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Mental Models and Understanding Student of Grade XI High School in the Reaction Rate Material

Hutdia Putri Murni , Minda Azhar *, Alizar Ulianas

Chemistry Department, Faculty of Mathematics and Natural Sciences
Universitas Negeri Padang
Jl. Prof. Hamka, Air Tawar Barat, Padang, 25131, Indonesia

Abstract - Each individual uses mental models in an effort to solve a problem, so is the reaction rate in the learning process. The purpose of this study was to obtain an overview of mental models and understanding of high school students (SMA) on the material reaction rate. The method used is descriptive research method. Subjects consisted of 35 high school students in the city of Padang State academic year 2018/2019. Instrument used is a two-tier diagnostic test and semi-structured interview guides. The results showed that students' understanding at the submicroscopic level for the material reaction rate is low and the students have not been able to interconnect all three levels of representation as well. Categories students' mental models ranging from the intermediate 2, intermediate 3 and the target model.

Keywords - mental models, three levels representation, reaction rate, chemistry learning

I. INTRODUCTION

Chemistry is the study of the composition, properties and transformations of matter and how the composition of a material affects its properties (Jespersen, et al., 2012). The chemistry covers concepts that are real to abstract concepts. One of them is the material reaction rate. Chemical concept can be well understood if students master or able to interconnect three levels of representation. Three levels of representation include macroscopic level, submicroscopic and symbolic (Johnstone, 1993).

Three levels of this representation is well aligned and become a strong foundation in the formation of students' mental models. The linkage can be seen in Figure 1.

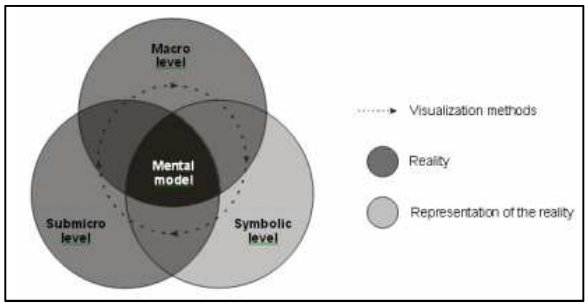


Figure 1. Three Level Representation Linkages with Mental Model (Source: Devetak, et al., 2009)

Mental model is a representation of an individual's personal mental against an idea or concept during the cognitive process takes place (Chittleborough and Treagust, 2007). Each individual uses mental models in an effort to solve a problem. Students' mental models can be established through interpretation, understanding and explanation of a phenomenon at the submicroscopic level. Mental models can produce a wide range of expression (Wang, 2007) according to one's understanding of construction. The expression packaged in various forms, such as verbal

Corresponding Author: Minda Azhar

descriptions, diagrams, simulations, or concrete models. The expression is used to communicate their ideas to others for solving problems as a form of mental activity.

Mental models are very important because it serves to support the establishment of a good understanding. If the students' understanding of both the students also have the critical thinking skills and higher level thinking is good (A. Hillen, Stefanie. 2013), Mental models can be identified through the interpretation of the expression of mental models, through speech, writing and pictures (Coll & Treagust, 2003). Mental models are classified into three categories based on the scores obtained by students in answering the test questions of mental models. These categories namely high mental models (if a student got a score ≥ 70), moderate mental models (if a student got a score of> 50 and <70), and lower mental models (if a student got a score ≤50) (Jaber and Boujaoude, 2012). Other researchers split the classification of mental models into three categories, namely low, medium and high (Wang, 2007). Furthermore, other classifications are presented in five categories, namely the initial model, intermediate 1, intermediate 2, intermediate 3 and the target (Park, et al., 2009).

This study aims to explore and evaluate the students' mental models in understanding the concepts in the material reaction rate. This study identifies how students describe the reaction rate in terms of three levels of representation.

II. METHOD

This research was conducted by using descriptive method. Samples were 35 high school students in the city of Padang country school year 2018/2019. Instrument used is a two-tier diagnostic test and semi-structured interview guides. Problem two-tier diagnostic test adopted from previous studies (Femintasari, 2015). Before use, the two-tier diagnostic instruments validated first. Two-tier diagnostic test consists of 18 items. These issues include three levels of diagnostic tests representation. Result then analyzed the mental models are grouped according to the classification of Park, et al. The semi-structured interviews were conducted for students aiming to obtain information and confirmation that support their answers on diagnostic two-tier test.

III. RESULTS AND DISCUSSION

Analysis of students' mental models in the material reaction rate describes how the image category of mental models of the students and explain the relationship with the three levels of chemical representation of categories of mental models of the students. Students' ability to connect or integrate all three levels will produce a complete mental model toward a concept so that the concept can be stored in long term memory.

Chemical material can be studied through three levels of representation, namely the level of macroscopic, submicroscopic and symbolic. The third level of interconnectedness and used to be used to understand a phenomenon that occurs. That is, the chemical representation is very important in chemistry learning (Chittleborough, 2004).

Level macroscopic were all obtained through real observations (tangible) against a phenomenon that can be seen (visible) and perceived by the five senses (sensory level), either directly or indirectly (Johnstone, 1993; Gilbert & Treagust, 2009; Taber, 2013). Submicroscopic level is described as a level that explains and explanation about the structures and processes at the level of particles (atoms / molecules) against the observed macroscopic phenomena (Gilbert and Treagust, 2009; Talanquer, Vicente, 2011). Level is the symbolic representation in the form of chemical symbols, chemical formulas, diagrams, chemical equations, stoichiometry and mathematical calculations (Gilbert and Treagust, 2009).

Based result two-tier diagnostic tests conducted on 35 students of class XI MIPA 6 high schools in the city of Padang, the findings obtained in the form of students' mental models categories that have been classified based on test scores. Grouping these values is then made in the form of a percentage in order to facilitate interpreting them. Problems diagnostic test has been adapted to the basic competencies (KD) of material which includes a reaction rate: the concept of reaction rate, collision theory and activation energy, the factors that influence the reaction rate and reaction order. Percentage category mental model reaction rates are summarized in Table 1.

Table 1. Percentage Category Mental Model

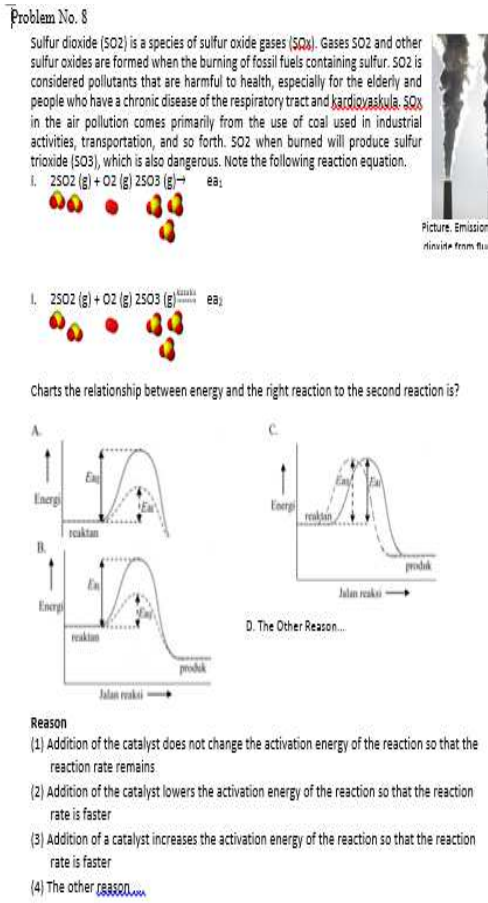
Mental Model	Percentage
Target models	5.71
intermediate 3	85.72
intermediate 2	8.57
intermediate 1	-
Initial models	-

Category initial model is a mental model that has been carried by a person since birth or mental models formed by the information from the wrong environment, or

concept and image structure created entirely unacceptable in science, or the student did not have a concept (Park , 2009). Based on Table 1, note that students do not have this mental model category. Furthermore, it is known also that there are no mental model of mental Intermediates 1. Model 1 is the mental model of someone who had already been formed or concept and explanations given to the truth of scientific and structural drawings created unacceptable, or vice versa (Park, 2009).

Category 2 intermediate mental models are as much as 8.57%. The meaning of this category is the concept of the students and the image structure created closer to the truth of science (Park, 2009). For the intermediate category 3 contained 85.72%. Category mental model is the most widely held by students. Mental models intermediates 3 is an explanation / acceptable scientific concept and image structure created closer to the truth, or otherwise explanation / concept owned can`t be received well in science, but images made structures are correct. Furthermore, the category of mental models is a mental model that targets expected of students. Mental model of the target obtained when the explanation / concept and image structure created right students in science. Based on analysis of two-tier diagnostic test,

Categories students 'mental models indicate the level of students' understanding of the material reaction rate. The rate of reaction material is divided into four major sections, namely the concept of reaction rate, collision theory and activation energy, the factors that affect the rate of reaction, and the reaction order and reaction rate equation. Problem two-tier diagnostic test consists of two questions about the concept of reaction rate, three questions on the collision theory and activation energy, eight questions about the factors that affect the rate of reaction, and five questions about the order of the reaction and the reaction rate equation. Here are examples of two-tier diagnostic test item is used.


Problem No. 8

Sulfur dioxide (SO2) is a species of sulfur oxide gases (SOx). Gases SO2 and other sulfur oxides are formed when the burning of fossil fuels containing sulfur. SO2 is considered pollutants that are harmful to health, especially for the elderly and people who have a chronic disease of the respiratory tract and kardiovaskula. SOx in the air pollution comes primarily from the use of coal used in industrial activities, transportation, and so forth. SO2 when burned will produce sulfur trioxide (SO3), which is also dangerous. Note the following reaction equation.

I. $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$ ea_1

Picture. Emissions of sulfur dioxide from flue industry

I. $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$ ea_2

Charts the relationship between energy and the right reaction to the second reaction is?

A. B. C.

D. The Other Reason...

Reason

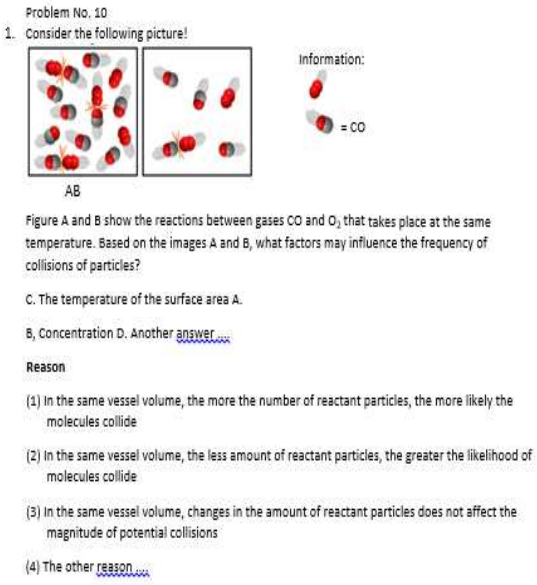
(1) Addition of the catalyst does not change the activation energy of the reaction so that the reaction rate remains

(2) Addition of the catalyst lowers the activation energy of the reaction so that the reaction rate is faster

(3) Addition of a catalyst increases the activation energy of the reaction so that the reaction rate is faster

(4) The other reason....

Figure 2. Example 1


Problem No. 10

1. Consider the following picture!

Information:

= CO

AB

Figure A and B show the reactions between gases CO and O_2 that takes place at the same temperature. Based on the images A and B, what factors may influence the frequency of collisions of particles?

C. The temperature of the surface area A.

B, Concentration D. Another answer....

Reason

(1) In the same vessel volume, the more the number of reactant particles, the more likely the molecules collide

(2) In the same vessel volume, the less amount of reactant particles, the greater the likelihood of molecules collide

(3) In the same vessel volume, changes in the amount of reactant particles does not affect the magnitude of potential collisions

(4) The other reason....

Figure 3. Example 2

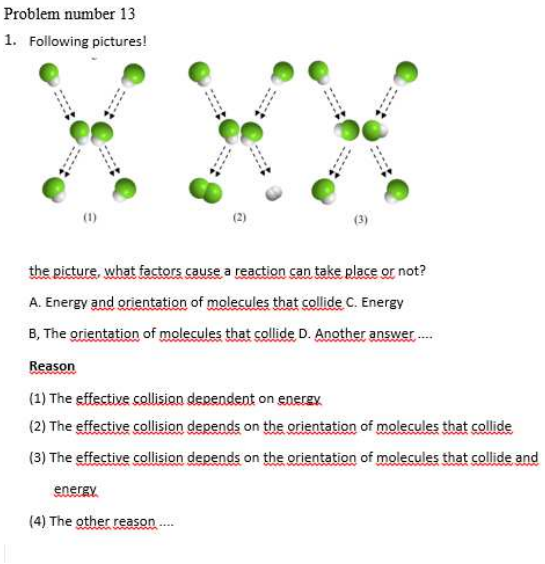


Figure 4. Example 3

The level of students' understanding of the concept of reaction rate is summarized in Table 2. The diagnostic instrument used consisted of two questions that discuss the concept of reaction rate. Problem was designed involving three levels of representation and connects all three levels as a whole so that there is no concept that is missing or occurs miss understood. Of the two questions, one about involving mathematical calculations that require students to be able to connect between concepts.

Table 2. Analysis of students' understanding of the material concept of reaction rate

No. Question	Understand	Less Understand	Do not understand
1	100	-	-
2	100	-	-
total%	100	-	-

Item number one is about the definition of the reaction rate. Category understanding is to understand the percentage of 100%. That is, all the students have been able to understand the definition of the reaction rate based equation for the unknown. Students are also able to give a reason of the answers given. In question number two, category understanding is also very high. That is, students are able to connect the submicroscopic level and symbolic level as a whole. Due to the finalization of the calculation of the student must master the relationship and linkages between concepts.

The level of students 'understanding of the collision theory and activation energy seen by the students' answer to item number 8, 12 and 13. The results of the analysis of the level of understanding are listed in Table 3.

Table 3. Analysis of students' understanding of the material concept of reaction rate

No. Question	Understand	Less Understand	Don`t understand
8	82.87	14.28	2,86
12	45.71	48.57	5.71
13	71.42	20	8.60
total%	66,66	21.62	5.72

Problem number 8, a matter that has relations with one another where students are required to be able to connect the macroscopic level to the submicroscopic and symbolic level to the submicroscopic level. To answer question number 8, students have been able to transform the symbolic level to the submicroscopic level is to imagine (to imagine) against the effect of the catalyst on the energy and the course of the reaction. Students are able to see the chemical equations without catalyst and with catalyst and then connecting it in graphic form (symbolic) are correct.

In question number 12, students are asked to determine the relationship between the collision theory to the activation energy. Requirements to answer these questions that students must be able to interpret the reaction equation (symbolic) in the form of visual images (submicroscopic). Difficulties students in problem solving contained in Question 12 show students the conceptual difficulty of obtaining knowledge. Conceptual knowledge is an important part that must be owned by students in learning a concept (Sunyono, 2011). Students should be encouraged to use mental models in connecting the three levels of chemical phenomena (macroscopic, submicroscopic and symbolic) so that the knowledge obtained by the students enters into long-term memory (long term memory) (McBroom, 2011).

In question number 13, students are asked to find out what factors because a reaction can take place based on an image (level submikrokopik). Based on Table 3, the highest category of understanding is to understand the percentage of 66.66%. In general, students have been able to answer this question properly, which means mastery of submicroscopic level students is also good.

Diagnostic instruments to discuss the factors that affect the rate of the reaction consisted of eight questions that Question 3, 4, 5, 6, 7, 9, 10 and 11. The percentage of the highest understands categories contained in item number 4,

6 and 11. Terms to answer question number 4 is to be able to interpret the submicroscopic level to the macroscopic level (verbal). Question number 6 and 11 on the effect of surface area on the reaction rate. To Question 6, students are asked to interpret the symbolic level (table) level to the macroscopic and submicroscopic level while the students were asked about the number 11 is able to interpret the submicroscopic level (image) to the macroscopic level. The level of students' understanding of factors that affect reaction rates are summarized in Table 4.

Table 4. Analysis of students' understanding of the material factors that affect the rate of reaction

No. Question	Understand	Less understand	Do not understand
3	71.43	28.57	-
4	94.28	5.71	-
5	14.28	42.85	42.85
6	82.86	11.43	5.71
7	74.28	14.28	11.44
9	42.85	51.44	5.71
10	74.29	22.86	2.85
11	85.72	8.57	5.71
total%	67.51	23.21	9.28

Percentage category less understanding about the utir highest in the number 5 on the effect of temperature and Question 9 about the influence of the catalyst to the activation energy. On the second question, the students have not been able to connect the three levels of representation well. Furthermore, the percentage of category do not understand about the highest in number 5 is the effect of temperature on the reaction rate. Students are not able to imagine and interpret the symbolic level (data in tables) to the macroscopic level and submicroscopic level so that students could not answer where the reaction rate is the fastest happens if that is known is the initial concentration and concentration finally alone.

Students' understanding of the material and order reaction rate equation is analyzed based on five items (Table 5). Based on the results of analysis show that the category of the highest understanding is less understood, as item number 14, 15 and 16. Those items number 14 on calculating reaction order. Lack of understanding means students can`t connect the macroscopic level and symbolic fine. Because in the process of settling the accounts, students are required to be keen in seeing concentrations of the reactants used.

Table 5. Analysis of students' understanding of the material and order reaction rate equation

No. Question	Understand	Less Understand	Do not understand
14	11.43	62.86	25.71
15	5.71	74.29	20.00
16	34.28	48.58	17.14
17	-	20.00	80.00
18	8.57	40.00	51.43
total%	11.99	49.15	38.86

Item number 15 deals with the relationship of concentration of the reaction order so that the requirements to answer the students should be able to read and interpret the number of particles in the image (submicroscopic) to the reaction rate and reaction order (symbolic). Furthermore, item number 16 discusses the rate equation associated with the completion of the calculation (symbolic). Students are required to be able to read the data in the table (symbolic) and imagining the process of passage of the reaction (macroscopic) so that it can solve the problem in question. Based on items 14, 15 and 16 can be seen that students are less able to find connections between the three levels of representation and are unable to resolve the issue appropriately.

In addition, the categories do not understand is highest on item number 17 and 18 on the unit reaction rate constant and reaction rate equation. Terms answered question number 17 was student must be able to associate with each other between one concept and master all three levels of representation while to answer Question 18 students need to know about the requirement in determining the rate equation. That is, students do not yet have the ability to solve these problems.

Learning to drive and engage students in using three levels of representation and interconnect the whole three levels can affect the development of students' mental models. Mental models are used every individual in an attempt to solve the problem through a process of reasoning, explaining, predicting phenomena or produce a model that is expressed in various forms (such as charts, graphs, stimulation or modeling, algebra / mathematical, even the description of words or writing print, and so on) which can then be communicated to others (Borges and Gilbert, 1999; Greca and Moreira, 2001). Thus, the students 'mental models in the material reaction rate can impact students' understanding of the material reaction rate.

After the achievement test and two-tier diagnostic test to determine students' understanding and mental models of the material reaction rate, further semi-structured interview to prove the answer and grounds chosen by the student. Other random is to determine the type of students' mental models. This interview was conducted by a method that is taken two students in each category is targeted, intermediates 3, and intermediates 2. Interviews showed that one of the factors that influence students' mental models namely the teaching process carried out by the teacher. There are various factors / sources of mental models, namely teaching, language and words, everyday experiences, social environment and intuition. Textbooks used by teachers during the learning process in the classroom teaching included into subcategories (Lin, 2007).

IV. CONCLUSION

Based on the results of data processing, research findings and a discussion of mental models of the reaction rate showed varying results. Student at the submicroscopic level of understanding for the material reaction rate is low and the students have not been able to interconnect all three levels of representation as well. Categories students' mental models ranging from the intermediate 2, intermediate 3 and the target model. The ability to connect third-level student representation may form a mental model intact.

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