

# Calculation of the Half –Life-Time and Rate Constant for the Formation Reaction of an Azo Dye Derived from Metoclopramide

\*Mohammad Mahmoud Hussein Al-Niemi, \*Alaa Abdul Azee Alashmta, \*May G Aldabbagh

\*Department of Chemistry, College of Education for Pure Science, University of Mosul- Iraq.

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## Abstract

This study involved kinetic analysis using a spectrophotometric method by monitoring the formation of an orange azo dye resulting from the reaction of the diazotized metoclopramide reagent ((Z)-5-chloro-4-(chlorodiazonyl)-N-(2-(diethylamino)ethyl)-2-methoxybenzamide) with resorcinol. The reaction was conducted at 294 K and a wavelength of  $\lambda_{\text{max}}=300\text{nm}$  (characteristic of the resulting dye) in an acidic medium (pH=4.41) under conditions optimized spectrophotometrically. A 1:1 mole ratio of reactants (resorcinol: diazotized metoclopramide reagent) was used, with an aqueous solution concentration of  $0.5 \times 10^{-3} \text{ mol.L}^{-1}$  for each. Dye formation kinetics were investigated by monitoring formation times using the aforementioned instrument. It was observed that increasing the reagent concentration tenfold (to  $5.0 \times 10^{-3} \text{ mol.L}^{-1}$ ) did not affect the rate constant ( $k_1$ ) of the dye formation reaction showing that the reaction follows pseudo-first-order kinetics with respect to resorcinol. This enabled the calculation of the dye formation rate-constant at four temperatures (274, 284, 294 and 304K), with the highest value recorded at 304 K ( $0.0705 \text{ min}^{-1}$ ) and the lowest at 274 K ( $0.0599 \text{ min}^{-1}$ ). In addition to calculating the half-lives for the dye formation reaction and determining the time required for the reaction completion ( $t_{1/2}=9.83 \text{ min}$  at 304K, 10.44 min at 294K, 10.93 min at 284K, and 11.57 min at 274K). The study results demonstrated that half-life values are inversely proportional to reaction rate constants as temperature increases under identical conditions. The low activation energy value ( $E_a=4.107 \text{ kJ/mol}$ ) indicates that the formation reaction proceeds rapidly and spontaneously without the need for catalysts a feature that enhances its industrial economic viability.

**Keywords:** diazotized-metoclopramide; azo-dye; rate-constant; resorcinol; half-life-time; stoichiometric-ratio.

## 1. Introduction

Metoclopramide is a drug compound used to treat stomach and esophageal problems [1]. It is often used to treat and prevent nausea and vomiting, to aid people with delayed gastric emptying, and to aid with gastroesophageal reflux disease (GERD). It is also used to treat migraines [2]. Generally side effects involve feelings of fatigue, diarrhea, motor insufficiency, and late-onset dyskinesia. The serious side effects involve neuroleptic malignant syndrome and depression [3]. Therefore, people are rarely advised to take the drug for longer than 12 weeks, and many pregnant women have not found any evidence of harm after taking the drug. It is also used as a second-option treatment for hyperemesis gravidarum (severe nausea and vomiting during pregnancy). It belongs to a group of drugs known as dopamine receptor antagonists and acts as an exercise promoter [2,3]. It is also used prophylactically in combination with paracetamol (acetaminophen) or aspirin for migraine headaches, as well as by some emergency medicine providers when transporting immobilized conscious individuals in the spinal cord [4]. Diabetes, age, and female

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gender are dangerous factors that increase the probability of neuropsychiatric and psychiatric side effects associated with metoclopramide [5].

The main objective of this work is to conduct a detailed spectrokinetic study monitoring the synthesis of a light-orange azo dye, chemically designated as (Z)-5-chloro-N-(2-(diethylamino)ethyl)-4-((2,4-dihydroxyphenyl)diazonyl)-2-methoxy benzamide). The dye was synthesized by reactant resorcinol with the primary aromatic amine (4-amino-5-chloro-N-(2-(diethylamino)ethyl)-2-methoxybenzamide), following its conversion into a diazonium reagent at a temperature of 294 K. Subsequently, the effect of temperature variation on the rate constants for the dye's formation was investigated. It is worth noting that such kinetic studies encompassing the determination of rate constants, half-life times, and activation energy for the dye formation reaction are importance across various scientific fields including chemistry, pharmacy and medicine.

## 2. Methodology

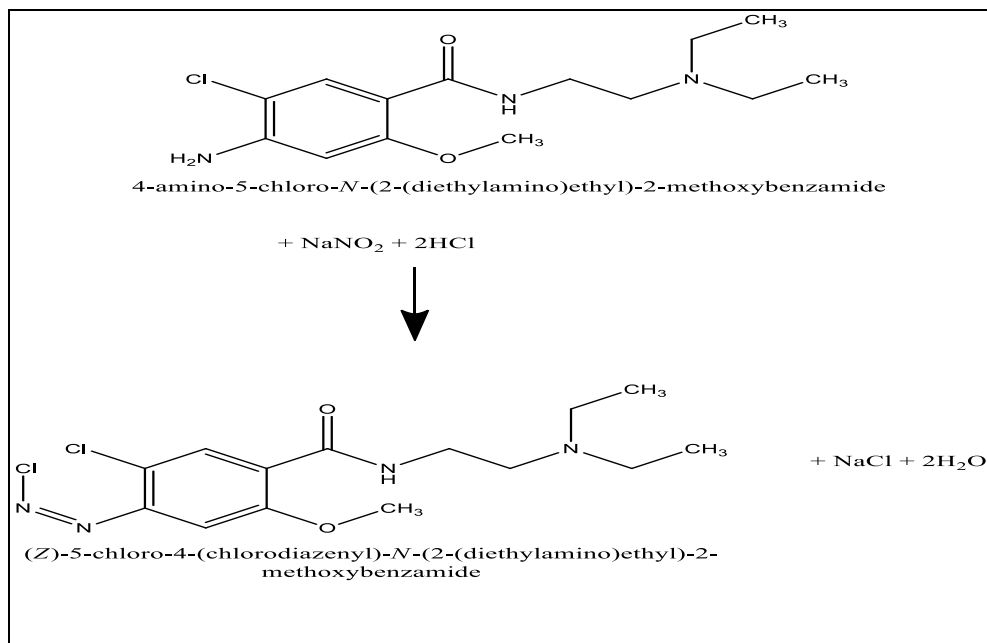
### 2.1. Lab instruments and chemicals used.

The chemicals used in this study namely resorcinol, metoclopramide, sodium nitrite, sodium hydroxide, ethanol, hydrochloric acid, and sodium carbonate were provided by several companies as: BDH (UK) and Fluka Switzerland. The laboratory method for preparing the nitrosating reagent used to synthesize the dye under investigation is described below. Research measurements were conducted using a spectrophotometer (Cecil model, manufactured in 2004 by Cambridge, UK) to determine the peak values for the dye formation reaction under study, as well as to find the wavelength that gives the highest absorption in nanometers within the range 190-1100 nm. The pH meter developed by JENWAY Corporation is a better tool for measuring acidity. It was very useful in the study because it allowed the acid levels in the tested solutions to be reliably analyzed and measured, as well as the preparation of the bright orange azo dye [6-10].

### 2.2 Experimental section.

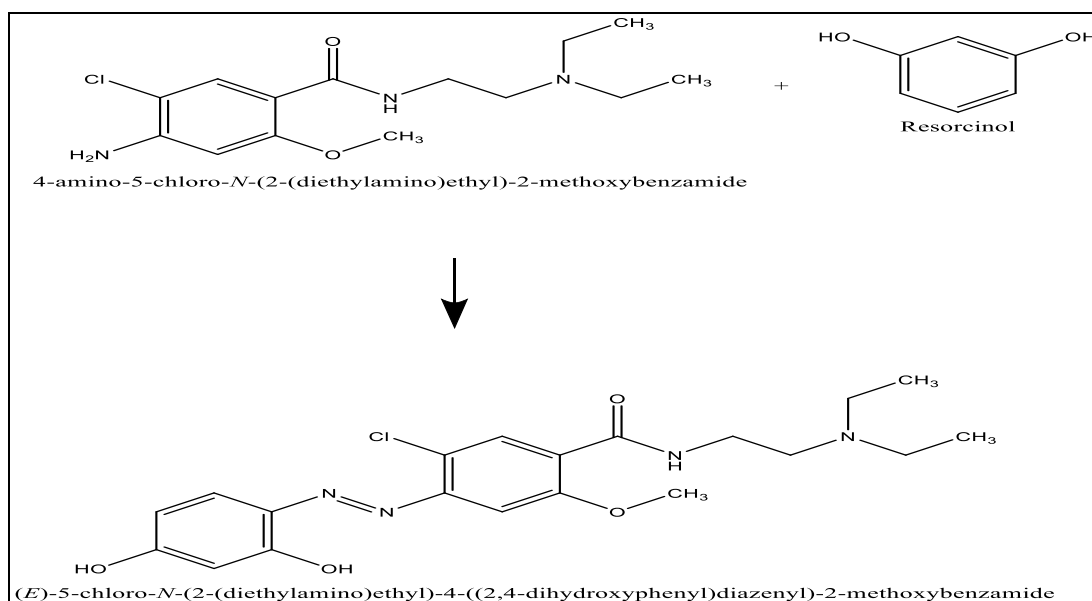
#### 2.2.1 Preparation of a diazotized reagent solution of ((4-amino-5-chloro-N-(2-(diethylamino)ethyl)-2-methoxybenzamide)

(0.01499) g of ((4-amino-5-chloro-N-(2-(diethylamino)ethyl)-2-methoxybenzamide) was dissolved in 50 mL of distilled water, followed by the addition of 20 mL of 1M HCl acid. The resulting mixture was then heated, transferred into a 250 mL volumetric flask, and cooled in an ice bath until the temperature reached 0-5°C. Subsequently, 8.65 mL of sodium nitrate solution (1% NaNO<sub>2</sub>) was added to the cold solution under continuous stirring to ensure homogeneous distribution. Cold water was added within five minutes of the start of mixing until the volume reached the calibration mark of the volumetric flask. The solution was stored in opaque (black-coated) glass containers inside a refrigerator to maintain stability and protect it from light. Additionally, an aqueous sodium carbonate solution (approximately 0.1M) and HCl (2.0 N) was prepared, allowing for flexibility in adjusting the pH using standard methods; values were adjusted as necessary to align precisely with the target value, thereby ensuring accurate measurement. The diazo-reagent ((Z)-5-chloro-4-(chlorodiazonyl)-N-(2-(diethylamino)ethyl)-2-methoxybenzamide) was prepared as shown in Scheme (1) below [9-15]. Based on data from the ChemOffice software, the coupling occurs at the carbon atom of the resorcinol molecule situated \*para\* to one hydroxy group, and \*ortho\* to of the other ( which bears a negative charge of - 0.150), thereby forming the azo dye to be subjected kinetic study in this research.



**Schem 1:** Preperation of diazotized reagent (4-amino-5-chloro-*N*-(2-(diethylamino)ethyl)-2-methoxy benzamide).

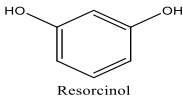
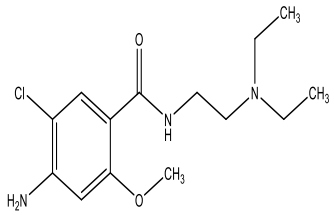
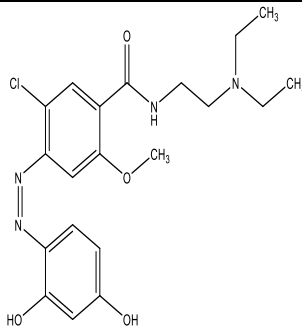
Then the azo group was used in the diazotized reagent and linked to resorcinol according to the coupling reaction , as follows:



**Scheme 2:** The coupling reaction of diazotized reagent with resorcinol.

The following table shows the names, symbols, and structural formulas of the compounds under study, as well as their formulas and weights:

**Table 1:** Names, symbols, and structural formulas of the compounds under study, as well as their structures and weights.

| No. | Symbol of Derivative | Name                                                                                         | Structure                                                                                                                                                                          | Molecular Formula                                                | M.wt (gm.mol <sup>-1</sup> ) |
|-----|----------------------|----------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|------------------------------|
| 1.  | Reso                 | Resorcinol                                                                                   | <br>Resorcinol                                                                                    | C <sub>6</sub> H <sub>6</sub> O <sub>2</sub>                     | 110.11                       |
| 2.  | 4Am5CIDR             | 4-amino-5-chloro-N-(2-(diethylamino)ethyl)-2-methoxy benzamide                               | <br>4-amino-5-chloro-N-(2-(diethylamino)ethyl)-2-methoxybenzamide                                | C <sub>14</sub> H <sub>22</sub> N <sub>3</sub> O <sub>2</sub> Cl | 299.8                        |
| 3.  | 4Am5CIDR+Re          | (Z)-5-chloro-N-(2-(diethylamino)ethyl)-4-((2,4-dihydroxyphenyl)diazenyl)-2-methoxy benzamide | <br>(Z)-5-chloro-N-(2-(diethylamino)ethyl)-4-((2,4-dihydroxyphenyl)diazenyl)-2-methoxybenzamide | C <sub>20</sub> H <sub>25</sub> N <sub>4</sub> O <sub>4</sub> Cl | 420.89                       |

**2.2.2.Optimal conditions for the production of Azo-Dye(4Am5CIDR+Reso):**

Through thorough screening and identification, our laboratory has utilized a range of chemical and physical techniques to establish the optimal conditions for the production of the complexes. During the synthesis, chalcone was combined with diazotized to produce azo-chalcone dye compounds. To elaborate further, 4-Amino Benzoic acid was diazotized and used as a nitrogen refrigerant within the temperature range of (274-304°K). Various crucial factors, such as maximum wavelength ( $\lambda_{\text{max}}$ ), appropriate volume relative to diazotized-reagent(4Am5CIDR), optimal sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>) concentration, favorable sequence order, ideal timeline starting at zero minutes impacting complex evolution, the onset of stability period during complex evolution, and suitable temperature conditions were identified as essential for achieving the best conditions for successful complex formation. They undergo influences at certain pH levels and temperatures reached 294°K  $\lambda_{\text{max}}$ =300nm., which are significantly elevated in smaller volumes to achieve equilibrium. 0.5 milliliters of (resorcinol) plus 0.15 milliliters of Na<sub>2</sub>CO<sub>3</sub> and 0.6 milliliters of diazotized-reagent (4Am5CIDR) [15-19].

**2.2.3.determenation of components ratio (stoichiometric ratio) for the Azo dye 4Am5CIDR+Reso:**

Several well-know and common methods exits for calculating component ratios in given reaction [19-22], including three methods :the mole-ratio, the operation, and the slope-ratio. Based on another study [23], indicating that the mole

ratio method is the most frequently used in experimental settings, we adopted this method to calculate stoichiometric ratios of the components for this reaction. A 1:1 molar ratio (Resorcinol : Diazo.- Reagent) was determined for the product under study; acidic pH conditions and a temperature of 294 K were employed.

### 2.3. Arrhenius equation:

The Arrhenius equation establishes a relationship between the rate constant and reciprocal of the temperature, it is used to determine the activation energy rate of reaction and expressed as follows:

$$k = A \cdot e^{-E_a/RT} \dots\dots\dots(1)$$

When taking the logarithm of the equation 1, yields the following form:

$$\ln(k) = \ln(A) - (E_a/RT) \dots\dots\dots(2)$$

Where  $k$  represents the rate constant,  $A$  is the frequency factor,  $E_a$  is the activation energy (in kJ/mol),  $R$  is the universal gas constant ( $8.314 \text{ J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$ ), and  $T$  is the absolute temperature (in Kelvin). By plotting  $\ln(k)$  versus the reciprocal of the absolute temperature ( $1/T$ ) in accordance with the Arrhenius equation (Equation 2), the activation energy can be calculated from the slope of the resulting straight line [6-10].

### 3. Results and Discussion:

The ease of synthesized dye particularly azo dyes and the diversity of their substituents (which confer vibrant colors and high stability) have led to their widespread application across various sectors including textiles, paper manufacturing, tanning, cosmetics, and numerous industrial, medical and everyday fields. This has driven researchers in the field to focus on advancing the industry and expanding the dyes applications. One such area of development involves “donor-acceptor” complexes a field that has evolved alongside advancements in electronic spectroscopic analysis techniques. This study initially focused on characterizing the synthesis dye produced via a coupling reaction between the electron donor resorcinol and the electron acceptor reagent (4-amino-5-chloro-N-(2-(diethylamino)ethyl)-2-methoxybenzamide) at 294 K and pH 4.41 and determining the optimal component ratio (specifically: 0.5 mL of  $10^{-3} \text{ M}$  Resorcinol + 0.6 mL of  $10^{-3} \text{ M}$  Diazotized reagent, resulting in a 10:1 ratio of resorcinol: diazotized reagent). It was also observed that the absorbance value, wavelengths and colours of the reactants (resorcinol and the diazotized reagent) differed significantly from those of the resulting dye. This indicates the occurrence of reaction and the formation of a new product that differs entirely from the reactants, as shown in the following table. The table presents absorbance values, natural pH values, and wavelengths of maximum absorbance ( $\lambda_{\text{max}}$ ) for the reactants and products, determined using UV-Vis spectrophotometry at a temperature of 294 K:

**Table 2:** Determination of the absorption values, natural pH values and wavelengths of maximum absorbance ( $\lambda_{\text{max}}$ ) for reactants and products using UV-Vis spectrophotometry at 294 K.

| No. | Symb. of Comp. | Natural-pH | Absorbance | $\lambda_{\text{max}}(\text{nm.})$ |
|-----|----------------|------------|------------|------------------------------------|
| 1   | Reso           | 6.05       | 1.081      | 288                                |
| 2   | 4Am5ClDR       | 3.69       | 0.700      | 318                                |
| 3   | 4Am5ClDR+Reso  | 4.41       | 1.857      | 300                                |

The data presented in Table (2) clearly demonstrate the absence of overlap between the solution of the resulting azo-dye and the reagent solution including the diazotized reagent as determined by electronic spectroscopy. Furthermore, the observed color change serves as strong evidence that a new reaction has occurred. Additionally the

wavelengths and colors of the reactants (resorcinol and the reagent) differ markedly from those of the resulting dye, indicates that a reaction has taken place and a new product has formed that is entirely distinct from the reactants.

### Kinetic Study:

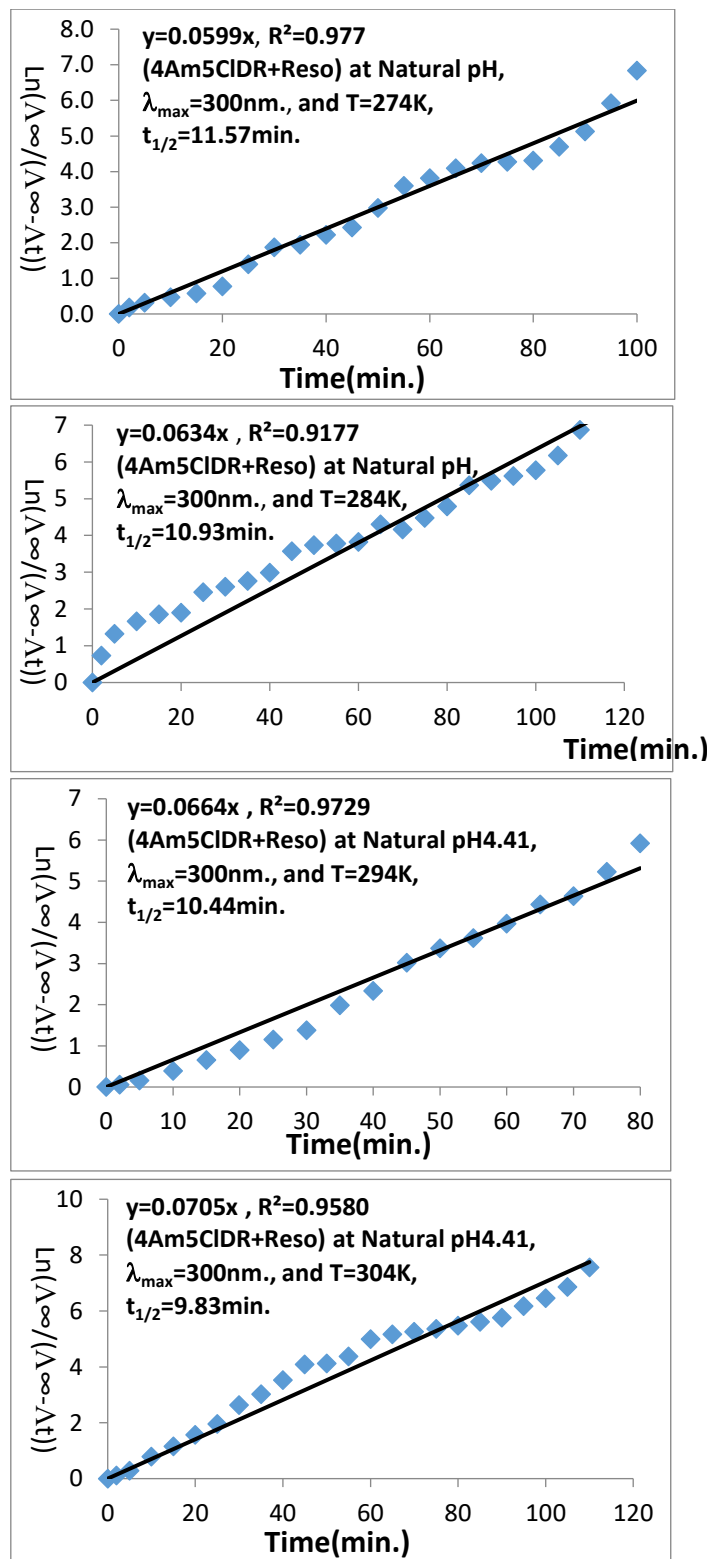
To determine the reaction order, the kinetic of the formation of the aforementioned dye (4Am5C1DR+Reso) were monitored spectrophotometrically under optimal conditions. The kinetic spectrophotometric data were fitted to a pseudo first order kinetic model with respect to resorcinol; this was achieved by tracking the formation of the light orange dye through the monitoring of its absorbance over a period of 120 minutes. Subsequently, the rate constant ( $k_1$ ) and the half-life ( $t_{1/2}$ ) for the dye formation reaction were calculated at a temperature of 294K and a pH 4.41. Initially, the solutions listed in Table (2) above were prepared at 294K, and the absorbance of the formation dye was monitored kinetically under optimal formation conditions (0.5 mL of  $10^{-3}$  M Resorcinol + 0.6mL of  $10^{-3}$  M Diazotized reagent). Measurements were taken at the optimal wavelength, continued until the reaction concluded or the maximum absorbance ( $\Lambda_{\infty}$ ) was reached with the reaction completion time ( $t_{\infty}$ ) determined as shown in Table (4). After attempts to apply second order equation using both equal and unequal concentrations proved unsuccessful, kinetic equations for pseudo first reactions were applied. In this study the integral method was employed to track the kinetics of the resulting dye formation reaction, and the following pseudo first order equation was applied to every obtained kinetic data:

$$\ln[\Lambda_{\infty}/(\Lambda_{\infty}-\Lambda_t)] = k_1 \cdot t \text{ -----(5)}$$

By plotting the graph between ( $\ln[\Lambda_{\infty}/(\Lambda_{\infty}-\Lambda_t)]$ ) versus time  $t$  (min), the results were good high correlation coefficient ( $R^2$ ) values ranging from (0.9177 - 0.9770) with good straight lines at all temperatures for the dye under study were obtained, and with a slope equal to the rate constants ( $k_1$ ) for their reactions, as in Figure (1). The research indicates the reaction of dye formation; the resulting orange is of the first order-pseudo reaction for resorcinol. The half-life ( $t_{1/2}$ ) represents the time required for half of the reactants to be consumed, which was calculated from the following equation:

$$t_{1/2} = \ln(2.0)/k_1 \text{ -----(6)}$$

These results are consistent with similar studies reported in the literature [14, 15]. To determine the reaction activation energy, the adsorption kinetics of the dye under study were monitored over time at five temperatures (274, 284, 294, and 304 K) using optimal conditions, the wavelength of maximum absorbance ( $\lambda_{\max}$ ), and the natural pH 4.41 (see Tables 3 and 4).



**Fig 1:** Absorption kinetics of the resulting orange azo dye (4Am5C1DR+Reso) versus time (in minutes) at different temperatures, at an acidic pH (pH 4.41), and at the optimal wavelength. ( $\lambda_{max}=300nm.$ ).

Figure 1 shown displays a clear relationship between the absorbance of the orange Azo dye (4Am5C1DR+Reso) and time when subjected to optimal conditions, natural pH levels, and different temperatures. It is worth noting that there is a sudden rise in absorbance following specific time intervals at different temperatures. Following these points, the absorption plateaus once the dye formation reaction is finished. These alterations do not affect the dye's  $\lambda_{max}$  values,

confirming that the reaction is complete. This is also backed up by the varying half-life durations seen in the dye-creation processes at various temperatures. The study utilized the integration method to monitor the kinetics of the formation reactions of the colored dye. By utilizing the pseudo first-order equation (5) on the kinematic data collected, we could investigate the reaction kinetics.

Plotting a diagram of  $\ln[A_{\infty}/(A_{\infty}-A_t)]$  versus time (in minutes) yielded straight lines at all four temperatures with ( $R^2$ ) values ranging from (0.9177 to 0.9770). The slope of these lines corresponds to the rate constants ( $k_1$ ) for the formation reactions of azo dye, indicating that the formation reaction of dye follows a pseudo-first-order mechanism as per the resorcinol. Through used values, determined the rate constant of the dye produced at temperatures of (274, 284, 294, and 304K). This allowed us to calculate the corresponding half-life-times ( $t_{1/2}$ ) using the equation (6).

( $t_{1/2}$ =9.83minutes at 304K), ( $t_{1/2}$ =10.44minutes at 294K), ( $t_{1/2}$ =10.93minutes at 284K), ( $t_{1/2}$ =11.57minutes at 274K). These results were identical to previous studies on the kinetics of the reaction of the formation of colored Azo Schiff complexes [15-20].

**Table 3:** Absorption of the resulting orange azo dye (4Am5ClDR+Reso) versus time (in minutes) at different temperatures, pH 4.41, and optimal wavelength ( $\lambda_{\max}$ =300nm).

| Time (min) |       | Temperature |       |       |          |                               |          |          |      |                                    |      |      |  |
|------------|-------|-------------|-------|-------|----------|-------------------------------|----------|----------|------|------------------------------------|------|------|--|
|            |       | Absorbance  |       |       |          | $A_{\infty}/(A_{\infty}-A_t)$ |          |          |      | $\ln(A_{\infty}/(A_{\infty}-A_t))$ |      |      |  |
|            | 274   | 284         | 294   | 304   | 274      | 284                           | 294      | 304      | 274  | 284                                | 294  | 304  |  |
| 0          | 0.000 | 0.000       | 0.000 | 0.000 | 1.0      | 1.0                           | 1.0      | 1.0      | 0.00 | 0.00                               | 0.00 | 0.00 |  |
| 2          | 0.314 | 0.999       | 0.102 | 0.199 | 1.2      | 2.1                           | 1.1      | 1.1      | 0.18 | 0.73                               | 0.06 | 0.11 |  |
| 5          | 0.505 | 1.411       | 0.278 | 0.463 | 1.4      | 3.8                           | 1.2      | 1.3      | 0.32 | 1.33                               | 0.16 | 0.28 |  |
| 10         | 0.699 | 1.555       | 0.600 | 1.044 | 1.6      | 5.2                           | 1.5      | 2.2      | 0.47 | 1.66                               | 0.39 | 0.79 |  |
| 15         | 0.823 | 1.621       | 0.891 | 1.311 | 1.8      | 6.4                           | 1.9      | 3.2      | 0.58 | 1.86                               | 0.65 | 1.16 |  |
| 20         | 1.007 | 1.633       | 1.098 | 1.512 | 2.2      | 6.7                           | 2.4      | 4.8      | 0.78 | 1.90                               | 0.89 | 1.56 |  |
| 25         | 1.405 | 1.756       | 1.272 | 1.641 | 4.0      | 11.6                          | 3.2      | 7.1      | 1.40 | 2.45                               | 1.16 | 1.95 |  |
| 30         | 1.581 | 1.778       | 1.388 | 1.774 | 6.5      | 13.4                          | 4.0      | 13.9     | 1.88 | 2.60                               | 1.38 | 2.63 |  |
| 35         | 1.600 | 1.799       | 1.602 | 1.819 | 7.0      | 15.7                          | 7.3      | 20.6     | 1.95 | 2.76                               | 1.99 | 3.02 |  |
| 40         | 1.665 | 1.824       | 1.677 | 1.856 | 9.3      | 19.8                          | 10.3     | 34.1     | 2.23 | 2.99                               | 2.33 | 3.53 |  |
| 45         | 1.702 | 1.867       | 1.766 | 1.880 | 11.4     | 35.6                          | 20.4     | 59.7     | 2.43 | 3.57                               | 3.02 | 4.09 |  |
| 50         | 1.771 | 1.875       | 1.793 | 1.881 | 19.6     | 41.8                          | 29.0     | 61.7     | 2.98 | 3.73                               | 3.37 | 4.12 |  |
| 55         | 1.815 | 1.877       | 1.807 | 1.888 | 36.6     | 43.7                          | 37.1     | 79.7     | 3.60 | 3.78                               | 3.61 | 4.38 |  |
| 60         | 1.825 | 1.879       | 1.822 | 1.899 | 45.5     | 45.7                          | 53.1     | 147.1    | 3.82 | 3.82                               | 3.97 | 4.99 |  |
| 65         | 1.835 | 1.895       | 1.835 | 1.901 | 60.2     | 73.9                          | 84.4     | 173.8    | 4.10 | 4.30                               | 4.44 | 5.16 |  |
| 70         | 1.839 | 1.891       | 1.839 | 1.902 | 69.1     | 64.0                          | 103.2    | 191.2    | 4.24 | 4.16                               | 4.64 | 5.25 |  |
| 75         | 1.840 | 1.899       | 1.847 | 1.903 | 71.8     | 87.3                          | 185.7    | 212.4    | 4.27 | 4.47                               | 5.22 | 5.36 |  |
| 80         | 1.841 | 1.905       | 1.852 | 1.904 | 74.6     | 120.1                         | 371.4    | 239.0    | 4.31 | 4.79                               | 5.92 | 5.48 |  |
| 85         | 1.849 | 1.912       | 1.857 | 1.905 | 109.8    | 213.4                         | $\infty$ | 273.1    | 4.70 | 5.36                               | -    | 5.61 |  |
| 90         | 1.855 | 1.913       | 1.851 | 1.906 | 169.6    | 240.1                         | 309.5    | 318.7    | 5.13 | 5.48                               | 5.73 | 5.76 |  |
| 95         | 1.861 | 1.914       | 1.411 | 1.908 | 373.2    | 274.4                         | 4.2      | 478.0    | 5.92 | 5.61                               | 1.43 | 6.17 |  |
| 100        | 1.864 | 1.915       | 1.386 | 1.909 | 933.0    | 320.2                         | 3.9      | 637.3    | 6.84 | 5.77                               | 1.37 | 6.46 |  |
| 105        | 1.866 | 1.917       | 1.312 | 1.910 | $\infty$ | 480.3                         | 3.4      | 956.0    | -    | 6.17                               | 1.23 | 6.86 |  |
| 110        | 1.711 | 1.919       | 1.292 | 1.911 | 12.0     | 960.5                         | 3.3      | 1912.0   | 2.49 | 6.87                               | 1.19 | 7.56 |  |
| 115        | 1.641 | 1.920       | 1.109 | 1.912 | 8.3      | 1921.0                        | 2.5      | $\infty$ | 2.12 | 7.56                               | 0.91 | -    |  |
| 120        | 1.514 | 1.921       | 1.023 | 1.899 | 5.3      | $\infty$                      | 2.2      | 147.1    | 1.67 | -                                  | 0.80 | 4.99 |  |
| 125        | 1.312 | 1.548       | 0.998 | 1.548 | 3.4      | 5.2                           | 2.2      | 5.3      | 1.21 | 1.64                               | 0.77 | 1.66 |  |
| 130        | 1.087 | 1.466       | 0.858 | 1.466 | 2.4      | 4.2                           | 1.9      | 4.3      | 0.87 | 1.44                               | 0.62 | 1.46 |  |

The highest absorbance ( $\Lambda_{\infty}$ ), formation expiration times ( $t_{\infty}$ ), formation rate constants ( $k_1$ ), and half-life times ( $t_{1/2}$ ) for the orange azo dye formation were obtained at the four temperatures from Table (3). It is also observed in Figure (1) that there is a variation in the rate constant at temperatures of (274, 284, 294, and 304K), resulting in a contrasting difference in their half-life times. As demonstrated in Table 4.

**Table 4:** Values of the maximum absorption ( $\Lambda_{\infty}$ ), average rate constants ( $k_1$ ), reaction completion times ( $t_{\infty}$ ), and half-lives ( $t_{1/2}$ ) for the resulting orange azo dye formation reaction (4Am5ClDR+Reso) at temperatures Different, and the normal acid function (pH4.41), and ( $\lambda_{\max}=300\text{nm}$ ).

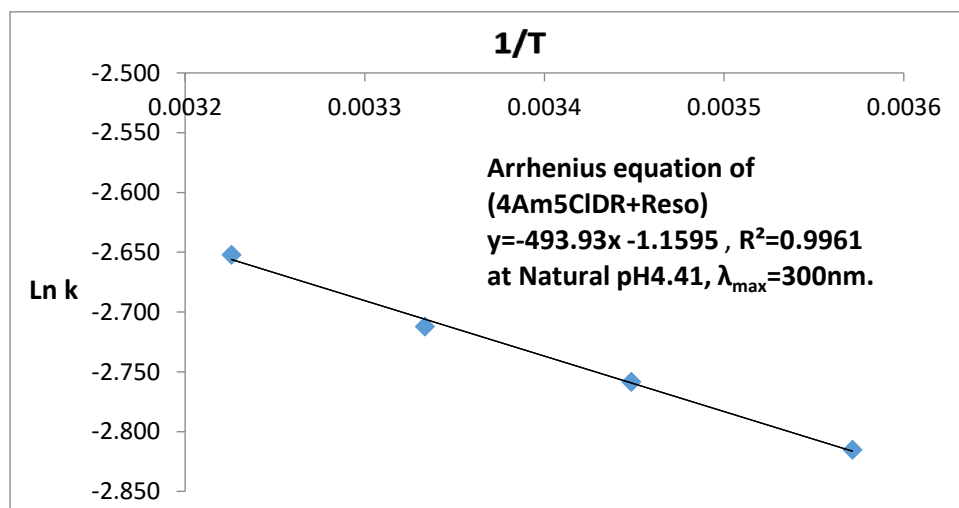
| Temp.(k) | $t_{\infty}$ (min.) | $\Lambda_{\infty}$ | $k_1$ (min. <sup>-1</sup> ) | ( $t_{1/2}$ ) (min.) |
|----------|---------------------|--------------------|-----------------------------|----------------------|
| 274      | 105                 | 1.866              | 0.0599                      | 11.57                |
| 284      | 120                 | 1.921              | 0.0634                      | 10.93                |
| 294      | 85                  | 1.857              | 0.0664                      | 10.44                |
| 304      | 115                 | 1.912              | 0.0705                      | 9.83                 |

Table (4) shows the following:

- 1- The rate constant of the dye formation rate under study is of pseudo-first order, where the highest value was at 304 K (0.0705 min<sup>-1</sup>) and the lowest value was at 274 K (0.0599 min<sup>-1</sup>). This consistent systematic difference was consistent with the kinetic studies of the various reactions found in references [15-20, 22].
- 2- The effect of temperature causes a direct change in the rate constant of the resulting compound formation rate ( $k_1$ ).
- 3- ( $k_1$ ) of the prepared dye is directly related to its half-life ( $t_{1/2}$ ) at the four temperatures.
- 4- The previous three paragraphs are consistent with the previous kinetic studies.

#### Activation energy and Application of the Arrhenius equation:

When the Arrhenius equation [22,23]., was applied a good straight line is obtained with a correlation coefficient ( $R^2$ ) value equal to (0.9961) and a slope equal to ( $-E_a/R$ ), from which the activation energy ( $E_a$ ) is calculated, as well as an intercept equal to  $\ln(A)$ . As in the following figure (2):



**Fig 2:** Application of the Arrhenius equation to the azo orange dye (4Am5ClDR+Reso) at pH4.41 and  $\lambda_{\max}=300\text{nm}$ .

Figure (2) shows that the values of the rate constants ( $k_1$ ) for the azo dye change according to the temperature of azo dye formation reaction, as the increase in temperature leads to an increase in the values of  $k_1$ , which indicates

that the formation reaction is subject to pseudo-first-order kinetics depending on the concentration of resorcinol. The change in the values of absorbance ( $\Delta$ ) due to the change in temperature also indicates the effect of temperature on the absorption of the formed product, which indicates the effect of temperature on the concentration of the product according to the Beer-Lambert law ( $\Delta = \epsilon_{\text{max}} \cdot b \cdot C$ ). This means a decrease in the half-life-time of the formation of the studied dye, and an increase in the speed of completion of the formation of the studied dye. Because the values of the half-life-time and the values of the rate constant are opposite. Finally, the low activation energy value ( $E_a = 4.107$  kJ) in kJ/ mole indicates the rate and spontaneity of the formation reaction without the need for catalysts, and this is considered an industrial economic feasibility.

#### 4. Conclusion:

- 1- The rate constant values ( $k_1$ ) for the formation of the dye change according to the temperature of its formation reaction, as the increase in temperature leads to an increase in the values of  $k_1$ , which indicates that the formation reaction is subject to pseudo-first-order kinetics according to the concentration of resorcinol, where the highest rate was observed at 304 K ( $0.0705 \text{ min}^{-1}$ ) and the lowest rate at 274 K ( $0.0599 \text{ min}^{-1}$ ).
- 2- The change in the values of absorbance ( $\Delta$ ) with the change in temperature indicates the effect of temperature on the absorption of the formed product, which indicates the effect of temperature on the concentration of the product according to the Beer-Lambert law.
- 3- The difference in the time for completing the formation reaction ( $t_{1/2}$ ) with the change in temperature indicates the effect of temperature on the ( $t_{1/2}$ ). This means a decrease in the half-life-time for the formation of the studied resulting dye, and an increase in the speed of completing the formation of the studied dye. Because the values of the half-life-time and the values of the rate-constant are opposite.
- 4- The low activation energy value ( $E_a = 4.107 \text{ KJ}$ ) indicates the speed and spontaneity of the formation reaction without the catalysts, and this is considered an industrial economic feasibility.
- 5- The four conclusions we mentioned are consistent with many previous studies on this type of studies on various other chemicals and drugs.

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