An investigation into the effect of different durations (0 hours, 8 hours, 16 hours, 24 hours, 48 hours) of UV light on the mass percentage (mass (g) of paracetamol after exposure/mass (g) before exposure) of paracetamol found within a Panadol tablet.

Introduction:
Paracetamol is widely considered as a temporary pain reliver, and is prevalently utilized by many people, including myself, suffering from minor discomfort such as headaches, backaches, and muscle pains. However, despite the established effectiveness and prevalence of its use, the analgesic drug is suggested to degenerate when exposed to sunlight (Olutayo, 2019). Paracetamol is packaged as Panadol tablets within a plastic blister pack sealed by aluminium foil. When the package is damaged and the Panadol tablet is exposed to light, it is suggested to undergo degradation (Pateh, 2007). This prompted me to investigate the impact of UV light on the concentration of paracetamol found within a Panadol tablet.

Background:
Paracetamol is an analgesic drug used to reduce mild and moderate pain by inhibiting the pathway mediated by neurotransmitters to signal pain, hence elevating the pain threshold (PubChem Compound Summary, 2021). Nevertheless, the stability of paracetamol, defined as the ability of the drug to retain its properties and characteristics at time of packaging, is often in dispute. The stability of paracetamol under light interested me, and I found out that more than 90% of mass percentage of paracetamol degrades under UV radiation (Jallouli, 2017).

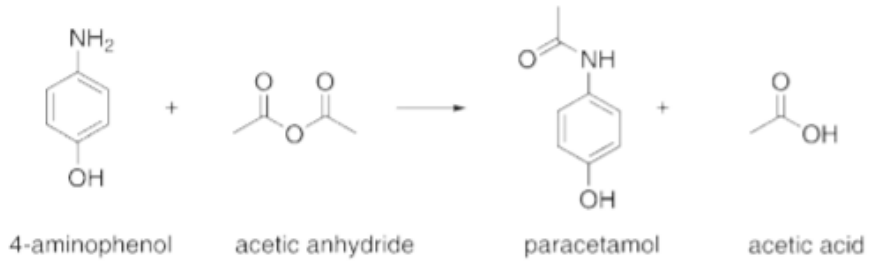


Diagram acquired from First Year Chemistry Laboratory Manual from Chemistry for Biomedicine at University of Melbourne

Paracetamol is commonly created from the acylation of 4-aminophenol with acetic anhydride (Synthesis of paracetamol from p-aminophenol, n.d.). I learnt that UV light with wavelengths 280 to 365 nm is known to photolytically degrade molecules (Jallouli, 2017). This process is termed photodegradation where photons dissociate molecules by breaking molecules into smaller pieces or changing the structure of the molecule by altering its shape (Haddad, 2013). When paracetamol is exposed to UV light, the light promotes the molecule from ground state to an excited state where the acetyl group moves onto the aromatic ring, decomposing paracetamol into 4-aminophenol (Wahba, 2020).

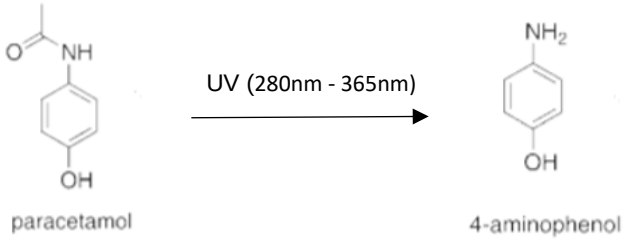
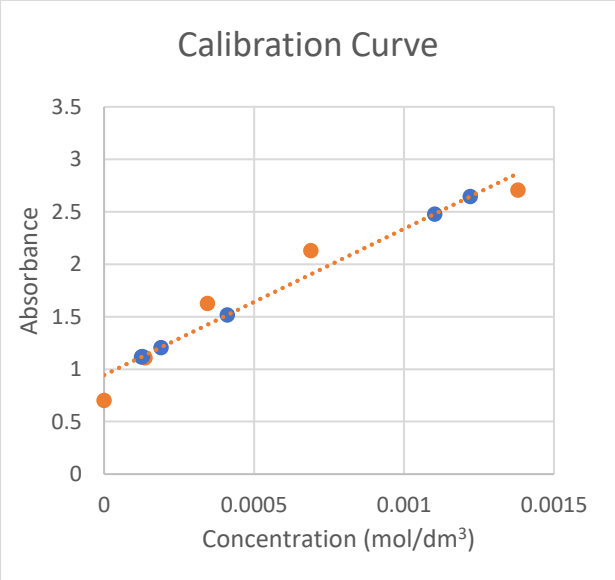


Diagram acquired from First Year Chemistry Laboratory Manual from Chemistry for Biomedicine at University of Melbourne

The formation of 4-aminophenol may result in reduced potency of paracetamol. Therefore, longer exposure of paracetamol to UV light should result in reduction in mass percentage of paracetamol. This experiment explores the impact of UV light on the concentration of paracetamol over durations of 0, 8, 16, 24 and 48 hours.
A spectrometer is used to detect the amount of paracetamol within a Panadol table. The spectrometer works by emitting a beam of light through the solution, collecting the light wavelength, and digitizing, from the wavelength the number of pixels in the detector, an absorbance value. To do this, firstly, known concentrations of paracetamol, called reference bases, are inserted into the spectrometer to generate corresponding absorbance value. According to Beer Lamber law, there is a linear relationship between

solute concentration and absorbance. Hence, the absorbance value (orange dots) is used to create a calibration curve (orange curve) to enable data to be plotted as value of wavelength (absorbance) over a known range of paracetamol concentrations. This calibration curve is then utilized to generate the concentration for unknown paracetamol concentrations (blue dots) to assess the impact of light on paracetamol.

Figure 1 – Calibration curve (own diagram)



To determine the transmittance of wavelength through the solution, the solution needs to be coloured first. I added additional reagents to create colouring of paracetamol following the method by P. Nagendra. The iron (III) solution was first added into the paracetamol solution for paracetamol to reduce iron (III) ions into iron (II) ions. The iron (II) ions are then reacted with potassium hexacyanoferrate (III) solution that is added, producing Prussian blue coloured complex (Nagendra, 2011).

However, while performing this experiment following the prescribed method, precipitation occurred after reaction of paracetamol with ferricyanide. As precipitation would impede the transmission of light in the spectrometer and greatly impact the relative absorbance reading, to overcome this, I utilized a centrifuge to separate the precipitation particles from the fluid and only took the fluid for measurement in the spectrometer.

Research question:
What is the effect of varying durations of UV light (0 hours, 8 hours, 16 hours, 24 hours, 48 hours) on the mass percentage (mass (g) of paracetamol after exposure/mass (g) before exposure) of paracetamol found within a Panadol tablet?

Independent variable:
<u>The duration (hours) of exposure to UV light, measured in 0 hours, 8 hours, 16 hours, 24 hours, 48 hours</u>
The time intervals of duration were 0 hours, 8 hours, 16 hours, 24 hours, 48 hours. The five different intervals were selected to maintain a consecutive different of 8 hours, with an exception between 24 and 48 hours. The consecutive difference would allow for a more accurate relationship to be drawn between durations of exposure and mass percentage of paracetamol.
The duration of UV light exposure is monitored by exposing paracetamol under a UV light lamp within a cupboard where the lamp and paracetamol are enclosed by a paper box to prevent the interruption of unintended light. A stopwatch is used to stipulate the time duration of exposure.

Dependent variable:
<u>The mass percentage of paracetamol found in a Panadol</u>
Mass percentage of paracetamol is chosen to show the mass of paracetamol after exposed to light in comparison to the mass percentage of the paracetamol without exposure within the sample.

$$\text{Mass percentage of paracetamol} = \frac{\text{Mass of paracetamol after exposure}}{\text{Mass of paracetamol before exposure}}$$

To determine the mass of paracetamol after exposure to UV light, exposed paracetamol is put into the spectrometer to generate relative light absorbance. According to Beer Lamber Law, there is a linear relationship between solute concentration and absorbance value. Hence, utilizing the function of calibration curve, the concentration of paracetamol can be deduced from corresponding absorbance value. The paracetamol concentration is then converted into mass to compare to the original mass before exposure.
To generate the absorbance value, the paracetamol solution is reacted with potassium ferricyanide and iron chloride to produce a coloured mixture. The coloured mixture is then placed within the spectrometer, where the colour of the mixture is used to measure the absorbance, hence concentration, which is used to determine the mass percentage.

Controlled variables

Table 1: Control of variables

Variable	Reason for control	Method of control
The wavelength of light emitting from the UV lamp	Varying wavelengths/intensity of UV light may lead to faster or slower degradation of paracetamol.	One consistent lamp is used in the experiment to ensure the intensity and wavelength of UV light is consistent.
The mass of the Panadol tablet in each sample	Variations in the mass of sample extracted from the Panadol tablet may contain different masses of paracetamol. This will impact the measurement of the dependent variable.	The same mass (0.100g) of granulated Panadol is weighted on the electric balance.
The brand of Panadol	Different Panadol brand may contain inactive ingredients within the tablet which may impact the reactions to produce colouring.	The brand Panadol – Paracetamol Tablets was used consistently throughout the experiment.
Durations of exposure to UV light.	Longer exposure to UV light may degrade the paracetamol within the Panadol tablet, impacting the relationship between IV and DV.	The time of exposure is measured by a stopwatch, and time is controlled at (3 hours, 8 hours, 24 hours, 48 hours, 72 hours)
Exposure to other lights	Any unintended exposure to light may degrade paracetamol within Panadol tablet.	The paracetamol is stored within cupboard enclosed by a box to prevent exposure to unintended light.
Temperature	Extreme temperatures are identified reduce the stability of paracetamol. (I Ahmad, 1994)	The experiment was controlled at room temperature, a temperature identified to be suitable for paracetamol storage. (I Ahmad, 1994)

Table 2: Risk Assessment:

Hazard	Potential Risk	Control Measure
UV light from the UV light lamp	Looking directly at the UV lamp for long terms may damage eyes.	The UV lamp is stored within a cupboard that is only opened to access the UV light.
Hydrochloric acid (5M)	Contact with skin and eyes may cause serious irritation. Hydrochloric acid is corrosive to skin, eyes, and lungs.	Lab coat, safety glasses, and hand masks are worn at all times in the experiment. The hydrochloric acid was stored within a plastic bottle that was only opened when used and closed immediately after use.
Iron (III) chloride (0.1M)	May be corrosive to metals. Contact with skin and eyes may cause serious irritation. Corrosive to skin, eyes and lungs.	Iron (III) chloride is stored in a glass bottle which is only opened when used and closed immediately after use. When used, Iron (III) chloride is placed in furthest distance from surrounding metals.
Solid paracetamol	Allergic reactions to paracetamol may result in dangerous repercussions. Small particles of paracetamol may irritate the skin, eyes, and lungs. Large doses of paracetamol is toxic and may lead to liver damage.	Paracetamol is bought as a tablet; it is then granulated and stored within a Ziploc bag to prevent inhaling of small paracetamol particles.
Volumetric flask	The flask is made up of glass, which is prone to break if dropped or handled uncarefully. If broken, glass fragments or chipped edges may cut the skin.	Safety glasses, lab coat and hand masks are worn. Broken glasses are immediately swept into a dustpan and disposed into the bin.

Ethical concern:

The ethical issue is not identified in the experiment as there was no living organism used.

Materials

Chemical

- 0.002M Potassium ferricyanide (50ml)
- Panadol tablet – Paracetamol 500mg x 5
- 0.1M Iron (III) chloride (50ml)
- 5M Hydrochloric acid (50ml)
- Distilled water

Apparatus

- Mortar and pestle
- Electric balance in grams (± 0.001g)
- 100ml volumetric flask x 5
- 20ml pipette (± 0.020) x 1
- Stopwatch (minutes and hours)
- Glass funnel
- 50ml beaker x 2
- UV light lamp
- Watch-glass x 1
- Spectrometer
- Spatula x 1
- 1ml pipette (± 0.001) x 2
- 10ml centrifuge tube x 5
- Plastic Ziploc bags x 5

Method

Making of standard paracetamol concentration

1. Granulate 1 Panadol tablet using motor and pestle
2. Place watch glass on the electric balance, set the mass to zero and weight 0.100 grams of granulated Panadol.
3. Transfer weighed Panadol into a 50ml glass beaker, rinse the watch glass used to carry granulated Panadol with distilled water to ensure all Panadol is transferred into the 50ml glass beaker.
4. Add 20ml of distilled water into the 50ml beaker and swell the solution to make sure Panadol is dissolved.
5. Transfer the solution from 50ml beaker into a 100ml volumetric flask using a glass funnel.
6. Add distilled water to the 100ml volumetric flask until it hits the calibration mark to produce standard 0.100g/100ml concentrated solution. For all solutions, covert measurement of the solution of Panadol into concentration of paracetamol (mol/dm^3), 0.100g/100ml = 0.552 x 10^{-2} mol/dm^3 (*see calculation workings below)*
7. Create dilutions of 0.276 x 10^{-3} mol/dm^3 by taking an aliquot of 5ml from the 100ml volumetric flask containing 0.552 x 10^{-2} mol/dm^3 concentrated paracetamol solution using a 5ml pipette, adding it to a new 100ml volumetric flask and filling it up to the calibration mark with water.
8. Create dilutions of 0.138 x 10^{-3} mol/dm^3 by taking an aliquot of 50ml from 100ml volumetric flask containing 0.276 x 10^{-3} mol/dm^{3}concentrated paracetamol solution using a 50ml pipette, adding it to a new 100ml volumetric flask and filling it up to the calibration mark with water.
9. Create dilutions of 0.689 x 10^{-4} mol/dm^3 by taking an aliquot of 50ml from the 0.138 x 10^{-3} mol/dm^3 paracetamol concentrated solution using a 50ml pipette, adding it to a new volumetric flask and filling it up to the calibration mark with water.
10. Create dilutions of 0.345 x 10^{-4} mol/dm^3 by taking an aliquot of 50ml from 0.689 x 10^{-4} mol/dm^3 solution using a 50ml pipette, adding it to a new volumetric flask and filling it up to the calibration mark with water.
11. Create dilutions of 0.137 x 10^{-4} mol/dm^3 by taking an aliquot of 20ml from 0.689 x 10^{-4} mol/dm^3 solution using a 20ml pipette, adding it to a new volumetric flask and filling it up to the calibration mark with water.

Making coloured solutions of standard paracetamol concentrations

1. Take 5ml from the volumetric flask containing 0.000661 mol/dm^3 paracetamol concentrated solution and add it into a 10ml empty centrifuge tube using a 5ml pipette.
2. Add 2ml of potassium ferricyanide into the 10ml centrifuge tube using a 5ml graduated pipette.
3. Add 0.4ml of Iron (III) chloride into the centrifuge tube using a 1ml graduated pipette.
4. Put the mixture aside for 10 minutes
5. Add 1.0ml of hydrochloric acid into the centrifuge tube using a 1ml graduated pipette
6. Add 1.6ml of water using a 5ml graduated pipette, close the centrifuge tube with a lid and mix thoroughly for 30 seconds.
7. Put the mixture put aside for 10 minutes
8. Repeat steps 1 to 7, but replace the solution in 1st step with just water, 0.138 x 10^{-3} mol/dm^3, 0.689 x 10^{-4} mol/dm^3, 0.345 x 10^{-4} mol/dm^3, 0.137 x 10^{-4} mol/dm^3.

Construction of the standard calibration curve

1. Create a table on excel, with independent variable being the concentration (mol/dm^{-3}) and dependent variable being the absorbance value.
2. Set up the spectrometer to absorb red light.
3. Open the cuvette and add 5ml of the 0.138 x 10^{-3} mol/dm^3 mixture into the cuvette using a 5ml pipette.
4. Close the cuvette and wipe all sides of the cuvette using a paper towel.
5. Insert the cuvette into the spectrometer and click 'start' button to generate the absorbance value.
6. Record the absorbance value on excel next to the corresponding concentration.
7. Repeat steps 3 to 6 for a solution with just water, 0.689 x 10^{-4} mol/dm^3, 0.345 x 10^{-4} mol/dm^3, and 0.137 x 10^{-4} mol/dm^3.
8. Plot the standard calibration curve on excel.

Exposure of paracetamol to UV light (0 hours, 8 hours, 16 hours, 24 hours, 48 hours)

1. Place 4 plastic Ziplock bag next to the UV lamp horizontally, labelling each plastic Ziploc bag on the top right corner: 0 hours, 8 hours, 16 hours, 24 hours, 48 hours from left to right in increasing order of hours.
2. Place a Panadol tablets into the mortar and granulate the tablets using the pestle.
3. Extract the granulated tablet using a spatula, place it into the 0 hours Ziploc bag, and seal the bag tight
4. Repeat steps 2 to 3 for Ziploc bags named 8 hours, 16 hours, 24 hours, 48 hours.
5. Place the Ziplock bag under the UV lamp horizontally to ensure they do not run over each other. Turn on the UV light and start the stopwatch
6. Extract each granulated Panadol in the bag at the corresponding time labelled on the top right corner of the bag.

Obtaining the absorbance rate for light exposed paracetamol solutions

1. After the Ziploc bag containing paracetamol is extracted, place the watch glass on the measuring balance and set the weight to zero.
2. Weight on the measuring balance 0.100g of the granulated Panadol from the 0 hour Ziploc bag using a spatula.
3. Wrapped the Ziploc bag with Panadol remnants in aluminium foil and placed behind the UV lamp to prevent further exposure.
4. Transfer weighed paracetamol into a 50ml glass beaker, rinse the watch glass used to carry granulated Panadol with distilled water ensure all paracetamol is transferred into the 50ml glass beaker.
5. Add 20ml of distilled water into the 50ml beaker and swell the solution to make sure paracetamol is dissolved.
6. Transfer the solution from 50ml beaker into a 100ml volumetric flask using a glass funnel.
7. The solution is too diluted. Create dilutions by taking an aliquot of 5ml from the paracetamol solution using a 5ml pipette, adding it to a calibration flask and filling it up to the calibration mark with water.
8. Create dilutions by taking an aliquot of 50ml from the paracetamol solution using a 50ml pipette, adding it to a calibration flask and filling it up to the calibration mark with water.
9. Repeat steps 1-7 of Making a coloured solution from granulated Panadol

10. Repeat steps 2-5 of Construction of a standard calibration curve
11. Repeat steps 1-8 for all unknown solutions.

Processed Data - Making of calibration curve

Calculation of paracetamol concentration (mol/dm^3) in standard solutions

As it would only be appropriate to express the unit of paracetamol as concentration (mol/dm^3) in the standard calibration curve, mass (g) of Panadol sample is converted into paracetamol concentration.

Calculation process:

- Find the percentage of paracetamol in a Panadol tablet (as a Panadol tablet contains inactive ingredients)

$$\%\ paracetamol\ = \frac{\text{The mass of paracetamol provided on the package}}{\text{The weighted mass of the panadol tablet}} \times 100$$

$$= \frac{0.500\text{g}}{0.598\text{g}} \times 100$$

$$\text{Percentage of paracetamol } = 83.3\%$$

- Find the concentration of paracetamol within 0.100g/100ml solution of Panadol

$$\text{Concentration} = \frac{\text{mol}}{\text{volumn}} \qquad \text{Mol(C8H9NO2)} = \frac{\text{mass (g)}}{\text{molar mass}}$$

$$= \frac{0.100}{12 \times 8 + 1.01 \times 9 + 14.01 + 16 \times 2} \times 83.3\%\ moles$$

$$= 0.000552 \text{ moles (3 sig)}$$

$$\text{Concentration} = \frac{0.000552}{100 \times 10^{-3}}$$

$$= 0.552 \times 10^{-2}\ mol/dm^3$$

Table 3: Conversion of the density of Panadol sample to concentration of paracetamol (mol/dm^3)

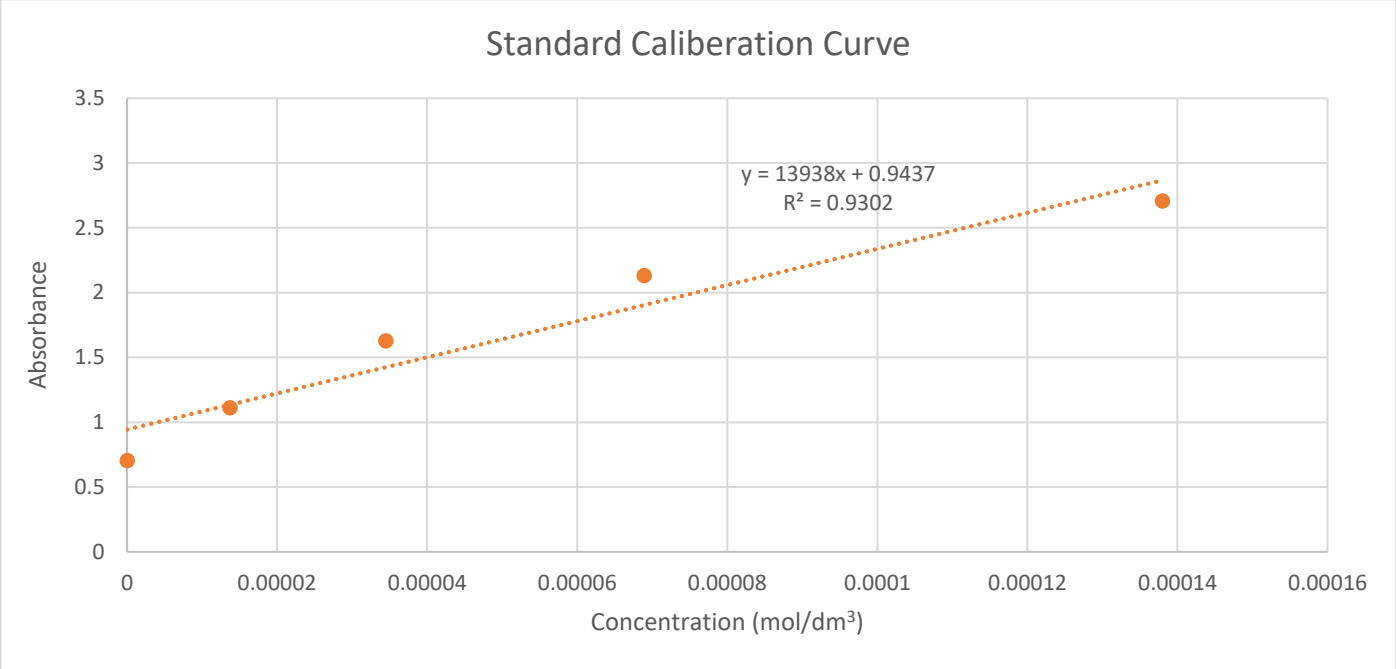
Panadol solution (g/100ml)	Paracetamol Concentration (mol/dm^3)
0.00250	0.138×10^{-3}
0.00125	0.689×10^{-4}
0.000625	0.345×10^{-4}
0.000250	0.137×10^{-4}
0	0

Table 4: The absorbance value at standard paracetamol concentrations

Paracetamol Concentration (mol/dm^3)	Absorbance
0.138×10^{-3}	2.706
0.689×10^{-4}	2.131
0.345×10^{-4}	1.626
0.137×10^{-4}	1.109
0	0.702

The absorbance value in table 4 is obtained from the spectrometer. Using known concentrations of paracetamol and corresponding absorbance value, a standard calibration curve is plotted as shown in Graph 1.

Graph 1: Standard calibration curve of paracetamol concentration with corresponding absorbance value and R^2 value



Standard Calibration function: 13938x + 0.9437

Processed data – Determining the mass percentage of paracetamol after exposure

Table 5: Absorbance of paracetamol solutions after different durations of UV light exposure

Duration of exposure to UV light (hours) (± 0.1)	Absorbance (± 7%)			Mean Absorbance (± 7%)
	Trial 1	Trial 2	Trial 3	
0	2.228	2.506	2.706	2.645
8	2.228	2.506	2.706	2.480
16	1.486	1.625	1.438	1.516
24	1.032	1.141	1.193	1.122
48	1.114	1.121	1.117	1.117

Calculation of uncertainties:

Calculation of uncertainty associated with spectrometer

- Spectrometer

The uncertainty for spectrometer is calculated from R^2 value in the standard calibration graph (Graph 1). R^2 value is calculated 0.93, which shows that there is a 7% variance between the data and the regression line. This percentage is also used to determine the uncertainty associated with the spectrometer.

$$\text{Spectromtery uncertainty} = 7\%$$

Calculation of percentage uncertainty associated with volumetric flask and the electric balance

- Electric balance:

Absolute Uncertainty = ± 0.001 g

$$\text{Percentage uncertainty} = \frac{\text{Absolute uncertianty with the electric balance}}{\text{Measured mass of panadol sample}} \times 100$$

$= \frac{0.001}{0.100} \times 100$

$= 1\%$

- Volumetric flask:

Absolute Uncertainty = ± 0.01ml

$\text{Percentage uncertainty} = \frac{\text{Absolute uncertianty with the volumetric flask}}{\text{The volume of the volumetric flask}} \times 100$

$= \frac{0.01}{100.00} \times 100$

$= 0.01\%$

As the percentage uncertainty with volumetric flask is too small, it is neglected in the calculation of total uncertainty.

Calculation of Total uncertainty

Total percentage uncertainty = % uncertainty of spectrometer + % uncertainty of electric balance

$= 7\% + 1\%$

$Total\ percentage\ uncertainty = 8\%$

Calculation of the concentration of paracetamol exposed to light from the corresponding mean absorbance

Beer Lamber law states that light absorbance is directly proportional to concentration. The concentration of paracetamol solution can be found applying Beer Lamber law using the calibration curve.

Calibration curve: $y = 13938x + 0.9437$

$x =$ concentration of paracetamol
$y = absorbance\ of\ light$

- Calculation of 8 hours:

$2.480 = 13938\,x + 0.9437$

$x = \frac{2.480 - 0.9437}{13938}$

$x = 0.110 \times 10^{-3}\ mol/dm^3$

Table 6: Relative concentration of paracetamol from mean absorbance value with absolute uncertainties

Duration of exposure to UV light (hours) (± 0.1)	Mean Absorbance (± 7%)	Concentration (mol/dm^3) (± 8%)
0	2.645	0.122 x 10^{-3}
8	2.480	0.110 x 10^{-3}
16	1.516	0.410 x 10^{-4}
24	1.122	0.128 x 10^{-4}
48	1.117	0.124 x 10^{-4}

Conversion of concentration into mass percentage

Concentration of paracetamol needs to be converted back into the mass percentage to identify the percentage of paracetamol lost from the exposure to UV light

Calculation process:

$\text{Concentration} = \frac{\text{mol}}{\text{volumn}}$ $\text{Mol(C8H9NO2)} = \frac{\text{mass (g)}}{\text{molar mass}}$

- To find the mass, the mol of paracetamol in each concentration needs to be identified first:

$\text{Mol(C8H9NO2)} = \text{concentration} \times \text{volume}$
$= 0.122 \times 10^{-3} \times 100 \times 10^{-3}\ moles$
$\text{Mol(C8H9NO2)} = 0.122 \times 10^{-4}$

$\text{Mass(C8H9NO2)} = \text{mol} \times \text{molar mass}$
$\text{Mass(C8H9NO2)} = 0.122 \times 10^{-4} \times (12 \times 8 + 1.01 \times 9 + 14.01 + 16 \times 2)$ grams
$\text{Mass(C8H9NO2)} = 0.184 \times 10^{-2}\ \text{g}$

- To find the mass percentage of paracetamol, the calculated mass needs to be divided by the mass of paracetamol originally in the sample. The original mass is found from the calculation of the mass of paracetamol in the weighted Panadol tablet (shown in table 3)

$\text{Mass of paracetamol} = 0.184 \times 10^{-2}\ \text{g}$ *(From above)*
$\text{Concentration of paracetamol in the sample} = 0.138 \times 10^{-3}$ *(From table 3)*

$$\text{Mass percentage} = \frac{\text{Mass of paracetamol}}{\text{Mass of paracetamol in the sample}} \times 100$$

- To calculate the mass of paracetamol originally in the sample, the concentration of paracetamol in the sample needs to be converted in mass. To find the mass, the mol of paracetamol originally in the sample needs to be identified first.

$$\text{Mol(C8H9NO2)} = \text{concentration} \times \text{volume}$$
$$= 0.138 \times 10^{-3} \times 100 \times 10^{-3}\ moles$$
$\text{Mol(C8H9NO2)} = 0.138 \times 10^{-4}$

$\text{Mass(C8H9NO2)} = \text{mol} \times \text{molar mass}$
$\text{Mass(C8H9NO2)} = 0.138 \times 10^{-4} \times (12 \times 8 + 1.01 \times 9 + 14.01 + 16 \times 2)$ grams
$\text{Mass(C8H9NO2)} = 0.184 \times 10^{-2}\ \text{g}$
$\text{Mass of paracetamol in the sample} = 0.209 \times 10^{-2}\ \text{g}$

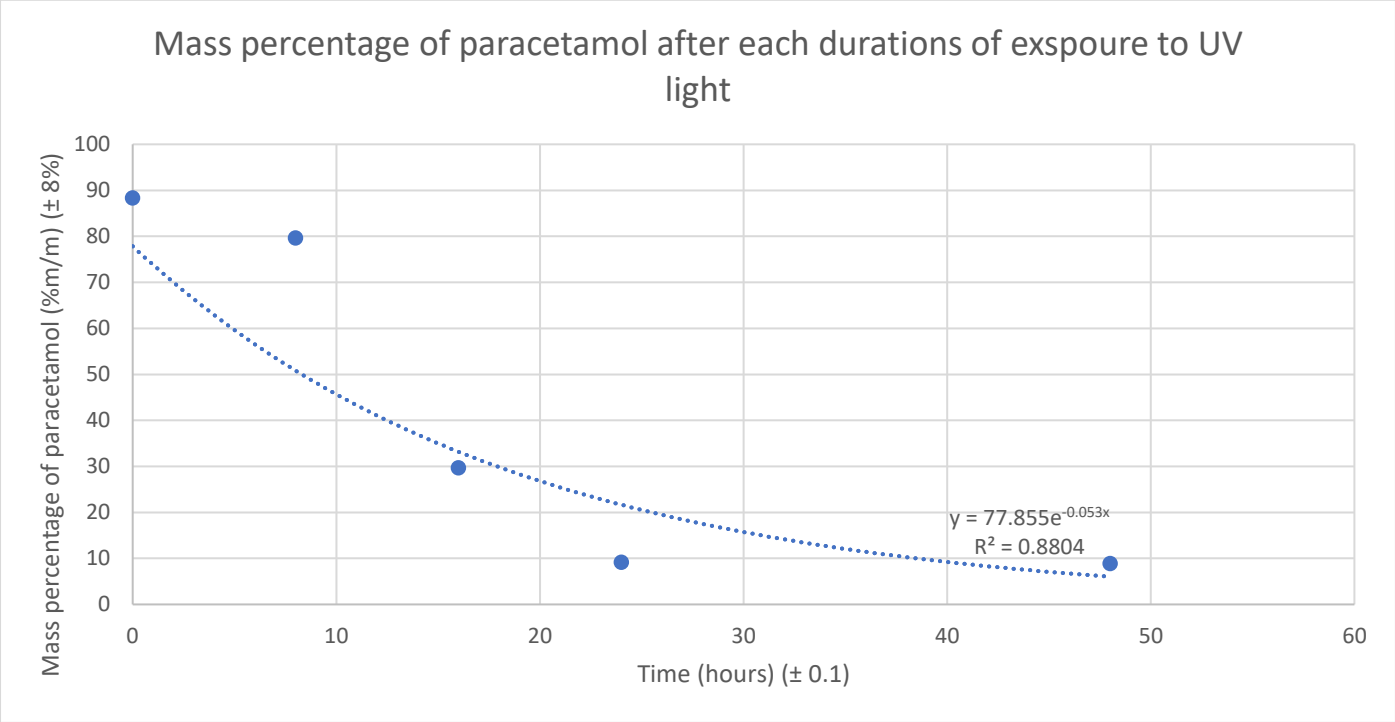
$$\text{Mass percentage} = \frac{0.184 \times 10^{-2}}{0.209 \times 10^{-2}} \times 100$$

$= 88.4\%$

Table 7: Mass percentage of paracetamol at corresponding concentrations

Duration of exposure to UV light (hours) (± 0.1)	Concentration (mol/dm^3) (± 8%)	Mass percentage (%mass of paracetamol/mass of sample) (± 8%)
0	0.122 x 10^{-3}	88.4%
8	0.110 x 10^{-3}	79.7%
16	0.410 x 10^{-4}	29.7%
24	0.127 x 10^{-4}	9.2%
48	0.124 x 10^{-4}	8.9%

Graph 2: The mass percentage of paracetamol after each hour of exposure to UV light with R^2 value



Analysis:

As observed in graph 2, there is a negative relationship between the duration of exposure to UV light and the mass percentage of paracetamol, showing that increasing hours of duration is directly proportional to decreasing mass percentage of paracetamol. The mass percentage of paracetamol steadily decreases within 8 hours of exposure. From 8 hours to 16 hours, the mass percentage precipitously decreases from 79.7% to 29.7%. This steep decrease may be attributed to the decomposition of paracetamol into 4-aminophenol under light exposure (Jallouli, 2017). However, the tablet seems to have reached minima by 24 hours of exposure. This is shown by the rather flat curve from 24 hours to 48 hours, suggesting mass percentage of paracetamol did not further decrease, hence signalling the mass percentage has reached a plateau. From 24 to 48 hours, only around 5% of paracetamol is identified out of the sample, suggesting that most of the available paracetamol have undergone photodegradation, and very little concentration of paracetamol remains intact.

As the mass percentage of paracetamol does not reach 0%, but constantly approaches the 0% threshold, an exponential curve is identified as more suitable to model the trendline of the graph. In addition, a higher R^2 value was generated with exponential trendline compared to trendline graph. R^2 value demonstrates proportion of variance between the dependent and independent variable with respect to the trendline. The high R^2 value in exponential trendline in contrast to linear trendline shows that an exponential trendline best represents the relationship between mass percentage of paracetamol over duration of light exposure. The exponential trendline shows mass percentage of paracetamol exponentially decreases over time when exposed to light.

Percentage error

The percentage error is calculated using theoretical value and experimental value. Theoretic value is the mass of paracetamol within the original sample. Experimental value is the mass of paracetamol when exposed to zero hours of duration to light. *(Both theorical value and experimental value calculation is shown in Conversion of concentration into mass percentage under table 6)*

$Theorical\ value\ = 0.209\ \times\ 10^{-2}\ g \qquad Experimental\ Value = 0.184\ \times\ 10^{-2}\ g$

$$\text{Percentage of error } = \frac{\text{Theorical value} - \text{experimental value}}{\text{Theorical value}}$$

$$= \frac{0.209 \times 10^{-2} - 0.184 \times 10^{-2}}{0.209 \times 10^{-2}}$$

$$= 11\%$$

The calculated percentage of error 11% reveals a moderately high percentage of error.

Conclusion

The aim of the investigation was to explore the impact of varying durations of exposure to UV light on the mass percentage of paracetamol in a Panadol tablet. The relationship is depicted as exponential, demonstrating that as the durations of exposure to UV light increases, the mass percentage of paracetamol decreases exponentially. The relationship is illustrated by the equation: $y = 77.855e^{-0.053x}$

This corollary is reinforced by literature discussed in Background where paracetamol mass percentage of 90% is found to eventually decompose under UV radiation overtime (Jallouli, 2017). This is because under exposure, the light promotes the molecule from ground state to an excited state, moving it onto the aromatic ring and photolytically decomposing paracetamol into its reactant 4-aminophenol (Wahba, 2020).

In the experiment, percentage of error is calculated to be bigger than percentage of uncertainty. Percentage error stands at 11%, as calculated above, and percentage uncertainty is 8%, shown in Calculation of uncertainties section under Table 5. As percentage error is greater than percentage uncertainty, this indicates that precision is greater than accuracy in the experiment, meaning that experimental measurements are more closely aligned to each other than with the literature value. This reflects that the systematic errors in the experiment are more significant than random errors, and hence suggests the need to seek greater accuracy by reducing systematic error instead of seeking more precise instruments.

Evaluation

Strength

Despite uncertainties associated with spectrometer, three trials for each paracetamol solution were performed to obtain three absorbance value, and a mean value was calculated. This helps to produce more conclusive and accurate absorbance values. Moreover, spectrometer is considered as highly sensitive, and hence is likely to give accurate readings of light absorbances. Furthermore, a moderately high R^2 value was observed in both graph 1 and 2 ($R^2 = 0.93$ and $R^2 = 0.88$). This indicates minimal variance of data points from the trendline in both graphs.

Weakness

Random errors

In the experiment, only three trials for each paracetamol solution were conducted to generate the absorbance rate. While this enables the calculation of mean absorbance, removing anomalous value would render the mean taken of only two data points, which reduces the reliability of the result. In addition, percentage uncertainties associated with the measuring balance and spectrometer totalled to 8% in total mass percentage of paracetamol, which is considerably high. To improve this, more trials can be performed to reduce the impact of these random errors, such as six trials per solution.

Systematic errors

1. Presence of inactive ingredients in the Panadol Tablet: The Panadol tablet contained paracetamol as active ingredient but had other inactive ingredients. When weighted, the mass of the tablet which claims on its package to contain 500mg of paracetamol was found to be 598mg. Whilst I had tried to calculate the percentage of paracetamol within each tablet in comparison to total mass of each tablet and used the ratio to calculate the concentration of paracetamol, the 500:598 ratio does not always stand correctly as when 0.100g was extracted for testing, the ratio of active ingredient within the extracted sample is unknown. This may render the calculation of mass percentage of paracetamol in the sample of solution as unreliable. This error can be improved by using pure paracetamol free from inactive ingredients.

2. Absorbance values with spectrometry: The percentage error (11%) in the experiment may be due to uncertainty with calibration curve (shown in graph 1). Calibration curve is created using referencing bases of known paracetamol concentrations. However, it is uncertainty how reliable the reference bases are. The calibration curve found to possess R^2 value of 0.93, indicating that reference bases varied the curve by 7%. The calibration curve can be made again to see if a curve with less variation can be generated. Furthermore, all absorbance readings of paracetamol ranged from 2.7 to 1.0. It is identified that absorbances higher than 2 means 99% of the light is absorbed (Vernier, 2020). Therefore, at an absorbance value greater than 2, the linearity of the curve is limited by chemical and instrumental factors, and hence has high relative error (Vernier, 2020). It is suggested to dilute the concentration down to prevent the relative error. Hence, the concentration of paracetamol should be further diluted.

3. The reaction with Iron (III) and potassium hexacyanoferrate (III) to make a coloured mixture: To make a coloured mixture, the iron (III) was first added into the paracetamol solution to reduce iron (III) ions into iron (II) ions. The iron (II) ions then react with potassium hexacyanoferrate (III) solution that is added, producing Prussian blue. However, precipitation occurred with the formation of Prussian blue, which may significantly impact measurement of the intensity of blue solution in the spectrometer to determine the concentration of paracetamol. This may contribute to the percentage error with the theorical value. Perhaps another reaction can be sought to produce a coloured solution with no precipitation.

Further investigation:

Establishing that increased durations of exposure to UV light decreases the mass percentage of paracetamol, a parallel investigation can be performed on aspirin, an analgesic drug just as commonly used as paracetamol but differs in chemical structure, to determine the stability of aspirin under UV light. Moreover, an investigation can be conducted on exposure of paracetamol in varying temperatures such at room temperature, in the summer heat, or the winter frosts. This propounds the research question 'How does varying temperatures in Celsius (10^oC, 15^oC, 20^oC, 25^oC, 30^oC) affect the mass percentage (mass (g) of paracetamol after exposure/mass (g) before exposure) of paracetamol found in a Panadol tablet?'

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