Why don't plants get sunburn?

Key Stage 4 Programme

Pupil Name	
Handbook Designed by	Dr L. A. Baker

Timetable and Assignment Submission

Timetable – Tutorials

1			
2			
3			
4			
5			
6 (Feedback)			

Timetable – Homework Assignments

Tutorial 1		
Tutorial 2		
Tutorial 3		
Tutorial 4		
Tutorial 5		

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after midnight on _____	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

The Brilliant Club KS4 Programme – Pupil Feedback Report

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at A-level
2:1	60-69	Performing to a good standard at AS-level
2:2	50-59	Performing to an excellent standard at GCSE
3rd	40-49	Performing to a good standard at GCSE
Working towards a pass	0-39	Performing below a good standard at GCSE
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Name of PhD Tutor	Dr L. A. Baker		
Title of Assignment	Why don't plants get sunburn?		
Name of Pupil			
Name of School	George Abbot School		
ORIGINAL MARK / 100		FINAL MARK / 100	
DEDUCTED MARKS		FINAL GRADE	

If marks have been deducted (e.g. late submission, plagiarism) the PhD tutor should give an explanation in this section:

Learning Feedback Comment 1 -	
What you did in relation to this Key Learning Priority	How you could improve in the future
Learning Feedback Comment 2 –	
What you did in relation to this Key Learning Priority	How you could improve in the future
Learning Feedback Comment 3 –	
What you did in relation to this Key Learning Priority	How you could improve in the future
Resilience Comment	
How you showed learning resilience during the course	How you could build learning resilience in the future

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Course Rationale

Why don't plants get sunburn? is a new interdisciplinary course delivered by a 'Researchers in Schools' teacher. It focusses on sunscreens, like those we would use on a beach holiday, as a way to protect our skin from the harmful effects of ultraviolet light. Amazingly, plants have already come up with this, beating humans to the idea by well over a hundred million years! They produce a sunscreen molecule (similar to those found in your sun cream) and place it in their leaves for protection. Surprisingly, although sunscreen products have been available on supermarket shelves for nearly a century, how they work is not well-known, and that's where this course begins.

Why don't plants get sunburn? introduces the topic of photochemistry; the study of what happens after light interacts with atoms. Photochemistry spans all areas of science, where examples include human vision, solar cells for renewable energy, organic switches, and of course, sunscreens. Over this course of six tutorials, we will answer many questions. What happens when a sunscreen absorbs ultraviolet light? How and why does this protect our skin? What would happen if we didn't protect our skin? Answering these questions is important to scientists as it could lead to the next generation of improved sunscreens, and even guide us to improving crop yields.

When it comes to ultraviolet light it is not all 'doom and gloom'; humans and plants both need some ultraviolet light for survival, but too much can cause damage. There exists some happy equilibrium, referred to as the 'burden of disease', which we will uncover in detail. The course ends with a final assessment, where you will produce an article in the style of a scientific journal, reporting on all aspect of the delivered content, discussions, and your own research. This final task gives you the opportunity to develop your scientific writing and literature research skills, where both are vital for a successful modern scientist.

For more information on Researchers in Schools see: http://www.researchersinschools.org/

Mark Scheme Table

	Skills	1st (70–100)	2:1 (60–69)	2:2 (50–59)
Subject knowledge	Knowledge and Understanding	○ All content included is relevant to the general topic and to the specific question/title ○ Good understanding of all the relevant topics. ○ Scientific terms are defined and used accurately throughout ○ Clear justification on how the content included is related to the specific issues that are the focus of the assignment	○ Most of the content included is relevant to the general topic and to the specific question/title ○ Good understanding of most the relevant topics ○ Scientific terms are used accurately but not always clearly defined. ○ Adequate justification on how the content included is related to the specific issues that are the focus of the assignment	○ Some of the content included is relevant to the general topic and to the specific question/title ○ Good understanding on some of the relevant topics but occasional confusion on others. ○ Scientific terms are used mostly accurately with occasional confusion and often not defined. ○ Some justification on how the content included is related to the specific issues that are the focus of the assignment
Critical thinking	Research and Evidence	○ Inclusion of rich sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas ○ Use evidence/calculations to support claims/assertions /ideas, consistently clearly and convincingly ○ Evidence of further reading beyond materials provided which were used in an appropriate context ○ Data is effectively analysed and appropriate assumptions/conclusions are reached	○ Inclusion of adequate sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas ○ Use evidence/calculations to support claims/assertions/ideas, mostly clearly and convincingly ○ Evidence of further reading beyond materials provided ○ Data is analysed and the assumptions/conclusions that are reached are mostly appropriate	○ Inclusion of some sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas ○ Use evidence/calculations to support claims/assertions/ideas, at times clearly and convincingly ○ Limited evidence of further reading beyond materials provided ○ There is an attempt to analyse data is and draw assumptions/conclusions

	Developing an Argument	○ A point of view or position in relation to the title or question is consistently clear ○ Argument/proof exceptionally well-developed and well-justified ○ A position is clearly established in relation to the question and is developed effectively and consistently throughout the essay ○ Makes links effectively between subjects that have not previously been associated ○ Uses concepts from the tutorials in an unfamiliar context, and does so accurately and confidently. ○ Content is analysed effectively to support the argument	○ A point of view or position in relation to the title or question is adequately clear ○ Argument/proof clear and well-developed and position justified ○ A position is established in relation to the question and is well-developed in most of the essay ○ Some evidence of linking subjects that have not previously been associated ○ Use some concepts from the tutorials in an unfamiliar context, but not always accurate ○ Analysis of content to support the argument	○ A point of view or position in relation to the title or question is somewhat clear ○ Argument/proof clear but not well-developed ○ A position is established in relation to the question and is well-developed in parts of the essay ○ Limited evidence of linking subjects that have not previously been associated ○ Limited use of concepts from the tutorials in other contexts ○ Some analysis of content to support the argument
	Critical Evaluation	○ Moved beyond description to an assessment of the value or significance of what is described ○ Evaluative points are consistently explicit/systematic/reasoned/justified ○ Effective critiques on the reliability of sources provided	○ Mostly description but some assessment of the value or significance of what is described ○ Evaluative points are mostly explicit/systematic/reasoned/justified ○ Some evidence of critiques on the reliability of sources provided	○ Only description with minimal assessment of the value or significance of what is described ○ Evaluative points are at times explicit/systematic/reasoned/justified ○ Limited evidence of critiques on the reliability of sources provided

Written communication	Structure and Presentation	○ Ideas are presented in paragraphs and arranged in a logical structure that is appropriate for the assignment ○ The introduction clearly outlines how the essay/report will deal with the issues ○ The conclusion summarises all the main points clearly and concisely ○ All calculations, formulas and methods are clearly structured, clear to follow and correct ○ Tables and graphs are effectively constructed including appropriate headings, units and scales. ○ All sources are referenced correctly in an agreed format	○ Ideas are presented in paragraphs and arranged in a structure that is mostly appropriate for the assignment ○ The introduction adequately describes how the essay/report will deal with the issues ○ The conclusion summarises most of the main points clearly ○ Calculations, formulas and methods are mostly structured, clear to follow and correct ○ Most tables and graphs are well constructed ○ Most sources are referenced correctly in an agreed format	○ Ideas are presented in paragraphs and arranged in a structure ○ The introduction mentions how the essay/report will deal with the issues ○ The conclusion summarises some of the main points clearly ○ Calculations, formulas and methods are not always structured, clear to follow and correct. ○ Some tables and graphs are well constructed but contain some errors ○ Some sources are referenced correctly in the agreed format with occasional errors
	Language and Style	○ No spelling, grammar or punctuation errors ○ Units and significant figures are presented accurately throughout ○ Writing style consistently clear, appropriate for scientific documents and easy to follow ○ Accurate and consistent use of technical language and vocabulary	○ Minimal spelling, grammar or punctuation errors ○ Units and significant figures are presented accurately throughout ○ Writing style mostly clear, appropriate for scientific documents and easy to follow ○ Some attempts of using technical language and vocab alary, but not always accurate	○ Some spelling, grammar or punctuation errors ○ Units and significant figures are presented accurately throughout with occasional errors ○ Writing style moderately clear, appropriate for scientific documents and easy to follow ○ Use of simple language and vocabulary effectively but struggles to use technical language

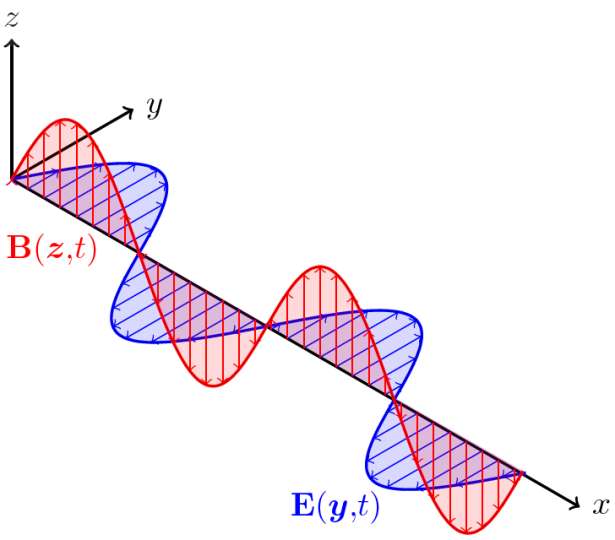
Glossary of Keywords

Fill this out after each tutorial. Feel free to add any others you think will be helpful.

Word	Definition	In a sentence
Amplitude		
Wavelength		
Frequency		
Peak		
Trough		
Time period		
Electromagnetic spectrum		
Wave speed		
Photon		
Electronic transition		
Absorption		
Emission		
Femtosecond		
Picosecond		

Ground electronic state		
Excited electronic state		
Vibrational state		
Photochemistry		
Internal conversion		
Vibrational relaxation		
Orbital (energy level)		
trans-cis isomerism		

Tutorial 1 – The electromagnetic spectrum



What is the Purpose of Tutorial 1?

- Baseline test
- Review of the electromagnetic spectrum
- Key features of electromagnetic waves
- The relationships between velocity, frequency, wavelength, and energy

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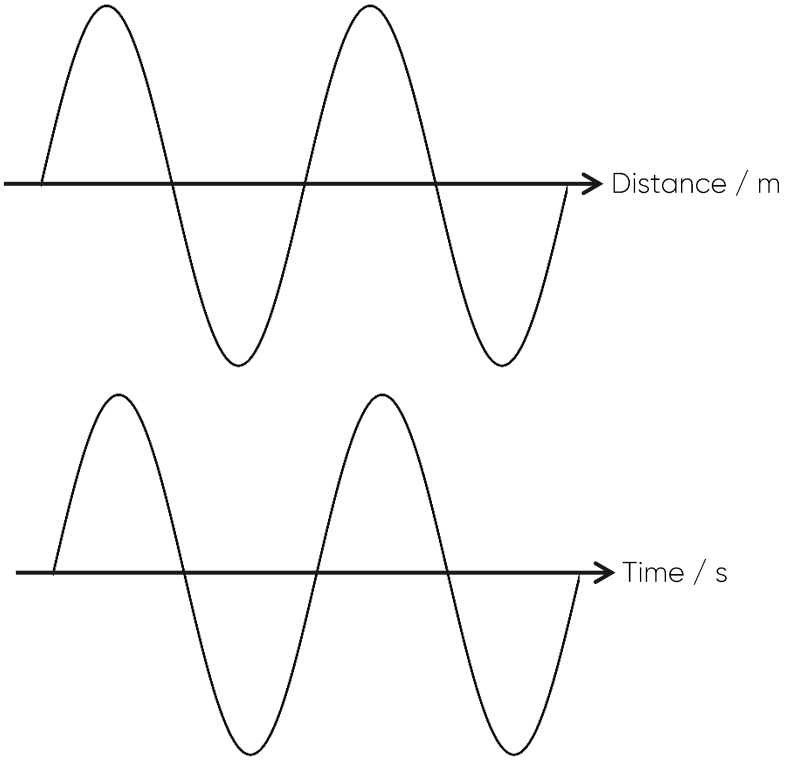
Starter: brainstorming. What words, ideas, concepts, and thoughts come to mind when you hear 'electromagnetic spectrum'?

The electromagnetic spectrum

Activity 1 – Label the following example waves with their key properties: amplitude, wavelength, peak, trough, time period, and frequency.



What is the 'y' axis on these waves? What about electromagnetic waves?

Activity 2 – complete the following sentences based on the lecture material, using the following words (some might be used more than once):

time period, amplitude, radio waves, wavelength, gamma waves, energy, electric, least, inverse, magnetic, frequency, transverse, electromagnetic spectrum.

All waves are simply the propagation of a disturbance. Sound waves are the propagation of vibrations in air particles, electromagnetic waves are the propagation of _____ and _____ fields.

Electromagnetic waves are an example of _____ waves, which mean their propagation direction is perpendicular to the disturbance.

The maximum disturbance for any wave is known as the wave's _____.

The distance between two identical disturbances is known as the wave's _____.

The time between two identical disturbances is known as the wave's _____, closely related to the wave's _____ by its _____.

There are many types of electromagnetic waves, what makes each wave unique from one another is its _____. Together, all electromagnetic waves make up the _____.

The highest frequency waves of this spectrum are known as _____ which have the most _____. Conversely, _____ are the _____ energetic part of the spectrum.

Reading – read through the following information and consider how it relates to the previous material, we will then discuss this as a group.

We have so far discussed some of the important properties of waves, such as wavelength and frequency, and hopefully, now you might have begun to suspect that they are closely related. Indeed, this is the case, they are related by the speed of the wave. This might not come as a surprise if one considers the units of wavelength (meters, m) and frequency (Hertz or s^{-1}). If you multiply wavelength and frequency together, this gives units of speed (meters per second, ms^{-1}). We can sum this up neatly into the following equation:

$$v = f \times \boldsymbol{\lambda},$$

where the wave speed is denoted by v, frequency by f, and wavelength by **λ**. It is here where one of the most important properties of electromagnetic waves is seen. For **an** electromagnetic wave travelling in a vacuum (such as space), it always travels at the speed $v = 3 \times 10^8\ ms^{-1}$ or roughly 186,000 miles per second. Why *this* speed? It turns out to be a fundamental law of nature, as first proposed by Albert Einstein in his theory of relativity. This is important since it explains the distinct components of the electromagnetic spectrum, they all travel at the same speed in a vacuum, which means the product of wavelength and frequency must always make the same number, $3 \times 10^8\ ms^{-1}$. As a final note, it should be remembered, however, that the above equation is true for any wave such as sound, not just electromagnetic waves.

We are now in the position to calculate unknown quantities of waves based on this equation. For example, if blue light has a wavelength of 400 nm, what is its frequency?

Equation: $v = f \times \lambda$
Rearrange: $f = v / \lambda$
Substitute known quantities: $f = (3 \times 10^8) / (400 \times 10^{-9}) = 7.5 \times 10^{14}$ Hz

Your turn – calculate the frequency and wavelength of the following (you can assume $v = 3 \times 10^8\ ms^{-1}$):

1) $\lambda = 1$ m; f = _____

2) $\lambda = 390$ nm; f = _____

3) f = 3000 Hz; λ = _____

Another amazing suggestion, by Albert Einstein in 1921, was that electromagnetic waves sometimes behaved as particles. This came as a surprise because we are used to waves being, well, wavy like. But this idea proved absolutely essential to understanding some key experiments, and in fact, lead to Einstein's Noble prize. He suggested that an electromagnetic particle, called a **photon**, has energy proportional to the frequency of the associated electromagnetic wave. This once again can be written neatly as

$$E = h \times f,$$

Where E is the energy of the photon, f is the frequency of the electromagnetic wave, and h is a number equal to 6.63×10^{-34} Js, known as Planck's constant. It is this equation which links the wave-like properties of electromagnetic waves to the particle-like properties of a photon. The idea of an entity having both wave and particle-like properties is known as wave-particle duality, and this marks your first steps into the field of *quantum mechanics*.

We are now in the position to begin calculating the energy of different photons of electromagnetic radiation. For example, what is the energy of a single 'blue' photon?

Equation: $E = h \times f$
Take 'f' from previous example, $f = 7.5 \times 10^{14}$ Hz
Substitute known quantities: $E = 6.63 \times 10^{-34} \times 7.5 \times 10^{14} = 5.0 \times 10^{-19}$ J

Notice how we can combine both these equations into a single expression by substituting the rearranged equation for frequency into the second expression:

Rearrange $v = f \times \lambda$ to $f = v / \lambda$. Substitute this into $E = h \times f$ gives: $E = h \times v / \lambda$

Your turn: calculate the energy and frequency of the following waves:

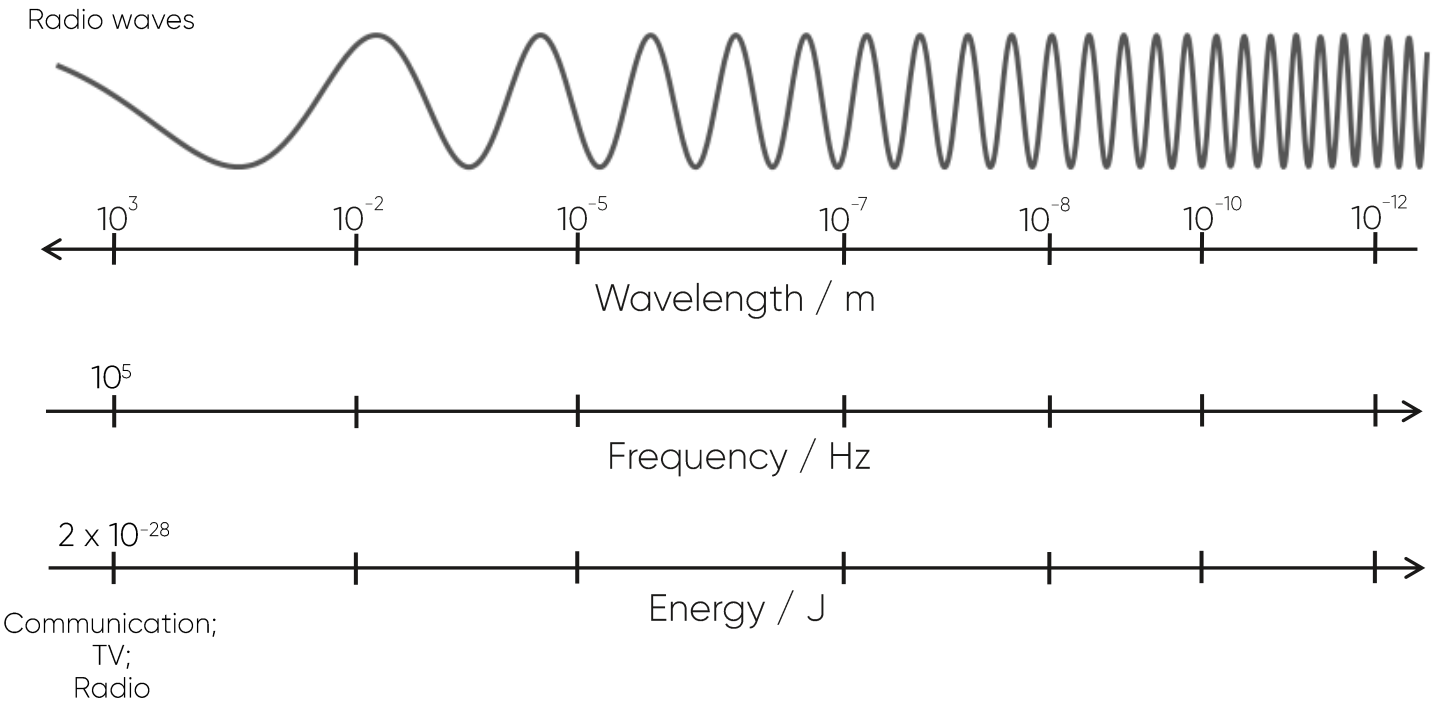
1) $f = 500 \times 10^{12}$; E = _____

2) E = 10 J; f = _____

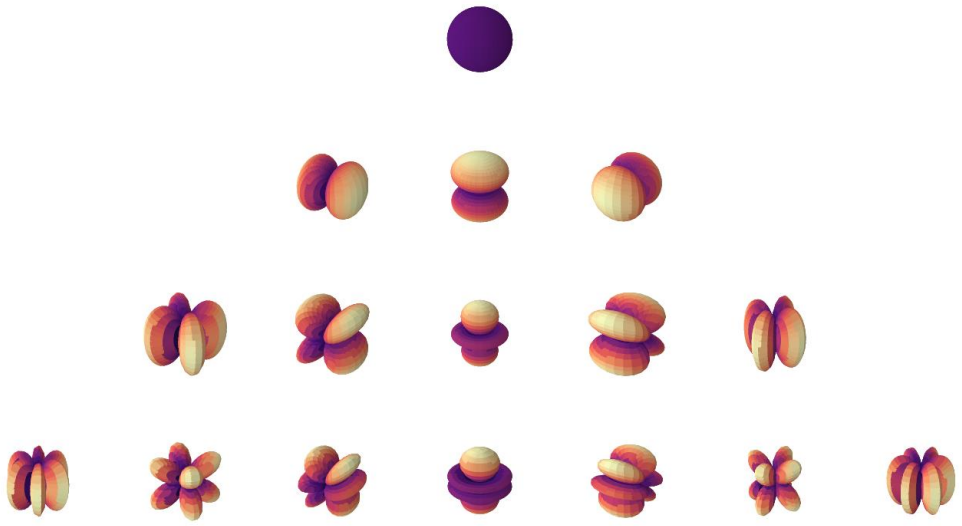
3) $\lambda = 400$ nm; E = _____

Homework assignment 1 – complete the electromagnetic spectrum figure below, you are of course encouraged to use the material covered in this tutorial as well as any additional research you find appropriate. 'Radio waves' has been done for you.

1) You will need to convert the given wavelengths into corresponding frequencies (rounded to the 1st significant figure), and then calculate the corresponding energy for a photon of each frequency.
2) (Approximately) label the different regions of the electromagnetic spectrum with radio waves, microwaves, infra-red, visible light, ultraviolet light, x-rays, gamma rays.
3) Can you give an example application for each of these regions of the electromagnetic spectrum?



Tutorial 2 – Electronic structure of atoms



What is the Purpose of Tutorial 2?

- Review the atomic structure of atoms
- Electrons can interact with electromagnetic radiation
- Introduction to electronic excited states
- Conservation of energy calculations

Starter – can you draw the atomic structure of the following atoms? Can you work out how many protons, neutrons and electrons are in each atom?

$^{12}_{6}C$ carbon	$^{24}_{12}Mg$ magnesium	$^{7}_{3}Li$ lithium

Lecture – make notes on the following introductory lecture on electrons and their interaction with electromagnetic waves. Try to answer these questions as the lecture proceeds. We will then discuss.

1) How are electrons arranged in an atom?

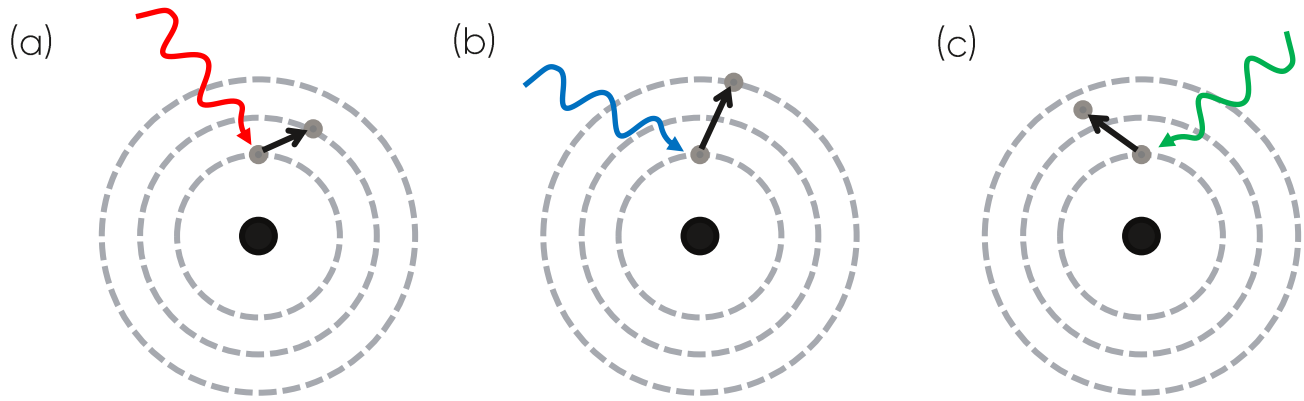
2) How does an electron absorb a photon? How does an electron emit a photon?

3) How does the phrase 'conservation of energy' relate to absorption and emission?

Any other notes you want to make?

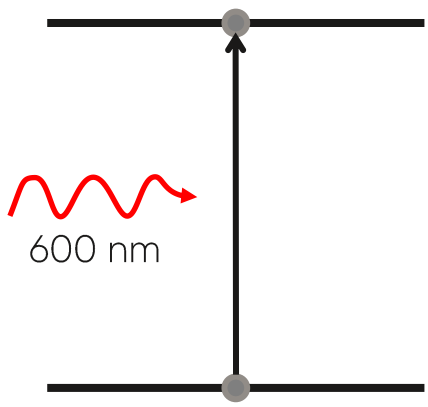
Activity 1 – read and complete the following text.

Electrons in an atom may interact with electromagnetic radiation. They can absorb the radiation and jump between two energy levels, known as an electronic transition. Look at the examples below, which of these are allowed transitions, and which are forbidden? Can you justify your answers? Can you write a rule which describes this?



Rule: _____

Transitions between energy levels can be depicted as simple two-state diagrams where the bottom line represents the where the electron was and the top line represents where the electron is now. The 'y' axis on these diagrams is, therefore, the energy of the electron. Here is an example:

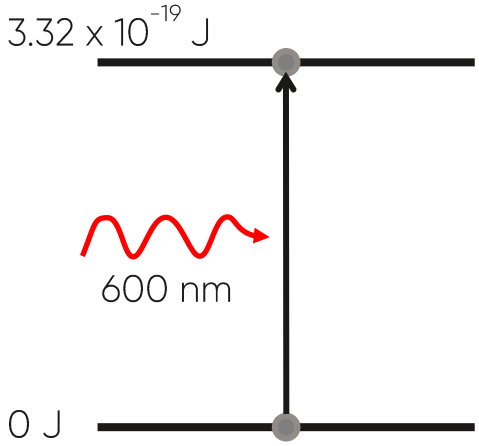


Red light with wavelength 600 nm is absorbed by an electron. In order to do this, the electron must jump to a higher energy level. The energy gap between the start and end energy level must EXACTLY match the energy of the red-light photon. This is an example of the conservation of energy, another fundamental law of nature. Given this information, can you write another rule which governs electronic transitions?

Rule: _____

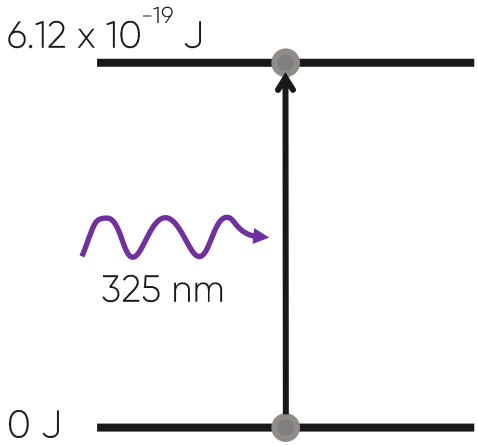
So, let's put this into practice. In the following examples, can you decide if each transition is allowed, and if it is not, can you calculate the wavelength of light needed for the transition to occur? What part of the electromagnetic spectrum do these wavelengths of radiation, causing the transitions, reside it? Note that 1 eV (1 electron volt) is equal to 1.6×10^{-19} J, a commonly used unit of energy in physics because it is on a similar scale to the energies of electrons in atoms.

(a)



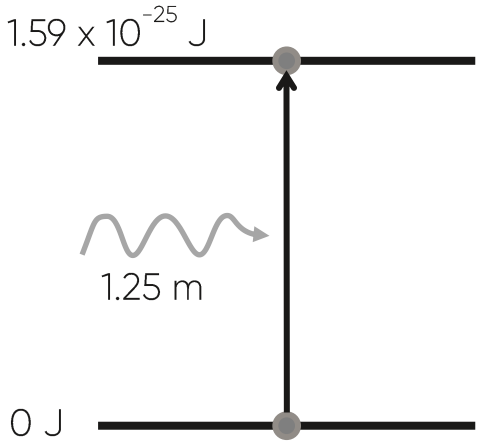
Allowed?

(b)



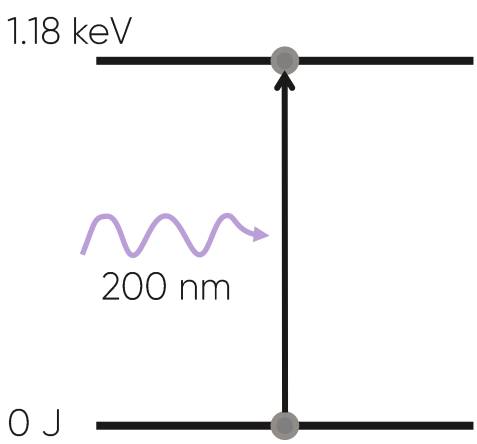
Allowed?

(c)



Allowed?

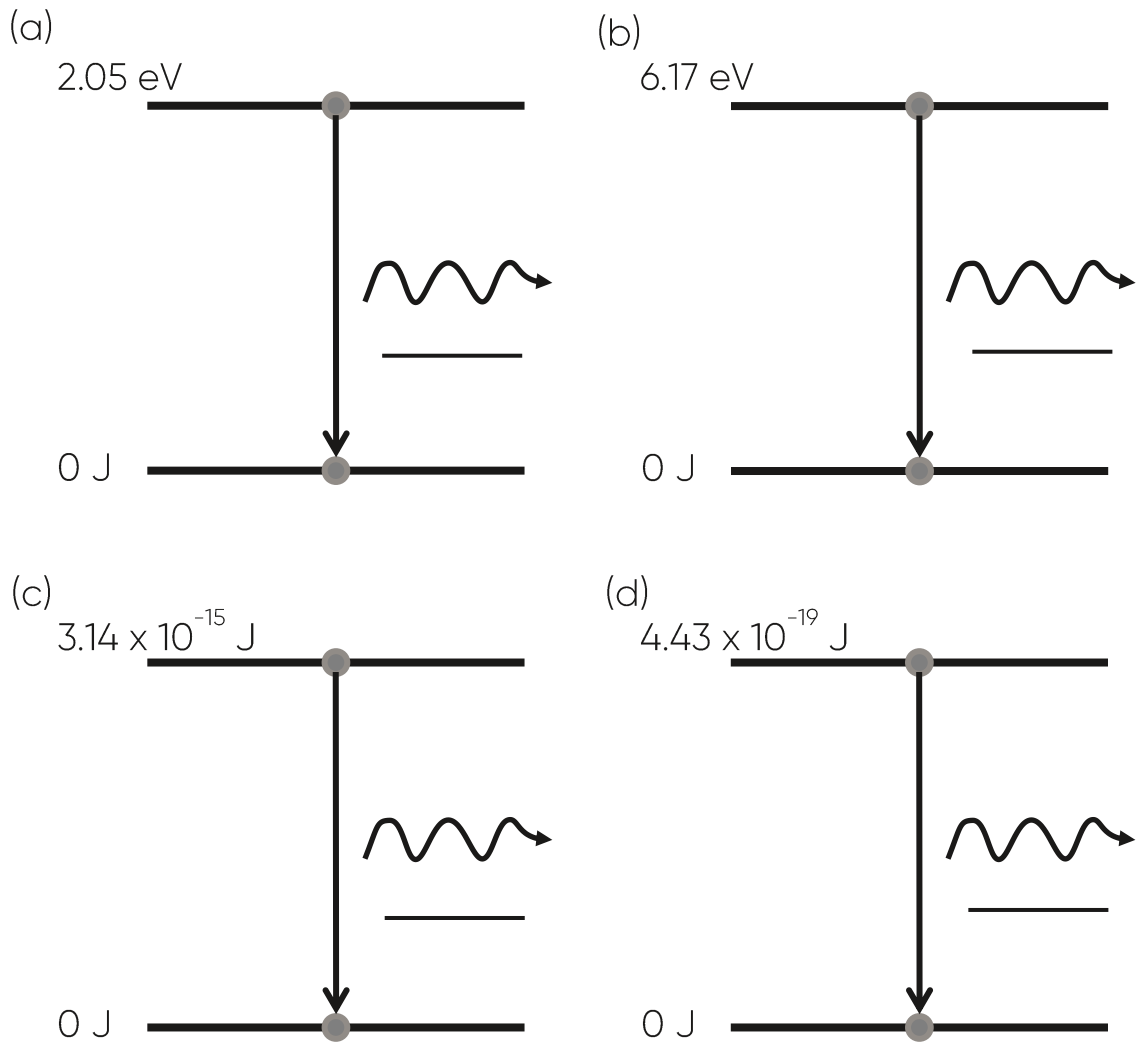
(d)



Allowed?

We have now covered absorption of radiation quite extensively, but what about the opposite process, what about an electron dropping down from a higher energy level to a lower energy level? Well, so long as the same rule discussed are followed, then this is possible. In this process, a photon with energy equal to the gap between the start and final energy levels is emitted; this process is referred to as emission.

Can you work out the wavelengths of the photons emitted from the following energy level diagrams? Remember 1 eV = 1.6×10^{-19} J.



Activity 2 – how do invisible ink pens work? I've brought some in, have a go. Can you draw a two-level energy diagram for it? Be sure to think about the energy of the photons involved – does it satisfy the rules we've discussed up to now?

Leave the space below empty for now, next tutorial we will come back to discuss this further.

Homework assignment 2 – read the following text from a scientific publication from 1991. This was the first time the some of the details of how human vision works were reported. This is a toughie, but see what you can pick out about how vision works. Be sure to Google any of the terms you are unfamiliar with. Feel free to bring anything else you find related to this topic in for discussion. You can annotate the text, and make notes on the next page as much as you would like to. I have highlighted some of the more important sentences.

The First Step in Vision: Femtosecond Isomerization of Rhodopsin

R. W. Schoenlein, L. A. Peteanu, R. A. Mathies, C. V. Shank

The kinetics of the primary event in vision have been resolved with the use of femtosecond optical measurement techniques. The 11-*cis* retinal prosthetic group of rhodopsin is excited with a 35-femtosecond pump pulse at 500 nanometers, and the transient changes in absorption are measured between 450 and 580 nanometers with a 10-femtosecond probe pulse. Within 200 femtoseconds, an increased absorption is observed between 540 and 580 nanometers, indicating the formation of photoproduct on this time scale. These measurements demonstrate that the first step in vision, the 11-*cis*→11-*trans* torsional isomerization of the rhodopsin chromophore, is essentially complete in only 200 femtoseconds.

Light detection by the visual system is one of nature's most important information transduction processes. It consists of a series of chemical reactions that are initiated by the absorption of a photon and culminate in the stimulation of the optic nerve. It has long been known that the primary step in vision is the photoisomerization of the retinal chromophore in rhodopsin (*1*). However, understanding the dynamics of this isomerization remains a fundamental problem in photochemistry and biology. The time course of many photochemical reactions can be studied with compressed femtosecond optical pulses (*2*). Such pulses were previously used to observe the isomerization of the retinal chromophore in bacteriorhodopsin, a related pigment which functions as a light-driven proton pump (*3*). Recent advances in the generation of femtosecond pulses in the blue-green spectral region now make it possible to study a much wider range of ultrafast processes with a time resolution of 10 fs (*4*). We report here the room temperature investigation of the *cis-trans* isomerization in rhodopsin which reveals that the first step in vision occurs on a 200-fs time scale and is one of the fastest photochemical reactions ever studied.

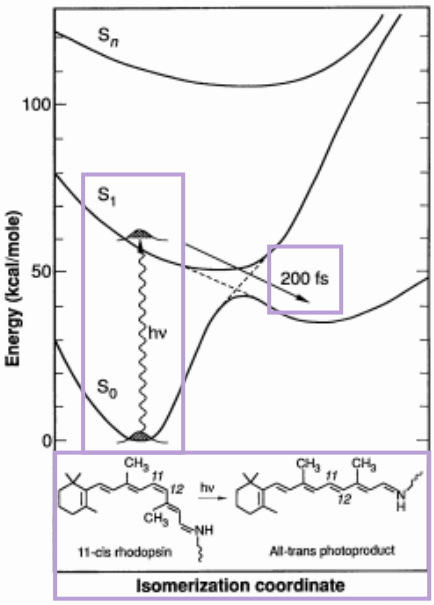
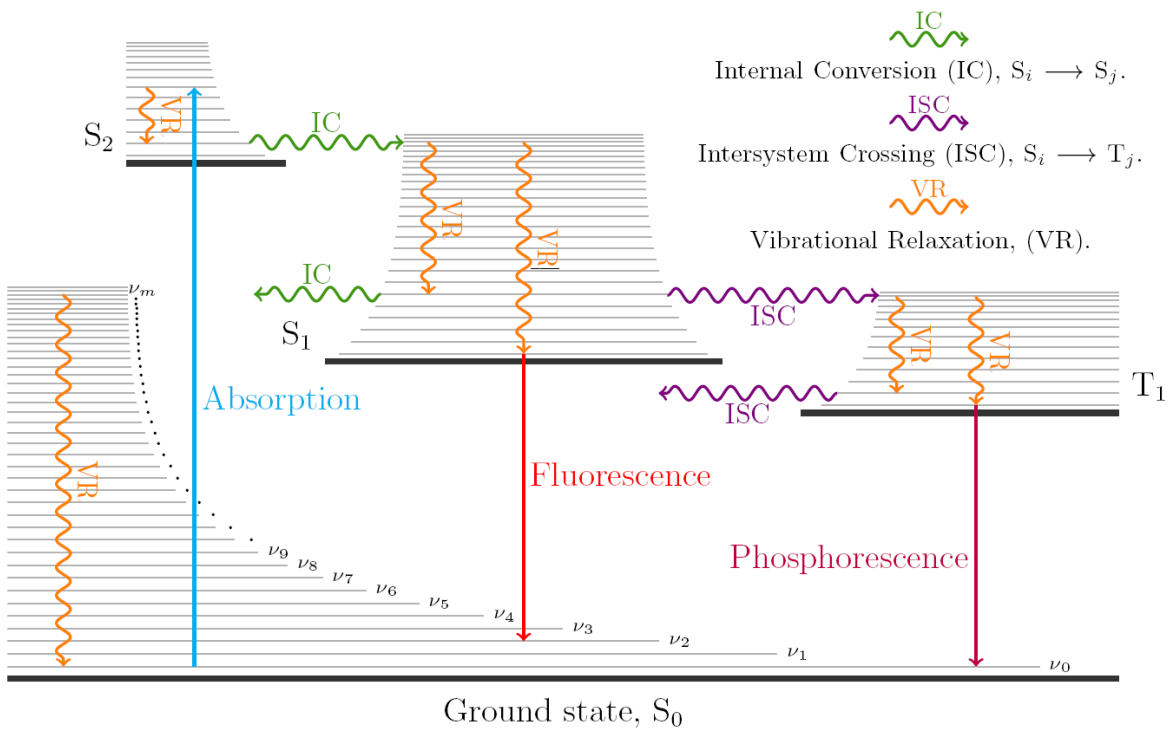


Fig. 1. Schematic ground-state and excited-state potential energy surfaces for the 11-*cis* → 11-*trans* isomerization in rhodopsin, adapted from (*14*). The reaction path of the photoisomerization is indicated by the nonadiabatic potential surfaces (broken lines).

Rhodopsin (λ_{max} ~500 nm) consists of the 11-*cis* retinal prosthetic group (Fig. 1) bound within the protein opsin. Yoshizawa and Wald (*5*) determined that the absorption of light results in the *cis*-to-*trans* isomerization of 11-*cis* retinal to form a red-absorbing photoproduct, bathorhodopsin. Early measurements of the isomerization kinetics by means of transient absorption spectroscopy showed the formation of a photoproduct within the 6-ps pulse duration (*6*). More recently, with lower intensity 25-ps pulses, Shichida *et al.* (*7*) detected a short-lived intermediate, photorhodopsin (λ_{max} ~570 nm), which decays to bathorhodopsin (λ_{max} ~535 nm) (*8*) in ~40 ps. In addition, studies of rhodopsin with resonance Raman spectroscopy show that the chromophore in the primary photoproduct, trapped at low temperature, has a twisted all-*trans* structure (*9, 10*). Time-resolved Raman studies reveal that at room temperature a similar chromophore structure is formed in less than 30 ps (*11*). Raman intensity analysis, as well as fluorescence quantum yield studies, have suggested that the initial isomerization dynamics occur on a subpicosecond time scale (*12, 13*), and theoretical simulations of the isomerization dynamics are qualitatively consistent with this picture (*14, 15*). However, the time scale for the formation of the primary photoproduct has never been experimentally determined.

Tutorial 3 – From atoms to molecules: The photochemistry around us



What is the Purpose of Tutorial 3?

- Understand what a ground state is, and why electrons want to stay there.
- Appreciate how vibrational energy levels affect how electrons return to the ground state
- Identify real-life applications of photochemistry around us.
- How does this link to sunscreens?

Starter – how does human vision work? Let's discuss your homework as a group, what did you find from your research? Feel free to make notes on what the group comes up with as well.

Lecture – make notes on the lecture material, what are ground states, why do electrons want to stay in their ground states? Take notes regarding vibrational energy levels.

1) What is the difference between an atom and a molecule?

2) How are electrons arranged in molecules? How is this different from atoms?

3) What do we mean by an electronic ground state?

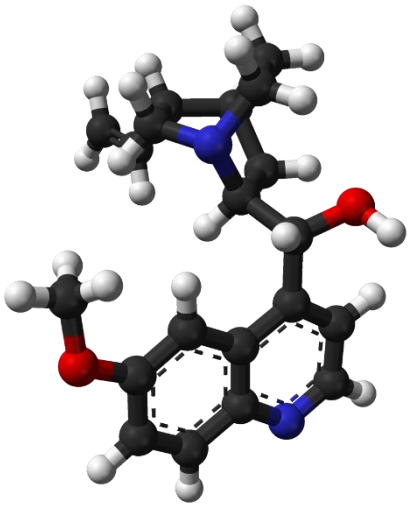
4) What's an electronic excited state?

5) What are vibrational energy levels?

6) Why might vibrational energy levels be important in photochemistry?

Any other notes you want to make?

Activity 1 – let's investigate tonic water, I bought some from the supermarket, and have provided you with a UV torch. The UV torch irradiates, you guessed it, UV light, at a wavelength of around 395 nm. Tonic water contains a molecule known as quinine, see the image below. The image is known as a 'ball and stick diagram', grey balls represent carbon atoms, oxygen is shown as red, nitrogen as blue, and hydrogen as white; sticks between atoms are (covalent) bonds, and the dotted lines indicate delocalised electrons (electrons which move between atoms).



Try to answer the following:

1) What did you observe?
2) Draw a two-level energy state diagram, with some vibrational energy levels. Estimate the wavelength of the observed light, and use this to draw the appropriate diagram.
3) What is this photochemical process called?

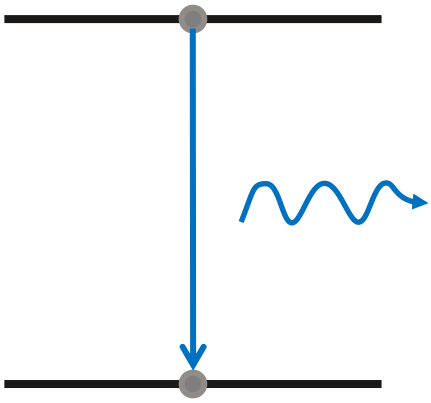
Activity 2 – reading exercise regarding other types of photochemical processes.

We have already discussed fluorescence and vibrational energy transfer as processes which allow an electron to lose its excess energy from absorbing a photon and 'relaxes' back to their ground state. We have also discussed isomerism (changes in bonds) after absorbing a photon. There are many more as the tutorial introduction picture illustrates. Here is an overview of the most commonly met ones:

Fluorescence

An electron drops back down to a lower-lying energy level and emits a photon. Often the photon given out is less in energy than the one which went in because it has also dropped down vibrational levels too.

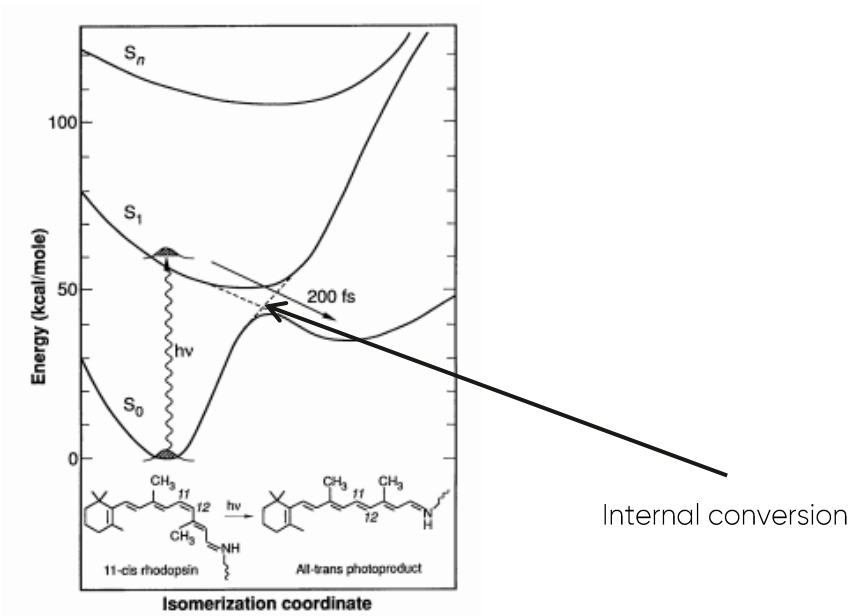
- Fluorescence typically occurs on the timescale of around 10^{-8} s.



Internal conversion

A molecule can twist, turn, and bend in a specific way which allows an electron to jump back down to an energy level, but without emitting a photon. This is because vibrational energy levels can couple electron energy levels together. In fact, this is exactly what happens with the rhodopsin we met in your homework. The isomerisation causes rhodopsin to change shape (geometry) and allows two electronic energy levels to couple – this is why our eyes do not fluoresce when we see!

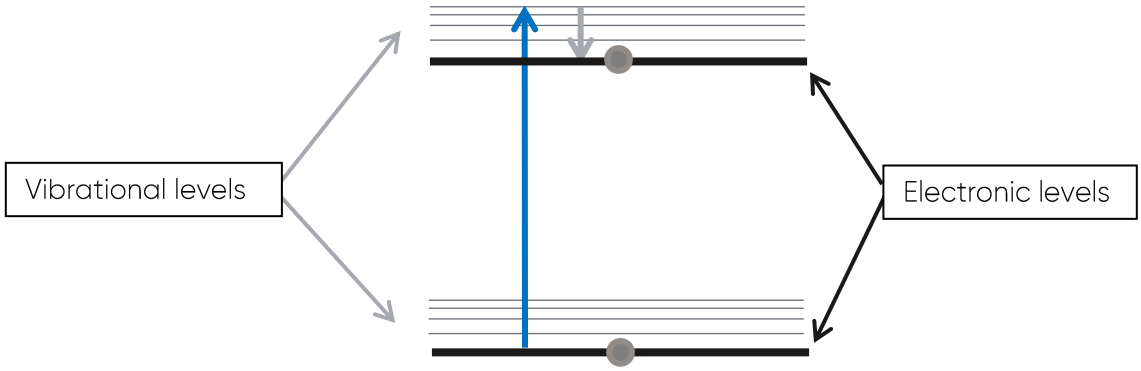
- Internal conversion typically occurs on the timescale of around 10^{-13} s.



Vibrational relaxation

When an electron drops down vibrational energy level, the excess energy is not given out as a photon, like we see with fluorescence. Instead, the excess energy is given to the surrounding molecules like solvents, or, even other molecules of the same species (remember, you don't ever have just one molecule, but millions together in the same test tube!).

- Vibrational relaxation typically occurs on the timescale of around 10^{-12} s.



Therefore, with fluorescence, the energy of an absorbed photon can be emitted at a lower energy because of some of the energy is given away by vibrational relaxation.

The last two of these processes (internal conversion and vibrational relaxation) are special because they do not give out photons. These are called non-radiative processes because radiation (photons) is not given out.

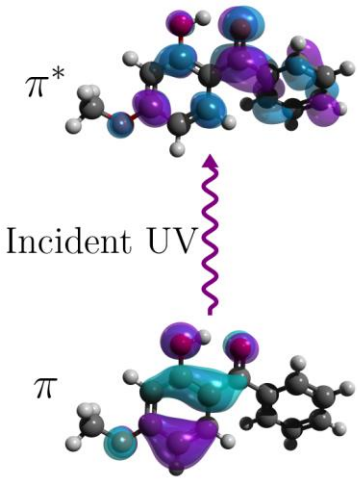
Activity – go back to last week's tutorial where we discussed UV pens, can you now explain the apparent violation of the rules for electronic transitions using your new knowledge of vibrational energy levels?

Activity – repeat your experiment of the fluorescing tonic water, but this time dissolve some salt into the tonic water. What do you observe? How is this different from last time when no alcohol was present? What could be causing the difference (**hint**: think about the timescales of the possible processes)?

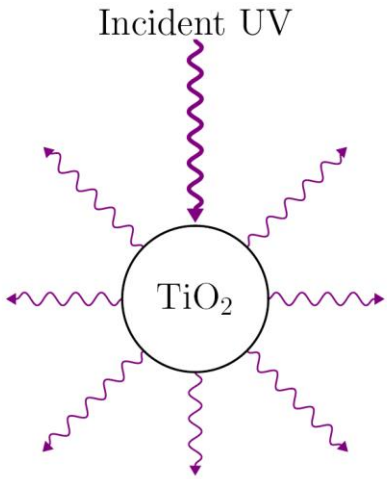
Homework assignment 3 – in the last tutorial we are going to begin discussing everything we have covered up to here, and applying it to the operation of sunscreens. I want you to research the following questions which we will discuss at the start of the next tutorial.

1) Why do we use sunscreens?
2) What wavelengths of the electromagnetic spectrum do sunscreens protect us from?
3) Why only these wavelengths?
4) Can you find the structure of a few common sunscreen molecules? You can search the internet, or even look at the ingredients of commercial products, which you can then Google.
5) Are there any similarities between these structures?

Tutorial 4 – UV damage and the operation of sunscreens



Organic filter



Inorganic particulate filter

What is the Purpose of Tutorial 4?

- Discuss how humans and plants are affected by ultraviolet light
- Understand the common ways sunscreens work
- Identify the properties that make a good sunscreen

Starter – let's discuss the answers to your homework together. If there is anything you missed which is discussed, you can add it here.

Lecture – make notes on the lecture, and try to answer the questions.

1) Can you give an illness associated with too little UV-B radiation and too much UV-B radiation which affects humans?

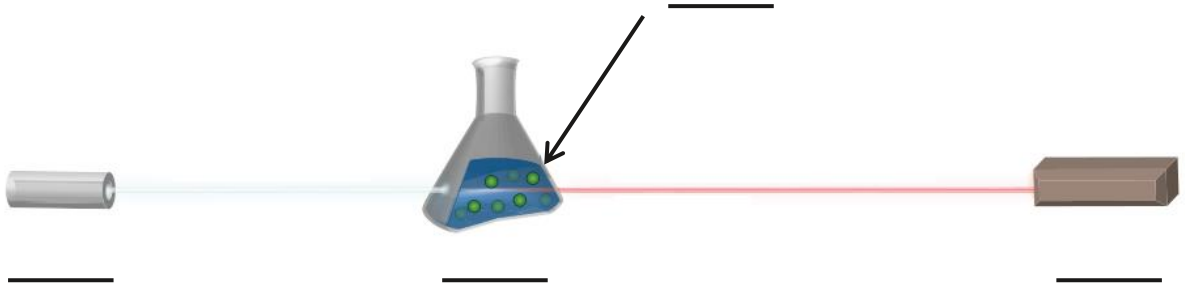
2) Similarly, for plants?

3) How does UV radiation cause damage, why don't other wavelengths of the electromagnetic spectrum?

4) How do humans and plants naturally protect themselves from UV radiation?

Any other notes you want to make?

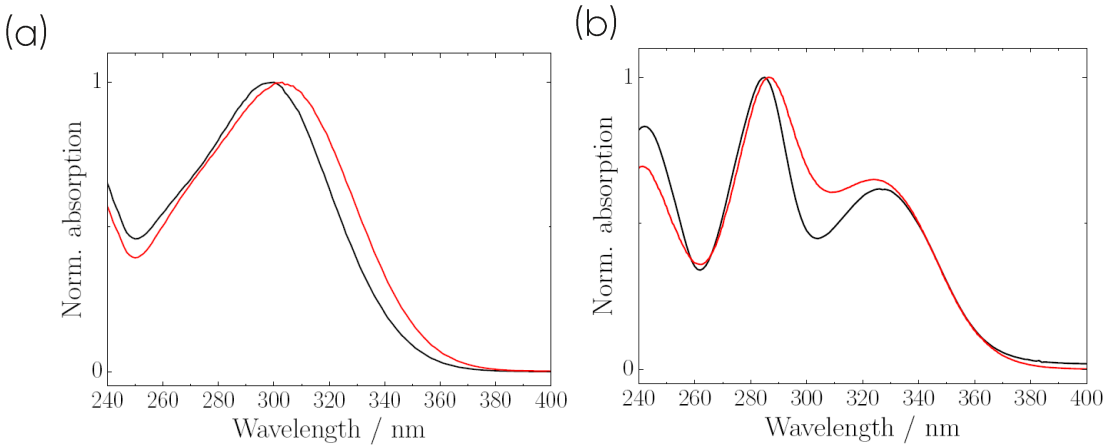
Activity 1 – absorption spectroscopy. Can you fill in the main parts of a typical absorption spectrum measurement?

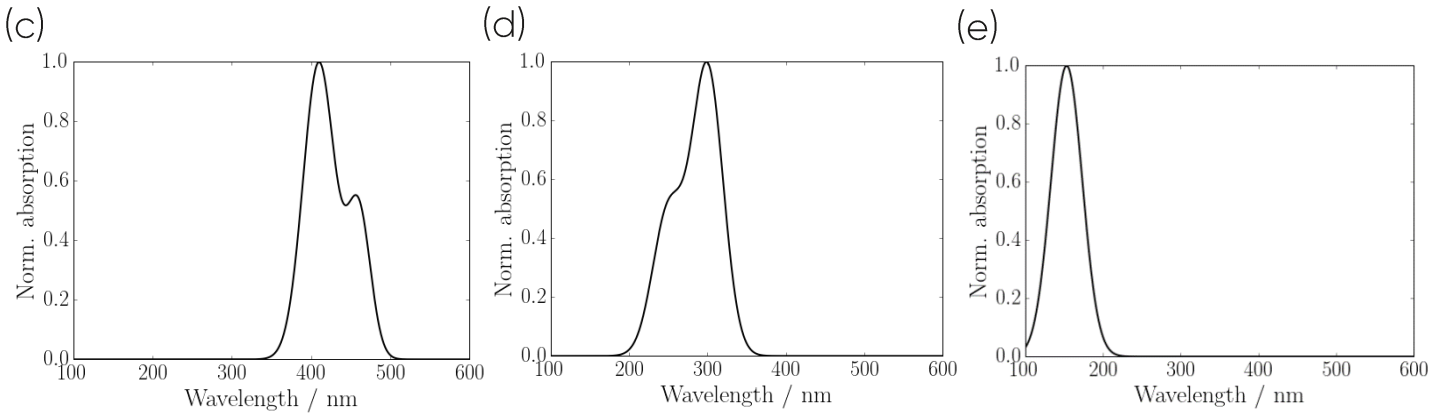


Incident light; Sample; Light source; Detector; Transmitted light; Absorption

What would make a good absorption spectrum for a possible sun screening molecule?

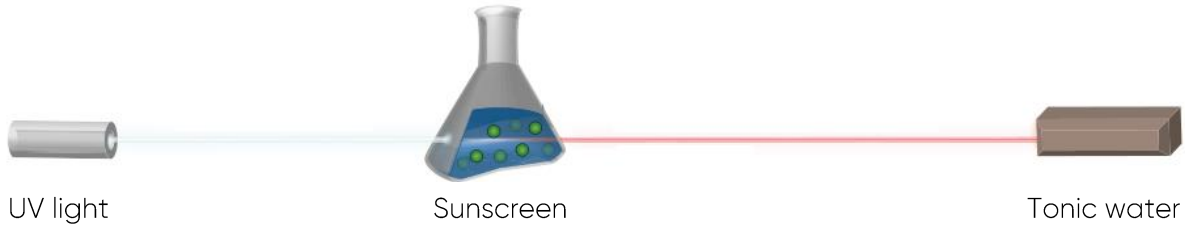
How about the following, which spectra would a sunscreen likely have?





Can you justify your answer(s)?

Activity 2 – let's check sunscreen works using absorption spectroscopy! It will work exactly like your labelled diagram on the previous page:

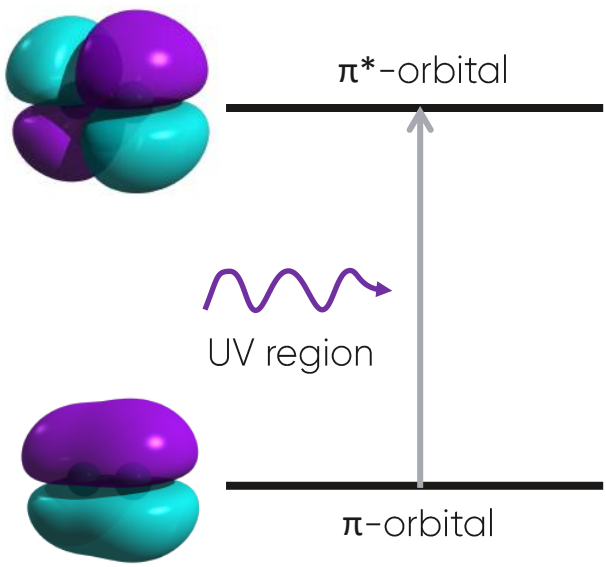


We can use the tonic water from the last tutorial as a detector – why?

Does the sunscreen work? How do we know?

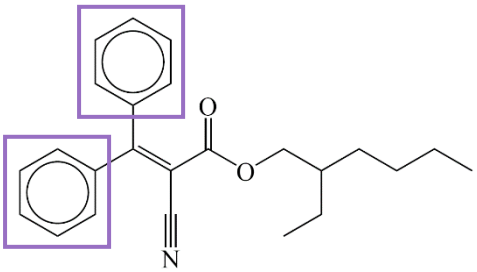
Reading - what is common among the sunscreen molecules?

So, by now you have probably seen many structures of different sunscreen molecules either from the lecture material or from your own research during the homework assignments. The key the many of the successful sunscreen molecules used in plants and the products we might use on our skin is a very specific electronic transition between two energy levels. We have discussed energy levels for atoms, but for molecules, these energy levels, or orbitals, can merge together. The orbitals of interest to sunscreens are known as π and π* orbitals (pronounced, 'pi' and 'pi-star' respectively), see below:

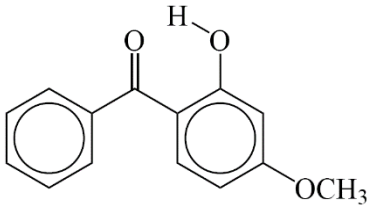


This forms when many carbon, oxygen, and/or nitrogen atoms are covalently bonded together, often in a ring, such as 6 carbons (look up the structure called benzene for example). This structure has lots of π and π^* orbitals because all the atoms share electrons between each other, which means there are lots of energy levels which can merge together in what is known as a 'delocalised electron system' or 'conjugated π system'. Thus, many of the sunscreens or natural photoprotective molecules will have these delocalised electron systems.

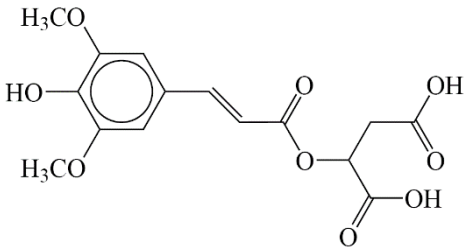
Can you label the delocalised systems in these examples? The first one has been done for you.



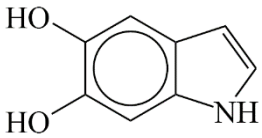
Octocrylene



Oxybenzone



Sinapoyl malate

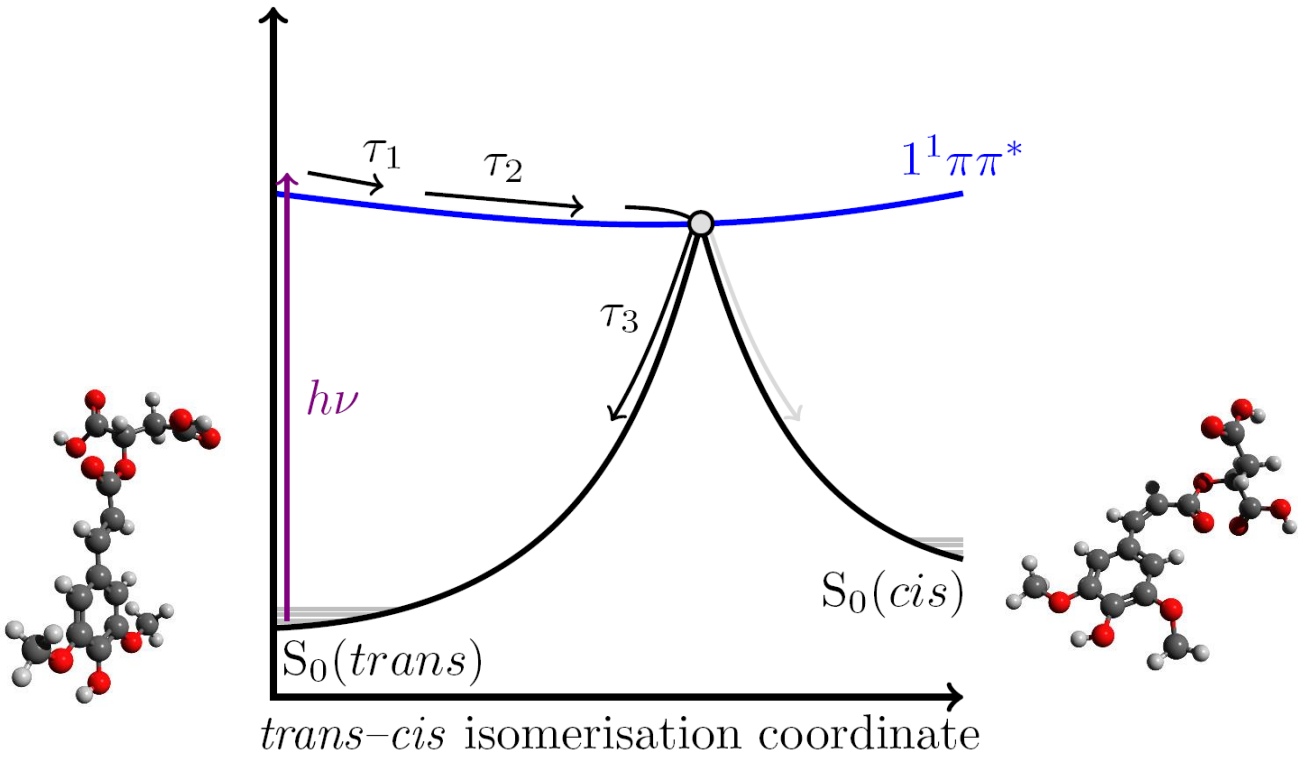


Dihydroxy indole

Homework assignment 4 – I have given you a copy of a scientific paper called "Ultrafast Photoprotecting Sunscreens in Natural Plants". I want you to have a read, particularly the introduction and conclusions which have been highlighted for you.

Don't worry if you find it difficult, I will introduce many of the topics the paper touches upon, but if you are familiar with the point of the paper (the introduction and the conclusions), we can work together to understand how the experiments conducted in the paper lead to an understanding on why plants don't get sunburn. Make any notes on the paper you find interesting or useful.

Tutorial 5 – So, why don't plants get sunburn?



What is the Purpose of Tutorial 5?

- To review current scientific literature regarding sunscreens in plants
- Discuss the cutting-edge experimental techniques used by scientists to understand how sunscreen molecules work

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Starter: brainstorming. What makes a good sunscreen?

Lecture – make notes on the technique called 'transient absorption spectroscopy' and how it has recently been used to understand the plant sunscreen molecule called sinapoyl malate. So, why don't plants get sunburn?

Final assessment

Your task is to write a short review article (no more than 2000 words) which introduces the topics we have discussed throughout these 5 tutorials. Review articles are common in science, they are there to introduce a topic to interested people, along with relevant citations or discussions on research in the field, in this case, the photochemistry of plant sunscreens.

- Imagine you are explaining these topics to a family member who is not familiar with science. How would you introduce and explain the science to them?
- My advice, assume the person reading it will have the same understanding as you did *before* this course.

In particular, I want you to have a go at writing this in the form as a scientific publication. I have provided a template with some helpful instructions. You should try to use the technical language we have learnt within the field of photochemistry (remember your glossary), but be remember who it is being pitched to, for example, do you think somebody without a scientific education would know what a *trans-cis* isomerisation is without the aid of a diagram, or a sentence describing it?

There are lots of tools and images available to you which you might find useful for your final assessment:

- I recommend Avogadro: https://sourceforge.net/projects/avogadro/, this is a good tool if you want to draw your own figures of molecules.
- You can also find images on the internet, just be sure to reference them.
- You can also draw images in Microsoft PowerPoint, and export the slide as a .png (portable network graphics file) which you can 'drag and drop' into Microsoft Word.

Areas you might touch upon:

- The effects of UV radiation on humans and plants
- Specifically, too much UV radiation
- The use of sunscreens
- Why understanding plant sunscreens can help us
- What is the current understanding of how plant sunscreens work

Be sure to use all the information in your booklet to help you. I have also given you a copy of a review article to get a feeling for the format and style.

I am also happy to discuss ideas you have or images you want to draw, to give you some direction, just come find me during breaks or lunch in the Science Staff room.

I very much look forward to reading your articles.

Tutorial 6 – Feedback tutorial

What is the Purpose of Tutorial 6?

- To receive feedback on final assignments.
- To share examples of best practice with the other pupils in your group.
- To write targets for improvement in school lessons.
- To reflect on the programme including what was enjoyed and what was challenging.

Final assignment feedback

What I did well…	What I could have improved on…
•	•
•	•
•	•

My target for future work is…

Reflecting on Uni Pathways

What did you most enjoy about Uni Pathways?
•   •   •

What did you find challenging about the programme?	How did you overcome these challenges?
• • •	• • •

Appendix 1 – Referencing correctly

When you get to university, you will need to include references in the assignments that you write, so we would like you to start getting into the habit of referencing in your Brilliant Club assignment. This is really important because it will help you to avoid plagiarism. Plagiarism is when you take someone else's work or ideas and pass them off as your own. Whether plagiarism is deliberate or accidental, the consequences can be severe. In order to avoid losing marks in your final assignment, or even failing, you must be careful to reference your sources correctly.

What is a reference?

A reference is just a note in your assignment which says if you have referred to or been influenced by another source such as book, website or article. For example, if you use the internet to research a particular subject, and you want to include a specific piece of information from this website, you will need to reference it.

Why should I reference?

Referencing is important in your work for the following reasons:

- It gives credit to the authors of any sources you have referred to or been influenced by.
- It supports the arguments you make in your assignments.
- It demonstrates the variety of sources you have used.
- It helps to prevent you losing marks, or failing, due to plagiarism.

When should I use a reference?

You should use a reference when you:

- Quote directly from another source.
- Summarise or rephrase another piece of work.
- Include a specific statistic or fact from a source.

How do I reference?

There are a number of different ways of referencing, and these often vary depending on what subject you are studying. The most important to thing is to be consistent. This means that you need to stick to the same system throughout your whole assignment. Here is a basic system of referencing that you can use, which consists of the following two parts:

1. A marker in your assignment: After you have used a reference in your assignment (you have read something and included it in your work as a quote, or re-written in your own words) you should mark this is in your text with a number, e.g. [1]. The next time you use a reference you should use the next number, e.g. [2].
2. Bibliography: This is just a list of the references you have used in your assignment. In the bibliography, you list your references by the numbers you have used, and include as much information as you have about the reference. The list below gives what should be included for different sources.

    a. Websites – Author (if possible), the title of the web page, website address, [date you accessed it, in square brackets].

    E.g. Dan Snow, 'How did so many soldiers survive the trenches?', http://www.bbc.co.uk/guides/z3kgjxs#zg2dtfr [11 July 2014].

    b. Books – Author, date published, the title of the book (in italics), pages where the information came from.

    E.g. S. Dubner and S. Levitt, (2006) *Freakonomics*, 7-9.

    c. Articles – Author, 'title of the article' (with quotation marks), *where the article comes from* (newspaper, journal etc.), date of the article.

    E.g. Maev Kennedy, 'The lights to go out across the UK to mark First World War's centenary', Guardian, 10 July 2014.

Appendix 2 – Using the VLE

VLE username	
VLE password	

Please remember the following key details…

- You are able to log into the VLE either through the link on our website (www.thebrilliantclub.org) or going directly to the VLE site at (https://portal.thebrilliantclub.org/sign-in).
- Please update your profile with your full name and email address- this will allow you to retrieve forgotten passwords or usernames
- If you forget your log-in details you can request them to be emailed to you by clicking the link on the VLE home page. (If you are still having problems you can email: schools@thebrilliantclub.org)

What is the VLE?

The VLE is a virtual learning environment for all pupils on Uni Pathways it is used for:

- messaging your tutor
- submitting homework
- submitting your final assignment
- accessing resources for your tutorials
- finding out more information about university and careers

How should I use the VLE?

The VLE is a professional academic environment in which pupils are able to message their PhD Tutor. Here are a few things to consider:

- Ensure you keep a professional tone in the messages you send to your tutors.
- Ensure you always reply to your tutors in a timely manner.
- Thank your tutor for the effort they are putting in to give you your feedback etc.
- Submit all homework to your tutor on time.

IMPORTANT: Final assignment

- When you submit your final assignment, please remember that you need to do so through the 'My Activities' tab and not as an attachment to a message.

Appendix 3 – Final assessment template

You will be provided with an electronic copy of this template to use.

Chemical Society Reviews

COMMUNICATION

Think of a catchy title to make someone read this work

First name Middle initial. Surname (e.g. Lewis A. Baker)

Received 00th January 20xx,
Accepted 00th January 20xx

DOI: 10.1039/x0xx00000x

www.rsc.org/

Abstract here. The abstract should be a single paragraph which summarises the content of the article. It should be no longer than 100 words. This abstract should be in a bold font to make it stand out!

Introduction

The introduction should provide a background to the science required to understand the case study. In many ways, this will resemble our first four tutorials. Choose a sensible order to present the information, something you think would make the reader understand article. Include details about:

- You will want to explain why someone should care about sunscreens and why plants sunscreens might be worthwhile to study.
- You will want to include details such as: how do sunscreens generally work?; examples of previous work on sunscreens (citing relevant literature).
- What could happen if we didn't have sunscreens?

You can include pictures/figures from the internet, or journal articles etc., but you must cite the sources from which they came from.

Guidance: the introduction will probably make up around half the article.

Absorption spectroscopy

You should provide a short overview of absorption spectroscopy and how this can be used to check sunscreens are doing their job. You can then take it further by introducing (briefly) transient absorption spectroscopy as a technique used to understand *how fast* sunscreens work.

[a] *Department of Science, George Abbot School, Guildford, Surrey, GU1 1XX.*

Guidance: this section will probably be between 300 and 500 words long. A picture of absorption spectroscopy (refer to your booklets) would probably be very useful here.

Case study: Plant sunscreens

You should use the paper we discussed in the last tutorial and summarise what the paper did, and what it found. What does this work mean in the wider context of sunscreen research? Using a case study is common in a 'review article' which this is. The idea is that you are introducing a topic to someone, and giving them some of the recent and relevant literature so that they can become familiar with the research in this field.

Guidance: the case study will probably be no more than 300 and 500 words. A figure will likely help here to introduce trans and cis.

Conclusions

The conclusions section should come in this section at the end of the article. You will want to summarise the main points of this work, what should people reading this have learnt or taken away from reading this work.

Guidance: the conclusion will probably be 100 – 200 words long. I wouldn't normally expect to see a figure here.

Notes and references

You should put any citations to literature, images, websites you have got information from, and place them here. Refer to the booklet on how to reference appropriately.

[1]
[2]
[3]
[4]
[5]

Notes

Notes

Notes

Why don't plants get sunburn?

Key Stage 4 Programme

researchersinschools.org