

## FACTORS THAT AFFECT THE LIGHT ABSORBED BY A TRANSITION METAL

### COMPLEX

#### DESIGN

##### Research Question

How does the concentration of Copper II sulphate solution affect its absorbency of light?

##### Variables

Independent Variable: Concentration of Copper II Sulphate Solution

Dependent Variable: Absorbency of light

Controlled Variables: Type of Chemical Solution  
(Determines Molar Extinction Coefficient)  
Light Wavelength  
Light Intensity  
Path Length  
Volume of Copper II Sulphate Solution

##### Procedure

##### Apparatus

Distilled Water  
0.5 M Copper II Sulphate Solution ( $\text{CuSO}_4$  (aq))  
Measuring Cylinder  
Cuvettes (about 5)  
Beakers  
Colorimeter & light filters

In this experiment concentration of the Copper II Sulphate solution is being varied to determine its effect on absorbency of light. These concentrations will be made from dilutions of the 0.5 M Copper II Sulphate solution provided. The dilutions are as follows:

Concentration of $\text{CuSO}_4$ [ $\text{mol dm}^{-3}$ ]	Volume of 0.5 Molar Aqueous $\text{CuSO}_4$ Solution [ $\text{dm}^3$ ]	Volume of Distilled Water [ $\text{dm}^3$ ]
0.5000	0.0500	0.0000
0.2500	0.0250	0.0250
0.1250	0.0125	0.0375
0.0630	0.0063	0.0437
0.0000	0.0000	0.0500

Two measuring cylinders were used in this case: one for the distilled water and the other for the 0.5 M Copper II Sulphate solution (to reduce inaccuracy of concentrations). Care was taken to ensure that the volumes were accurate with the volume reading taken from the bottom of the meniscus of the liquid and making sure that all the liquid was emptied from the

measuring cylinder. The uncertainties of the measuring cylinders were noted (equal to the smallest division of measurement, which in this case was  $0.1 \text{ cm}^3$ ).

The water and the solution were poured into a beaker and mixed thoroughly before a sample was taken and stored in one of the cuvettes, ready for analysis by the colorimeter. The mixing made sure that the correct concentration was taken for analysis with the appropriate ratio of water and solution.

- The same colorimeter was used throughout the experiment so that the path length would remain a constant value (controlling that variable). Before inserting the concentrations in the machine several factors had to be decided and variables controlled:
- The outsides of all the cuvettes were cleaned of all dust and dirt so that there would be minimal interference with the light shone through the solution and so that we would get an accurate reading.
- The cuvettes also had to be inserted so that the light beam was directed through the 'clear' sides without the texturing and 'cloudiness' so that there would be no interference with the absorption reading.
- The colorimeter had to be calibrated to zero using the distilled water so that there would be no systematic error in the results and the readings would be accurate.
- An appropriate filter had to be selected. The Copper II Sulphate solution used was blue in colour so the filter had to be able to give clear results within that range of wavelengths of light. In the end a filter with a wavelength of 600 nm was found to be in the range where results could be taken.
- The same colorimeter and type of cuvette was always used so that the path length remained a constant (in this case 1 cm).

- Power was then supplied to the colorimeter. Before each series of results it was calibrated to zero using the distilled water sample.
- Each cuvette with solution was inserted into the machine and the absorbency reading was noted along with its respective error of measurement.

- Three sets of results were taken in total for this experiment due to time limitations. Ideally one should take three or more so that anomalous results can be clearly identified and more accurate mean average absorbency values can be calculated.
- The total range of values was set from 0.5 M to 0.0 M, using the maximum concentration available and the concentration best able to show any systematic error/the y-axis intercept of the trend line. Several readings were taken between these values to confirm a relationship if any existed between these variables (absorbency and concentration).
- Results were recorded on a Table of Results before total uncertainty values were calculated as well as the mean average absorbency. These values were then plotted onto a graph using the Microsoft Excel computer programme.

## Data Collection and Presentation

### Tables of Results

#### Rough Collected Data

Concentration of $\text{CuSO}_4$ [ $\text{mol dm}^{-3}$ ] (see Graphs and Calculations for Uncertainties)	Absorbency Uncertainty = $\pm 0.01$		
	Repetition 1	Repetition 2	Repetition 3
0.0000	0.00	0.00	0.00
0.0625	0.06	0.06	0.06
0.1250	0.12	0.12	0.12
0.2500	0.26	0.26	0.26
0.5000	0.50	0.50	0.50

#### Observations:

- Copper sulphate solution was blue in colour and the distilled water was colorless.
- The more concentrated the solution was the darker/more intense the blue colour of the solution.
- The needle of the colorimeter found the reading quite quickly and remained steady on the value.

#### Processed Data

Concentration Of $\text{CuSO}_4$ [ $\text{mol dm}^{-3}$ ]	Absorbency				
	Repetition 1	Repetition 2	Repetition 3	Mean Average Absorbency	Measuring Error
0.0000	0.00	0.00	0.00	0.00	$\pm 0.01 = \pm 0.000\%$
0.0625	0.06	0.06	0.06	0.06	$\pm 0.01 = \pm 16.667\%$
0.1250	0.12	0.12	0.12	0.12	$\pm 0.01 = \pm 8.333\%$
0.2500	0.26	0.26	0.26	0.26	$\pm 0.01 = \pm 3.846\%$
0.5000	0.50	0.50	0.50	0.50	$\pm 0.01 = \pm 2.000\%$

DCP 1

DCP 2/3

DCP 3

Concentration Of $\text{CuSO}_4$ [ $\text{mol dm}^{-3}$ ]	Uncertainties		
	Volume of 0.5 Molar Aqueous $\text{CuSO}_4$ Solution [ $\text{dm}^3$ ]	Volume of Distilled Water [ $\text{dm}^3$ ]	Total Error for Concentration of $\text{CuSO}_4$ [ $\text{mol dm}^{-3}$ ]
0.5000	$0.0500 \pm 0.0001 = 0.0500 \pm 0.200\%$	$0.0000 \pm 0.0001 = 0.0000 \pm 0.000\%$	$\pm 0.200\%$
0.2500	$0.0250 \pm 0.0001 = 0.0250 \pm 0.400\%$	$0.0250 \pm 0.0001 = 0.0250 \pm 0.400\%$	$\pm 0.800\%$
0.1250	$0.0125 \pm 0.0001 = 0.0125 \pm 0.800\%$	$0.0375 \pm 0.0001 = 0.0375 \pm 0.267\%$	$\pm 1.067\%$
0.0630	$0.0063 \pm 0.0001 = 0.0063 \pm 1.587\%$	$0.0437 \pm 0.0001 = 0.0437 \pm 0.229\%$	$\pm 1.816\%$
0.0000	$0.0000 \pm 0.0001 = 0.0000 \pm 0.000\%$	$0.0500 \pm 0.0001 = 0.0500 \pm 0.200\%$	$\pm 0.200\%$

The percentage uncertainties of the absorbency reading and the percentage error generated by creating the concentrations were added together and plotted as error bars on the y-axis of the graph. The percentage uncertainties for 'Mean Average Absorbency' are those values.

Example: At a concentration of 0.25 M copper sulphate solution:

DCP 3

**Total Error for Concentration of  $\text{CuSO}_4$ :  $\pm 0.800\%$**

**Absorbency Error of Measurement:  $\pm 3.846\%$**

$$0.800\% + 3.846\% = 4.646\%$$

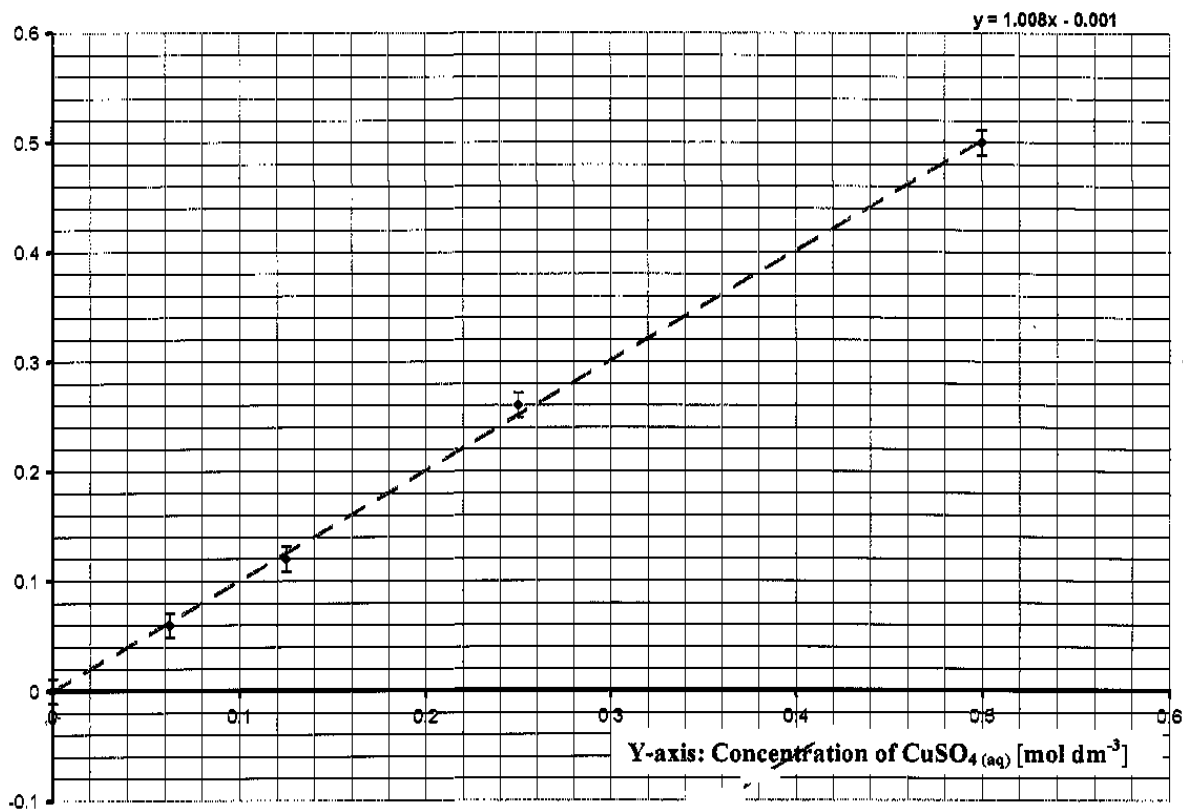
#### Plotted Data

DCP 3

X-axis: Concentration of $\text{CuSO}_4$ [ $\text{mol dm}^{-3}$ ]	Y-axis: Mean Average Absorbency
0.0000	$0.00 \pm 0.200\% \sim 0.00 \pm 0.2\%$
0.0625	$0.06 \pm 18.483\% \sim 0.06 \pm 20\%$
0.1250	$0.12 \pm 9.400\% \sim 0.12 \pm 9\%$
0.2500	$0.26 \pm 4.646\% \sim 0.26 \pm 5\%$
0.5000	$0.50 \pm 2.200\% \sim 0.50 \pm 2\%$

### Graph: The Relationship between Concentration and Absorbency

Y-axis: Absorbency



### Conclusion & Evaluation

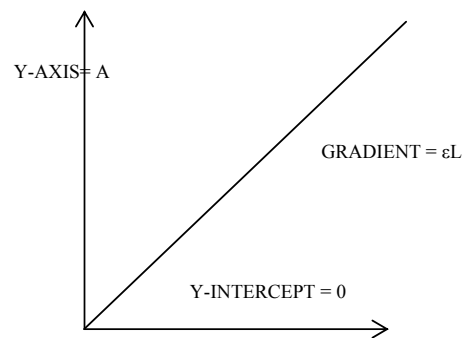
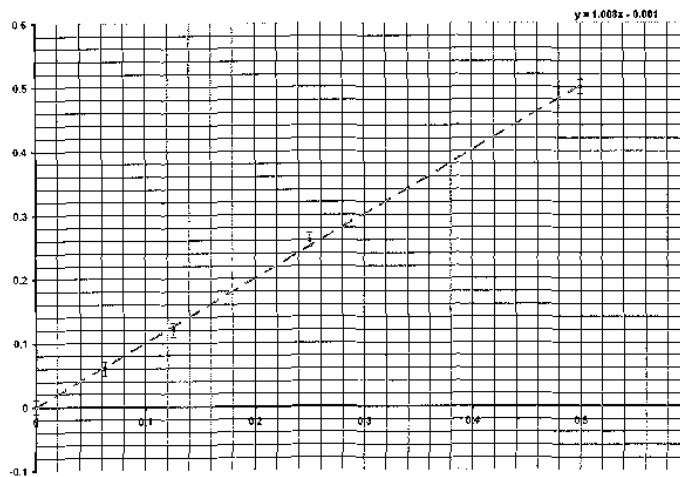
CE 1

The relationship between the concentration of the solution and the moles of molecules absorbing the light should be directly proportional. Thus, an increase of concentration increases proportionately the absorbency of light (assuming that all other variables are held constant). This is according to the Beer-Lambert Law:

$$A = \epsilon C L$$

where A is the absorbance and C the concentration. ( $\epsilon$  is molar extinction coefficient and L is pathlength).

Overall, the data generated from the experiment appears to support this relationship and the theory behind it. As we can see from the graph there is a clear directly proportional linear relationship between absorbency (A) and concentration (C). The trend line crosses the y-axis at 0, so there appears to be no systematic error. In the hypothesis it was stated that according to the prediction the graph would approximately resemble the graph drawn below (to the right). The real graph is shown below (to the left). They are very similar:



CE 2 The accuracy of the real results does not detract from the probable veracity of this conclusion. The errors are relatively small and appear to be random. Even so the trend line still falls within the error bars on the graph - a testament to the remarkable accuracy of the results obtained in this investigation. Of course, these small random errors are not ideal although more repetitions of the data would most likely have eliminated these after multiple repetitions. CE 3 These are probably small human errors which would not be CE 2 eliminated by altering the apparatus used. In all this experiment was a success as we could draw firm conclusions from the data generated.

CE 3 Further work could be done to expand our knowledge of transition metal complexes and their light absorbing qualities. Variables such as path length could be varied in further experiments to confirm the linear relationship with absorbency as predicted by the Beer-Lambert Law. It would also be interesting to take results for different wavelengths of filter in the colorimeter for a fixed concentration in order to determine an approximate, if not exact range for the wavelengths absorbed by complex ions. Work could also be done to investigate the effects of using different solutes to dissolve the copper sulphate or other transition metal salts in. In this way we could find out the relative ability of ligands to split d-orbitals.