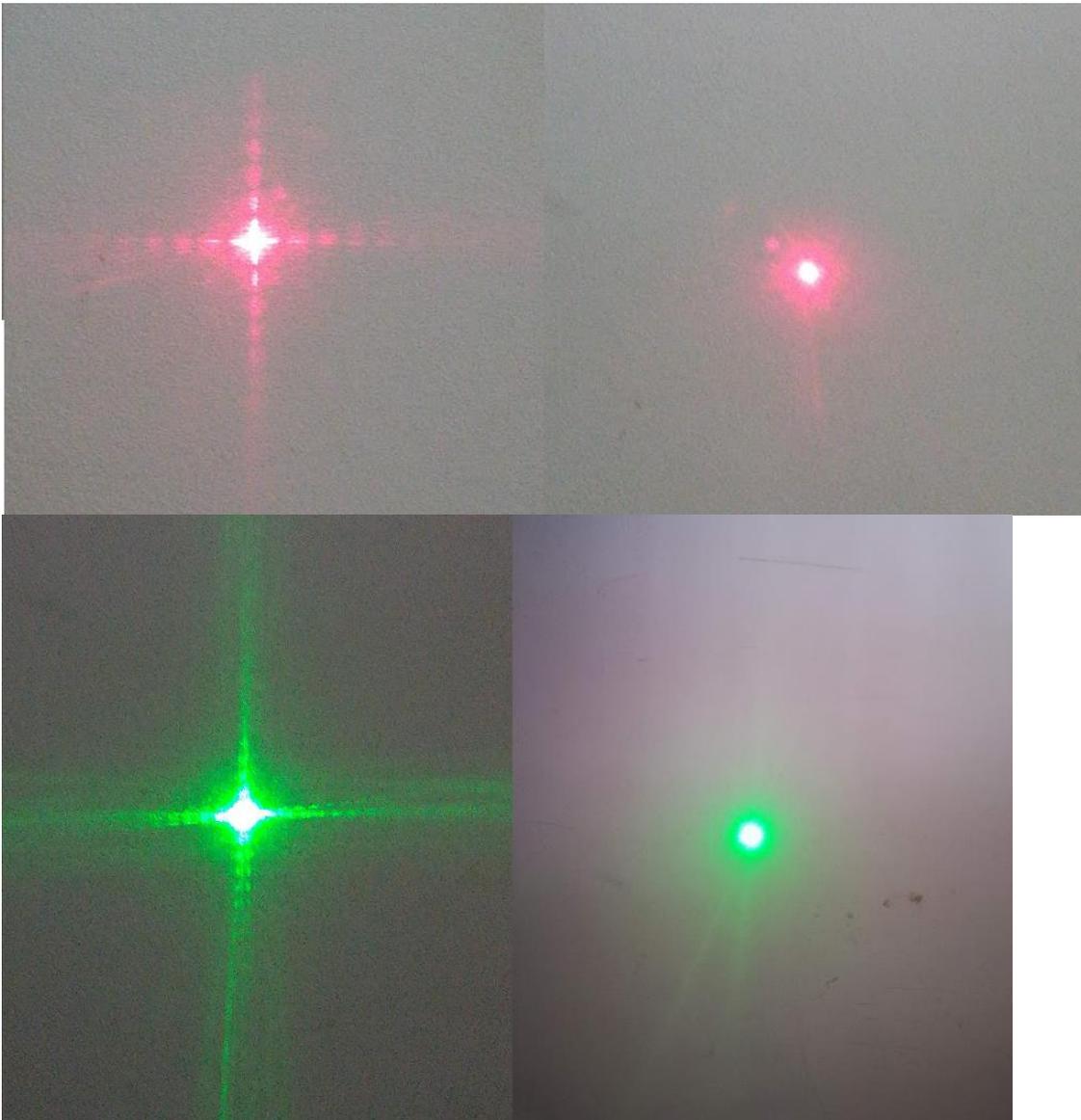


scheme was introduced over 40 years ago to provide guidance to users of lasers. The laser classification scheme in this document is taken from BS EN 60825-1.

- Buy laser pens from the UK and with a maximum power output of 1 milliwatt (mW). In the UK, the threshold for toy laser pointers is lower, at 0.39 mW.
- Educate children about the dangers of lasers and consequences if they misuse them: in particular, holding them against skin or pointing them at eyes.

Public Health England, publichealth@rospa.com

Appendix 2. Laser pen diffraction patterns



Appendix 3. Answers to Fingerprinting Mars Mud

Sample 1 contains no apatite, **Sample 3** contains 1% apatite, and **Sample 2** contains 10% apatite (10% is at the high end of the spectrum of natural samples containing this mineral).