

Analysis of prospective chemistry teachers' understanding about rate of reaction concept

A C Wardah¹, A Wiyarsi¹ and A K Prodjosantoso¹

¹Chemistry Education, Universitas Negeri Yogyakarta, Sleman, Indonesia

Corresponding author: annisachiyarotul.2018@student.uny.ac.id

Abstract. This research was carried out to reveal prospective chemistry teachers' understanding in rate of reaction concept. A survey with a quantitative approach study was conducted toward 61 of prospective chemistry teachers who were taking a basic chemistry course. Data were obtained using a true and false test which containing 30 questions related to the rate of reaction topic. They were categorized into five concepts covering rate of reaction basic concept, rate of reaction law, collision theory, factors that affect the rate of reaction, and reaction mechanism concept are 3, 4, 3, 14, and 6 questions respectively. The results proved that most of them had a low understanding in the rate of reaction concept, especially on the first concept but in the concept of collision theory they had a relatively high understanding. The efforts are needed by them as prospective chemistry teachers to increase their understanding of the rate of reaction concept. However, this research did not explore their description in explaining about the concept. Therefore, there is a need for further research to discuss the mental models of prospective chemistry teachers in the rate of reaction concept understanding.

Keywords: *chemistry understanding, prospective chemistry teachers, rate of reaction*

1. Introduction

Chemistry phenomena cannot be accessed only through sensory [1]. Likewise, [2] stated that understanding abstract and complex chemistry phenomena cannot be achieved without using various chemical representations. Similar research results were also conducted by [3] who stated that learning chemistry requires a lot of intellectual thought and affirmation because chemical content was full of abstract concepts, so students and even teachers have difficulty in understanding chemical concepts. In an effort to overcome chemistry learning difficulties, they sometimes make their own interpretations of the concepts being studied. However, it was not uncommon for the results of these interpretations to deviate from the concept agreed upon by the experts. That was supported by previous researches about understanding the concept of the atom [4], [5], [6] and describing prospective chemistry teachers' understanding of phase changes and dissolution at macroscopic, symbolic, and microscopic levels [7].

The other results of the research by [8] show that students are not interested in learning chemistry and tend to use memorization methods without understanding concepts. Furthermore, [9] stressed that the concepts students accepted were rote because they did not integrate the three levels of chemical representation. Meanwhile in the theory revealed by [10] that chemistry problems can be better solved by students if students understand their basic chemical concepts first.



Understanding of three levels of chemical representation is often known as a mental model [11]. All three were interrelated and reflected the development of mental models [12]. The development of mental models at this time did not seem to be as expected, as in the research of [13] which revealed that only 14.1% of participants were able to build a scientific model on liquid vapor pressure material under various conditions. Another mental model research was also conducted by [14] which showed that 57.89% of students experienced misconceptions so that they were categorized as low mental models.

The development of students' mental models cannot be separated from the role of their teachers. As suggested by [15], teachers have to facilitate the development of students' mental models, while ensuring that students did not develop false mental models, so that students' understanding of chemical concepts can be improved. In addition, it was necessary to develop students' mental model through experiences, interpretations, and explanations to make predictions, tested new ideas, and solved problems in chemistry learning [16]. However, unfortunately there had not been a good collaboration between teachers and students, as research on mental models conducted by [17] stated that there was not a discussion between teachers and students regarding the use of mental models in chemical problem-solving.

The rate of reaction was one of the concepts that is possible to be represented in various levels [18, [19]. Units in the rate of reaction that cover many basic chemical concepts, including activation energy, collision theory, enthalpy, factors that affect the rate of reaction, and reaction mechanism [20]. However, in practice there were still many students who rely on alternative concepts in the rate of reaction learning [21]. As research of students' alternative concepts on the rate of reaction topic which conducted by [22] that resulted that some alternative concepts emerged because most of the students found it difficult to visualize chemistry phenomena and process at submicroscopic and symbolic of each other. The high school and university students had various misconceptions about the rate of reaction [23]. Misunderstanding of prospective chemistry teachers about the reaction mechanism and this misunderstanding was very likely to be passed on to students and even worse the misunderstanding was difficult to change [24]. This research aims to analyze the understanding of prospective chemistry teachers regarding the rate of reaction concept.

2. Research methods

2.1. The Research Design

As a whole, this research used a survey with a quantitative approach. This was carried out to analyze the prospective chemistry teachers' understanding of the rate of reaction concept using a true and false test. The prospective chemistry teachers' understanding was analyzed quantitatively using percentages. The subjects of this research were prospective chemistry teachers who were taking a basic chemistry course. The selection of research subject was done by purposive techniques sampling because they were prepared to be a facilitator in improving chemical concepts understanding in a learning process.

2.2. Data Collection

Data were collected using a true and false test. It was containing 30 questions related to rate of reaction topic. They were categorized into five concepts cover basic concept of rate of reaction definition (3 questions), rate of reaction law (4 questions), collision theory (3 questions), factors that affect the rate of reaction (14 questions), and reaction mechanism concepts (6 questions). The instrument consisted of four columns, the first column stated the number of questions, the second column contained questions, the third and fourth columns were true and false columns respectively. Respondents were asked to put a checkmark (✓) in the third column if they assumed that the question was true, and likewise when they thought the question was wrong so they gave a checkmark (✓) in the fourth column.

2.3. Data Analysis

The criteria for the test score was the respondents got a score of 1 when their answer was correct and got a score of 0 when wrong. The level of prospective chemistry teachers' understanding of the test was grouped into understanding and not understanding. The analysis was presented on each question, then each sub-concept and concept was analyzed again so that the analysis was obtained in the percentage form.

3. Results and discussion

Based on the analysis of prospective chemistry teachers' understanding in the rate of reaction concept, a percentage was obtained for each question, sub-concept, and concept. The 30 questions on the research instrument were categorized into five concepts and each concept had sub-concepts which were not the same amount. The distribution of concepts, sub-concepts, and each question in it can be seen in Table 1.

Table 1. The distribution of questions in each concept and sub-concept.

Concept	Sub-concept	Question's number
Rate of reaction basic concept	Term	1
	Symbol	2
	Definition	3
Rate of reaction law	Reaction order	4 and 5
	Reaction rate constant	6 and 7
Collision theory	Effective collision	13, 14, and 15
Factors that affect the rate of reaction	Concentration	18
	Temperature	16 and 17
	Surface area	20
	Catalyst	21, 27, 28, and 29
	Activation energy	22, 23, 24, 25, and 26
	Enthalpy	19
Reaction mechanism	Relationship between the rate of reduction of reactants with the time	8, 9, and 10
	Relationship between the rate of addition of products with the time	11 and 12
	Elementary stage	30

3.1. Rate of reaction basic concept

Table 2. Percentage of definition concept understanding.

Number	Question	Answer Choices		Percentage of correct answer
		True	False	
1	The term rate of reaction is the same as reaction velocity		√	32.79%
2	The rate of reaction symbol is stated in the letter "v" which means velocity		√	6.56%

3	The time is required to a reaction take place until finished	√	60.66%
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As seen in Table 1 and Table 2, the first concept containing of three sub-concepts, the first sub-concepts consisted one question (number 1) related to the consistent use of the rate of reaction term which resulted 32.79% of respondents who answered correctly that the term rate of reaction is not the same as the reaction speed. This is in accordance with the theory from [25] which stated that viewed in terms of physics, the course of the reaction from reactants into products, it can be said that the reaction has value and direction. The second review, seen from the definition “changes in molarity at any given time” did not show any direction of the reaction, because this definition showed changes in molarity can be seen from both reactants and products. If viewed from the reactants, the molarity will reduce while if viewed from the products, the molarity will increase. Based on these definitions, the more appropriate term to use is the rate of reaction. In the second sub-concept also consisted of one question (number 2) about the use of appropriate symbols for the rate of reaction is not “ v ” but “ r ” which means rate [26]. In this sub-concept only 6.56% of respondents managed to answer correctly. This showed that they were lacking in mastering the level of symbolic representation. This result was not in line with the previous study by [27] which stated that the dominant competency of representation owned by students was at the symbolic level rather than the macroscopic level, with a ratio of 8:1. In addition, another previous study by [28] also resulted that students more understand symbolic and mathematic representations than submicroscopic in the rate of reaction concept. Then, the last sub-concept on this concept asked about the rate of reaction definition (number 3) which most around 60.66% of respondents answered correctly. They assumed that the rate of reaction does not represent the time needed to carry out a reaction to completion. This is true because the rate of reaction is an increase in product concentration or a decrease in reactant concentration per unit time [29].

3.2. Rate of reaction law concept

Table 3. Percentage of the rate of reaction law concept understanding.

Number	Question	Answer Choices		Percentage of correct answer
		True	False	
4	The reaction order is the same as the reaction coefficient		√	59.02%
5	In reactions that have zero order, the reaction of rate is not affected by reactant concentration	√		78.69%
6	In reactions that have zero-order, the reaction of rate is not only affected by the rate constant (k)		√	63.93%
7	According to the Arrhenius equation, if the temperature increases so the rate constant also increases	√		85.25%

Based on Table 1 and Table 3, the second concept consisted of two sub-concept, each of which contained two questions. The first sub-concept asked whether the reaction order was the same as the reaction coefficient (number 4) and the results stated that 59.02% respondents answered both were not the same, and this was true that the reaction order cannot be known directly from the reaction equation, but must go through experiments [26]. The next question (number 5) was in reactions that have zero-order, the rate of reaction is not influenced by reactant concentration and 78.69% of respondents agree with this, because the change in reactant concentration does not affect the rate, this applies to reactions that have zero-order [26]. The second sub-concept asked whether, in a reaction that has zero-order (number 6), the rate of reaction is not only influenced by the rate constant (k). This is not quite right because the rate law consisted of a constant factor and reactant concentration raised by the order of reaction. So if the reaction order is zero, then what affects the reaction rate is only the rate constant. As many as 63.93% of respondents managed to answer this correctly. The next question was related to the Arrhenius equation, as the temperature increases the rate constants increase (number 7).

This is true because based on that equation, the reaction rate is directly proportional to temperature [26]. The question was answered correctly by 85.25% of respondents.

3.3. Collision theory concept

Table 4. Percentage of collision theory concept understanding.

Number	Question	Answer Choices		Percentage of correct answer
		True	False	
13	Effective collisions occur when the amount of kinetic energy is equal to or greater than the activation energy	√		72.13%
14	Effective collisions depend on the accuracy of the orientation of the collisions between reactant molecules	√		91.80%
15	Collisions with the right orientation only occur on similar atoms		√	67.21%

As presented in Table 1 and Table 4, the third concept consisted of only one sub-concept that was related to effective collision and there were three questions in it. The first question (number 13) asked whether effective collisions will occur if the amount of kinetic energy is equal to or greater than the activation energy and 72.13% of respondents answered correctly. The second question (number 14) about effective collision dependence on the accuracy of the orientation of collision between reactant molecules and 91.80% of respondents answered correctly. Both of these were supported by the statement of [29] that effective collisions will occur if they have energy kinetic with such conditions. In addition, effective collisions also depend on the accuracy of the orientation of the collisions between reactant molecules and the orientation does not only occur in similar atoms. This is agreed with 67.21% of respondents answered correctly related to the third question (number 15).

3.4. Factors that affect the rate of reaction concept

Table 5. Percentage of factors that affect the rate of reaction concept understanding.

Number	Question	Answer Choices		Percentage of correct answer
		True	False	
16	The higher the temperature, the greater the rate of reaction because effective collisions are faster		√	1.64%
17	The higher the temperature, the greater the rate of reaction because the chances of more effective collisions are due to the fast movement of reactant molecules	√		93.44%
18	The higher the concentration of reactant molecules, the more the number of chances of an effective collision, so that the reaction rate is greater	√		96.72%
20	A substance that has a large particle size has a large surface area		√	29.51%
21	The catalyst increases the rate of reaction by decreasing the activation energy		√	14.75%
27	The catalyst increases the start of the reaction process	√		55.74%
28	The catalyst reacts but it is produced again at the end of the reaction	√		37.70%
29	The catalyst reacts to form an intermediate but it is not produced again at the end of the reaction	√		59.02%
22	Activation energy shows the minimum amount of energy		√	6.56%

	released in reaction		
23	The greater the activation energy, the greater the kinetic energy	√	57.38%
24	Reactions that have a greater activation energy than the rate of reaction is greater	√	73.77%
25	The amount of activation energy can be changed	√	39.34%
26	The increases in temperature affect the reactant activation energy	√	40.98%
19	A reaction that has a greater enthalpy value has a greater rate	√	68.85%

As displayed in Table 1 and Table 5, the fourth concept had the most sub-concepts among the other concepts, namely as many as six sub-concepts. In the temperature sub-concept, there was an imbalance of results which showed that only 1.64% of respondents answered number 16 correctly, while others considered the higher the temperature, the greater the rate of reaction because effective collisions were faster, whereas what was fast was the movement of reactant molecules instead of effective collisions. It related to question number 17, respondents who answered correctly were 93.44%. On both questions there were oddities in the respondents' answer, this was because they thought that the fast effective collision was the same as the fast reactant molecular movement. In the concentration sub-concept (number 18), the majority of respondents namely 96.72% answered correctly about the concentration factor which was directly proportional to the rate of reaction. In addition, it turned out that the respondents did not fully understand the surface area sub-concept in question number 20, as many as 29.51% considered that if a substance had a large particle size then the surface area was also large even though this was the opposite.

Then, in the next sub-concept related to the catalyst listed in question number 21 where only 14.75% answered correctly by stating disagreement if the catalyst increased the rate of reaction by lowering the activation energy. This was consistent with the theory which revealed by Taber [30] that the catalyst increases the rate of reaction by choosing an alternative route to produce a product that has lower activation energy than the activation energy it should because the activation energy for the reaction is fixed or unchanged. In addition, other questions related to catalysts were stated in numbers 27, 28, and 29 in which all three states that the catalyst accelerates the start of the reaction process, the catalyst reacts but is regenerated at the end of the reaction, and the catalyst reacts to form intermediates but these substances are not reproduced at end of reaction. From the three questions, respondents who managed to answer correctly were 55.74%, 37.70%, and 59.02% respectively.

Then, questions 22, 23, 24, 25, and 26 tested the respondents' understanding regarding activation energy. There were 6.56% of respondents who considered activation energy as the minimum amount of energy released in a reaction even though the correct concept related to activation energy was the minimum amount of energy needed for chemical reactions to occur [29], so the greater the activation energy the greater its kinetic energy. This was in accordance with question number 24 where there were 73.77% of respondents who agreed concerning this question. Then, as stated by that activation energy is inversely proportional to kinetic energy so that the greater the activation energy, the greater the kinetic energy, question number 23 was wrong and there were 57.38% of respondents successfully answered. Then the statement Taber (2012) refuted question number 25 namely the amount of activation energy can be changed, and there were only 39.34% of respondents who agreed with the denial. The last question number 26 in the activation energy sub-concept was related to the increasing temperature affects the reactant activation energy, even though this was not the case. This question was answered correctly by 40.98% of respondents. In the last sub-concept in this concept, which was about enthalpy successfully answered correctly by 68.85% of respondents, question number 19 stated a reaction that had a greater enthalpy value, then the rate of reaction is greater even though the rate of reaction cannot be determined if only using the enthalpy data involved in the reaction. In accordance with the Arrhenius equation, the rate of reaction to depending on the value of the rate constant (k), it

also depends on the activation energy, collision frequency between reactant molecules, and temperature [29].

3.5. Reaction mechanism concept

Table 6. Percentage of reaction mechanism concept understanding.

Number	Question	Answer Choices		Percentage of correct answer
		True	False	
8	The rate of reactant concentration reduction at the beginning of the reaction is zero		✓	50.82%
9	The reactant reduction rate graph is shaped like a normal curve that shows the initial and final rates are zero and the middle is maximum		✓	57.38%
10	Increasingly, the rate of reaction to reduce the reactants increases		✓	52.46%
11	Increasingly, the rate of reaction to form products increases until it ends at the maximum point		✓	60.66%
12	Increasingly, the rate of reaction to form products increases but at the endpoint, the reaction is in a stable state	✓		59.02%
30	An overall reaction consists of the one elementary stage		✓	29.51%

As shown in Table 1 and Table 6, this last concept related to the reaction mechanism that asked the relationship between the rate of reactant reduction with time (questions 8, 9, 10) for which each respondents answered correctly 50.82%, 57.38%, and 52.46 % respectively. The mechanism reaction was described during the reaction process, the reactants were used continuously so that the concentration of reactants decreased. At the beginning of the reaction, the reactant concentration was in the maximum amount, so many collisions occur. Therefore, the rate of reactant reduction at the beginning of the reaction was at its maximum point. Over time, reactants were reduced so that reactant concentrations decreased and collisions occur less frequently so the rate of reactant reduction decreased [29].

Then the next question (numbers 11 and 12) related to the relationship of the rate of product additions with the time to which each question, respondents answered correctly were 60.66% and 59.02% respectively. At the beginning of the reaction, the product concentration was still zero, because the product had not formed at the beginning of the reaction. Over time, the number of products increased until the addition was stable. When the reactants run out of reaction, the product is no longer produced [26]. The last question number 30 confirmed that an overall reaction does not always consist of one elementary stage, but only 29.51% of respondents agreed with this question.

4. Conclusion

Based on the results and discussion, it can be concluded that in general the prospective chemistry teachers' understanding regarding the rate of reaction concept is not as expected, especially on the rate of reaction basic concept. This indicates that there is still a need for further development to explore their way of thinking in the rate of reaction concept representing or we often call it a mental model. Through the exploration of mental models will provide an alternative view for the chemistry teacher to overcome the problems experienced by students when learning the rate of reaction concept.

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