XMaS WITH PROFESSOR TOM HASE AND DR DIDIER WERMEILLE

TALKING POINTS

KNOWLEDGE

1. What is the ESRF?
2. What is a beamline?

COMPREHENSION

3. How does the ESRF generate high-powered X-rays?
4. What keeps the ESRF researchers safe from radiation?

APPLICATION

5. What questions would you ask the XMaS team to learn more about their work?
6. Tom says, "The best science emerges when the brightest scientists meet and discuss what they are doing." Why do you think this is the case? Can you think of examples where a conversation has led to something good happening for you?

ANALYSIS

7. Why do you think the ESRF upgraded its equipment all at once, rather than several smaller upgrades over a longer time?
8. Why do you think medical X-rays are generally considered safe for patients, but the X-rays used at the ESRF are not?

EVALUATION

9. Experiments at the ESRF are very expensive. How would you assess whether the XMaS beamline is value for money? Do you think this is a useful exercise?

CREATIVITY

10. Think about some of the issues facing society. Do you think the expertise and facilities of the XMaS team could help address some of these challenges? How might their research help?

ACTIVITIES YOU CAN DO AT HOME OR IN THE CLASSROOM

1. Materials scientists often use X-rays to look at the microscopic structural properties of different materials. Professor Maisoon Al-Jawad's research on teeth and bones, and Professor Wuge Briscoe's studies of surfactants, lipids and polymers, are two examples.

Using strands of uncooked spaghetti and glue, you can make different structures that reflect different structural principles. For instance:

a. Build the tallest self-supporting structure you can, the base of which should fit on an A4 piece of paper.
b. Build a structure at least 10cm off the table's surface that can support the weight of a light exercise book.
c. Build a bridge, with the supporting pillars at least 50cm apart.

When you have tested these structures, think about what shapes and techniques led to the most successful structures. Compare with your classmates for extra insight. Then, think about how materials might incorporate these structural techniques at the microscopic level. For instance:

- What structural properties might give teeth and bones their strength?
- How might oil be transformed into plastics that are either rigid or flexible?

Once you have come up with some ideas, use the internet to check your answers.

2. For the functioning of many devices, such as batteries, catalysts and photovoltaics, a greater surface area for reactions to happen leads to a more efficient device. Materials scientists are therefore often interested in maximising the area of these surfaces at the microscopic level. You can test this idea in practice. You will need:

- Large Vitamin C tablets or something similarly effervescent
- Stopwatch
- Beakers
- Water
- Ruler
- Calculator
- Knife

1. First, use the ruler and calculator to measure the surface area of the tablet – this will probably involve calculating the surface area of a cylinder.
2. Place the tablet in a beaker of water and time how long it takes to dissolve. Make a note of the surface area and time taken.
3. Next, repeat the exercise, but first carefully cut the tablet in half and calculate the total surface area of both halves. Time how long it takes to dissolve in a fresh beaker of water.
4. Keep repeating the exercise by cutting the tablet into smaller and smaller pieces, so the surface area increases with each experiment. Note each surface area and corresponding time.
5. Once you have repeated this until it is not possible to safely cut the tablet into smaller pieces, put your notes into a table.
6. Use the table to draw a graph to represent surface area against time to dissolve. Is it a linear relationship, or something else?
7. See if you can use your mathematics skills to devise a formula of how surface area (S) relates to time (T) to dissove.
8. Considering your results, think about why greater microscopic surface areas might be beneficial in:

   a) Batteries
   b) Photovoltaics (found in solar panels)
   c) Catalytic converters

   As Dr Peter Wells says, "Contemporary catalysts are often classed as nanomaterials. These small size domains not only thrift expensive metals by increasing the surface to volume ratio (catalysis happens at the surface of materials), but also impart different reactivity on the surface sites."

3. Diffraction describes the way that waves (e.g., sound, electromagnetic waves like light or X-rays, or on water) bend and interfere when they encounter a particular obstacle. Professor Mark Dowsett says, "Measuring 'diffracted' beams allows us to measure the interatomic spacing, identify the compound(s) doing the scattering and much more."

Dr Jakob Kjelstrup-Hansen says, "Using a technique called grazing incidence X-ray diffraction (GIXRD) at XMaS, we are able to study features and functions of thin layers."

A simple activity to observe the phenomenon is to drop a coin into a bowl of water and watch the ripples as they move towards the edge of the bowl. What happens when you drop two or more coins into the water at the same time? How do the ripples interfere with each other?

HINT: Use small coins and a large frying pan with water about 2 cm deep. Drop the coins from 10 cm or less with their faces parallel to the water. You need to observe quickly – the waves do not last long!

BBC Bitesize has a section dedicated to interference and diffraction, which also features a Q&A:
www.bbc.co.uk/bitesize/guides/z99kkqt/revision/3

4. Spectroscopy is the study of the absorption and emission of light and other radiation by matter.

George Tierney says, "X-ray absorption spectroscopy (XAS) is an element specific measurement, which provides precise information on the structural and electronic properties of materials. This, coupled with a high intensity X-ray source from the synchrotron, allows us to probe materials under working conditions."

Science Buddies has a wonderful experiment, which involves building a simple spectrophotometer from a mobile (cell) phone to investigate how visible light is absorbed by different coloured solutions:
www.sciencebuddies.org/science-fair-projects/project-ideas/Chem_p100/chemistry/make-a-cell-phone-spectrophotometer

MORE RESOURCES

- The ESRF website has plenty of information about how synchrotrons work, the findings of the different research groups, plus a range of education and outreach materials: **www.esrf.fr**
- This video from Nature talks to ESRF scientists over 24 hours, getting an insight into their work and their daily routines: **www.youtube.com/watch?v=UsJ1j4_1Di0**
- This article provides an introduction to what materials science is all about: **www.explainthatstuff.com/materials-science.html**