Study on the Formation of Glycine by Hydantoin and Its Kinetics
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ABSTRACT: The preparation of glycine by the hydantoin method is currently a relatively advanced process. The raw materials of this process are nontoxic, the operation process is simple and safe, the side reactions are few, and the yield of glycine is high. The core reaction of the hydantoin method is the hydrolysis of hydantoin. The hydrolysis is divided into two steps: first, hydantoin is hydrolyzed into hydantoin acid, and hydantoin acid is further hydrolyzed into glycine. At a temperature of 423.15 K, a molar ratio of sodium hydroxide to hydantoin of 1:3, and a total reaction time of 6 h, the conversion rate of hydantoin reached 100% and the yield of glycine reached 91%. At the same time, by calculating the hydrolysis kinetic parameters, the reaction was determined to be a first-order series reaction, and a kinetic model was established, which laid the foundation for the development of a green glycine process and a new reactor.

1. INTRODUCTION
The main process of producing glycine in China uses ammonia, ammonia, and chloroacetic acid as raw materials, uses tropine as a catalyst, and simultaneously adds a large amount of methanol or ethanol. Although this method effectively solves the problem that ammonium chloride is difficult to remove, it increases the cost, the reaction time is as long as 48 h, and the catalyst is difficult to recover, resulting in serious environmental pollution. Today, under the policy of environmental protection and high pressure, the chloroacetic acid method can no longer meet the policy requirements, and this process has been eliminated abroad.

The process of producing glycine abroad mainly uses formaldehyde, ammonia, hydrocyanic acid, and carbon dioxide as raw materials in a tubular reactor, but hydrocyanic acid is a highly toxic substance, and the process takes a long time, the post-treatment is complicated, the operation requirements are harsh, and it is also unable to meet domestic environmental requirements.

The most effective herbicide currently used in the world is glyphosate. There is no new herbicide to replace glyphosate. Most glycine is used as the main raw material for glyphosate production; thus, it is very important to ensure its production capacity. The total annual production capacity of glyphosate in China can reach 560,000 tons. The herbicide consumption of glycine is as high as 440,000 tons/year, and 20% is used in food, medicine, and other industries. However, under the conditions of environmental protection and high pressure, the operating rate of manufacturers has decreased year-by-year, and the supply of glycine is slightly insufficient. At the same time, glycine is used in medicine, food, and other fields. Therefore, it is urgent to explore a new production process of glycine.

This subject uses hydantoin, sodium hydroxide, and water as raw materials to hydrolyze hydantoin in a high-pressure reactor. Generally, hydantoin is produced by the reaction of hydroxyacetanilide, ammonium bicarbonate, and carbon dioxide at 85 °C for 4 h. Hydantoin undergoes two steps of hydrolysis to produce glycine. The raw materials are nontoxic, and the reaction proceeds in an aqueous solution. The experimental operation is convenient and safe. The first step of the hydrolysis has almost no byproducts, and the yield is stable and higher than that of the conventional process. Therefore, the hydantoin method is a relatively advanced method.

In this paper, the two-step hydrolysis process for the preparation of glycine by hydantoin was studied. The effects of the stirring rate, temperature, hydrolysis time, and alkali dosage on the reaction were discussed, and a hydrolysis kinetic model was established.

2. EXPERIMENTAL STEPS
2.1. Experimental Instruments and Reagents. 2.1.1. Instrument. Miniature reaction kettle (Beijing Century Senlang
Co., Ltd.), Agilent 1260 Infinity LC (Agilent Instruments), pH detector MP51 (Samsung Precision Instruments), circulating water vacuum pump SHZ-D(III) (Gongyi City Yuhua Instrument Factory), and ultrasonic cleaner KQ2200E (Kunshan Ultrasonic Instrument Co., Ltd.) were used.

2.1.2. Reagent. The water was obtained from "Milli-Q purification unit", and hydantoin (homemade), sodium hydroxide (AR) (Xiyu Science Co., Ltd.), ammonium dihydrogen phosphate (GR) (National Pharmaceutical Group Chemical Reagent Co., Ltd.), acetonitrile [high-performance liquid chromatography (HPLC)] (Zhongguo Group Chemical Reagent Co., Ltd.), methanol (HPLC) (Zhongguo Group Chemical Reagent Co., Ltd.), and phosphoric acid (AR) (Zhongguo Group Chemical Reagent Co., Ltd.) were used.

2.2. Experimental Procedure.

(1) The hydrolysis reactor used in this subject is a microreactor. Weigh 2.0 g of hydantoin and a certain molar ratio of sodium hydroxide, dissolve in 27 mL of pure water (the water was obtained from "Milli-Q purification unit"), and pass the prepared solution into the reaction kettle to rapidly heat up the hydrolysis. Hydrolyzate is detected by HPLC.11

(2) Specific steps for calculating kinetic parameters: input the experimentally measured concentration data into Excel cells, in A1–A7, enter the reactant concentrations measured at various times at a certain temperature, and in B1–B7 also input the measured values measured at various times at a certain temperature. For reactant concentration, enter the concentration data measured at all temperatures in this way. Enter the reaction time in F1–F7, set the variable cell N1, enter the initial value $n = 2$ and the concentration data at a certain temperature. Bring in, set the target cell K1, enter the correl function, set the constraints: $K_1 ≤ 1$, and click solve; you can find the best $n$ value, so that the target cell value is closest to 1, in which $n$ is the reaction order.12

2.3. Detection Conditions of HPLC. The detection conditions are as follows: HPLC for Agilent 1260, using Hedera-C18 column, room temperature, detection wavelength is 205 nm, mobile phase: 1:9:0.5 (v/v/v) (acetonitrile, phosphate buffer solution, triethylamine), phosphate buffer salt is formulated with ammonium dihydrogen phosphate and water in a certain ratio. pH 3.0, flow rate: 1.2 mL/min, injection volume: 20 μL.13 Preparation of the test solution: take 1 mL of the reaction solution and prepare a 25 mL sample to be tested with a mobile phase.

2.4. Hydrolysis Equation. Hydantoin is usually hydrolyzed in weak alkaline environment, and substituted hydantoin at C-5 position can generate corresponding amino acids. Figure 1 shows that hydantoin is hydrolyzed to hydantoin acid in sodium hydroxide solution. Weigh 2 g of hydantoin and a certain molar ratio of sodium hydroxide. At normal temperature, first dissolve the sodium hydroxide in water to form a sodium hydroxide solution, and then pour the hydantoin into the sodium hydroxide solution to dissolve and configure the reaction solution. The reaction liquid is passed into the reaction kettle, and hydrolysis is performed at a certain temperature. The initial pressure is not set, and the pressure is self-boosting. Generally, within the first hour, hydantoin is completely hydrolyzed.

Figure 2 shows that all of the hydantoin in the reactor are converted to hydantoin acid, and hydantoin acid starts to convert to glycine, and the pressure of the reactor rises; therefore, the reaction conditions do not need to be changed at this time.

3. RESULTS AND DISCUSSION

3.1. Effect of Stirring Rate on Hydrolyzation of Hydantoin. 3.1.1. Experimental Conditions. The molar ratio of hydantoin to sodium hydroxide is 1:2. The hydrolysis temperature is 383.15 K, the hydrolysis time is 30 min, and the stirring rate is 100–600 rpm. It can be seen from Figure 3 that when the stirring rate is between 100 and 300 rpm, the conversion of hydantoin is obvious, and when the stirring rate is between 300 and 400 rpm, the increase is gentle, and after 400 rpm, the conversion rate of hydantoin is no longer increased. This is because during the reaction, proper agitation can make hydantoin dissolve more fully in the sodium hydroxide solution, and at the same time, make the entire reaction solution heated evenly, improving the mass and heat transfer efficiency. When the rotation speed exceeds 400 r/min, the effect of heat and mass transfer is the best, even if the speed is increased, the effect will not be improved. The hydrolysis reaction is carried out in an aqueous solution, the phase of the reactants is unchanged, and the hydantoin is completely dissolved in the alkaline solution; therefore, the
hydrolysis reaction is considered to be a homogeneous reaction, and the entire reaction system is controlled by kinetics. Therefore, the hydantoin hydrolysis experiment selected a stirring rate of 400 rpm.

3.2. Effect of Hydrolysis Temperature and Hydrolysis Duration on the Hydrolysis Process of Hydantoin.

3.2.1. Experimental Condition. The mole ratio of hydantoin and sodium hydroxide is 1:2, the hydrolysis temperature is 373.15−443.15 K, and the hydrolysis time is 7 h. Samples are taken every 5 min in the first hour, and every other hour in the second to sixth hours. Figure 4 shows that when the hydrolysis time reaches 30 min, the conversion rate of hydantoin is almost 100%. Figure 5 shows that the yield of glycine reaches the highest at 6 h at each temperature, and when the temperature is 423.15 K, the glycine yield is higher than other temperatures. However, after the seventh hour, the yield of glycine decreases. This is because under high temperature and high pressure, glycine will polymerize to form glycine polymers such as diglycine, trihepatic peptide, and so forth. At the same time, the long-term reaction is partially unreacted. The side reaction of finished hydantoin acid and its derivatives will inhibit the formation of glycine to a certain extent. Therefore, it is more suitable to choose the temperature of 423.15 K and the hydrolysis time of 6 h.

3.3. Effect of Molar Ratio of Hydantoin to Sodium Hydroxide on the Hydrolysis Process of Hydantoin.

The hydrolysis was carried out at 423.15 K, the hydrolysis time was 6 h, and the molar ratio of hydantoin to sodium hydroxide was 1:1, 1:2, 1:3, 1:4, and 1:5. Figure 6 shows that hydantoin is completely hydrolyzed only when the molar ratio is 1:1, and the hydantoin is completely hydrolyzed when the amount of alkali is increased. Figure 7 shows that when the molar ratio is 1:3, the yield of glycine is much higher than that of the other four groups, and when the alkali dosage is more than 1:3, the yield of glycine is significantly reduced. This is due to the fact that glycine is an amino acid and contains amino and carboxyl groups. The reaction with acid is the reaction between the amino group and acid. The reaction with alkali is the reaction between the carboxyl group and alkali. Both are acid−base neutralization reactions to produce salt. The presence of excess sodium hydroxide will form sodium glycine with glycine, which reduces the yield of glycine. At the same time, hydantoin acid and hydantoin acid can be hydrolyzed in a weakly alkaline environment. Too high an alkaline solution will cause new side reactions, and these intermediates will play a competitive role in the formation of glycine. The byproducts produced during the degradation process at high temperatures are indeed detected by HPLC. Therefore, the molar ratio of hydantoin to sodium hydroxide is 1:3, which is a suitable condition.

3.4. Determination of Hydrolysis Condition. Based on the above experimental results, it is determined that the stirring rate is 400 rpm, reaction temperature is 423.15 K, hydrolysis time is 6 h, and molar ratio of sodium hydroxide to hydantoin is 3:1, which is a suitable condition.

3.5. HPLC Test Results. Test results of standard: Chromatogram of glycine, hydantoin acid, and hydantoin (Figures 8, 9, and 10) standards: Detection results of hydantoin hydrolysate:
Figure 11 shows the situation within the first hour of the hydrolysis of hydantoin. This stage is mainly due to the hydrolysis of hydantoin to generate hydantoic acid. Figure 12 shows the situation within 2–6 h of the hydrolysis of hydantoin. This stage is mainly due to the hydrolysis of hydantoin to glycine. As shown in Figure 11, within the first hour, the hydantoin has been completely hydrolyzed, while a little glycine is produced, and the next five hours are the hydrolysis of hydantoin. As the temperature increases, hydantoin decreases and glycine is formed. Impurity 1 and impurity 2 are formed during the reaction, and impurity 2 appears in 353.15–383.15 K. This may be because the hydantoin derivative cannot be hydrolyzed when the temperature is not high, and impurity 2 is completely degraded as the temperature increases, and it is found that impurity 1 is always present in it. The content of hydrolysate is low at 353.15–443.15 K, and there is no decomposition in this temperature range, which may be caused by the temperature that is not high enough, but considering that too high temperature will aggravate the polymerization of glycine, in order to suppress impurities. In the future, it may be necessary to control the reaction time and consider using other types of bases.

Table 1 shows that the peak times of the three standards are 6.813, 6.550, and 10.169 min, respectively. The average peak

| standard       | peak time/min |
|----------------|---------------|
| hydantoin      | 6.813         |
| hydantoin acid | 6.550         |
| glycine        | 10.169        |

Table 2. Chromatographic Peak Time Table of Hydantoin Hydrolysate at Various Temperatures

| hydantoin hydrolyzate temperature/°C | hydantoin peak time/min | hydantoin acid peak time/min | glycine peak time/min |
|--------------------------------------|-------------------------|----------------------------|----------------------|
| 80                                   | 6.811                   | 6.536                      | 10.119               |
| 90                                   | 6.827                   | 6.538                      | 10.103               |
| 100                                  | 6.803                   | 6.532                      | 10.381               |
| 110                                  | 6.798                   | 6.534                      | 10.350               |
| 120                                  | 6.796                   | 6.528                      | 10.257               |
| 130                                  | 6.785                   | 6.523                      | 10.194               |
| 140                                  | 6.897                   | 6.602                      | 9.576                |
| 150                                  | 6.868                   | 6.598                      | 9.527                |
| 160                                  | 6.888                   | 6.595                      | 9.756                |
| 170                                  | 6.878                   | 6.596                      | 9.767                |
| mean                                 | 6.835                   | 6.558                      | 10.003               |

ACS Omega 2020, 5, 13463–13472
times of the three standards in Table 2 are 6.835, 6.558, and 10.003 min, which are basically consistent with the peak time of the standard product. Therefore, the external standard method can be used to calculate the content of each substance in the hydrolyzate. Table 2 shows that with the increase of temperature, the peak time of hydantoin and hydantoin acid is delayed, while the peak time of glycine is advanced, which may be related to the content of three substances. With the increase of temperature, the content of glycine in hydrolysate increases, and its elution ability increases, while the decrease of hydantoin and hydantoin acid makes the elution ability decrease.

3.6. Establishment of Dynamic Model. 3.6.1. Rate Equation. In alkaline condition, hydantoin is formed by ring opening, while hydantoin can be hydrolyzed to glycine. Therefore, the reaction is considered as a series reaction.

\[ A \xrightarrow{P} B \xrightarrow{P} D \]

A—hydantoin, B—hydantoin acid, D—glycine, P—sodium hydroxide, \( k_1 \)—hydantoin hydrolysis rate constant, \( k_2 \)—hydantoin acid hydrolysis rate constant, \( c_A \)—hydantoin concentration, \( c_B \)—hydantoin acid concentration, \( c_D \)—glycine concentration, and \( c_P \)—sodium hydroxide concentration. The kinetic model is established

\[
-\frac{dc_A}{dt} = k_1 c_P c_A^\alpha \\
\frac{dc_B}{dt} = k_1 c_P c_A^\alpha - k_2 c_B^\beta \\
\frac{dc_D}{dt} = k_2 c_B^\beta \\
\]

Because the type and concentration of the base are stable, \( k_1 c_P \) can be considered as a constant, denoted as \( k_3 \), and the above formula is

\[
-\frac{dc_A}{dt} = k_3 c_A^\alpha \\
\frac{dc_B}{dt} = k_3 c_A^\alpha - k_2 c_B^\beta \\
\frac{dc_D}{dt} = k_2 c_B^\beta \\
\]

3.6.2. Determination of Reaction Order and Rate Constant. The method of determining the reaction order usually has the differential method, integral method, and half-life method. However, only by these methods, the engineering quantity error is very large, and the reaction order of this experiment is solved by Excel macroplanning. For the first-order reaction, \( \ln c - t \) is linear, while for the non-first-order reaction, \( 1/c^{(n-1)} - t \) is linear. Enter the reaction time at different temperatures and the concentration of the corresponding time obtained in the experiment in Excel software. When \( n \) is equal to 1, solve the linear relationship of \( \ln c - t \); when \( n \) is not equal to 1, set different \( n \) (level) value, applying the correl function to find the maximum \( r^2 \) value of \( 1/c^{(n-1)} - t \) at different temperatures.

Table 3 shows the actual concentration measured in each time period during the hydrolysis of hydantoin. These concentration data will be brought into the calculation step in Section 2.2.
Table 4 shows the actual concentration measured in each time period during the hydrolysis of hydantoin acid. These concentration data will be brought into the calculation step in Section 2.2.

Table 5 shows the calculation results of the first step of the hydrolysis of hydantoin, \( n = 2 \) is the preset number during the calculation of the series, and \( 1/c(n - 1) \) is the calculation result after bringing the preset number. According to the calculation method in Section 2.2, when the initial value is 2, the calculated five \( 1/c(n - 1) \) values at each temperature are shown in the table. When Excel starts to solve, the system will automatically introduce different preset values \( n \) in addition to 2, so that \( r^2 \) is close to 1, then \( n \) value is the required sequence. According to Table 5, the average reaction order of the first step of the hydrolysis of hydantoin is 1.03.

Table 6 shows the calculation results of the second stage of the hydrolysis of hydantoin. According to Table 6, the average reaction order of the first step of the hydrolysis of hydantoin is 1.05.

The average series calculation results in Tables 5 and 6 are 1.029 and 1.048, respectively. This indicates that the two-step hydrolysis reaction of hydantoin is a first-order reaction, and the total reaction is a first-order series reaction.

3.6.3. Rate Constant of Hydantoin Hydrolysis. Figures 13 and 14 show the linearity of \( \ln c \) and \( t \). It can be seen from the figure that the five groups of data are in a linear relationship, and the relationship expression is \( \ln c = -kt + b \). According to Table 7, the rate constant increases with the rise of temperature, and the rate constant in the first step of the hydantoin hydrolysis is larger than that in the second step; thus, the hydrolysis reaction in the second step is considered as the rate control step of the whole hydantoin hydrolysis process. Compared with most serial reactions, the difference of this subject is that the target product is not an intermediate, that is, the target product is glycine rather than hydantoin acid. Therefore, in addition to improving the first step reaction rate and conversion rate of hydrolysis, it is necessary to improve the second step rate and conversion rate, so as to improve the yield of glycine.

\( R^2 \)-squared is the ratio of the sum of squared regressions to the sum of squared deviations. SSR is the sum of squared residuals. It represents the effect of random errors. The smaller the sum of squared residuals of a set of data, the better the fit is. Sum squared residual calculation formula

\[
SSR = \sum_{i=1}^{n} (Y_i - \hat{Y})^2
\]  

\( \hat{Y} \) is the fitted value of \( Y_i \).

The fitting results from Tables 8 and 9 show that the values of the five groups of SSR are all close to 0, and both the \( R^2 \) value and the corrected \( R^2 \) value are close to 1, indicating that the fitting result is good.

3.6.4. Model Significance Analysis. In order to verify the applicability of the kinetic model, the \( t \)-sample test and \( F \)-sample test were performed using Origin software to test the regression coefficient and overall significance of the model. The \( t \)-sample test uses the \( t \)-distribution theory to infer the probability of the occurrence of the difference. The \( F \)-test is a test under the null hypothesis \( (H_0) \), and the statistical values follow the \( F \)-distribution to compare the difference between the two averages significantly. In the analysis results of Origin, if the probability of \( P > |t| \) and the probability of \( P > |F| \) are less
than 0.05, there is a statistical difference, if they are less than 0.01, there is a significant statistical difference, and if they are less than... than 0.05, there is a statistical difference, if they are less than 0.01, there is a significant statistical difference, and if they are less than, there is an extremely significant statistical difference.

The analysis results in Table 10 are the analysis of the results of the rate constant $k_1$ curve fitting at different temperatures. SEM is the standard error. Generally speaking, the value of SEM represents the representativeness of the batch of samples to the overall sample. The smaller the standard error, the stronger the strap is. According to Table 10, we can see that when $n = 2$, the value of $1/c(\ln n)$ is close to 0, and the standard errors of only 433.15 and 443.15 K are slightly higher, which shows that the samples used in $k_1$ fitting are more representative. At the same time, under each temperature model of the result of the $t$-test sample, the value of $|t| > |F|$ in the analysis is less than 0.05, and the variance of $P > |F|$ in the analysis is less than 0.05, indicating that the model is good. The results show that within this temperature range, the $k_1$ fitting results are credible.

The analysis results in Table 11 are the analysis of the results of the rate constant $k_2$ curve fitting at different temperatures. It can be seen from Table 11 that the standard errors in the temperature range of 373.15–443.15 K are close to 1, which shows that the samples used in $k_2$ fitting are highly representative. At the same time, under each temperature model of the result of the $t$-test sample, the value of $|t| > |F|$ in the analysis is less than 0.05, and the variance of $P > |F|$ in the analysis is less than 0.05, there is a significant statistical difference, and if they are less than, there is an extremely significant statistical difference.

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than 0.05, indicating that the model is good. The results show that in this temperature range, the fitting result is credible.

3.6.5. Activation Energy Calculation. According to the Arrhenius equation,

\[ k = A \exp\left(-\frac{E_a}{RT}\right) \]  

(8)

\[ \ln k = \ln A - \frac{E_a}{RT} \]  

(9)

which is plotted as \( \ln k - T^{-1} \).

According to the fitting results in Figures 15 and 16, in the first step of hydantoin hydrolysis, \( \ln k_1 \) and \( T^{-1} \) show a linear relationship in the temperature range of 373.15–403.15 and 413.15–443.15 °K, while in the second step of hydantoin hydrolysis, \( \ln k_2 \) and \( T^{-1} \) show a linear relationship in the temperature range of 373.15–413.15 and 423.15–443.15 °K, respectively, and \( R^2 \) is close to 1; thus the fitting results are good. The obtained slopes are \( \gamma_1 = -327 \), \( \gamma_2 = -105 \), \( \gamma_3 = -8550 \), and \( \gamma_4 = -9652 \), and the four direct slopes are substituted into the Arrhenius derivation formula to obtain the reaction activation energy.

![Figure 15. Relationship between \( \ln k_1 \) and \( T^{-1} \).](https://dx.doi.org/10.1021/acsomega.9b03868)
Figure 16. Relationship between ln k and T⁻¹.

\[ \ln k = \ln A - \frac{E_i}{RT} \]  \hspace{1cm} (10)

\[ E_i/R = \gamma \]  \hspace{1cm} (11)

\[ E_{i1} = R \times \gamma_1 = 2.718 \times 103 \text{ J} \cdot \text{mol}^{-1} \]  \hspace{1cm} (12)

\[ E_{i2} = R \times \gamma_2 = 0.873 \times 103 \text{ J} \cdot \text{mol}^{-1} \]  \hspace{1cm} (13)

\[ E_{i3} = R \times \gamma_3 = 7.108 \times 104 \text{ J} \cdot \text{mol}^{-1} \]  \hspace{1cm} (14)

\[ E_{i4} = R \times \gamma_4 = 8.025 \times 104 \text{ J} \cdot \text{mol}^{-1} \]  \hspace{1cm} (15)

\[ A_1 = 1.2 \times 10^3 \text{ s}^{-1} \]  \hspace{1cm} (16)

\[ A_2 = 2.5 \times 10^3 \text{ s}^{-1} \]  \hspace{1cm} (17)

\[ A_3 = 6.0 \times 10^4 \text{ s}^{-1} \]  \hspace{1cm} (18)

\[ A_4 = 4.4 \times 10^5 \text{ s}^{-1} \]  \hspace{1cm} (19)

According to the calculated activation energy, it is found that the activation energy of each step of the reaction of hydantoin changes, and the boundary temperature is 413.15 K, which indicates that for the reaction of hydantoin hydrolysis, a stepwise hydrolysis method can be adopted. In the first step of hydrolysis, the activation energy is in the temperature range of 373.15–403.15 K. C is 3.1 times the interval of 413.15–443.15 K, and the rate constant increases with increasing temperature, taking into account the range of 413.15–443.15 K. The rate constant does not increase much; therefore, we choose 413.15 K as the first hydrolysis temperature of hydantoin. Because the hydantoin is completely hydrolyzed within 1 h, it is preliminarily determined that the first hydrolysis period is 1 h. In the second step of the hydrolysis of hydantoin, the activation energy in the temperature range of 423.15–443.15 K is only 1.1 times the temperature range of 373.15–413.15 K, but the rate constant is much larger than the temperature range of 373.15–413.15 K, taking into account the target product of this series of reactions is glycine rather than hydantoin, so the reaction rate for increasing the second step reaction is the main target. 443.15 K was selected as the temperature of the second stage of hydantoin hydrolysis, and the glycine yield reached the highest at the 6th hour; therefore, the second hydrolysis period was initially determined to be 5 h.

4. CONCLUSIONS

Through experimental research, the optimal reaction conditions were determined as follows: stirring rate 400 rpm, temperature 423.15 K, molar ratio of hydantoin sodium hydroxide 1:3, and reaction time of 6 h, so that the hydantoin conversion rate reached 100%. The yield of glycine reached 91%. At the same time, the kinetic parameters of hydantoin hydrolysis were calculated, proving that the total reaction of hydantoin hydrolysis was a first-order series reaction, and the rate constants of the two-step hydrolysis at 423.15 K were 5.22 \( \times 10^{-3} \) and 2.0 \( \times 10^{-4} \), respectively, and the kinetic model of hydrolysis was established, and the significance and reliability of the kinetic model of hydrolysis of Hein were verified by the origin statistical function. The kinetic model was regarded as a reliable model.

The calculation of the rate constant and the activation energy of the hydrolysis reaction provides a new way for the hydrolysis of hydantoin. The original single constant temperature hydrolysis method is changed to the segmented constant temperature hydrolysis. The segmented temperature is 413.15 and 443.15 K, respectively, and the segmented hydrolysis time is 1 and 5 h, respectively. This is the innovation of this topic. At present, most of the intermediate products of the series reaction are the final products needed; thus, most of the means are to delay its degradation. The target product of hydantoin hydrolysis is glycine rather than intermediate; therefore, accelerating the degradation of intermediate hydantoin acid is also the focus of the study. The research of this subject is to increase the rate of the two-step reaction, provide basic data for the design and development of a new glycine reactor, and lay a foundation for the industrialization of glycine production by the hydantoin method.

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Complete contact information is available at: https://pubs.acs.org/10.1021/acsomega.9b03868

https://dx.doi.org/10.1021/acsomega.9b03868

ACS Omega 2020, 5, 13461–13472
Notes
The authors declare no competing financial interest.

ACKNOWLEDGMENTS
The research comes from the key coal-based scientific and technological research project of Shanxi Province, “Technological Development of Using Synthetic Ammonia Gas or Coke Oven Gas to Produce Glycine”, number MH2014-09. The author thanks Shanxi Yangquan Coal Industry Group and Nanjing University of Technology for their financial and technical support for this research institute, as well as their free laboratories. At the same time, thanks to Professor R.Y. for the experimental guidance and data support.

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