Excel-Word Practice Assignment

Solutions

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Presented to

Incoming Engineering Students

Smith Faculty of Engineering and Applied Science

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1. Luminol and Fluorescin to Detect Blood

1.1 Introduction

An experiment was performed to collect data on two chemicals, luminol and fluorescin, and investigate methods to detect blood using chemiluminescence. Each chemical was mixed into a separate solution with hydrogen peroxide and blood then the concentrations of the chemicals were measured over time. Results are included in Table 1 and Table 2. Figure 1 displays the concentration of both chemicals over 45 seconds. The plot includes error bars and trendline equations. The trendline equations from Figure 1 were used to find the reaction rate of both luminol and fluorescin. This data was used to determine differences the reaction of chemicals used to detect blood.

1.2 Results and Analysis

In Table 1 and Table 2, the second columns display the results of the experiment, and the third column displays uncertainty. The concentration data was used with the time in seconds to construct the plots displayed in Figure 1. The uncertainty in mol/L for the concentration of each chemical was calculated using Equation 1. The error bars were created using Equation 1.

$$Uncertainty\ (concentration) = \pm\sqrt{concentration} \tag{1}$$

Table 1: Concentration of Luminol in mol/L and uncertainty.

Time (s)	[Luminol] (mol/L)	Uncertainty (±mol/L)
0	20.00	4
5	18.43	4
10	14.05	4
15	12.79	4
20	8.60	3
25	7.07	3
30	4.11	2
35	2.16	1
40	1.04	1
45	0.42	1

Table 2: Concentration of Fluorescin in mol/L and uncertainty.

Time (s)	[Fluorescin] (mol/L)	Uncertainty (±mol/L)
0	20.00	4
5	19.78	4
10	19.03	4
15	18.45	4
20	16.39	4
25	15.21	4
30	13.01	4
35	10.26	3
40	8.99	3
45	8.01	3

For the zeroth order reaction of luminol and fluorescin, plotting concentration against time will produce a linear trend [1]. The data from Table 1 & Table 2 were plotted on Figure 1 below. For the purposes of reporting the trendline equations, the variable t has been defined as time in seconds, and C has been defined as concentration in mol/L or M. Concentration of luminol and fluorescin has been delineated by subscripts, using C_l for luminol and C_f for fluorescin.

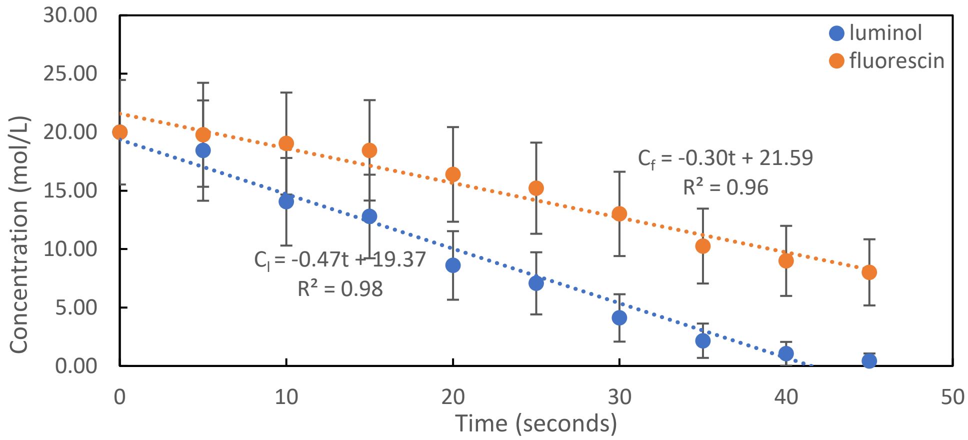

Figure 1: Change in concentration over time for both luminol and fluorescin

Both series in Figure 1 are very good fits for the data, with correlation coefficients of higher than .95 for both of them. The equations from the trendlines of Figure 1 have been depicted as equations 2 & 3 below for luminol and fluorescin respectively.

$$C_l = -0.47t + 19.37 \tag{2}$$

$$C_f = -0.30t + 21.59 \tag{3}$$

The slope of the trendlines represent the rate of reactions for both luminol and fluorescin, using units of mol/(L*s) or M/s. For luminol, equation 2 corresponds to a reaction rate of .47 M/s. Equation 3 corresponds to fluorescin, with a reaction rate of .30 M/s. These reaction rates are taken over the first 45 seconds, and due to the fit of the data being very good for both trendlines, the reaction rate should remain consistent over larger periods of time.

Using equations 1 & 2, the time it takes for the luminol and fluorescin concentrations to reach zero can be calculated. The calculations were completed following the same method as the sample calculation represented by calculation 1 below, which calculates the time it takes for the fluroescin concentration to hit zero using equation 3.

Calculation 1: Determining the time t it takes for the fluorescin concentration C_f to reach 0

$$C_f = -0.30t + 21.59$$

$$t = \frac{C_f - 21.59}{-0.30}$$

$$t = \frac{0\ M - 21.59\ M}{-0.30\frac{M}{s}}$$

$$t = 71.97\ s$$

From calculation one and an additional calculation for luminol, it takes 71.97 seconds for the fluorescin concentration to reach zero and it takes 41.21 seconds for the luminol concentration to reach zero.

1.3 Conclusion

The reaction of luminol and blood occurs more quickly than the reaction of fluorescin and blood. A slower reaction results in less light being emitted at one time so the reaction using fluorescin would need to be observed in a darker room. If it was difficult to block all light out of a location it would be beneficial to use luminol. The luminol reaction won't produce light for as long because the reaction occurs more quickly so it would need to be recorded quickly to ensure the data was usable. The reaction can only occur once and missing the reaction would make it difficult to detect the blood splatter in an investigation.

One other method is using Amido Black. Its reaction does not produce light and it is not specific to blood. The chemical is a general protein stain and is used to enhance the visibility of patterns to allow for easier documentation. This method would be best used when investigators know what a stain is already and want to enhance patterns or markings, such as those made by the tread on boots [2].

2. Climate Change in Kingston

2.1 Introduction

Data was collected in the City of Kingston from 1873 – 2006. Figure 2 displays the average annual temperature, Figure 3 displays the total annual precipitation, and Figure 4 displays the total annual snowfall. The plots include trendline equations which were generated with linear regression. For each set of data regression analyses were performed to determine if the equations were good fits for the data. Conclusions were drawn from the data to determine if the city has experienced significant climate change.

2.2 Results and Analysis

Figure 2, Figure 3 & Figure 4 display the provided data for temperature, precipitation, and snowfall respectively in Kingston. The data was taken between 1873 to 2006 and is missing some years in that range. In order to examine the trendlines of the plots, y has been defined as the independent variable, representing the year of given climate data. T has been defined as temperature in °C, P has been defined as precipitation in mm and S has been defined as snowfall in cm. Figure 2 displays the provided data for the average temperature in Kingston, measured in °C.

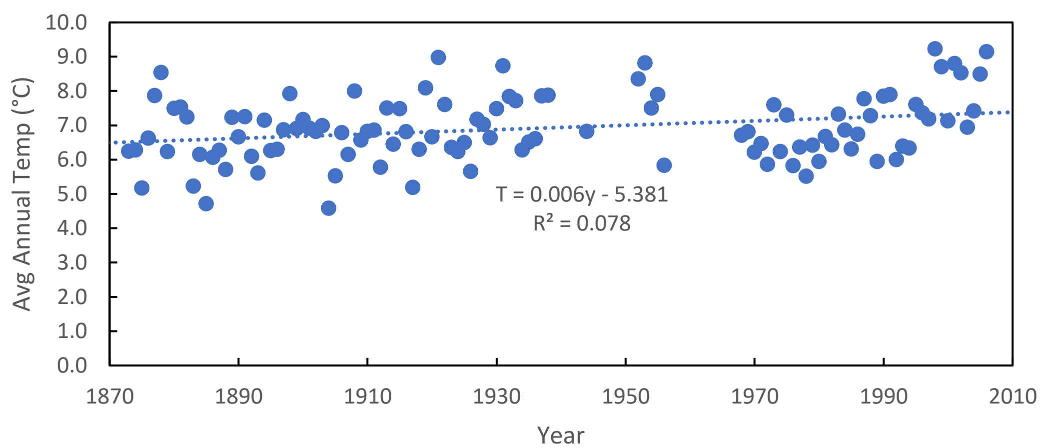

Figure 2: Relationship between years and average annual temperature in °C in Kingston

The trendline from Figure 2 has been depicted by equation 4 below. A regression analysis was also performed, depicted later in this section, in order to determine the error in the slope & intercept, as well as provide more insight into the fit of the data.

$$T = 0.006y - 5.381 \tag{4}$$

The average yearly rainfall data in Kingston has been depicted by Figure 3 below, measured in mm.

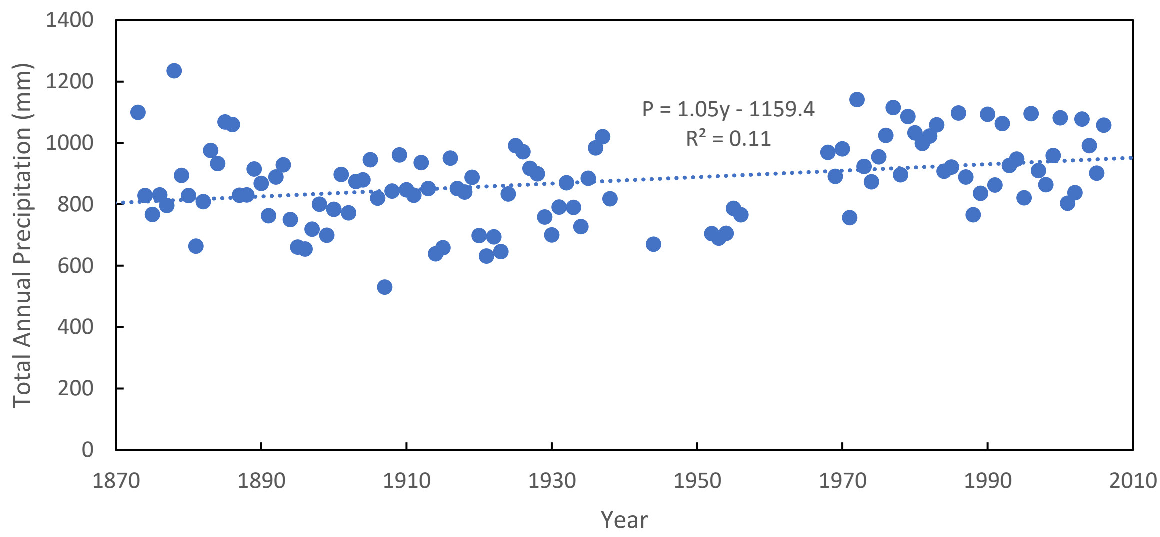

Figure 3: Relationship between years and total annual precipitation in mm in Kingston

The trendline from Figure 3 has been depicted by equation 5 below. A regression analysis was also performed, depicted later in this section, in order to determine the error in the slope & intercept, as well as provide more insight into the fit of the data.

$$P = 1.05y - 1159.4 \tag{5}$$

The average yearly snowfall data in Kingston has been depicted by Figure 4 below, measured in cm.

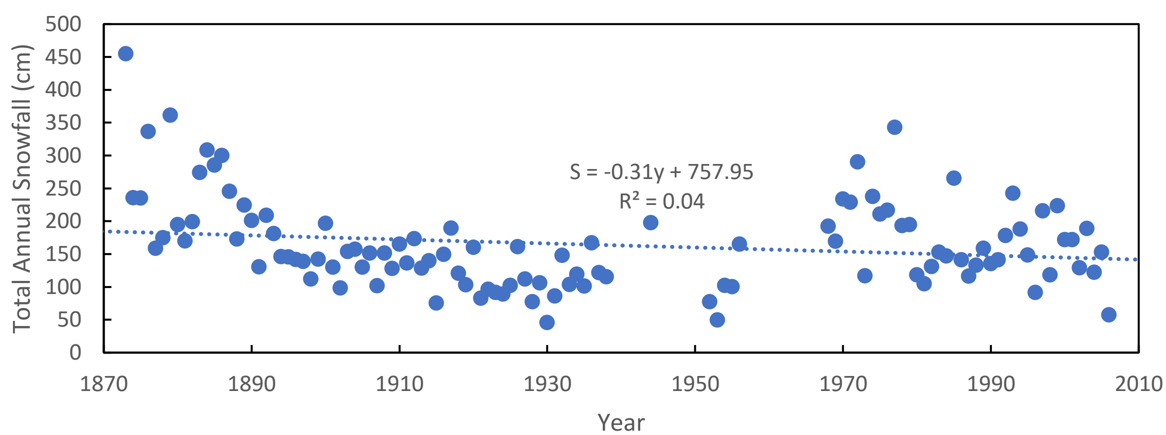

Figure 4: Relationship between years and total annual snowfall in cm in Kingston

The trendline from Figure 4 has been depicted by equation 6 below.

$$S = \ -0.31y + 757.95 \tag{6}$$

Regression analyses were performed on each of the data sets to determine the best fit for the data set and the error in the slopes & intercept of the linear equations. The temperature regression analysis results have been presented in Table 3.

Table 3: Results of regression analyses for Temperature Data

Temperature Change Per Year [°C/year]	Standard Error [±°C/year]	Intercept [°C]	Intercept Standard Error [±°C]
0.006	0.002	-5	4

The regression analysis also produced a residual plot, presented by Figure 5 below.

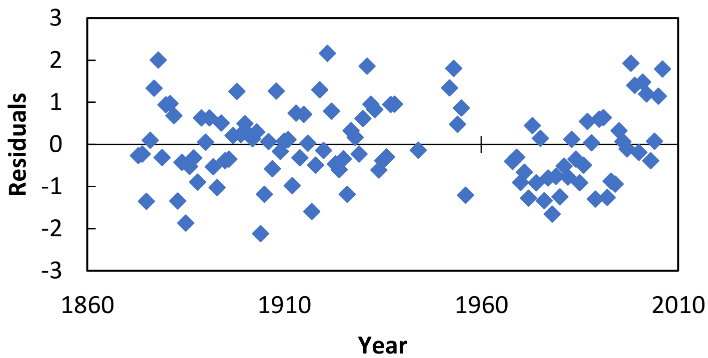

Figure 5: Residual Plot for the Regression analysis for Temperature data. The Residuals appear to have no pattern, and are evenly distributed, suggesting that a higher order fit would not be better for the data.

The residuals appear to be randomly distributed, and do not have a pattern. Due to this and the fact that the residuals are close to evenly distributed across the axis, it can be said that a linear fit is the best for the temperature data set. That being said, though the style of fit may be appropriate, the correlation coefficient shown in Figure 2 shows that the trendline is still a very poor fit for the data set; there is simply just not a better fit available, suggesting very weak correlation, if any. The regression analysis from Table 3 can be used to rewrite equation 4 to include error, which has been presented in equation 7 below.

$$T = \left(0.006 \pm 0.002\ \frac{°\mathrm{C}}{year}\right) y - (5 \pm 4°\mathrm{C}) \tag{7}$$

The regression analysis performed on the precipitation data, with the results presented in Table 4 below.

Table 4: Results of regression analyses for Precipitation Data

Precipitation Change Per Year [mm/year]	Standard Error [±mm/year]	Intercept [mm]	Intercept Standard Error [±mm]
1.1	0.3	-12×10^2	6×10^2

A residual plot was also produced with the precipitation's regression analysis, presented by Figure 6 below.

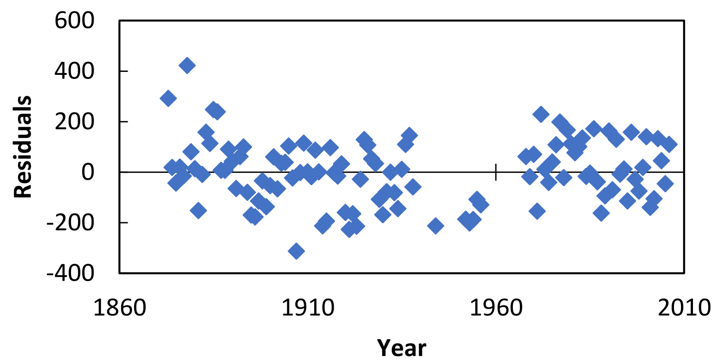

Figure 6: Residual Plot for the Regression analysis for Precipitation data. The Residuals appear to have no real pattern, however most of the residuals are negative. Despite this, a higher order fit still may not be better for the data set.

The residuals are still randomly distributed in Figure 6, however the residuals are mostly below the axis and not as evenly spread on both sides. While this does not constitute a pattern, it suggests that the trendline is not as good of a fit for the precipitation data as equation 7 is for the temperature data. Without a pattern, it cannot be said that the data should have a higher order fit, suggesting that a linear fit is still the best for the data, even if the correlation coefficient from Figure 3 suggests very weak correlation, if any. The regression data from Table 4 was combined with equation 5 to produce equation 8 below.

$$P = \left(1.1 \pm 0.3\ \frac{mm}{year}\right) y - (12 \pm 6) \times 10^2\ mm \tag{8}$$

The last set of data is the snowfall data, where the results of the regression analysis has been presented in Table 5 below.

Table 5: Results of regression analyses for Snowfall Data

Snowfall Change Per Year [cm/year]	Standard Error [±cm/year]	Intercept [cm]	Intercept Standard Error [±cm]
- 0.3	0.2	8 x 10^2	3 x 10^2

The snowfall's regression analysis also produced a residual plot, presented by Figure 7 below.

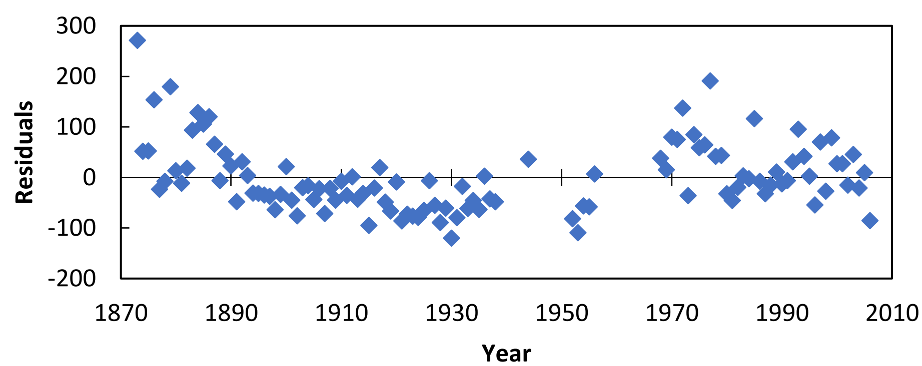

Figure 7: Residual Plot for the Regression analysis for Snowfall data. The Residuals appear to have a slight quadratic relation and is not entirely evenly split above and below the axis due to the curve-like dispersion.

There is a slightly quadratic pattern to the residuals in Figure 7, centered around 1930. This suggests that a higher order fit may be better for the data then a linear fit. This is also supported by the lowest correlation coefficient of the three data sets, at only 0.03 in Figure 4. Though the snowfall equation is most likely not the best fit for the data set, but the regression results presented in Table 5 was combined with equation 6 to produce equation 9 below.

$$S = \left(-0.3 \pm 0.2 \ \frac{cm}{year}\right) y \ + \ (8 \pm 3) \times 10^2 \ cm \tag{9}$$

The average temperature in 1992 was 6°C, and the significant increase of 1.5°C would result in an average temperature of 7.5°C. Using the values of equation 7 without error, the year when there is a significant increase in heat was calculated. This calculation has been depicted by calculation 2 below.

Calculation 2: Determining the year when the average temperature is 7.5°C using equation 7

$$\begin{aligned} T &= 0.006y - 5 \\ y &= \frac{T + 5}{0.006} \\ y &= \frac{7.5°C - 5°C}{0.006° \dfrac{C}{year}} \\ y &= 2083 \end{aligned}$$

It should be noted that the year would change drastically depending on the number of significant figures used and where the error should be. Using equation 4 instead of 7 would result in an answer of 2044. This range in the data is partially the result of poor correlation of the trendline, and the high error values when compared to their respective values.

The City of Kingston's drainage system can withstand 1200 mm of precipitation per year. Using equation 8, the year when the rainfall exceeds the maximum the drainage system can withstand was calculated and has been depicted by calculation 3 below.

Calculation 3: Determining the year that the average rainfall exceeds the amount that the city of Kingston can withstand using equation 8.

$$\begin{aligned} P &= 1.1y - 12 \times 10^2 \\ y &= \frac{P + 12 \times 10^2}{1.1} \\ y &= \frac{1200 \ mm + 12 \times 10^2 \ mm}{1.1 \dfrac{mm}{year}} \\ y &= 2181.8 \rightarrow 2182 \end{aligned}$$

Using the values that can be guaranteed from the error of the regression analysis, the city will need to update its drainage system in 2182. If using equation 5 instead, the drainage system would need to be updated in 2247.

The total annual snowfall in 2002 was 128.9 cm and a significant change is required when snowfall has changed by 20% or more since 2002. Using 2021 (the year of the original assignment) as the current year for this question, equation 9 was used to determine the snowfall, demonstrated in calculation 4 below.

Calculation 4: Determining the snowfall in 2021 using equation 9

$$S = -0.3y + 8 \times 10^2$$
$$S = -0.3\frac{cm}{year}(2021) + 8 \times 10^2\ cm$$
$$S = 193.7\ cm$$

With the amount of snowfall for 2021 calculated, the % change can be calculated using equation 10.

$$\%\ change = \frac{final - initial}{initial} \times 100\% \qquad (10)$$

Using equation 10, an initial value from 2002 of 128.9 cm and a final value from 2021 of 193.7 cm, calculation 5 below can be used to determine the percent change between 2002 and 2021.

Calculation 5: Determining the percent change in snowfall between 2002 and 2021 using equation 10.

$$\%\ change = \frac{final - initial}{initial} \times 100\%$$
$$\%\ change = \frac{193.7\ cm - 128.9\ cm}{128.9\ cm} \times 100\%$$
$$\%\ change = 50.27\ \%$$

The change was found to be significant in calculation 5, meaning the city of Kingston should update their spending habits concerning salt and sand for the winter months.

2.3 Conclusion

It was found that by 2083 the average annual temperature will have increased significantly. The projected increase in the average annual temperature means the summers will continue getting hotter in Kingston and the city should update bylaws to make air conditioning a requirement in rental homes before the temperatures become regularly unsafe.

The residual plots suggest that the rainfall and temperature data have a linear trend if any, though the correlation coefficients of the data itself is so low that there is most likely not any correlation, linear or not. The snowfall data has a pattern in its residual plot, shown by Figure 7, which suggests that a higher order fit may provide a better fit for the data then the currently awful fit from the linear data set. This is the only data set where linear may not be the style of relation.

3. References

[1] R. Curtis, J. Martin and D. Cao, Zero-Order Reactions, 15 August 2020. [Online]. Available: https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Kinetics/02%3A_Reaction_Rates/2.10%3A_Zero-Order_Reactions.

[2] Bureau of Criminal Apprehension,, "Amido Black," Minnesota Department of Public Safety, 2021. [Online]. Available: https://dps.mn.gov/divisions/bca/bca-divisions/forensic-science/Pages/forensic-programs-crime-scene-amido.aspx.