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The Analysis of Students Misconceptions by Using Four-Tier Diagnostic Test on Periodic Table of the Elements Lesson

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Abstract:The Analysis of Students Misconceptions by Using Four-Tier Diagnostic Test on Periodic Table of the Elements Lesson . Periodic Table of the Elements is an abstract topic with many new terms and vocabularies, encompassing subjects such as groups, periods, and periodic properties of elements—such as atomic or ionic radius, ionization energy, electronegativity, electron affinity—as well as the physical and chemical properties of elements. These characteristics make it a challenging topic often leading to misconceptions. This research aimed at finding out student misconceptions regarding Periodic Table of the Elements lesson and finding out the extent of these misconceptions. Mixed method was used in this research with explanatory sequential design. The samples consisted of 35 the eleventh-grade students of class A1 at State Senior High School 1 Rambah, and they were selected by using purposive sampling technique. The instruments of collecting data were four-tier diagnostic test, interview, and documentation. The research findings showed that misconceptions were present across all concepts tested within Periodic Table of the Elements lesson. The highest rate of misconception, 53%, was found in indicator (6), determining the relationship between an element electron configuration and its group placement in the periodic table. The lowest rate of misconception, 11%, was observed in indicator (4), determining isotopes, isobars, and isotones. The mean percentages of student concept comprehension level on Periodic Table of the Elements lesson at the eleventh-grade of class A1 at State Senior High School 1 Rambah were 32% of students understanding the concepts with moderate criterion, 19% of students partially understanding the concepts with moderate criterion, 38% of students experiencing misconceptions with moderate criterion, and 11% of students who did not understand the concepts with low criterion.

Keywords: Misconceptions, Four-Tier Diagnostic Test, Periodic Table of the Elements

Abstrak:Analisis Miskonsepsi Siswa Menggunakan Tes Diagnostik Four-Tier pada Materi sistem Periodik Unsur. *Sistem periodik unsur merupakan materi yang bersifat abstrak yang memiliki banyak istilah dan kosa kata baru, meliputi pokok bahasan mengenai golongan, periode, sifat sifat keperiodikan unsur yaitu jari-jari atom atau ion, energi ionisasi, keelektronegatifan, dan afinitas elektron serta sifat fisik dan sifat kimia unsur sehingga dianggap sulit dan mengalami miskonsepsi. Penelitian ini bertujuan untuk mengetahui miskonsepsi siswa pada materi sistem periodik unsur dan mengetahui berapa besar miskonsepsinya. Jenis penelitian yang digunakan berupa*

Mixed Methods dengan tipe Explanatory Sequential Design. Sampel dalam penelitian ini adalah siswa kelas XI.A1 SMA N 1 Rambah sebanyak 35 orang dengan teknik pengambilan sampel adalah purposive sampling. Instrumen pengumpulan data yang digunakan dalam penelitian ini berupa tes diagnostik Four-Tier, wawancara, dan dokumentasi. Hasil penelitian menunjukan bahwa terjadi miskonsepsi pada materi sistem periodik unsur pada semua konsep yang diujikan. Miskonsepsi paling tinggi terjadi pada indikator (6) menentukan hubungan konfigurasi elektron suatu unsur dengan letak golongannya dalam tabel periodik sebesar 53% dan miskonsepsi paling rendah terjadi pada indikator (4) menentukan isotop, isobar, dan isoton sebesar 11%. Secara keseluruhan persentase miskonsepsi pada materi sistem periodik sebesar 38%, paham konsep sebesar 32%, paham sebagian 19%, dan tidak paham konsep sebesar 11%.

Kata kunci: *Miskonsepsi, Diagnostik Four-Tier, Sistem Periodik Unsur*

• INTRODUCTION

Education is the root of a nation's progress. Through education, we can create the future of the nation and also a superior generation that is able to compete with developments over time (Rosa dkk., 2024), so that humans are more honorable and have a higher position than those who are not educated. as we know, it is stated in the 1945 Constitution article 31 Paragraph 1 which states that: "every citizen has the right to education". So, it is clear that education is the right of every individual to achieve it because education can give birth to the nation's intelligent and qualified next generation (Fitri, 2021).

One of the lessons given to high school or MA students is chemistry. Learning chemistry is synonymous with memorization, calculations and understanding a concept. Students must be critical in connecting all knowledge with real life (Angraeni & Rahmawan, 2024). The materials taught are interrelated, so if students have difficulty understanding one material, this can make it difficult for students to understand other materials. It is feared that this difficulty will continue and lead to diverse understandings, resulting in the opportunity for misconceptions (Okmarisa & Hasmina, 2021)

Misconception is a mistake or error in a concept in explaining the relationship between different concepts that are interconnected with each other, so that the concept does not match scientists (Siska & Ritonga, 2021). According to Suparno, misconception is an understanding that students have that does not match the correct concepts or uses the wrong concept (Suparno, 2013). Misconceptions can occur due to two factors, namely internal factors and external factors. Internal factors are in the students themselves, while external factors can come from ineffective teaching methods, teachers who do not understand the concept, writing in books that is not interesting and vocabulary that is difficult to understand (Ayuni & Arif, 2023)

Many studies have been conducted, both in Indonesia and in other countries, which have succeeded in revealing misconceptions in the material on the periodic system of elements, one of which is a study conducted by (Mellyzar et al., 2022) which showed that misconceptions in the material on the periodic system of elements were 38% and in a study (Yusran et al., 2020) showed that the level of students' understanding of the periodic system of elements is still relatively low, namely 20.2%

of students were identified as having misconceptions, 8.5% understood the concept, and 71.3% of students did not understand the concept (Yusran et al., 2020).

Based on the results of interviews conducted between researchers and one of the chemistry teachers at SMA N 1 Rambah, they said that students still find it difficult to understand the material on the periodic system of elements because the material on the periodic system of elements is abstract and has many new terms and vocabulary, including discussion points regarding groups and periods. , the periodic properties of elements, namely atomic radius, ionization energy, electron affinity, and electronegativity (Halimatusya'diah et al., 2020). This can be proven from the low chemistry learning results of 30.6%.

Misconception problems can be identified by using diagnostic tests. Diagnostic tests are one way to detect misconceptions that occur in students (Izza et al., 2021). This test can identify students' weaknesses so that appropriate treatment can be given from these weaknesses (Arikunto, 2012). Diagnostic tests are needed in learning to identify students' weaknesses in learning. One form of diagnostic test instrument that can be used to identify student misconceptions is by conducting interviews, concept maps, portfolios, and multiple-choice tests (Wahyunigtyas dkk., 2020). To overcome the weaknesses of multiple choice as well as interviews and concept maps in detecting misconceptions, the reasons why students choose these answers are added and measuring students' confidence in answering questions and reasons known as the four-tier diagnostic test (Roghdah dkk., 2021).

The four-tier diagnostic test is one of the instruments that can be used to detect students' misconceptions in learning. This instrument is based on the development pattern of the three-tier diagnostic test instrument (Hidayat dkk., 2020). In a study conducted by (Siska & Ritonga, 2021) also used a four-tier diagnostic test to detect misconceptions because the four-tier diagnostic test is considered the most accurate in detecting misconceptions in students because this test can provide complete information.

Based on the problem description in the background, there are still many students who are less than optimal and have not studied material on the periodic system of elements. So if the misconceptions experienced by students are not followed up, they will have a continuous impact on the student's learning process. Therefore, this research is interested in finding out the misconceptions that occur in the material on the periodic system of elements and how many misconceptions students experience in the material on the periodic system of elements.

- **METHOD**

The method used in this study is a mixed-method (Sugiyono, 2016). namely quantitative and qualitative methods. In this study, quantitative data was used to collect data on students' misconceptions on the material of the periodic system of elements using a four-tier diagnostic test while qualitative data was used to explain the misconceptions experienced by students on the material of the periodic system of elements using a four-tier diagnostic test. The object of this study is students' misconceptions using four-tier diagnostics on the material of the Periodic System of Elements (Widoyoko, 2012). The subjects of this study were students of SMA N 1 Rambah in grades XI and XII in the 2024/2025 academic year. The population in the study was all students of grade XI of SMA N 1 Rambah in the 2024/2025 academic year. The sample in this study was 35 students of class XI.A.1 of SMA N 1 Rambah.

The sampling technique used by the researcher was using the purposive sampling technique. The purposive sampling technique according to (Sugiyono, 2016.) is a sampling technique with certain considerations. The consideration of why the researcher took this sampling technique was because the researcher chose students who have studied the Periodic Table of Elements material to avoid students forgetting the relevant material.

The data collection techniques used in this research are as follows:

1. Instrument Analysis

a. Validity of Content

Content validity refers to the accuracy in measuring understanding of material that should be understood according to learning objectives (Widoyoko, 2012).

b. Empirical Validation

Empirical validity is used to test the validity of an instrument by checking whether the instrument can measure what it should measure. In this study, validity will be measured using the biseral correlation coefficient, which aims to assess the validity of the instrument (Arikunto, 2012). The formula is:

$$r_{pbi} = \frac{Mp - Mt}{SDt}\sqrt{\frac{p}{q}}$$

Information: Rpbi = Point biseral correlation coefficient, Mp = Average score calculated for correctly answered, Mt = Average score of the total score, SDt = Standard deviation of the total score, P = Proportion of students who answered correctly, using the following formula:

$$p = \frac{\text{Banyak siswa yang benar}}{\text{Jumlah seluruh siwa}}$$

q = Proportion of students who answered incorrectly, using the following formula:

$$q = 1 - p$$

The empirical validity testing criteria are: If r count ≥ r table then the instrument is valid

If r count ≤ r table then the instrument is invalid

1. Reliability Test

Test reliability is the extent to which a test can prove consistency of measurement results shown in the level of certainty and accuracy of a result (Kurniawati, 2018). This reliability test can be done using the Cronbach Alpha formula. The formula used is:

$$r11 = \left[\frac{k}{k-1}\right]\left[1 - \frac{\sum \sigma b^2}{V_{1^2}}\right]$$

Information: r11 : Instrument reliability, k : Number of questions or number of questions, $\sum \sigma b^2$: Number of question item variants, V_{1^2} : Total Variance

By using this method, the research instrument criteria are said to be reliable. if the Cronbach's Alpha reliability coefficient > 0.6.

Table 1. Reliability Interpretation

NO	Range	Criteria
1	r11 ≤ 0,20	Very low
2	0,20 ≤ r11 ≤ 0,40	Low

3	$0,40 \leq r11 \leq 0,60$	Enough
4	$0,60 \leq r11 \leq 0,80$	Tall
5	$0,80 \leq r11 \leq 1,00$	Very high

(Kurniawati, 2018)

Distinguishing Power In the instrument used, a discriminating power test was also carried out. by using Microsoft Excel assistance program. a question has a discriminatory power that is asked by a student's question if they have high ability, it shows high results, while if they have low ability, it shows low results. The discriminatory power value of the question can be calculated using the following formula:

$$D = Pa\text{-}Pb$$
$$Pa = Ba/Ja \text{ dan } Pb = Bb/Jb$$

Information : D = Discrimination index, Pa = Proportion of test participants in the upper group who answered correctly, Pb = Proportion of test participants in the lower group who answered correctly, Ba = Number of participants in the upper group who answered the question correctly, Ja = Number of participants in the upper group, Bb = Number of participants in the lower group who answered correctly, Jb = Total number of participants in the lower group

The differentiating power criteria can be seen in the following table:

Table 2. Distinguishing Power Criteria

Range	Criteria
≤ 0	Very ugly
0,00 – 0,20	Bad
0,21 – 0,40	Enough
0,41 – 0,70	Good
0,71 – 1,00	Very good

(Magdalena dkk., 2021)

2. Level of Difficulty

A good instrument is one that is not too easy and not too difficult. difficult. To determine the level of difficulty of instrument items, you can use the following formula:

$$P = B/JS$$

Information : P = Difficulty Index, B = Number of Students Who Answered Correctly, JS = Number of Students Taking the Test.

Next, the difficulty index category can be seen below:

Table 3. Difficulty Level Criteria

Range	Criteria
P < 0,70	Very high
0,30- 0,70	Tall
P >1,00	Enough

(Arikunto, 2013)

2. Data Analysis

Misconception diagnosis is done by researchers by taking and adjusting the combination of answer analysis techniques to identify student misconceptions. Researchers use the Four-tier test which includes two levels of belief, namely sure and not sure, which are then presented in table 4.

Table 4. Four-Tier Answer Combinations

Tier-1	Tier-2	Tier-3	Tier-4	Conception Level
1	Y	1	Y	U
1	Y	1	TY	PU
1	TY	1	Y	
1	TY	1	TY	
1	Y	0	Y	
1	Y	0	TY	
1	TY	0	Y	
1	TY	0	TY	
0	Y	1	Y	
0	Y	1	TY	
0	TY	1	Y	
0	TY	1	TY	
0	Y	0	Y	M
0	Y	0	TY	NU
0	TY	0	Y	
0	TY	0	TY	
There are tiers that are not answered or answer more than one answer				UC

(Source: Ritonga & Yasthophi, 2019)

Information : U = Understand the concept,

PU = Partially understand,

M = Misconception,

NU = Don't understand the concept,

UC = No coding done, 1 = Correct, 0 = Wrong, Y = Sure, TY = Not sure

The percentage of students was analyzed using the following formula:

$$\mathrm{U} = \frac{\text{Students understand the concept}}{total\ number\ of\ students} \times 100\%$$

$$\mathrm{PU} = \frac{\text{Students understand partially}}{total\ number\ of\ students} \times 100\%$$

$$\mathrm{M} = \frac{\text{Students who have misconception}}{total\ number\ of\ students} \times 100\%$$

$$\text{NU} = \frac{\text{Students who do not understand the concept}}{total\ number\ of\ students} \times 100\%$$

Keterangan: U : Students understand the concept, PU : Students understand partially, M : Students who have misconceptions, NU : Students who do not understand the concept

The results of the analysis of the percentage of conceptual understanding, not understanding the concept, and misconceptions in the material of the periodic system of elements are presented through a bar chart. The percentage for each concept is also presented in a table to facilitate analysis. The level of student misconceptions is classified as high or low based on certain criteria: Source : Modified from (Nisa & Sudrajat., 2021)

Tabel 5. Misconception Criteria

Criteria	Percentage (%)
Tall	61-100
Currently	31- 60
Low	0 – 30

- **RESULT AND DISCUSSION**

Based on research conducted using a four-tier diagnostic test instrument to analyze students' misconceptions about the material of the periodic system of elements, which was tested on 35 students of class XI A.1 at SMA N 1 Rambah. Students worked on multiplechoice tests with closed reasons, accompanied by the level of student confidence in answering questions and reasons. This test consists of 10 questions covering the development of atomic theory, protons, electrons, and neutrons, mass numbers, isotopes, isobars, and isotons, quantum numbers, groups and periods, and periodic properties of elements.

From the research results obtained from the four-tier diagnostic test instrument, it was analyzed to determine the percentage of students' conceptual understanding through the test, so that it is possible to distinguish students who understand the concept, do not understand the concept, and who experience misconceptions. The average number of students who experience misconceptions in the material of the periodic system of elements is 38%, those who understand the concept are 32%, those who understand some are 19%, and those who do not understand the concept are 11%. According to these results, it can be concluded that the level of students' conceptual understanding has moderate criteria because only 32% of the total number of responses are correct in the answers and reasons, and are sure in the answer choices and their reasons.

Based on the results of the calculation of the percentage of conceptual understanding using the Four-tier diagnostic test, it can be seen in Table 1 and the visualization of the percentage of conceptual understanding of each indicator is presented in Figure 6.

Table 6. Percentage of Students' Understanding of Four-Tier Concepts

Indicator	Number	Percentage (%)

	Question	U	PU	M	NU
Explaining the development of atomic theory	1	23%	14%	46%	17%
Average percentage (%)		**23%**	**14%**	**46%**	**17%**
Determining protons, electrons, and neutrons	2	54%	23%	14%	9%
Average percentage (%)		**54%**	**23%**	**14%**	**9%**
Determining the mass number of an element	3	23%	31%	37%	9%
	4	31%	17%	43%	9%
Average percentage (%)		**27%**	**24%**	**40%**	**9%**
Determining isotopes, isobars, and isotones	5	60%	23%	11%	6%
Average percentage (%)		**60%**	**23%**	**11%**	**6%**
Define the configuration quantum number electron	6	31%	23%	23%	23%
	7	17%	9%	63%	11%
Average percentage (%)		**24%**	**16%**	**43%**	**17%**
Determining the relationship electron configuration of an element with its group position in the periodic table	8	23%	14%	57%	6%
	9	17%	20%	49%	14%
Average percentage (%)		**20%**	**17%**	**53%**	**10%**
Summarizing the relationship between atomic number and periodic properties of elements	10	40%	20%	37%	3%
Average percentage (%)		**40%**	**20%**	**37%**	**3%**

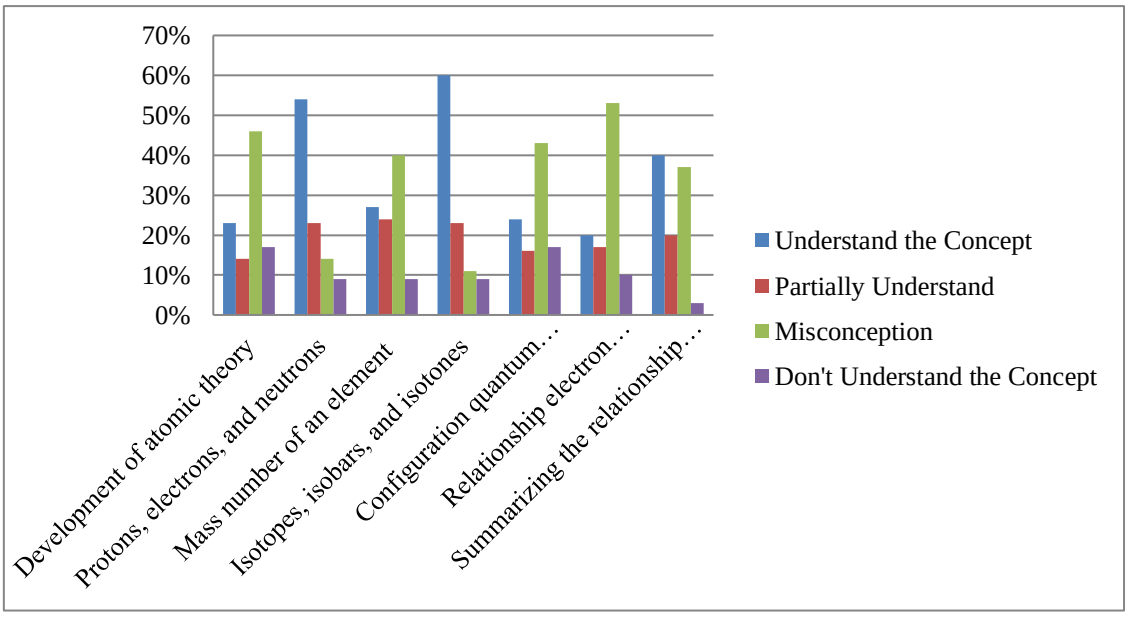

Figure 1. Percentage of Concept Understanding for Each Indicator

Based on Figure 1, it can be seen that students' misconceptions regarding the material on the periodic table of elements vary depending on the question indicators given.

1. Identification of the Level of Conceptual Understanding of Students of Grade XI A.1 SMA N 1 Rambah

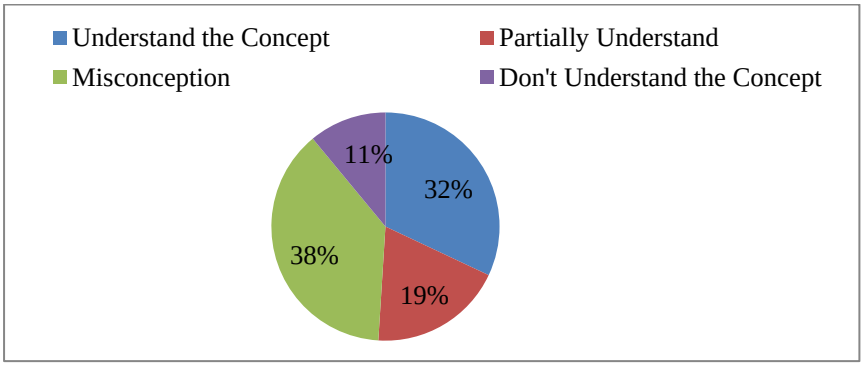

Figure 2. Percentage of Student Concept Understanding

Based on Figure 2 Overall, the average misconception that occurs in students reaches 38% with a moderate category. 32% show conceptual understanding which is also in the moderate category. 19% show partial understanding which is also in the low category and 11% of students are classified as not understanding the concept which is included in the low category.

For this reason, further interviews were conducted to explore the misconceptions experienced by students. In this study, after analyzing the results of the conceptual understanding data, students who experienced the highest misconceptions were interviewed in order to determine the factors causing these misconceptions.

2. Student Misconceptions on Each Indicator

A. The concept explains the development of atomic theory.

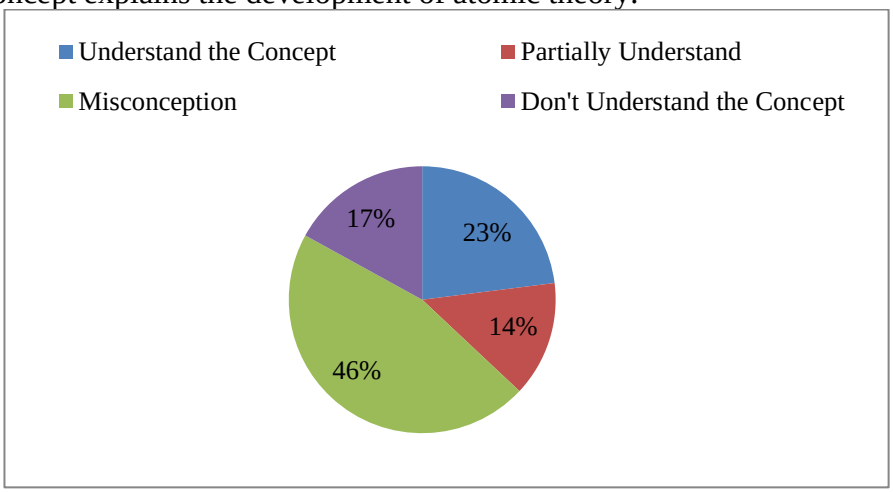

Figure 3. Concept of Development of Atomic Theory

Based on Figure 3. Determining the development of atomic theory is in question number 1. In this indicator, misconceptions are classified as moderate with a percentage of 46%, this is due to a mistaken understanding of the term solid ball without considering the aspects of positive and negative charges. Dalton only explained that atoms are in the form of solid balls without mentioning the existence of a charge. On the other hand, the theory of the existence of a positive charge with negatively charged electrons spread throughout the atom was introduced by JJ Thomson.

B. The concept of determining protons, electrons, and neutrons

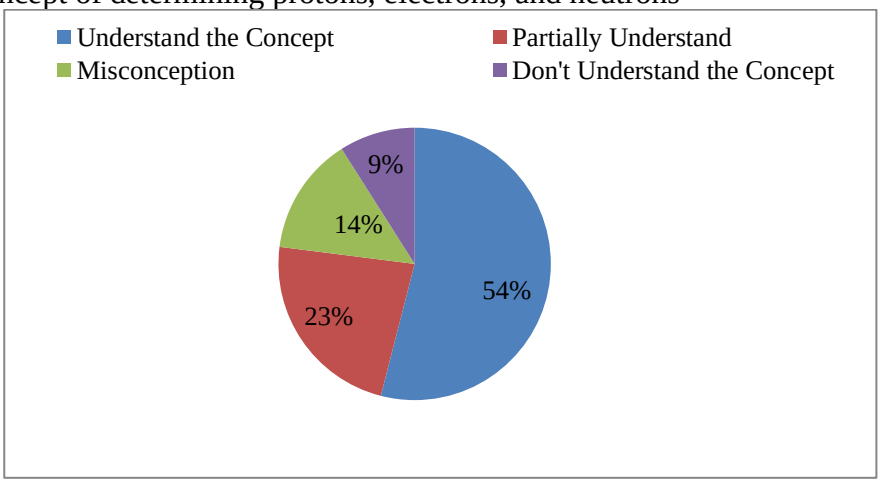

Figure 4. Concept of Determining Protons, Electrons, and Neutrons

Based on Figure 4. Determining protons, electrons, and neutrons is in question number 2. In this indicator, misconceptions are classified as low with a percentage of 14%. This is because students do not understand how to determine the number of protons, electrons, and neutrons. Students assume that to calculate the number of protons in element Ba, the number of protons is the same as the atomic number, and the number of electrons is also the same as the atomic number, while to calculate the number of neutrons in element Ba, the mass number is the same. The next mistake is that students are still wrong in calculating the number of neutrons in element Ba, namely by adding the mass number to the number of electrons.

C. The concept of determining the mass number of an element

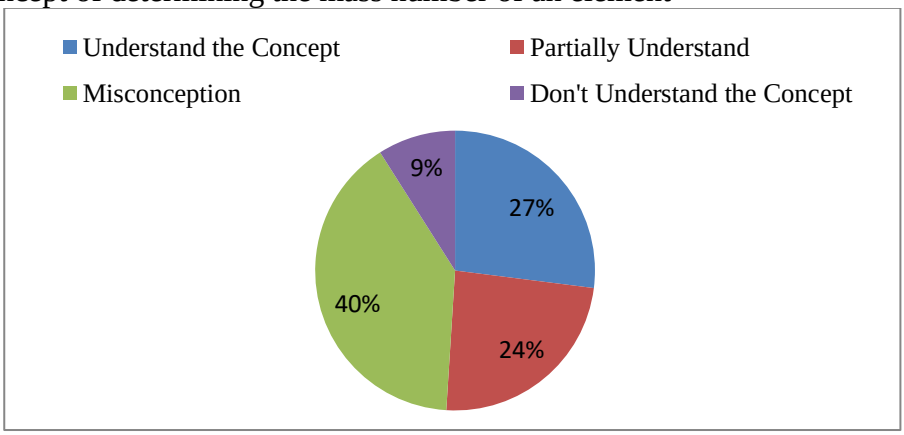

Figure 5. Concept of Determining the mass number of an element

Based on Figure 5. Determining the mass number of an element is in questions 3 and 4. In this indicator, misconceptions are classified as moderate with a percentage of 40%. This is because students do not master the concept of determining the mass number of element A, students assume that the mass number of element A is obtained from the number of neutrons-charge A+2 so that 0-2 = 28. The next error is that students are still wrong in determining the mass number, namely the number of protons-neutrons.

D. The concept of determining isotopes, isobars, and isotons

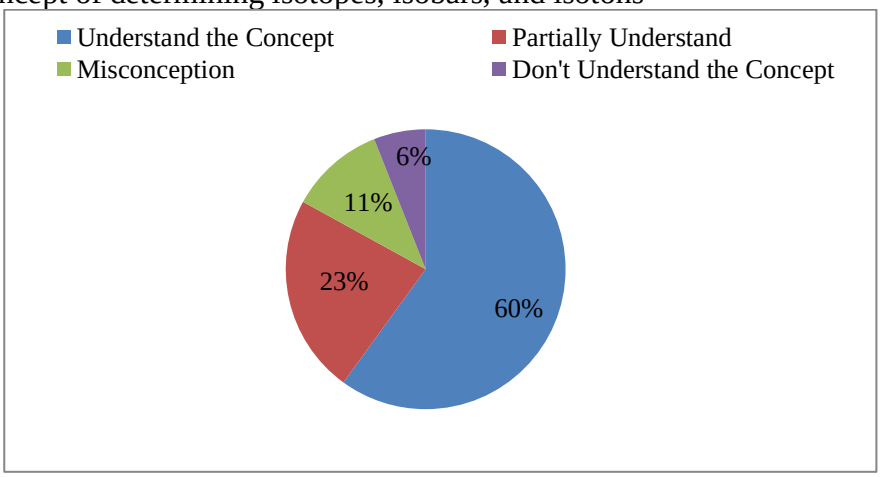

Figure 6. The concept of determining isotopes, isobars, and isotons

Based on Figure 6. Determining isotopes, isobars, and isotons is in question number 5. In this indicator, misconceptions are classified as low with a percentage of 11%. This is because students do not master the concept of determining isotopes, isobars, and isotons in an element. Students assume that isotons are elements that have the same mass number but have different atomic numbers.

E. The concept of determining the electron configuration of quantum numbers

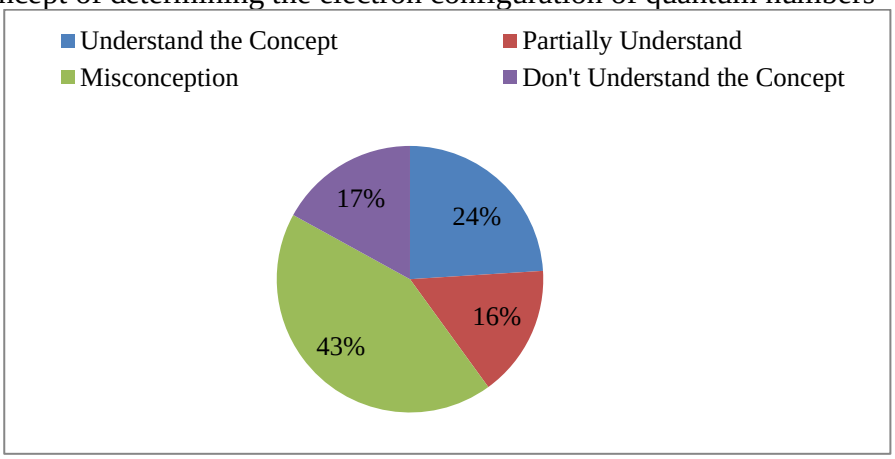

Figure 7. The concept of determining the electron configuration of quantum numbers

Based on Figure 7. Determining the electron configuration of quantum numbers is in questions 6 and 7. In this indicator, misconceptions are classified as moderate with a percentage of 43%. This is because students have difficulty understanding quantum numbers and students are wrong in determining the last electron and wrong in identifying the main quantum number, magnetic quantum number, azimuth quantum number, and spin quantum number.

F. The concept of determining the relationship between the electron configuration of an element and its group position in the periodic table.

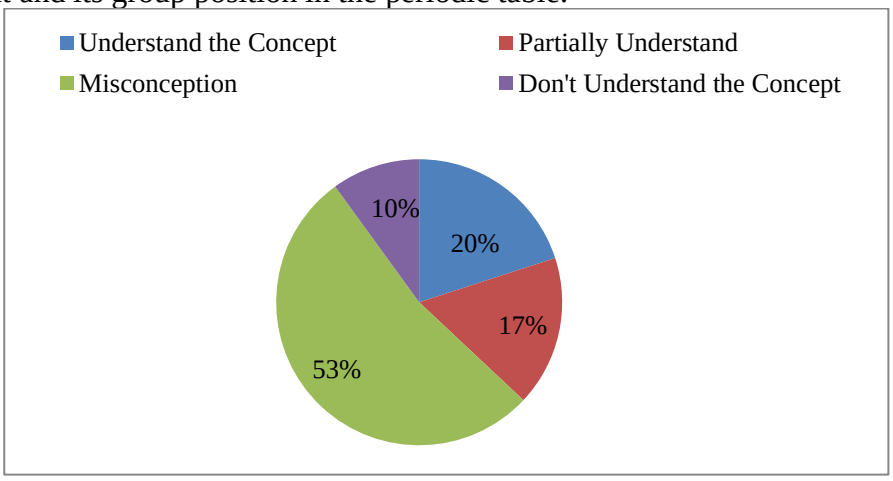

Figure 8. Determining the relationship between the electron configuration of an element and its location its group in the periodic table.

Based on Figure 8. Determining the relationship between the electron configuration of an element and its group position in the periodic table is in questions 8 and 9. In this indicator, misconceptions are classified as moderate with a percentage of 53%. This is because students have difficulty writing electron configurations, making it difficult to determine groups and periods.

G. The concept of concluding the relationship between atomic number and the periodic properties of elements

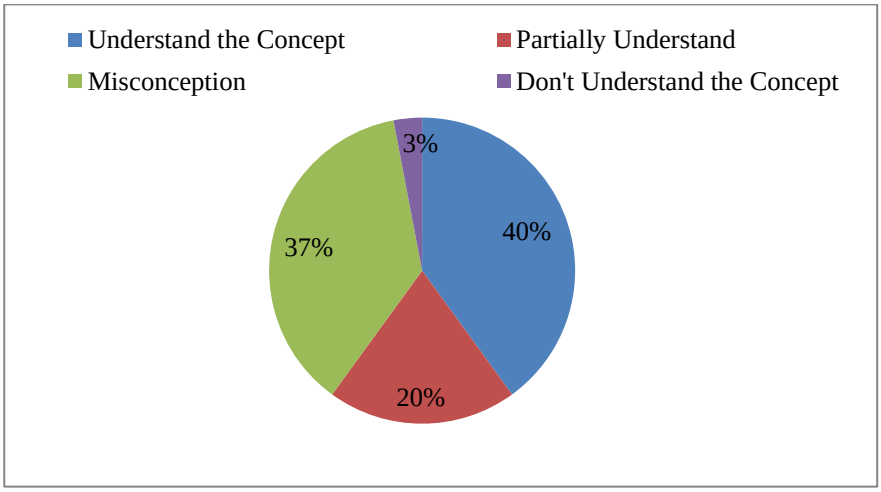

Figure 9. Conclude the relationship between atomic number and properties periodicity of elements

Based on Figure 9. Concluding the relationship between atomic number and periodic properties of elements is in question number 10. In this indicator, misconceptions are classified as moderate with a percentage of 37%. This is caused by a mistaken understanding of electronegativity in the periodic system. Students do not realize that in the halogen group, electronegativity decreases from top to bottom.

Students mistakenly assume that electronegativity increases with increasing atomic number, so they arranged the elements in the wrong order.

Misconceptions can be caused by external and internal factors. External factors include learning resources (books and the internet), the influence of other people, and teachers (Rosita et al., 2020). If the three external factors are explained with what happens in the field, the conditions are: (1) Learning resources: the books used by students are textbooks that are in accordance with the curriculum used at SMA N 1 Rambah, which books are in accordance with the concept according to experts and there are no errors in writing or mistranslation of the explanations of the book, so the possibility of causing misinterpretation or misconceptions is very low. (2) The influence of other people: classmates, dormitory friends and seniors of students. (3) Teachers: focus more on exercises than explaining in detail, less special emphasis on material that is considered difficult.

Internal factors are factors that come from within (the students themselves). This factor is the most likely cause of students experiencing misconceptions. These factors are conceptual errors, because students only learn mainly through memorization rather than understanding, lack of student accuracy in chemical calculations, incorrect reasoning, lack of ability to understand and remember material, students' ability to link concepts, lack of interest and motivation to learn, and difficulty in understanding the meaning of the terms used.

This is the task and concern of educators at SMA N 1 Rambah to improve the learning process for the better, emphasize concepts and analyze misconceptions about the books or worksheets used. In addition, students must also improve their understanding of the concept of the periodic system of elements, namely by students having to study more, discuss with teachers or ask questions, this is done in order to reduce the occurrence of misconceptions (Trisan Amelia, Rina Elvia, 2022).

• CONCLUSION

Based on the results of the data analysis, it can be concluded that there are misconceptions about the material of the periodic system of elements in all questions tested on the sample, with varying percentage levels for each question. The results of the study showed that there were misconceptions in all concepts of the periodic system of elements tested. The highest misconception occurred in indicator 6 at 53% in the indicator determining the relationship between the electron configuration of an element and its group position in the periodic table, while the lowest misconception occurred in indicator 4 at 11% in the indicator determining isotopes, isobars, and isotons. Overall, the percentage of misconceptions identified in the material of the periodic system of elements was 38% with a moderate category. The percentage for students who understood the concept was 32% with a moderate category, the percentage for students who partially understood was 19% with a low category, and for students in the category of not understanding the concept was 11% with a low category.

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