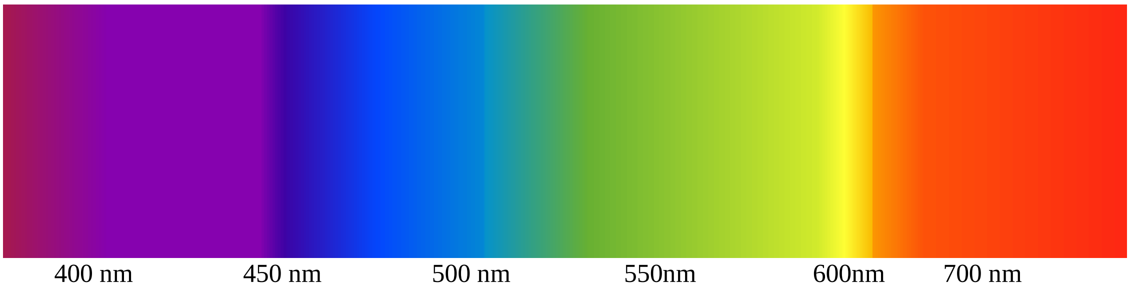
E1 CHEMISTRY WITH LIGHT
Recording an Image using Photochemistry

Colour and light

Visible light is just the part of the 'electromagnetic spectrum' (see Appendix 1) that is detected by the human eye. Visible light is a mixture of colours and can be split into different colours by a prism or rainbow. These colours consist of waves of different wavelengths and a typical human eye can see light with wavelengths from about 400 to 700 nm:

Visble part of the electromagnetic spectrum



Objects around us have colours because they absorb these wavelengths to different extents. Visible light interacts with the electrons in molecules. When light is absorbed by a molecule, it can have two consequences for the electrons:

- Electrons can become briefly excited before quickly returning to normal and emitting the light
- Electrons can become so excited that they cause bonds to break.

The first of these processes is non-destructive and is the origin of the colour of dyes, solutions and solids. The second process causes chemical reactions to occur which may be beneficial (such as photosynthesis in plants) or unwanted (such as sunburn). Chemicals that interact with light in this way are called *photochemicals*.

In this experiment, you will synthesize a photochemical which is used in blueprinting. When this chemical is exposed to light, it reacts to form the blue solid used to make a negative image.

Origin of colour

White light, such as sunlight, is a combination of all colours. Materials that are black absorb all the visible light which is shone on them. Materials that are white or colourless absorb no visible light.

The colours of other objects are due to the particular wavelengths of light that they absorb. A solid that absorbs red light and reflects all the other colours will appear green. We perceive a green colour when we see white light with the red part removed. Similarly, red wine absorbs green light and allows the other colours to pass through. White light with the green part removed is perceived by us as a red colour.

Red and green are examples of **complementary colours**. Complementary pairs include:

- red and green.
- blue and orange
- yellow and purple

Complementary colours have been known to artists for thousands of years. In Newton's colour wheel, complementary colours are on opposite sides of the wheel.

Newton's colour wheel

Experimental Notes

In this experiment, you make the photochemical tris(oxalate)iron(III). Like many compounds containing transition metals, it is coloured. Absorption of light also starts an internal chemical reaction in which an electron is transferred from oxalate to the iron. The iron(II) formed by this photochemical process is then reacted with potassium ferricyanide to give an insoluble solid called Prussian blue. This solid has the deep blue colour seen in a blueprint.

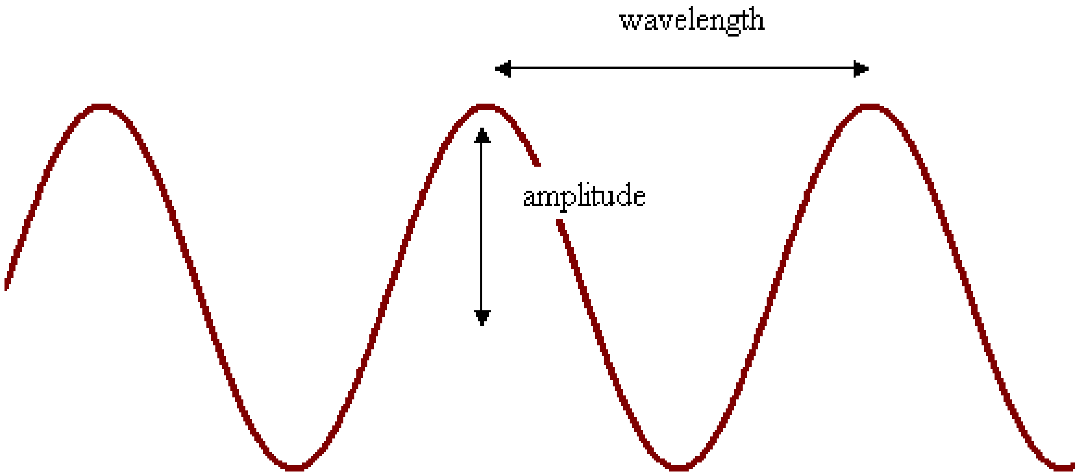
APPENDIX 1

The electromagnetic spectrum
The electromagnetic spectrum shows the range of energies (or equivalently frequency or wavelength) of electromagnetic waves. Familiar types of electromagnetic waves include (in increasing energy) radio waves, microwaves, infrared, visible light, ultra violet, X-rays and gamma rays.

Like all waves, the type of electromagnetic radiation is characterized by its:

- Frequency ν (measured in Hertz (Hz)): the number of waves passing each second,
- Wavelength λ (measured in metres or, more conveniently, nanometres (1 nm = 10^{-9} m)): the distance from peak to peak (or from trough to trough),
- Speed (measured in ms^{-1}) : the distance travelled by the wave every second and
- Amplitude: the height of the peak (or trough).

All electromagnetic waves travel at the speed of light, c = 2.99 x 10^{8} ms^{-1}.



The speed, wavelength and frequency of light are linked:

$$c = \lambda\nu \qquad (1)$$

The energy of an electromagnetic wave is related to its frequency by Planck's equation:

$$E = h\nu \qquad (2)$$

where h = 6.634 x 10^{-34} Js.

The table below shows the approximate wavelengths, frequencies and energies for selected regions of the electromagnetic spectrum.

Region	Wavelength (nm)	Frequency (Hz)	energy (kJ mol^{-1})
Radio	> 10^{8}	< 3 x 10^{9}	< 0.01

Microwave	10^8 - 10^5	3×10^9 - 3×10^{12}	0.01 – 1
Infrared	10^5 - 700	3×10^{12} - 4.3×10^{14}	1 -170
Visible	700 - 400	4.3×10^{14} - 7.5×10^{14}	170 - 300
Ultraviolet	400 - 1	7.5×10^{14} - 3×10^{17}	300 – 10^5
X-Rays	1 - 0.01	3×10^{17} - 3×10^{19}	10^5 – 10^7
Gamma Rays	< 0.01	> 3×10^{19}	> 10^7

In chemical terms, the different parts of the spectrum have different affects on atoms and molecules. Radio and microwave radiation causes molecules to rotate. Infrared radiation causes bonds to stretch and bend leading to us feeling heat. Visible and ultraviolet light causes electrons to become excited, giving rise to colours and promoting bonds to break and reactions to occur. X-rays and gamma rays cause electrons to be completely removed and can lead to molecules breaking up or rearranging, sometimes with harmful consequences to the body.