Orbital
The electronic journal of chemistry

the electronic journal of chemistry

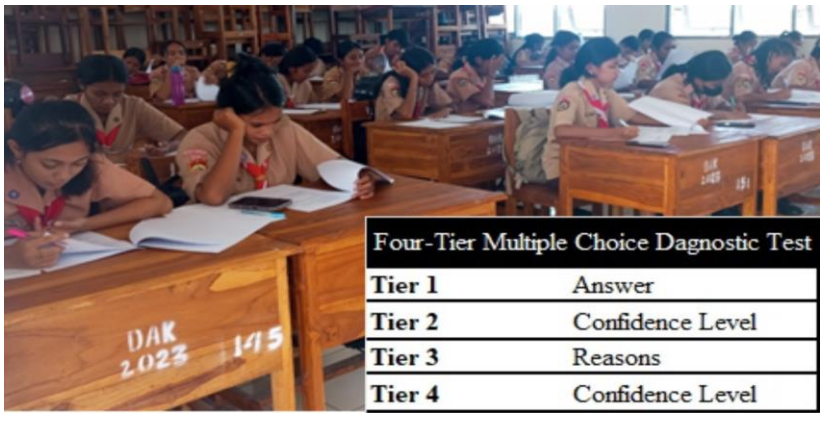
Paper on Education | http://dx.doi.org/10.17807/orbital.v17i5.22292

Analysis of Students' Misconceptions on Mole Concept Materials and Chemical Formula Using Four-Tier Multiple Choice Diagnostic Test Based Indonesian Curriculum

Heru Christianto* [a], Mariana Carvalho [a], and Lolita Agusta Magdalena Parera [a]

This research aims to determine the percentage level of students' misconceptions regarding the concept of moles and chemical formulas as well as each sub-concept where there are misconceptions and their causes in class XI-C SMA Negeri 5 Kupang. Misconceptions were measured using a four-tier diagnostic test instrument based on mixed method research with explanatory sequential design. The research sample was 32 students from class XI-C at SMAN 5 Kupang, who were determined using purposive sampling technique. Data collection techniques were carried out using a four-tier multiple choice diagnostic test, interview guide questionnaire and documentation. Based on the research results, the misconceptions that occur in class XI-C students at SMAN 5 Kupang are classified as moderate misconceptions with a percentage of 41.56%. Significant misconceptions were identified in 5 sub-concepts with an average CR (confidence rating) score above 4.00, namely: (1) Relative Atomic Mass and Relative Molecular Mass 18.75%; (2) Calculation of Mole Concept 24.99%; (3) Reaction Equalization 21.87%; (4) Empirical Formula and Molecular Formula 18.75%; (5) Hydrate Compound 23.43%. Students' misconceptions are caused by 5 factors based on questionnaire and interview data, namely: (1) Students 35.416%; (2) Teachers 6.25%; (3) Learning methods 25.78%; (4) Teaching context 13.125%; (5) Textbooks 20%.

Graphical abstract



Keywords

Misconception
Diagnostic test
Four-tier multiple choice
Mole concept materials
Chemical formula

Article history

Received 16 Nov 2024
Revised 21 Jul 2025
Accepted 12 Nov 2025
Available online 22 Nov 2025

Handling Editor: Adilson Beatriz

1. Introduction

Education has been dedicated as a fundamental thing for the life of every country in the world as one of the channels to

[a]Chemistry Education Study Program, University of nusa Cendana, Adisucipto Street, Kupang, Province East Nusa Tenggara, Indonesia.
*Corresponding E-mail: **rhuechrist@gmail.com**

prepare and develop human resources that are able to compete, including Indonesia which is still classified as a developing country. As a process in humanizing humans, it is very important for the education process to be carried out properly because it is a determining factor in achieving success in making the nation's life intelligent [1]

Given the importance of education in Indonesia, the level of students' understanding of a concept is very influential, so that the active learning process is expected to be carried out properly and correctly. The initial concept that students have even before participating in class learning is called preconception. This initial concept helps students in building an understanding of the concept of the material taught by the teacher. Each student has different abilities in receiving and understanding the concepts presented, so there is a possibility that some students have wrong conceptions called misconceptions [2]. Misconceptions occur when the conceptions that students have of a particular concept conflict with the scientific concepts that have been agreed upon by experts. Misconceptions can be caused by wrong preconceptions, learning methods, student abilities, lack of interest and motivation in learning, wrong intuition, misconceptions from teachers, learning methods used [3] and information from different book sources.

Chemistry as a branch of science is one of the subjects in high school that really needs a strong understanding of concepts because it has abstract material characteristics, generally simplified from the actual state, material concepts are interrelated and systematic [4]. In addition, chemistry also has calculation concepts from simple to complex.

The concept of moles and chemical formulas as the basis of chemical calculations must be understood first before studying the concept of further chemical materials such as thermochemistry, reaction rates, chemical equilibrium and others. This is in line with research conducted by Zakiyah., et.al [5], which states that students' difficulties in understanding thermochemistry materials cannot be separated from the difficulties in students' understanding of stoichiometry materials because thermochemistry materials still involve the concept of moles, balancing chemical equations and algebraic procedures.

Misconceptions are very resistant to change and problematic for further scientific knowledge, so it is very important to determine them correctly. Determining the existence of misconceptions can be done by identifying students through interviews, concept maps, openended tests and multiple choices [6]. However, in its application, these instruments still have weaknesses in identifying students' actual misconceptions so that they can be overcome using diagnostic test instruments.

The two-tier multiple choice diagnostic test is a multiple-choice test consisting of two levels containing content-based alternatives at the first level (answer tier) and principles that justify the answer tier at the second level (reason tier) [7]. However, in this two-tier diagnostic test it is very possible to conclude that misconceptions occur because all wrong answers are considered misconceptions [8]. Thus, it cannot distinguish misconceptions caused by incorrect initial conceptions or lack of knowledge, and cannot distinguish correct responses due to correct understanding or guessing.

A three -tier multiple choice diagnostic test was developed to add the level of student confidence in answering questions. However, this diagnostic test has a single level of confidence so that it is not yet able to detect the level of student confidence in choosing reasons [9]. The four -tier multiple choice diagnostic test complements this by adding a fourth level in the form of the level of confidence in choosing reasons [10] so that it can be used to identify misconceptions that occur in students regarding a particular concept, one of which is the concept of chemistry.

Based on the results of distributing the initial needs questionnaire of students at SMA Negeri 5 Kupang, it was found that as many as 65% of the number of class XI C students who had received the material on the concept of moles and chemical formulas did not understand the material and considered this material to be difficult to understand.

Many similar studies on misconceptions in the field of chemistry have been conducted because this is very important in understanding the problems experienced by students. In a study conducted by Aswita et al. [11] on thermochemistry material, the results showed that the average percentage of misconceptions was 63.72% where the concept of thermochemical equations and the concept of moles were poorly understood by students. Rayhana Tsabitah [12] also in her research on the concept of chemical equilibrium obtained the results of the percentage of misconceptions as much as 11.7%.

Other studies on the concept of moles and chemical formulas have been conducted by several previous researchers. Aini et al. [13], obtained the results of the percentage of misconceptions in their research on misconceptions in stoichiometry material. As many as 38.33% of students misconceive in calculating the number of moles of products in a reaction by assuming that the mass of the product is determined based on the sum of the masses of the reactants. In addition, students also misconceive in the sub-concepts of empirical formulas and molecular formulas by 1.67% where students use the comparison of the masses of the constituent elements as an index that states the empirical formula. Karim [14], obtained the same results of misconceptions in the sub-concepts of empirical formulas and molecular formulas with a percentage of 42.86%. Kristyowati & Priatmoko [15], identified student misconceptions in the same sub-concept and found that students assume that the molecular formula is the formula with the simplest comparison while the empirical formula is the actual comparison. Astuti et al. [2], in their research identified that students had misconceptions about balancing chemical reactions, the relationship between atomic mass and the number of particles, the relationship between moles and mass, Ar and Mr.

The causes of students' misconceptions have been identified by several previous researchers on the material of mole concepts and chemical formulas. Suparno [16], grouped the causes of misconceptions into 5 groups, namely students, teachers, learning methods, teaching contexts and textbooks. Lailia & Suyono [17], in their research on identifying students' misconceptions on the concept of stoichiometry identified four factors causing misconceptions including learning models, books, friends and teachers. Astuti et al. [2], also identified two factors causing students' misconceptions, namely students' conditions and textbooks.

Based on the description above, the researcher feels it is important to analyze students' misconceptions that occur in the concept and each sub-concept of the mole concept and chemical formula material which is the basis of chemical calculations using a four-tier multiple choice diagnostic test instrument. Thus, the researcher raised the title "analysis of students' misconceptions on the mole concept and chemical formula material using a four-tier multiple choice diagnostic

test at SMA Negeri 5 Kupang".

2. Results and Discussion

The purpose of this study was to determine the percentage level of students' misconceptions on the material of the concept of moles and chemical formulas and each sub-concept that contained misconceptions and their causes using a four-tier multiple choice diagnostic test instrument. After validation with material experts, a test instrument trial was carried out which was then analyzed for validity tests, reliability tests, question discrimination tests and question difficulty level tests. A significant diagnostic test instrument to be used was obtained from 20 questions from a total of 25 questions covering 5 sub-concepts contained in the concept of moles and chemical formulas, namely: Relative Atomic Mass and Relative Molecules, Calculation of the Mole Concept, Empirical and Molecular Formulas, Balancing Chemical Reactions and Hydrate Compounds. Based on the research data, the percentage of each category was obtained, namely misconceptions, understanding concepts, not understanding concepts, and errors in the overall sub-concept of moles and chemical formulas. The following data is presented in the form of a graph diagram in Figure 1.

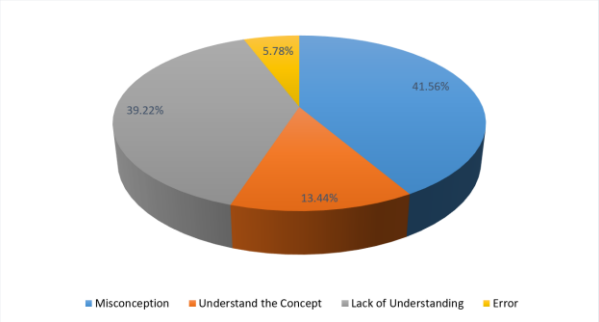


Fig. 1. Percentage Diagram of Each Category.

The percentage of the four categories of students' level of understanding for each sub-concept is presented in Table 1.

Table 1. Percentage of Students' Level of Understanding for Each Sub-Concept.

No	Sub Concept of Mole and Chemical Formula	Category Percentage (%)			
		Misconception	Understand the Concept	Lack of Understanding	Error
1.	Relative atomic mass and relative molecular mass	31.25	30.21	36.46	2.08
2.	Mole concept calculation	38.89	12.5	40.28	8.33
3.	Balancing chemical reactions	48.44	14.06	37.5	0
4.	Empirical and molecular formulas	50	4.17	34.38	5.21
5.	Hydrate compound	45.31	8.33	44.79	6.25

Determination of significant misconceptions is carried out first before discussing students' misconceptions on the concept of moles and chemical formulas. Misconceptions experienced by students are classified into strong, medium and weak misconceptions. Significant misconceptions are determined with the aim of being able to distinguish answers chosen by students by chance alone. Significant misconception data are shown in Table 2.

Table 2. Significant Misconception Data for Each Question Item.

No	Sub Concept of Mole and Chemical Formula	Significant Misconceptions						
		No	Tier Answers-Reasons	F	%	CR Value	Average %	Average CR Value
1.	Relative Atomic Mass and Relative Molecular Mass	1	D-C	2	6.25	4.50	18.75	4.80
		2	D-E	6	18.75	4.80		
		3	D-C	4	12.5	5.50		
2.	Mole Concept Calculation	4	C-B	2	6.25	4.00	24.99	5.04
		5	B-D	7	21.87	4.50		
		6	C-D	6	18.75	4.90		
		7	C-C	9	28.12	5.00		
		8	C-A	4	12.5	4.00		
		9	E-C	3	9.37	4.80		
		10	B-C	4	12.5	4.00		
		11	C-C	9	28.12	5.80		
		12	A-C	9	28.12	5.00		
3.	Balancing reactions	13	D-C	7	21.87	5.53	21.87	5.53
		14	C-E	4	12.5	6.00		
4.	Empirical formula and molecular formula	15	C-D	8	25	4.30	18.75	5.03
		16	E-B	5	15.62	5.60		
		17	B-B	6	18.75	5.60		
		18	B-B	5	15.62	4.50		
5.	Hydrate compound	19	A-D	9	28.12	5.00	23.43	5.08
		20	B-B	6	18.75	5.10		

Based on the data above, significant misconceptions that occur in the 5 main sub-concepts based on the data above have an average percentage score, namely: (1) Relative Atomic Mass and Relative Molecular Mass of 18.75%; (2) Mole Concept Calculation of 24.99%; (3) Reaction Equilibration of 21.87%; (4) Empirical Formula and Molecular Formula of 18.75%; (5) Hydrate Compound of 23.43%. The average CR (confidence rating) score of each sub-concept with a value above 4.00 so that the identified misconceptions are classified as strong category misconceptions. Based on the pattern of answers of students whose misconceptions were identified, misconception data was obtained for each sub-concept as shown in Table 3.

Table 3. Significant Misconceptions in Each Sub-Concept.

No	Sub concepts of mole and chemical formula	Code	Misconceptions that occur
1.	Relative atomic mass and relative molecular mass	MIS-1	Determining the relative molecular mass of a compound is determined from the number of relative atomic masses of the elements. Students experience misconceptions in determining the type of number called an index which states the number of elements in the compound.
2.	The concept of moles	MIS-2	The relationship between moles and mass, determining moles in a mole bridge based on mass, students experience the misconception that moles are obtained from the ratio of Mr of a compound to its mass.
		MIS-3	Determining mass based on moles, students experience the misconception that mass is obtained from the comparison of Mr compound to the number of moles.
		MIS-4	In determining the number of particles based on mass, students experience the misconception that the number of atoms is obtained from the comparison of Avogadro's number to the number of moles.
		MIS-5	Determining the moles of products based on the mass of reactants, students experience the misconception that the number of moles of products is determined by the comparison between the mass of the reactants and the Mr of the product compound.
3.	Balancing reactions	MIS-6	Balancing the decomposition reaction of H_2O_2, students experience the misconception that balancing is only carried out on compounds with the largest number of elements in the reaction.
4.	Empirical formula and molecular formula	MIS-7	Determining the empirical formula, students experience the misconception that the empirical formula is a simple comparison of masses.
		MIS-8	Determining the molecular formula, students experience the misconception that the molecular formula is determined based on the comparison of the masses of the constituent atoms.
		MIS-9	In determining the type of compound that is classified as an empirical formula, students experience the misconception that the type of compound with the least number of atoms is an empirical formula.
5.	Hydrate compound	MIS-10	Determining the number of water molecules in the formula of a hydrate compound, students experience the misconception that the number of bound water molecules is determined based on the comparison of the masses of salt and water.

1. Relative Atomic Mass and Relative Molecular Mass

Misconceptions that occur in Determining the relative molecular mass of compounds based on relative atomic mass data of elements with the MIS-1 code have a percentage of 18.75% and an average CR score of 4.80. Students experience misconceptions in determining the type of number called an index that states the number of elements in the compound. So that the results of the calculation of the relative molecular mass are incorrect. The correct concept is that the relative molecular mass is obtained from the total number of relative atomic masses of the constituent elements multiplied by their respective indices. Based on the results of the interview, students misunderstood the index so that they incorrectly determined the number of atoms in the compound. As a result, one of the elements was not included in its index so that the results were incorrect. This is in accordance with research conducted by Astuti et al., [2] where students misunderstood that the index does not affect the calculation of the number of atoms.

2. Mole Concept Calculation

In MIS-2: Relationship between moles and mass, Determining moles in mole bridges based on mass, students have a misconception that moles are obtained from the comparison of Mr of a compound to its mass with a significance percentage of 21.87% with an average CR score of 4.50. In MIS-3: Determining mass based on moles, students have a misconception that mass is obtained from the comparison of Mr of a compound to the number of moles with a significance percentage of 18.75% with an average CR score of 4.9. Students assume that whether determining mass or number of moles, it is always Mr that is compared to the number of masses or number of moles of a substance. The correct concept in determining the number of moles based on mass is to compare the mass of a substance with its relative molecular mass. While the amount of mass of a substance is determined based on the multiplication of the number of moles by its relative molecular mass. Based on the results of the interview, it was found that students had difficulty remembering formulas and believed that the formulas they had memorized were correct. This is in line with research conducted by Astuti et al., [2] where solving problems based on memorization can lead to misconceptions if you remember the formula equations related to the problem incorrectly.

In MIS-4 in calculating moles using the mass comparison with Ar oxygen and incorrect use of the mole relationship formula and the number of particles. The correct concept is that the number of moles of oxygen gas is determined based on the mass comparison with Mr O_2 so that the number of atoms can be calculated based on the number of moles

multiplied by Avogadroo's number. This student misconception can be strengthened by the misconception in the sub-concept of relative atomic mass and relative molecular mass where students have difficulty understanding the index and coefficient so that they are wrong in determining the number of atoms. Based on the interview results, students use Ar O because they assume that oxygen gas has the symbol O so that 1 mole is obtained and then by comparing Avogadroo's number to the number of moles, the same value is obtained as Avogadroo's number. Astuti et al., [2] also found the same misconception results in their research which were caused by incorrect use of the formula.

In MIS-5 in determining the number of moles of product based on the mass of reactants in the reaction equation where students assume that the number of moles of product is determined based on the comparison of the mass of the reactant substance with the Mr of the product compound. The correct concept is that in determining the number of moles of product, a coefficient comparison must be used where the moles asked are the same as the coefficient of the substance asked per coefficient of the known substance multiplied by the moles of the known substance. Based on the interviews conducted, students assume that the mass of the product is obtained from the result of the total mass of the reactants. This is in accordance with the results of the study by Aini et al., [13] where 38.33% of students assume that the mass of the product is the result of adding the mass of the reactants. In addition, in determining the mass of the reactant based on the moles of the product, students use the number of moles of the product as the number of moles of the reactant to calculate the total mass of the reactant. This is because the data on the number of moles of other product substances is unknown so it is considered the same as the number of moles of the reactant because there is no comparison. The correct concept is that the number of moles of the reactant must be determined using the coefficient comparison formula which is then calculated for the total mass of the substance. This misconception is reinforced by the previous misconception where in calculating the moles of the product, students do not use the coefficient comparison formula because they do not know the reaction coefficient comparison formula.

3. Balancing of Reactions

In MIS-6 in chemical reaction balancing, students experienced misconceptions with a significance percentage of 21.87% and an average CR score of 5.00. Students assume that balancing is done on the type of compound with the most elements. The correct concept is that balancing must be done on all elements so that the amount in the reactant section is the same as the product. Based on the interview, students were confused in answering when asked by stating that based on their understanding, balancing is done on the front number in compounds with more elements.

4. Empirical Formula and Molecular Formula

In MIS-7: Determination of empirical formula, students experienced misconceptions with a percentage of 25% and a CR score of 4.30 by assuming that the empirical formula is a simple mass comparison. In MIS-8: Significant misconceptions that occurred were 18.75% and an average CR score of 5.60 where in Determination of molecular formula, students experienced misconceptions that the molecular formula is determined based on the comparison of the masses of the constituent atoms. The correct concept is that the empirical formula is the simplest mole comparison of the constituent elements and the molecular formula is the actual mole comparison. So the molecular formula can be determined based on the empirical formula and its relative molecular mass.

Based on interviews, students assume that to determine the formula, the simplest mass comparison of each element is calculated. This is in line with research conducted by Norjanah, et al ., [18] and Karim, [14] which obtained results that students assume that the simplest mass comparison number indicates the index number of the elements forming the compound in the empirical formula and molecular formula.

In MIS-9, the determination of the type of compound included in the empirical formula of students assumes that the compound with the least number of atoms is an empirical formula which has a significance percentage of 15.62% and an average CR score of 4.50. Based on the results of the interview, students conveyed the reason for choosing this answer based on their understanding which is in accordance with the teacher's presentation that if a compound has an index number then it is included in the empirical formula, if the index number then it is included in the molecular formula.

5. Hydrate Compounds

In MIS-10, in calculating the number of molecules of each salt and water involved in the hydrate compound by assuming that the number of water molecules involved is determined by the ratio of the masses of salt and water. Based on the results of the interview, students answered based on their understanding of determining the empirical and molecular formulas that using the mass ratio. This is because in this material has not been taught significantly the process of determining the molecular formula of hydrate compounds. The teacher only explains the definition of hydrate compounds and has not discussed the calculation of the formula of hydrate compounds.

Factors Causing Misconceptions

1. Students

Students are the main characters in learning who are responsible for their own understanding. Based on the results of the questionnaire distribution of the causes of student misconceptions, the percentage results obtained were 35.416% of misconceptions caused by the students themselves. Based on the results of the interviews conducted, some students did not pay attention to chemistry learning on the material of the concept of moles and chemical formulas properly because the material consisted of concepts and calculations involving formulas, making learning less enjoyable. Students often have difficulty understanding and remembering formulas in the concept of moles and chemical formulas which are caused by not studying related materials when they are at home.

Amelia, [3] in her research found that the cause of misconceptions was the way students learned by memorizing, where 3.79% of students had difficulty memorizing the main topic of stoichiometry. In this research, another cause was also found, namely the lack of interest in learning by students.

Based on interviews conducted with subject teachers, it was revealed that students' interest in learning is still lacking, which is caused by learning that uses technology where students are encouraged to bring cellphones to school, but are not utilized properly while studying. Even the material sent by the teacher is only opened when requested by the teacher.

Students are also still lazy to repeat the material, causing difficulties when asked for the material again at the next meeting.

2. Teacher

As a motivator and facilitator, the role of a teacher is very large in the learning process of students. Teachers' mistakes in providing materials during the learning process can cause misconceptions in related students. Based on the results of the distribution of questionnaires on the causes of misconceptions, the provision of materials is quite clear and in accordance with the textbooks used and often provides opportunities for students to ask questions. However, the results of the questionnaire obtained 6.25% of the causes of misconceptions are teachers. These results are supported by research conducted by Lailia & Suyono [17], which found that 4% of the causes of student misconceptions are teachers. Amelia [3], also in her research obtained results that teachers were the cause of student misconceptions with a percentage of 1.78%. Based on follow-up interviews conducted with students, it was found that teachers often did not properly check students' understanding of the related material which caused students to hold the wrong concept.

3. Learning methods

Learning methods are one of the important components for the process of student understanding. Good and targeted learning methods can increase students' interest in learning. However, based on the results of the questionnaire distribution on the causes of misconceptions, it was obtained that 25.78% of students' misconceptions were caused by the use of methods in the learning process that were still less targeted, thus decreasing students' interest in learning. This was also expressed by Amelia [3], in her research that 2.67% of misconceptions were caused by the learning methods used being less appropriate.

Based on the results of interviews with teachers, teachers revealed that so far they have only used the usual methods, namely lectures and discussions combined, with learning models based on the discovery learning model. Teachers also said that the current learning method still does not answer the differentiated learning method so it will continue to be improved.

4. Teaching context

The use of a good teaching context can cause the material delivered to be well absorbed by students. Based on interviews with students, students expressed that they preferred studying at school because the explanations were given in easy-to-understand language, making it easy to listen to the material given. However, based on the results of distributing questionnaires on the causes of student misconceptions, it was found that 13.125% of misconceptions experienced by students were caused by the context in teaching.

5. Textbook

As the main medium in learning, the role of books for students' understanding is also very important. Based on the results of the questionnaire distribution of the causes of misconceptions, it was found that 20% of students' misconceptions were caused by textbooks. Lailia & Suyono [17], in their research, found that 43% of students' misconceptions were caused by textbooks. Based on follow-up interviews conducted with students, it was found that students were not interested in reading material from books and relied more on teacher explanations. This is due to conceptual errors in the textbooks used. The textbooks used are translations of Cambridge International AS & A levels written by Peter Cann & Peter Hughes. The arrangement of the material in this book is also not organized according to the correct sequence of material, causing confusion for students when reading the material. In addition, the material presented is not complete, for example in the concept of determining relative atomic mass, only the determination is explained based on the mass of hydrogen atoms, but the process of obtaining the formula for determining relative atomic mass based on the mass of C-12 atoms is not explained. While in the concept of relative molecular mass, the wrong concept is presented in the formula pattern. In the concept of empirical formula and molecular formula which are sub-concepts with the highest percentage of misconceptions, incorrect example question data is presented, then the process of determining the molecular formula is not explained completely, causing difficulties for students in understanding the material well. This textbook factor is supported by the teacher factor who does not emphasize the concept properly to students, which becomes the basis for students experiencing misconceptions.

3. Material and Methods

Types of research

This study uses a mixed method with the design used being explanatory sequential design.

Population and Research Sample

The population studied in this study were students of SMAN 5 Kupang in the 2023/2024 academic year. The samples taken in this study were all students in class XI-C (IPA 3) of SMAN 5 Kupang who had received material on the concept of moles and chemical formulas with the number of samples taken being 32 students. The sampling technique used was purposive sampling.

Research Design

This research design uses a mixed method, namely explanatory sequential design according to Creswell [19]. The flow of this research is divided into four groups of stages, namely the initial stage, the research instrument creation stage, the instrument trial stage and the data collection and processing stage. As well as drawing conclusions.

Research Instruments

The instrument used in this study was a four -tier multiple choice diagnostic test instrument.

Data collection technique

The data in this study were obtained in two types of data, namely quantitative data and qualitative data. Quantitative data were obtained by administering a four-tier multiple choice diagnostic test instrument to class XI-C students of SMA Negeri 5 Kupang who were the subjects of the study. Qualitative data were obtained through questionnaires, interview sheets and documentation.

Data analysis techniques

The data in the study were analyzed in two stages, namely instrument analysis in the trial of the test instrument consisting of validity tests, reliability tests, test of question discrimination power and test of question difficulty levels. Analysis of student misconception data was carried out based on the modified student answer patterns of Karim [14] in Table 4.

Table 4. Student Answer Patterns on the Four-Tier Multiple Choice Diagnostic Test.

Category	Answer	Level of confidence	Reason	Level of confidence
Misconception	Correct	1 – 6	Wrong	≥ 4
	Wrong			
Understand the concept	Correct	≥ 4	Correct	≥ 4
Not understanding the concept	Correct	1 – 6	Correct	≤ 3
			Wrong	
	Correct	≤ 3	Correct	≥ 4
	Wrong	1 – 6	Correct	≤ 3
			Wrong	
Error	Wrong	1 – 6	Correct	≥ 4

Based on the misconception categories that have been obtained, misconceptions are then changed into significant misconceptions. Misconceptions are said to be significant if the answer-reason tier that indicates misconception is chosen by ≥14% of all students and the average CR (confidence rating) score has a score of ≥4.00 [14].

4. Conclusions

Based on the research data on the analysis of student misconceptions obtained using the four-tier diagnostic test instrument in class XI-C of SMAN 5 Kupang, it was concluded that:

1. Misconceptions that occur among students have the highest percentage among the other three categories with a percentage of 41.46%.
2. The misconception with the highest percentage occurred in the sub-concepts of Empirical Formula and Molecular Formula with a percentage of 50% and the misconception with the lowest percentage occurred in the sub-concepts of Relative Atomic Mass and Relative Molecular Mass with a percentage of 31.25%.
3. Significant misconceptions were identified in 5 sub-concepts with the percentage of each sub-concept, namely: (1) Relative Atomic Mass and Relative Molecular Mass of 18.75%; (2) Mole Concept Calculation of 24.99%; (3) Reaction Equilibration of 21.87%; (4) Empirical Formula and Molecular Formula of 18.75%; (5) Hydrate Compound of 23.43%. Each sub-concept has an average CR (confidence rating) score above 4.00.
4. Student misconceptions are caused by 5 factors based on questionnaire and interview data with the percentage of each cause, namely: (1) Students 35.416%; (2) Teachers 6.25%; (3) Learning methods 25.78%; (4) Teaching context 13.125%; (5) Textbooks 20%.

The main recommendation from this research is the four tier diagnostic test instrument can be further developed using artificial intelligence technology so that teachers can use it at any time and can determine misconception results quickly and accurately.

Acknowledgments

Thank you to the chemical education program of the FKIP Undana specialized lecturers who joins the research team and their dedication that has helped in collecting and processing of data. Thank you also to all the students who are involved in this research.

Author Contributions

Heru Christianto: Conceptualization, Methodology, Format analysis, Validation, Visualization, Review & Editing. Mariana Carvalho: Conceptualization, Methodology, Resources, Investigation, writing-Original Draft, Review & Editing. Lolita A. M. Parera: Investigation, Resources, Visualization, Formal analysis.

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How to cite this article

Christiano, H.; Carvalho, M.; Parera, L. A. M. *Orbital: Electronic J. Chem*. **2025**, *17*, 502. DOI: **http://dx.doi.org/10.17807/orbital.v17i5.22292**