Mission: Starlight
A global experiment on UV protection

Image credit: ESA

CREST Awards
A British Science Association programme

principia mission

UK SPACE AGENCY

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Image Courtesy of Minoru Yoneto

Contents

Introduction

Ultraviolet light: an unseen danger
The sun gives off a spectrum of different light. You can see these different types of light when you look at a rainbow. Reds, yellows, blues and purples are clear and easy to spot but the sun also gives off light that's invisible.

Ultraviolet (UV) light is an example of light produced by the sun that we can't see. It can be good for us as it helps our bodies produce vitamin D – but too much is harmful. This is why we cover our bodies with sunblock. The Earth's atmosphere can protect us from some of this harmful light but astronauts, living and working high above the clouds, are in real danger from UV light.

There are three types of UV light. They are all invisible to us and all are potentially harmful.[1]

The astronauts in the International Space Station (ISS) are at risk from UV light because they're closer to the sun and above the Earth's protective ozone layer.

Figure 1

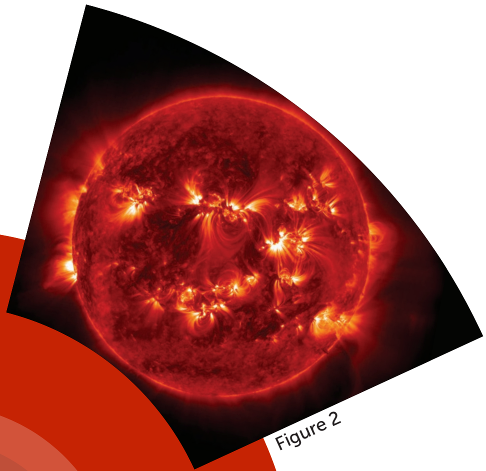


Figure 2

Figure 3

Figure 1
A rainbow: evidence that starlight contains a spectrum of light

Figure 2 *Image credit: NASA/SDO)*
UV light produced by the sun

Figure 3 *Image credit: ESA*
An exposed astronaut

The global experiment:
an overview

Mission: Starlight is a global experiment on UV protection.

Mission objective: protect astronauts from UV light in space.

Mission directives:

- Determine what materials could help block dangerous UV light.
- Explore how we can use these materials for spacesuits, visors or even the International Space Station (ISS).
- Consider liquid coatings as a UV block.
- Investigate the effect particle sizes have on formulating the most effective suspension.
- Create an effective UV block for use in space.

Mission: Starlight consists of four standalone experiments. They have been designed to challenge all ages and abilities with all resources being easily sourced and affordable.

Each experiment can be completed in an hour-long lesson but can also be extended. They are designed to be safe and easily resourced to incorporate key science skills into core curricula.

To test any material's ability to block UV light you will need a UV sensor. This experiment uses UV colour changing beads which are cheap and widely available from online retailers[2]. You will need to purchase these and use our colour chart to record the results for each experiment.

The final colour of your experiment bead may vary depending on where you are on the planet, as well as the season and the light intensity on the day of experimenting. This is an opportunity to observe and record seasonal changes and underline the importance of UV protection.

Each experiment has named substances to test. This allows you to post your results on our website and compare them with schools around the world. However, if you are unable to source everything or if you want to extend the experiment to include materials of your own choice, please do. We strongly recommend posting any results of the experiments to **http://rsc.li/mission-starlight** as it will strengthen your students' scientific inquiry.

We have supplied simple worksheets for each experiment, with the basic information you need to take part in the experiments. This not only saves paper but should encourage independent investigation – giving you the flexibility to deliver individual or group learning.

Students will have opportunities to investigate, predict, observe, record, compare, conclude and make suggestions for improvements. They are encouraged to question, discuss and analyse.

We also encourage you to take photos and post them with your data. If you're having difficulty posting to our website you can always email us at **learn-chemistry@rsc.org** with your data, images and location.

These experiments can lead to a CREST Award for your students (see page 6). In order to work towards a CREST Award your students will need to complete multiple global experiments with their own choice of materials and formulations to demonstrate creativity while using this resource.

The experiments: a guide

The experiments can be run consecutively or individually: each one is a standalone lesson allowing you to pick and choose the objectives you want your students to learn.

Experiment 1a: Which materials block some or all UV light?
Experiment 1b: Which materials are suitable for an astronaut's visor?

These experiments investigate which materials are most effective at blocking UV light by using colour changing UV beads.

Experiment 1a can be used to decide which material will be best for an astronaut's spacesuit before considering the needs of an astronaut's visor in experiment 1b.

Experiment 2: Can liquid coatings block UV light?

This experiment investigates liquids and coatings to see if different depths can be used to better protect astronauts in space. This experiment also requires the use of UV colour changing beads. You can easily extend this experiment to test greater depths or different liquids.

Experiment 3: What particle size produces the most effective suspension?

If you can't get any UV beads but still want to take part in the global experiment then this experiment is for you.

Sunscreens are effective at blocking UV light. They are a suspension of an insoluble solid (titanium dioxide) in liquid. Without the liquid the solid will not be held in place and will therefore not be effective at blocking UV light. This experiment investigates how a suspension can be affected by varying particle sizes.

Experiment 4: Can you make your own effective UV block for use in space?

This experiment encourages students to use their own filter materials or formulations and investigate how effective they are at blocking UV light. Students can investigate a range of oils with additives (titanium dioxide or zinc oxide powders, for example) or simply experiment with different material combinations.

This is an open investigation. It urges students to use the knowledge they gained in previous experiments to create an effective UV block for any part of the International Space Station (ISS) or an astronaut's suit.

How to use the experiment pages

How to use the experiment pages

The global experiment is a hands-on student activity for individuals or small groups. For this reason, the experiments have been presented in two ways:

1. **Separate worksheets for students:** to encourage independent learning, either individually or through group work.

   A simple explanatory sheet for each experiment consists of: method, results and conclusions.

2. **This booklet for teachers:** to provide detailed background information and resourcing requirements.

   Each experiment in this booklet has been laid out as follows:

Lesson Opener
A 'mission brief' explaining the aim of the experiment.

Vocabulary
Key words to be used during the activity.

Key concepts
A checklist of the scientific concepts students should be able to demonstrate their understanding of by the end of the experiment.

Resources
The equipment needed to take part in the experiment.

Teacher notes
Ideas to help extend learning.

Method
An explanation of how to complete the experiment.

Results
What the students discover during the experiment. (These results should be posted to our global experiment website.)

Conclusions
Thoughts about the results and a discussion of any discoveries.

Follow-on suggestions
Extension activities specifically related to each experiment.

Further information
An easy-to-understand scientific explanation of the experiment.

Tweet us
Tell us what was discussed in your experiment. Let us know if you have any further questions. Share your discoveries.

Tweet using **#globalexperiment @RoySocChem** or post to **http://rsc.li/mission-starlight**

Health and Safety

The experiments in this document have been safety-checked by CLEAPSS.

UV-sensitive colour changing beads are **low hazard** materials and strictly not for ingestion.

- The main risks to participants during the experiment are: looking directly at the sun; swallowing the UV beads; and allergies to the natural oils or coatings suggested. Students should be warned of the dangers of gazing directly at the sun. Check that none of the participants are allergic to any of the products being used.

Experiments 2 and 3 involve the transfer of liquids or oils where spillages are possible.

- It is recommend that the tea prepared for experiment 2 is made by the teacher before the experiment, with cooling time allowed to minimise any risk of scalding by the hot water. Ensure paper towels are present to mop up spillages.

Experiment 4 formulations should not be applied directly onto skin.

- The use of titanium dioxide (TiO_2) and/or zinc oxide (ZnO) (toxic) could be investigated in experiment 4. These are very fine powders and could affect asthma sufferers if a lot of dust is generated. Ensure access to fresh air in such instances. All formulations should be disposed of in the general waste collection in the classroom after the experiment.

See **ASE Be Safe!** for further guidance:
https://www.ase.org.uk/documents/be-safe/be-safe-sample-pages.pdf

Earn a CREST/CREST Star Award

Why not use the global experiment as a basis for a CREST/CREST Star Award?

CREST

Run by the British Science Association, CREST is Britain's largest award scheme for project work in science, technology, engineering and maths (STEM), and is suitable for anyone aged 11–19. The Awards are widely recognised and can be used to enhance applications to colleges, universities and employers as well as counting towards the skills element of the Duke of Edinburgh's Award.

The level of CREST Award your student chooses to do through the global experiment will depend on the length of time they spend on their projects and the level they are working at. KS3 students need to do 10+hrs of project work to achieve a Bronze Award, while those working at KS4 could do 30+hrs and achieve a Silver Award.

You or your student should contact your CREST Local Coordinator at the start of the project by going to **www.britishscienceassociation.org/crestcontacts**. Your coordinator will help you through the simple registration process.

Once registration is complete, your student will be given a profile form and guide. Students need to fill in the profile form as they complete the project work. The guide will help them through all the necessary steps and ensure their project qualifies for the Award.

Learn more about CREST on the British Science Association website:
www.britishscienceassociation.org/crest-awards

CREST Star

Aimed at primary-age students, this programme is all about relevant and creative, hands-on practical science. CREST star activities and log books are free to download from **http://www.britishscienceassociation.org/crest-star**

Each global experiment counts as one superstar sticker. Students need 12 stickers to complete their log book so once you've finished the global experiment, check out the CREST Star pages for more great activities to do.

A **British Science Association** programme

Experiment 1a: Which materials block some or all UV light?

Mission brief: UV light is harmful. Whether you're playing in the park or swimming in the sea, you need to reduce your exposure to UV light. Astronauts on the International Space Station (ISS) need the strongest protection we can provide.

Mission objective: Protect an astronaut from UV light.

Mission directive: Investigate what materials will block UV light and still allow an astronaut to carry out vital work on the ISS.

Your students will learn to:

- understand basic experimental procedure for an investigation
- predict the possible outcomes
- observe and record UV bead colour changes in response to exposure to UV light
- observe and record the effectiveness of different materials in blocking UV light
- compare data with other students worldwide.

Each group will need:

- two same-colour UV colour changing beads (one as a control)[2]
- two petri dishes without lids
- material samples (eg white cotton, such as a t-shirt, polyester, such as a football top, aluminium foil and HDPE plastic as used for milk cartons)[3]
- cardboard box or tray (eg a shoe box)
- colour chart and results table (provided as part of this resource).

Teacher notes

We recommend splitting the class into small groups – approximately four students per group.

If you have plenty of petri dishes you could get each group to run all the materials together at the same time. This will allow you to discuss 'fair testing' as the amount of sunlight will be the same in this type of experiment.

Alternatively, if groups of students are working on one material at a time, try to get them to record their results at the same time so that the sunlight remains constant and will allow the results to be 'comparative' between groups.

UV colour changing beads are available online.[2] Only use the purple, mid-blue, deep blue or deep pink beads to ensure the most accurate readings. Match these to our colour chart, ranging from 0 (white: UV blocked) to 10 (deep colour: no UV protection).

The samples of material must be large enough to cover the petri dish completely.

You may need to stick the sample to the petri dish as it could blow off. The beads can be used many times so repeating or taking part in new experiments is cost effective.

We have added extra space below the suggested materials on the results table to allow further investigation with different materials.

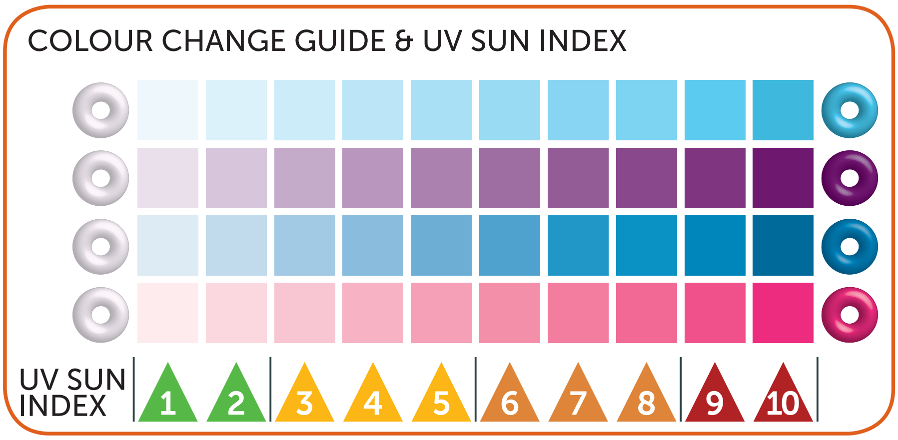
Vocabulary

UV, block, materials, properties, fair test, comparative test, prediction, control.

Method

1. Discuss what materials you would like to test.
2. Become familiar with any colour changes that take place when the beads are inside or outside in the sunlight. (NB note how quickly they change colour when brought indoors)
3. Predict the colour change you expect for each material using the colour chart.
4. Write your predictions on the results table.
5. Place two petri dishes in a box (without lids).
6. Place one bead in each petri dish.
7. Cover the first dish with your chosen material. Leave the second uncovered as a control.
8. Take the box outside to expose the samples to sunlight (for ground floor classrooms you could hold the samples outside an open window).
9. Wait for 30 seconds or until the control turns to the deepest colour on the chart (number 10), whatever comes first.
10. Quickly bring the box inside and remove the material from the first dish to reveal the bead's colour. Match it to the nearest colour on the colour chart (NB the bead may lose colour quickly. If the change is too quick to record, repeat steps 7–9).

    TIP: take a photo of the bead to help with the colour chart reading.
11. Record the colour chart number for your material on the results table.
12. Repeat with more materials or compare class data to complete the results table.
13. Post your results to **http://rsc.li/mission-starlight** and compare with schools worldwide.



Results

Material	Prediction	Result
White cotton (eg t-shirt)		
Polyester (eg football top)		
Aluminium foil		
HDPE plastic (eg milk carton in the UK)		

Conclusions

- What material blocked the UV light best? Is this material useful for a spacesuit?
- Why is it important to have a control bead in your experiment?
- Did each material give the result you predicted?
- Can you think of how to improve this experiment and/or the recording of the results?

Follow-on suggestions

- Can you predict the results of other materials, eg card, paper, coloured fabrics, metal, wood, glass or transparent, translucent and opaque plastics?
- Can we block more UV light by adding more layers of the same material? Will the thickness of the material affect the amount of UV light getting to the bead?
- If possible, examine the materials under a microscope or even a magnifying glass. Can you see spaces between the fibres that would allow UV light to pass through?

Further information about the experiment

UV light[1] cannot be seen but can be investigated using the UV colour changing beads. (NB our experiment only investigates the effect for UVA and UVB as UVC is already blocked by the Earth's atmosphere).

UV beads contain pigments that absorb UV light. Pigments in the UV-sensitive beads change from white to various colours depending on the intensity of the UV light at the time of the experiment.

Tweet us

What materials did you try? Do you have any other class results or questions?

Tweet us using **#globalexperiment @RoySocChem** or leave a comment on our website: **http://rsc.li/mission-starlight**

Experiment 1b: Which materials are suitable for an astronaut's visor?

Mission brief: While on spacewalks, astronauts need to see clearly but still be protected from UV light.

Mission objective: Find a transparent material to fulfil this role.

Mission directive: Investigate how well different materials block UV light and find the best one for an astronaut's visor.

Your students will learn to:

- understand basic experimental procedure for an investigation
- predict possible outcomes
- observe and record the effectiveness of different transparent materials at blocking UV light
- observe and record the effectiveness of varying numbers of layers at blocking UV light
- compare data with other students worldwide.

Each group will need:

- four same-colour UV colour changing beads (one as a control)[2]
- four petri dishes without lids
- six pieces of transparent material samples (eg polystyrene, such as petri dish plastic, polyvinyl chloride, such as cling film, and red and yellow coloured cellophane, such as sweet wrappers) – large enough to cover the petri dish
- cardboard box or tray (eg shoe box)
- colour chart and results table (provided as part of this resource).

Teacher notes

We recommend splitting the class into small groups – approximately four students per group.

Each group will work on one material at a time. Try to get all the groups to record their results at the same time so that the sunlight remains constant and allows their results to be 'comparative'. After the experiment you could pool their results but – if time permits – each group could swap materials and repeat. By repeating the experiment and averaging the results you can discuss the reliability of the results with the class.

UV colour changing beads are available online.[2] Only use the purple, mid-blue, deep blue or deep pink beads to ensure the most accurate readings. Match these to our colour chart, ranging from 0 (white: UV blocked) to 10 (deep colour: no UV protection).

The samples of material must be large enough to cover the petri dish completely.

You may need to stick the sample to the petri dish as it may blow off.

The beads can be used many times so repeating or taking part in new experiments is cost effective.

We have added extra space below the suggested materials on the results table to allow further investigation with different materials.

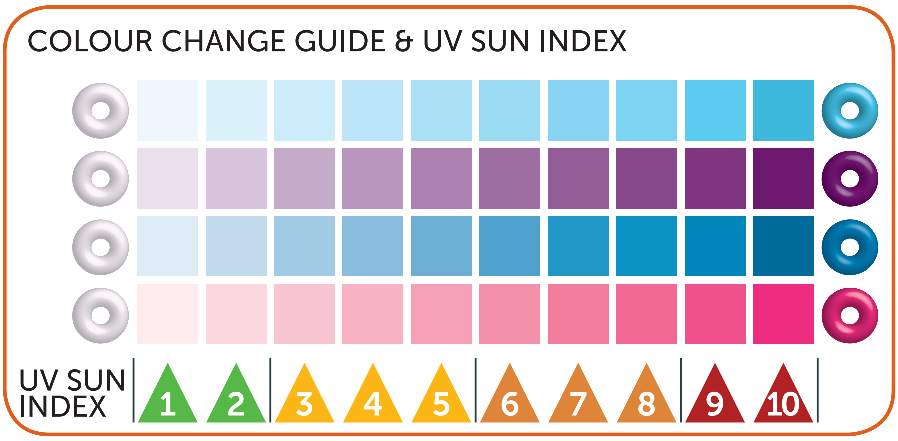
Vocabulary

UV, block, materials, properties, fair test, comparative test, prediction, control, transparent

Method

1. Before carrying out the experiment, discuss what properties a spacesuit visor may need and what materials you would like to test.
2. Become familiar with any colour changes that take place when the beads are inside or outside in the sunlight. (NB note how quickly they change colour when brought indoors)
3. Predict the colour change you expect for each material using the colour chart numbers.
4. Write your predictions in the results table.
5. Place four petri dishes in a box (without lids).
6. Place one bead in each petri dish and choose your first material to test.
7. In petri dish 1: cover the bead with one layer of your chosen test material.
8. In petri dish 2: cover the bead with two layers of your chosen test material.
9. In petri dish 3: cover the bead with three layers of your chosen test material.
10. In petri dish 4: leave the bead uncovered to act as a control.
11. Take the box outside to expose the samples to the sunlight (for ground floor classrooms you could hold the samples outside an open window.) Wait for 30 seconds or until the control turns to the deepest colour on the chart (number 10), whatever is first.
12. Quickly bring the box inside and remove the materials to reveal the beads' colours. Make a nearest match on the colour chart.
    (NB the bead may lose colour quickly. If the change is too quick to record, repeat steps 7–11).

    TIP: take a photo of the beads to help with the colour chart reading.
13. Record the colour chart number for each experiment layer on the results table.
14. Repeat with more materials or compare class data to complete the results table.
15. Post your results to **http://rsc.li/mission-starlight** and compare with schools worldwide.



Results

Material	Prediction	One layer – results	Two layers – results	Three layers – results
Polystyrene (eg petri dish plastic)				
Polyvinyl chloride (eg cling film)				
Red coloured cellophane (eg sweet wrapper)				
Yellow coloured cellophane (eg sweet wrapper)				

Conclusions

- From your results, which material do you feel is most suitable for an astronaut's visor?
- Why is it important to have a control bead in your experiment?
- Did increasing the number of layers of each material give the result you predicted?
- Can you think of how you could improve this experiment and/or the recording of the results?

Follow-on suggestions

- Use the UV beads to investigate how effective different types of sunglasses are at blocking UV light. Is there a difference between cheap and expensive sun glasses?
- See appendix 3 for an extensive list of other plastics to try.

Further information about the experiment

Astronauts' visors have coverings to reflect sunlight. Outer visors are made from UV-resistant polycarbonate, a type of plastic that is light in weight and allows visible light to pass through. They are coated with gold to reflect UV light. Spacesuits contain reflective coatings of Mylar which offer some protection from UV light, but it is the multiple-layer approach from many different durable fabrics which offers the full protection.

Tweet us

What materials did you try? Do you have any other class results or questions?

Tweet us using **#globalexperiment @RoySocChem** or leave a comment on our website: **http://rsc.li/mission-starlight**

Experiment 2: Can liquid coatings block UV light?

Mission brief: Astronauts complete many EVAs whilst in space. EVA stands for 'extra vehicular activity' but this is commonly known as a spacewalk. During a spacewalk, astronauts are exposed to the full glare of the sun so this is when they need the best protection. Spacesuit materials alone offer some protection from UV light, but can we do better?

Mission objective: Find out if liquid coating can be used to block UV light.

Mission directive: Investigate the UV protection provided by different depths of liquids.

Your students will learn to:

- understand basic experimental procedure for an investigation
- predict the possible outcomes
- observe and record UV bead colour changes resulting from different depths of liquids
- measure accurate volumes to ensure a comparative test
- compare data with other students worldwide.

Each group will need:

- Four same-colour UV colour changing beads (one as a control)[2]
- Four petri dishes with lids
- Liquids for testing (eg vegetable oil, pre-prepared black tea, sun cream SPF 8–10, tap water)
- A paintbrush
- A measuring cylinder/beaker or syringes (to measure 10ml and 30ml)
- Teaspoon (this can be used as a 5ml measure for transferring the sun cream)
- Cardboard box or tray (eg shoe box)
- Colour chart and results table (provided as part of this resource)
- Labels and pen.

Vocabulary

EVA, UV, block, materials, properties, fair test, comparative test, prediction, control, measuring ($ml = cm^3$)

Teacher notes

We recommend splitting the class into small groups – approximately four students per group.

Fair testing should be discussed during this experiment. As sunlight varies, each material and layer should be tested at the same time. The class groups should expose the beads to sunlight (step 10) at the same time for their results to be truly comparable. This might not always be possible but should be highlighted to the students.

Where resources are limited and the weather is constant, it is possible to use one petri dish for each liquid to be tested (making a total of two petri dishes per group, as one petri dish acts as the control). Start with a thin coating of the liquid in an upturned lid. After recording the result, add 10mls to the same petri dish. After recording this result, add a further 20mls (making a total of 30mls).

UV colour changing beads are available online.[2] Only use the purple, mid-blue, deep blue or deep pink beads to ensure the most accurate readings. Match these to our colour chart, ranging from 0 (white: UV blocked) to 10 (deep colour: no UV protection).

The beads can be used many times so repeating or taking part in new experiments is cost effective.

Before the lesson, prepare some tea: add 0.5 litres of boiling water to a tea bag in a jug and allow it to soak and cool with occasional stirring.

Due to its viscosity, when measuring the sun cream in this experiment use a teaspoon (approximately 5ml) rather than a measuring cylinder.

We have added extra space below the suggested liquids on the results table to allow further investigation with liquids of your choice.

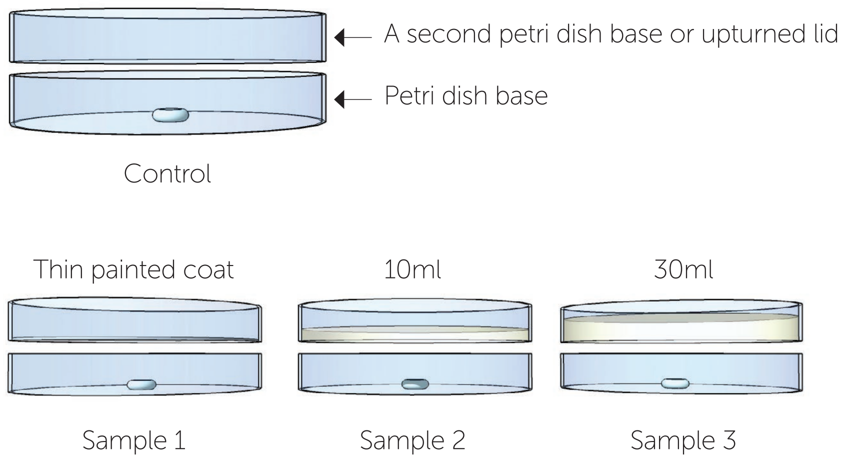


Diagram 1

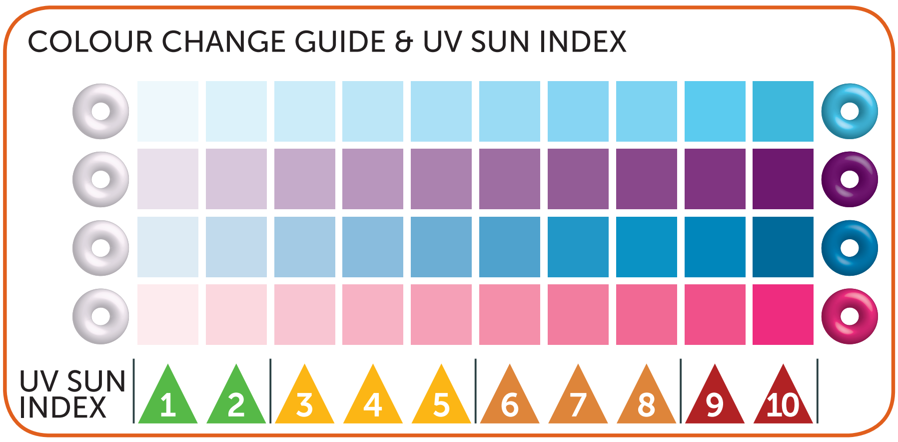
Method

1. Become familiar with any colour changes that take place when the beads are inside or outside in the sunlight. (NB note how quickly they change colour when brought indoors)
2. Predict the colour change you expect for each liquid using the colour chart.
3. Predict how effective at blocking UV light you think one thin coating will be for each liquid using the colour chart.
4. Write your predictions in the result table.
5. Place four petri dish bases in a box (without lids).
6. Place one bead in each petri dish and stack either an upturned lid or a second petri dish base on top (see diagram 1).
7. Choose your liquid to test and paint a thin layer of the liquid on the surface of the upturned lid/top petri dish base. (you could label this if needed)
8. Measure out 10ml of the liquid and add this to the surface of a different upturned lid/top petri dish base. (you could label this if needed)
9. Measure out 30ml of the liquid and add this to the surface of the final upturned lid/top petri dish base (you could label this if needed).

   You should also have a control petri dish (see diagram 1).
10. Take the box outside to expose the samples to sunlight.
    (For ground floor classrooms you could hold the samples outside an open window)
11. Wait for 30 seconds or until the control turns to a deep colour.
12. Quickly bring the box inside and remove the materials to reveal the beads' colours. Make a nearest match on the colour chart.
    (NB the bead may lose colour quickly. If the change is too quick to record, repeat steps 7–11).

TIP: take a photo of the beads to help make the colour chart reading.

13. Record the colour chart number for each liquid sample on the results table.
14. Repeat with different liquids or compare class data to complete the results table.
15. Post your results to **http://rsc.li/mission-starlight** and compare with schools worldwide.



Results

Liquid	Prediction	Thin coat	10ml	30ml
Vegetable oil				
Black tea				
Sun cream (SPF 8–10)				
Tap water				

Conclusions

- From your results, what happened to the colour of the beads as the depth of the liquid was increased? Suggest an explanation for why this may have happened.
- How close were your predictions to your results?
- From your results, which were the most effective liquids at blocking UV light? Suggest how you can use this information in your everyday life.
- Can you think of how you could improve this experiment and/or the recording of the results?

Follow-on suggestions

- Compare manufactured sunscreens of similar SPF rating. Do they provide the same UV protection?
- Does increasing the amount of sunscreen increase its effectiveness in blocking UV?
- Does increasing the depth or turbidity (eg river water and sea water that are less clear than tap water) affect results?
- Does temperature have any effect on the performance of the filters or coatings?
- How effective are other oils at blocking UV light (eg coconut, grapeseed, sunflower, carrot seed or raspberry seed oils. See appendix 4 for more details).
- Anti-ageing creams and even toothpaste contain titanium dioxide (a known UV blocker) so do these work in this experiment?

Further information about the experiment

Researchers have found that some plant oils contain natural sunscreens. Many natural oils and vitamins (such as vitamins E and C) may provide some protection from damaging UV light because they contain anti-oxidants. By adding these oils to sunscreens, manufacturers claim they can use less-conventional UV filters whilst retaining a high SPF. See appendix 4 for more information.

Tweet us

What materials did you try? Do you have any other class results or questions?

Tweet us using **#globalexperiment @RoySocChem** or leave a comment on our website: **http://rsc.li/mission-starlight**

Experiment 3: What particle size produces the most effective suspension?

Mission brief: Astronauts need to be protected using the best blockers of UV light. Scientists have discovered an ingredient that has many uses including protection from harmful UV light. It is called titanium dioxide. It's a white powder that doesn't dissolve in water or oil, is highly reflective and often used in paints and sun creams.

Titanium dioxide can be spread over smooth or uneven surfaces because when it's mixed in oil the insoluble solid particles are dispersed evenly so the oil can be applied to a surface. However the oily mixture can separate out over time.

Mission objective: Determine the best particle size for making a long-lasting suspension.

Mission directive: Use different types of sugar (a cheaper alternative to titanium dioxide) to investigate the best particle size for a suspension.

Your students will learn to:

- understand the basic experimental procedure for an investigation
- predict the possible outcomes
- observe and record how changing particle size affects a suspension
- measure accurate volumes to ensure a comparative test
- compare data with other students worldwide.

Each group will need:

- 100ml vegetable oil x4
- Transparent disposable plastic cup x4
- Measuring cylinder/beaker (to measure 100ml)
- Teaspoon
- Samples of sugar (eg icing, caster, granulated, Demerara)
- Clock or stopwatch
- A black permanent marker **for teacher use** (see teacher notes).

Vocabulary

Materials, properties, prediction, suspension, stable, particles, solution, solid, average, reliability, measuring (ml = cm^3)

Teacher notes

We recommend splitting your class into small groups – approximately four students per group.

Before the experiment, you will need to mark each groups' transparent cups with a short horizontal line in black permanent marker at the point exactly halfway (50ml) between the bottom of the cup and the top of the oil surface (see diagram 2).

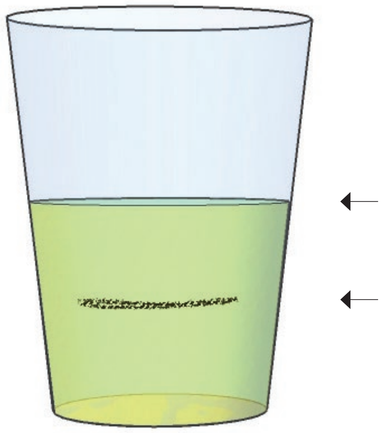


Diagram 2

This activity can be extended through repetition to get an average result for each sugar. The results table has been designed to fit this. If you have time, it's good practice for the students to do this and then discuss the reliability of their results.

An alternative method could be to measure the performance of all four sugars at once in four separate cups , laid out in a line. This may increase pupil engagement.

Method

1. Examine the sugar samples and list them in order of particle size (largest to smallest) on the results table.
2. Predict which of the sugars will stay in suspension for the longest time after stirring.

   The sugar that I predict will remain suspended for the longest time is

   ....

3. Measure 100ml of vegetable oil into a transparent cup.
4. Starting with the largest sugar grain, add one teaspoon (5g) to the cup. (To be consistent each time, make sure it is a level measure.)
5. Stir the sugar in the oil for 20 seconds.
6. Start the timer and measure how long it takes for all the sugar particles to fall below the black line.

   TIP: for smaller sugar particles, the initial mixture looks cloudy but will fall below the line eventually.

   (NB stop after 10 minutes if the particles are not all below the line – record this as 'stable'.)

7. Record the time in the results table.
8. Repeat steps 3–7 (with a clean cup and fresh oil) for the remaining sugars.
9. Post your results to **http://rsc.li/mission-starlight** and compare with schools worldwide.

Results

Particle size	Type of Sugar	Time (min:sec, 00:00)	Time (min:sec, 00:00)	Time (min:sec, 00:00)	Average (min:sec, 00:00)
Large grains					
Small grains					
Very small grains					
Tiny grains (powder)					

Conclusions

- Which sugar stayed in suspension for the longest time? This is what we call the 'best suspension' or 'most stable suspension'. How does this relate to particle size?
- Why do you think there was a difference in the results?
- From your results, which of these suspensions do you feel would spread most evenly on a surface and how do you think this knowledge might impact on the manufacturing of sunscreen?
- From your results what particle size would you recommend for a suspension of titanium dioxide for an astronaut?

Follow-on suggestions

- Investigate different oils. Do they give the same results?
- Investigate product labels and their instructions, from a variety of different sunscreens. If the phrase 'shake before use' is written, you can conclude that it is a suspension containing some form of UV-blocking ingredient (eg titanium dioxide or zinc oxide).

Further information about the experiment

The smaller the particles, the longer they will stay in suspension and the more evenly they will spread throughout the mixture. This will result in a more even coating on the surface to be protected.

Tweet us

What materials did you try? Do you have any other class results or questions?

Tweet us using **#globalexperiment @RoySocChem** or leave a comment on our website: **http://rsc.li/mission-starlight**

Experiment 4: Can you make your own effective UV block for use in space?

Mission brief: The International Space Station (ISS) is an astronaut's first line of defence. It needs to be able to protect the astronauts inside at all times.

Mission objective: Get creative and make your own UV block.

Mission directive: Determine whether a suspension, liquid or series of material layers is the best blocker of UV light. For inspiration, review data from the global experiment website (http://rsc.li/mission-starlight) or see what other people have tried via twitter (#globalexperiment).

For students aiming for a CREST award, this activity should be written up as part of their application (see page 6).

Teacher notes

In pairs or as a group discussion, students should decide where on the ISS UV protection will be essential and suggest different combinations of coatings and filters.

For example:

- a visor for the astronaut on a spacewalk
- a coating for the ISS
- a coating for a spacesuit
- a filter for the ISS windows

Students should also consider whether their block will be fit for purpose. For example, the coating of a spacesuit needs to be flexible and evenly spread but not so thick that an astronaut can't move freely. Another example would be that any window or visor would need to be transparent.

Students can follow the method of any previous experiment in order to complete the investigation.

Substances to test are all widely available (sunscreens, natural oils, substances containing titanium dioxide, like toothpaste, or even natural substances, like mud or living plant leaves). Students could even consider using a mixture of substances.

You may be tempted to trial your own suspensions of titanium dioxide or zinc oxide (using the solid chemicals) with your class. This should only be done with a planned procedure and risk assessment.

Tweet us

What did you try and was it effective?

Tweet us using **#globalexperiment @RoySocChem** or leave a comment on our website: **http://rsc.li/mission-starlight**

Vocabulary

UV, block, materials, properties, transparent, measuring (ml = cm^3)

Results

Visor:
Best material discovered to date is

……………………………………………………………

Spacesuit:
Best material discovered to date is

……………………………………………………………

Space station:
Best material discovered to date is

……………………………………………………………

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Glossary

Absorb	To soak up or take in (eg light rays).
Atmosphere	The various gases that surround the Earth.
Control	A sample that stays the same in each experiment. It is used to compare the impact of the independent variable being tested.
Inorganic	Combining two or more chemical elements other than carbon.
HDPE	High-density polyethylene. There are many different types (see appendix 3 for more details).
Organic	Substances containing the element carbon.
Ozone layer	Found in the upper region of the atmosphere, it contains enough ozone (O_3 gas) to block most of the sun's ultraviolet light.
Pigment	A substance that can give colour to a material.
Solution	A mixture in which one substance is dissolved in another.
SPF	Sun Protection Factor.
Suspension	A mixture containing insoluble solid particles dispersed evenly in a liquid that will eventually separate.
Turbidity	The measurement of how clear a liquid (eg water) is. The more suspended particles the liquid has the less clear it becomes and the higher its turbidity. Pure water has a turbidity score of 0.
Transparent	Can be seen through clearly.
UV	Ultraviolet light. Ultraviolet light comes in three wavelengths: UVA; UVB; and UVC (see appendix 1 for more details).

Appendices

1. The three different wavelengths of ultraviolet light are: UVA; UVB; and UVC. Each wavelength can damage in different ways.

   On earth, UVA fades colours and causes ageing while UVB can cause damage to our DNA. Some people like to get suntans (and often get painful sunburns) but these just show that they have exposed themselves to dangerous levels of UVB.

   UVC does not reach earth thanks to the ozone layer high in our atmosphere. But in space, UVC is present and is considered the most damaging UV light to our DNA. That's why astronauts are at high risk.

   http://www.who.int/uv/faq/whatisuv/en/index2.html

   https://en.wikipedia.org/wiki/Ultraviolet

2. An internet search for 'UV colour changing beads' or a search via online retailers should help you find cheap suppliers.

   The beads often come in large multi-coloured packs. For the most accurate results only use the deep coloured beads (purple, mid blue, deep blue or deep pink) Match these to our colour strip ranging from 0 (white: UV blocked) to 10 (deep colour: no UV protection)

3. Resin identification codes, based on *How do I identify different type of plastic?* **www.lincolnshire.gov.uk/upload/public/attachments/540/PlasticID.doc**

Resin identification codes	Name of plastic	Description	Some uses for 'virgin' plastic	Some uses for plastic made from recycled waste plastic
01 PET	Polyethylene terephthalate (PET)	Clear, tough plastic; may be used as a fibre.	Soft drink and mineral water bottles, filling for sleeping bags and pillows, textile fibres.	Soft drink bottles, (multi-layer) detergent bottles, clear film for packaging, carpet fibres, fleecy jackets.
02 PE-HD	High density polyethylene (HDPE)	Very common plastic; usually white or coloured.	Crinkly shopping bags, freezer bags, milk and cream bottles, bottles for shampoo and cleaners, milk crates.	Compost bins, detergent bottles, crates, mobile rubbish bins, agricultural pipes, pallets, kerbside recycling boxes.
03 PVC	Unplasticised polyvinyl chloride (UPVC)	Hard, rigid plastic; may be clear.	Clear cordial and juice bottles, blister packs, plumbing pipes and fittings.	Detergent bottles, tiles, plumbing pipe fittings.
03 PVC	Plasticised polyvinyl chloride (PPVC)	Flexible, clear, elastic plastic.	Garden hose, shoe soles, blood bags and tubing.	Hose inner cores, industrial flooring.

04 PE-LD	Low density polyethylene (LDPE)	Soft, flexible plastic.	Lids of ice cream containers, bin bags, rubbish bins, black plastic sheets.	Film for builders, industry packaging, plant nursery bags.
05 PP	Polypropylene (PP)	Hard, but flexible plastic – many uses.	Ice cream containers, potato crisp bags, drinking straws, hinged lunch boxes.	Compost bins, kerbside recycling boxes, wormeries.
06 PS	Polystyrene (PS) Expanded polystyrene (EPS)	Rigid, brittle plastic. May be clear, glassy.	Yogurt containers, plastic cutlery, imitation crystal 'glassware', hot drink cups, takeaway food containers, meat trays, packaging.	Clothes pegs, coat hangers, office accessories, spools, rulers, CD cases.
07 OTHER	All other plastics, including acrylic and nylon. These cannot be recycled.			

4. The following natural oils have measurable Sun Protection Factors (SPF). They are all widely available from supermarkets and online retailers but can be expensive.

   Red raspberry seed oil (SPF 30–45) > carrot seed oil (SPF 30) > wheat germ oil (SPF 20) > hazelnut oil and coconut oil (SPF 15) > soy bean oil (SPF 10) > shea butter (SPF 6–10) > grape-seed, macadamia, jojoba, sesame, rice bran, hemp, avocado and peanut oil (all SPF 5).

   Raspberry seed oil has high proportions of vitamins E and A as well as omega-3 fatty acids and is a good broad-spectrum UV light block. Plants contain additional substances that can be useful in skincare. Research is ongoing.

   SPF is an imperfect measure of skin protection because it only measures UVB block. Conventional sunscreens provide very little UVA protection. UVA causes skin aging but does not primarily cause reddening or pain. New broad-spectrum sunscreens are designed to protect against both UVB and UVA. This has been highlighted in the media recently due to research linking high levels of UVA exposure to DNA damage.

   Sunscreens contain active ingredients that can be 'organic', which tend to absorb UV, or 'inorganic', which tend to block UV. Organic sunscreens form a thin coating on the skin that absorbs the harmful UV light before it passes through the skin. Inorganic sunscreens contain metal oxides such as zinc or, more often, titanium dioxides which are insoluble particles that absorb and reflect UV away from the skin. Most modern-day sunscreens contain a mixture of organic and inorganic materials.

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