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Numerical Capacity Profile of Eleventh-Grade High School Students in Stoichiometry

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Abstract: PISA results for 2022 report that Indonesian student's numeracy skills have improved. However, the results are still below the global average and require continuous improvement. One attempt to enhance student's numeracy skills is by providing numeracy-based assessments that can be applied to chemistry subjects, one of which is stoichiometry. The study aims to identify and describe the numeracy profile of eleventh-grade high school students on stoichiometry. The method used is quantitative descriptive. The study subjects were eleventh-grade high school students who had received stoichiometry instruction. The instruments used consisted of nine questions that were validated and empirically tested (reliability score of 0.528, indicating a fairly reliable category). The study results showed that the students' numerical abilities obtained an average score of 67%, which was categorized as good. The percentage of students in the excellent category was 26%, in the good category was 47%, in the sufficient category was 24%, and in the less-than-sufficient category was 3%. The indicator accuracy rate was 61% for analyzing information such as tables, charts, and diagrams, 80% for using numbers and symbols, and 56% for interpreting analysis results. Numeracy skills in chemistry, particularly in stoichiometry, are crucial for achieving learning objectives and supporting global efforts toward quality education, as aligned with the SDGs. Enhancing these skills equips students with better problem-solving abilities in academics and real-life situations.

Keywords: assessment; numeracy; stoichiometry

INTRODUCTION

The results of the PISA 2022 survey indicate that Indonesia has experienced improvements in literacy, science, and numeracy (Kemendikbudristek, 2023). However, the results are still globally below the average, with a further decline in 2022 compared to 2018 (OECD, 2023). School development across Indonesia, in particular, still requires sustainable monitoring aligned with the Sustainable Development Goals (SDGs). The SDGs aim to ensure equitable and inclusive education and lifelong learning opportunities for all (OECD, 2023). Challenges to achieving the SDGs targets include the complexity of measuring literacy and numeracy (Grotlüschen et al., 2020). One of the efforts to realize the SDGs goals is to provide assessments that support students in their learning process (Rozhana & Sari, 2019).

Assessment as part of classroom activities is a fundamental process necessary to improve learning and ultimately enhance student achievement (Swaffield & Rawi, 2022). Assessments are tools used to gather information about student learning outcomes, including knowledge, attitudes, and skills (Rozhana & Sari, 2019). This assessment aims to identify students' progress in mastering their learned competencies. One essential skill that needs to be developed is numeracy. Numeracy refers to a person's ability to solve real-life mathematical, quantitative, and statistical problems (Gal et al., 2020). There are three indicators of numeration literacy: analyzing information in tables, images, and graphs; using numbers and symbols related to mathematics in everyday life; and interpreting the results of analysis to make decisions (Han et al., 2017). Although numeracy is often associated with mathematics, it can also be integrated into other subjects, such as chemistry. Chemistry is the part of science that studies the structure and composition of matter, the properties and changes of matter, and the energy involved in these changes. Compared to other sciences, the distinctive

characteristic of chemistry is the transformation that occurs when substances interact to form new substances, often involving energy changes (Hernani, 2014).

Stoichiometry is a branch of chemistry that quantitatively studies and calculates the relationship between reactants and products in a chemical reaction. Stoichiometry is often connected to other chemical concepts, as it is the foundation for basic chemical calculations, including moles, mass, atomic mass, and molecular mass. It is characterized by its reliance on fundamental concepts, principles, laws, and calculations in chemistry, which require consistent practice to ensure retention and prevent forgetting (Noorarnie et al., 2019).

Stoichiometry is closely related to numeracy because it involves calculations that can be applied in everyday life. For example, to determine the percentage of a gas in a mixture, one must calculate the mass of the desired gas relative to the total mass and then multiply by 100 to find the percentage. Additionally, stoichiometry can calculate the relative molecular mass of substances found in foods, such as citric acid, which gives oranges their sour taste. It can also determine the chemical reaction during fermentation, such as when glucose is converted into alcohol in making 'tape' (fermented cassava). Therefore, understanding stoichiometry requires students to have strong analytical and calculation skills and the ability to draw conclusions that help solve real-world problems. This is in line with the numeracy literacy indicators proposed by Han, which emphasize the importance of analyzing and calculating in problem-solving.

Learning in the classroom must be linked to the phenomena that occur in everyday life so that students can fully understand the learning process. Often, students are not allowed to understand the concepts, even at the beginning of direct learning; they are given abstract and concrete concepts simultaneously without being allowed to associate the two concepts. If the student is not trained to blend concepts, his knowledge is limited and will not develop (Ardhana, 2020).

Studies on high school student's numerical abilities in chemistry subjects are still rare. However, research conducted at MA Darul Ma'wa Plandirejo, Plumpang, Tuban, revealed that the numeracy skills of eleventh-grade students in solving science problems are still low, with 61.90% of students scoring below 50 (Winata et al., 2021). Another study conducted on twelfth-grade students studying evolutionary material found that 49% of students were categorized as having low numerical abilities (Rezky et al., 2022). Meanwhile, the numeracy literacy profile of tenth-grade students in mathematics subjects showed that 61% were in the medium category (Asriyanti et al., 2023).

Interviews with chemistry teachers at 1st State High School, Karangrejo Tulungagung, revealed that teachers often use written tests when conducting evaluations in chemistry subjects. These tests are considered more effective in accurately assessing student's abilities, particularly in subjective or descriptive formats that can better differentiate one student's abilities from another. However, few numeracy assessment instruments are still available, especially in chemistry. The school has not developed a numeracy assessment tool, so the student's numeracy profiles in stoichiometry have not been fully explored.

This study aims to identify and describe the numeracy skills profile of eleventh-grade high school students in stoichiometry. Despite the importance of numeracy skills in understanding stoichiometry and achieving learning objectives, there is limited information on how students at the high school level apply these skills. Therefore, this research will explore student's numeracy skills profile and provide valid information about their abilities in stoichiometry. The findings are expected to offer valuable insights into curriculum development and teaching methods in chemistry.

METHOD

This research is a type of quantitative descriptive research. Sampling techniques are purposive sampling, i.e., samples taken based on criteria. This criterion is based on the selection made by the chemistry teacher, that is, students who have almost the same abilities and have received the material of stoichiometry. The study involved 38 students from class XI of SMAN 1 Karangrejo Tulungagung. The data collection technique by writing tests uses a nine-question justified double-selection instrument representing three numeracy indicators: analysis of information in tables, diagrams, and graphs; using numbers and symbols related to mathematics in everyday life; and interpreting the results of analysis to make decisions. The question used is a multiple-choice question where students not only select an answer but also provide a justification for their choice. This format allows students to reflect on the reasoning behind their selected answer. It helps distinguish students who can reason and apply numeracy skills based on the established indicators. The question instrument was developed and evaluated for content validity, achieving a 90.88% rating, indicating a high level of agreement among experts regarding its coverage of the relevant content. Additionally, the instrument was empirically tested with a Cronbach's alpha of 0.528, indicating moderate internal consistency.

The interpretation of values is done by processing the scores obtained into the numbering ability scores formula as follows:

$$\text{Level of understanding} = \frac{\text{Student score}}{\text{Maximum score}} \text{ x } 100\%$$

In addition, the student's achieved grades are grouped into categories of numerical skill levels by the following formula:

$$\text{Student numeracy ability level} = \frac{\text{Number of students in a particular category}}{\text{Total Students}} \text{ x } 100\%$$

The achievement of the numerical ability indicator consisting of three indicators, according to Han, is categorized by the following formula:

$$\text{Indicator level} = \frac{\text{Student indicator score}}{\text{Indicator maximum score}} \text{ x } 100\%$$

Descriptive data analysis of this study is carried out by grouping student's answers according to the already established evaluation rubric and adjusted to the understanding category in the student's learning process as follows:

Table 1. Numeracy skills in the learning process (Arikunto, 2015)

Student end score	Student end score
80-100	Very good
60-80	Good
40-60	Enough
20-40	Less
0-20	Very less

RESULTS AND DISCUSSION

Results

The highest average score of 8.68 was achieved on issue number six, while the lowest average score, 2.66, was recorded on issue number seven. These scores represent the average scores obtained by students on each question, with an overall average score of 60.36.

Table 2. The average score on each question

1	2	3	4	5	6	7	8	9	Average total
8.32	5.21	5.39	7.89	7.58	8.68	2.66	8.00	6.63	60.36

Based on the results of the numeracy skill test that has been performed on 38 students of SMAN 1 Karangrejo Tulungagung, it was obtained that the numbering skill level of students, in general, is 67%, with a good category.

Table 3. Student numeracy skills based on scores

Student score	Total score	Percentage	Category
2294	3420	67%	Good

Students' numeration skills were acquired with varying levels of understanding based on the five categories presented in Table 1, where 26% had excellent numeration abilities with an average score of 83.42, and 3% had less numeration ability with a mean score of 36.6.

Table 4. Numeracy skills of students based on frequency and achievement of average value

Number	Frequency	Percentage	Average value	Category
1.	10	26%	83.42	Very good
2.	18	47%	68.27	Good
3.	9	24%	48.97	Enough
4.	1	3%	36.6	Less
5.	0	0%	0	Very less

Next, the percentage availability data of the numeration indicator was adopted from Han (2017). According to the study results, the level of numeracy ability of SMAN 1 Karangrejo Tulungagung students was reviewed from the numeracy indicator and spread into two of the five categories: very good and good. Students can master indicators using numbers and symbols, with a percentage of 80% in the very good category, while the indicator interpreting the analysis results obtained lower percentages, namely, 56% in the good category.

Table 5. Student numeracy ability based on numeracy indicators

Number	Indicator	Percentage	Category per indicator
1.	Analyses information in the form of tables, images, and graphs	61%	Good
2.	Using numbers and symbols related to mathematics in everyday life	80%	Very good
3.	Interpret analysis results to make decisions	56%	Good

Discussion

Student's numeracy skills generally obtained a 67% percentage with a satisfactory level. The results were in line with interviews with chemistry teachers who stated that students were still facing challenges with numeracy issues because they were unfamiliar with their work, in addition to the numerical tasks given accompanied by data such as tables, graphs, charts, or diagrams that required students to be able to analyze the provided information and use the numbers and symbols obtained to calculate and find answers and interpret the results of analysis to make decisions or conclusions. This is one factor in the reason that there are still few students who can answer numeration questions, especially on the material of stoichiometry. The student's mistake is to rush to work, not understand the information of the data on the subject that should be written, and not be able to write a conclusion properly (Khoirunnisa et al., 2023). Numbering skills can be said to be still medium. Although students can solve problems as a whole, some indicators are still not met, such as using numbers and symbols, the ability to read data, and errors in counting (Rizki et al., 2022).

The numeracy skills of the students in the category are excellent, 26%. The students in this category get an average score of 83.42. Overall, the students can answer questions according to the numeracy indicator. The answers of students who acquired the numeracy skills category excellently are shown in Figure 1. Figure 1 shows the question: "*Based on the table above, a 200-gram sample of pineapple juice yields a 7% citric acid extract. Assume the juice yield from pineapple is proportional to the citric acid extract in the juice. If 300 grams of pineapple are used, how many grams of juice will be produced? Provide your reasoning*!" Based on the answers given, students can analyze the data in a table that shows that the 200 grams of pineapple mass used produced 7%, and then students were able to write the second mass asked, namely, 300 grams. In their calculations, the student was able to determine the correct formula for finding the answer, namely multiplying the percentage of fruit pineapple by the weight of 200 grams and 7% by the mass of 300 grams asked, resulting in the correct answer, 21 grams. After finding the answer, the student can conclude that when using 300 grams of pineapple, in 7% of the pineapples, there are only 21 grams that produce a fruit cider. So, this student's answer has met the three numeration indicators.

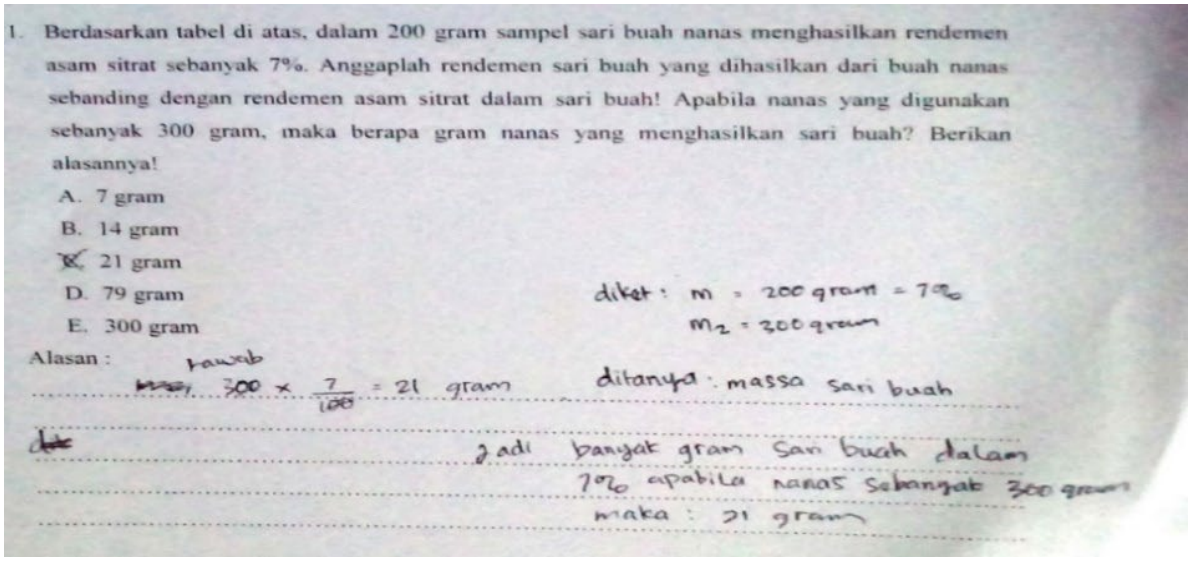
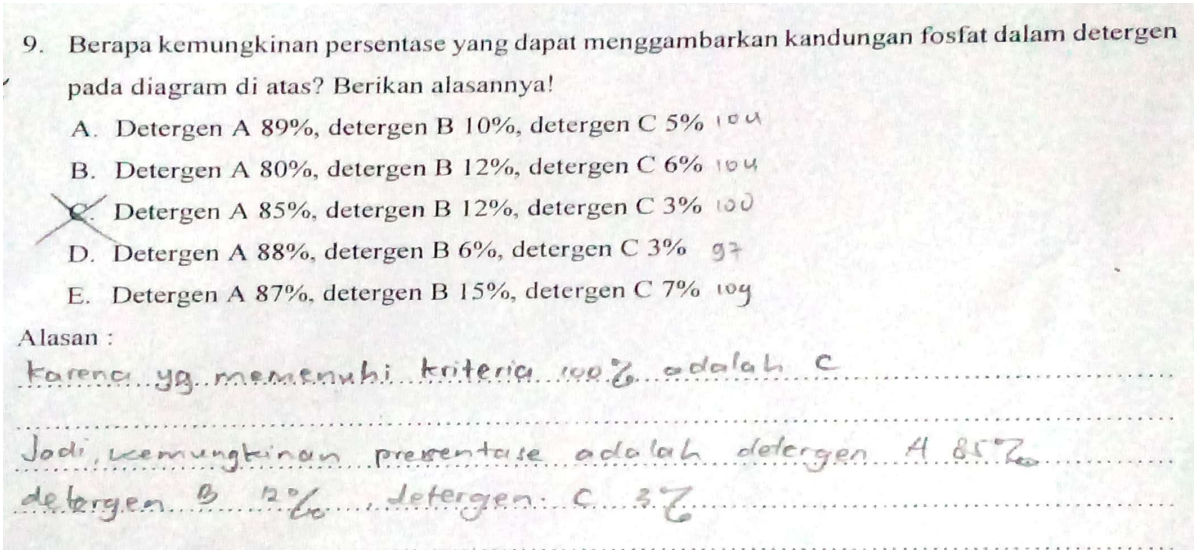


Figure 1. The student's answer presented excellent numeracy skills

The numeracy skills of the well-classified students are 47%. The students in this category have an average score of 68.27. The answers of the students who have achieved a good numeracy skills category are shown in Figure 2. Figure 2 shows the question: "*What is the possible percentage that could represent the phosphate content in the detergent in the diagram above? Provide your reasoning!*" The student did not include the information in the chart, so the student's answers did not meet the data-based information analysis indicator. However, suppose the student has met the second indicator using numbers and symbols marked with the total number of answers as a percentage result on each listed option. In that case, the student chooses an answer of 100%. In addition, students were able to conclude from the answers that had been obtained that the probability of the respective percentages of detergents A, B, and C was 85%, 12%, and 3%. So, this student's answer meets only indicators using numbers and symbols as well as interpreting the analysis results, even though it does not write down the information derived from the data described.

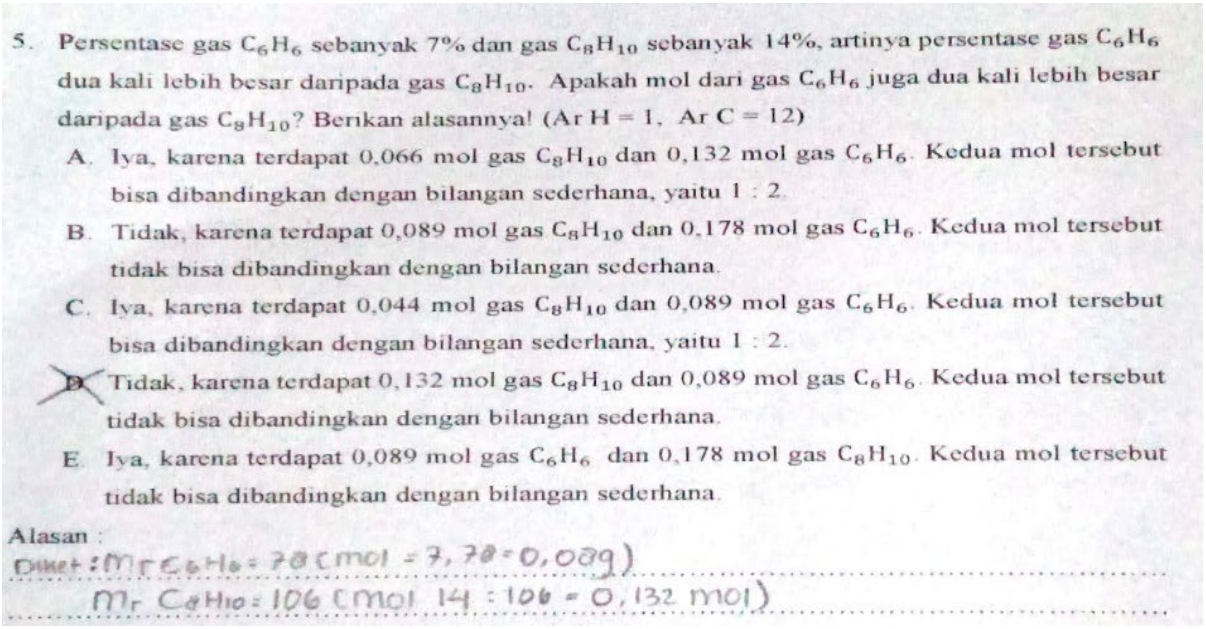

9. Berapa kemungkinan persentase yang dapat menggambarkan kandungan fosfat dalam detergen pada diagram di atas? Berikan alasannya!

A. Detergen A 89%, detergen B 10%, detergen C 5% 104
B. Detergen A 80%, detergen B 12%, detergen C 6% 104
C. Detergen A 85%, detergen B 12%, detergen C 3% 100
D. Detergen A 88%, detergen B 6%, detergen C 3% 97
E. Detergen A 87%, detergen B 15%, detergen C 7% 109

Alasan :
karena yg memenuhi kriteria 100% adalah C
Jadi, kemungkinan presentase adalah detergen A 85%
detergen B 12%, detergen C 3%

Figure 2. The student's answers showed good numeracy skills

The numeracy skills of the students in the category are 24%. The students in this category have an average score of 48.97. The answers of students who have achieved a good numeracy skills category are shown in Figure 3. As shown in Figure 3, the question reads: "*The percentage of gas C_8H_{10} is 7%, and gas C_6H_6 is 14%, meaning that gas C_6H_6 is twice as much as that of gas C_8H_{10}. Is the number of moles of gas C_6H_6 also twice as large as that of gas C_8H_{10}? Provide your reasoning!*" This student's answer did not show any results from analyzing the information. However, the students answered that they should look for moles by dividing the mass by the relative atomic mass of each of the gases asked. So, this student's answer did not meet the indicators of data-based information analysis and did not match the indicator of interpreting the analysis results, but it was correctly filled with indicators using numbers and symbols.


5. Persentase gas C_6H_6 sebanyak 7% dan gas C_8H_{10} sebanyak 14%, artinya persentase gas C_6H_6 dua kali lebih besar daripada gas C_8H_{10}. Apakah mol dari gas C_6H_6 juga dua kali lebih besar daripada gas C_8H_{10}? Berikan alasannya! (Ar H = 1, Ar C = 12)

A. Iya, karena terdapat 0,066 mol gas C_8H_{10} dan 0,132 mol gas C_6H_6. Kedua mol tersebut bisa dibandingkan dengan bilangan sederhana, yaitu 1 : 2.

B. Tidak, karena terdapat 0,089 mol gas C_8H_{10} dan 0,178 mol gas C_6H_6. Kedua mol tersebut tidak bisa dibandingkan dengan bilangan sederhana.

C. Iya, karena terdapat 0,044 mol gas C_8H_{10} dan 0,089 mol gas C_6H_6. Kedua mol tersebut bisa dibandingkan dengan bilangan sederhana, yaitu 1 : 2.

D. Tidak, karena terdapat 0,132 mol gas C_8H_{10} dan 0,089 mol gas C_6H_6. Kedua mol tersebut tidak bisa dibandingkan dengan bilangan sederhana.

E. Iya, karena terdapat 0,089 mol gas C_6H_6 dan 0,178 mol gas C_8H_{10}. Kedua mol tersebut tidak bisa dibandingkan dengan bilangan sederhana.

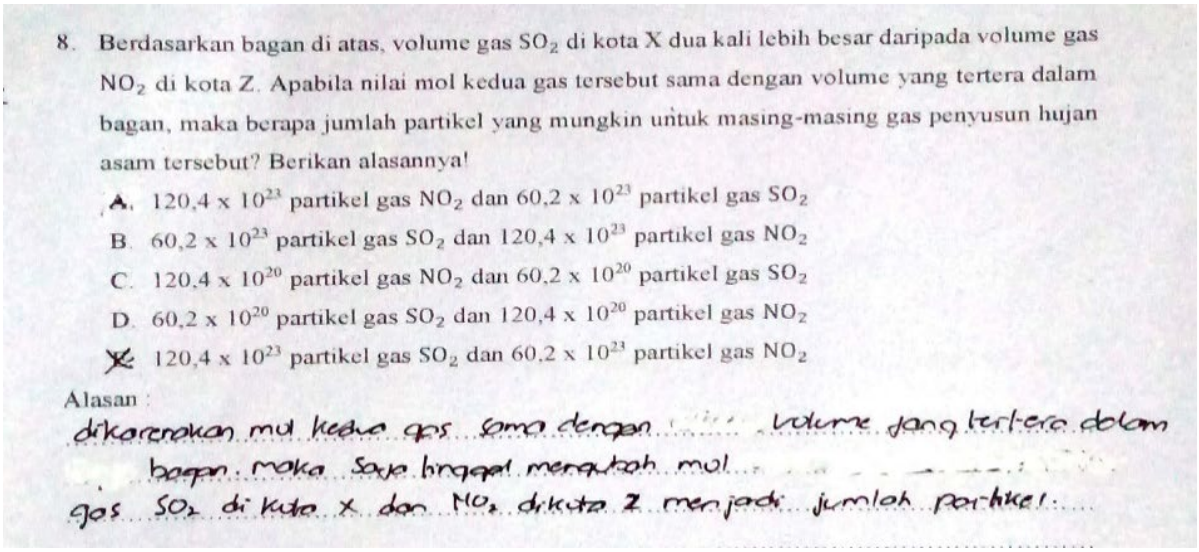
Alasan :

Diket: $M_r C_6H_6 = 78$ (mol = 7,78 = 0,089)

$M_r C_8H_{10} = 106$ (mol 14 : 106 = 0,132 mol)

Figure 3. The student's answer pictures sufficient numeracy ability

The numeracy skills of the students in the category are less than 3%. The students in this category have an average score of 36.6. The answers of the students who have achieved a good numeracy skills category are shown in Figure 4. As shown in Figure 4, the question reads: "*Based on the chart above, the volume of SO_2 gas in city X is twice as large as the volume of NO_2 gas in city Z. If the moles of both gases are equal to the volumes shown in the chart, what is the possible number of particles of each gas contributing to acid rain? Provide your reasoning*!" The student's answer only displays the result of analyzing the information without writing a method or calculation to obtain such an answer. Moreover, the student does not conclude the result from the answer received. Thus, the student's answer did not meet the indicators using numbers and symbols and did not match the indicator interpreting the analysis results, but already met an indicator analyzing the information from the data listed.


8. Berdasarkan bagan di atas, volume gas SO_2 di kota X dua kali lebih besar daripada volume gas NO_2 di kota Z. Apabila nilai mol kedua gas tersebut sama dengan volume yang tertera dalam bagan, maka berapa jumlah partikel yang mungkin untuk masing-masing gas penyusun hujan asam tersebut? Berikan alasannya!

A. $120{,}4 \times 10^{23}$ partikel gas NO_2 dan $60{,}2 \times 10^{23}$ partikel gas SO_2

B. $60{,}2 \times 10^{23}$ partikel gas SO_2 dan $120{,}4 \times 10^{23}$ partikel gas NO_2

C. $120{,}4 \times 10^{20}$ partikel gas NO_2 dan $60{,}2 \times 10^{20}$ partikel gas SO_2

D. $60{,}2 \times 10^{20}$ partikel gas SO_2 dan $120{,}4 \times 10^{20}$ partikel gas NO_2

X $120{,}4 \times 10^{23}$ partikel gas SO_2 dan $60{,}2 \times 10^{23}$ partikel gas NO_2

Alasan :

dikarenakan mol kedua gas sama dengan volume yang tertera dalam bagan. maka saya bisa mendapat mol gas SO_2 di kota X dan NO_2 di kota Z menjadi jumlah partikel

Figure 4. The student's answers depicted a lack of numeracy skills

The highest average indicator of student numeracy ability is found on the indicator using numbers and symbols related to mathematics in everyday life, which is 80% with very good categories. The

high average on this indicator is because the student can determine the formula to be used in completing the issue and can write the numbers on information such as tables, graphs, or diagrams according to the placement of symbols on the formula. It is increasingly empowered with the right students in the calculation to obtain answers listed in the double choice. The proper steps in determining these answers can be one of the strong reasons for describing his numerical abilities. A maximum score of 4 is given to students who can answer accurately and follow the specified evaluation section.

The next indicator in the second position is that the indicator analyzes information in the form of tables, graphs, or diagrams with either category of 61%. The student's ability to complete the question on this indicator is shown by data that must be analyzed to guide the student to acquire information before going to the next step of using numbers and symbols to find answers. The maximum score is 3 if the student can write the information contained in the data of the table, graph, or diagram displayed on the question.

On the indicator interpreting the results of the analysis to decide obtained the lowest percentage when compared to the other two indicators, which is 56% with a good category. In meeting this indicator, the student must write down a conclusion of all the steps taken on the previous indicator until finding the correct answer. A maximum score of 3 is given if the student can conclude. However, many students who did not write the conclusion of the process found the answer. They assume finding answers is the last step in answering questions.

Based on the data obtained, in general, the numeration ability of eleventh-grade high school students on the material stoichiometry is in a good category. This is proved by the average student score of 60.36, with a percentage of 67%. Compared to the research that has ever been done in completing the issue of mathematical numeration acquired, 61% of students are in the middle category (Asriyanti et al., 2023). In addition, in solving the science problem obtained, more than 50% of students who took the test earned a score below 50 (Winata et al., 2021). Even other research states that as much as 49% of students are in the category of less in completing the matter of evolution (Rezky et al., 2022). Although the average numbering skills in this study show good results, behind the results, there are still some students who need further monitoring to obtain excellent results, so teachers still need to give assessments in the field of numeration in chemistry subjects, especially in the material stoichiometry to be one of the efforts to the goal of SDGs is to get a quality education.

CONCLUSIONS

The numeracy ability of eleventh-grade high school students on the stoichiometry of high School students in SMAN 1 Karangrejo obtained a good category with 67%. The numeracy skills of students in the good category obtain the most significant percentage, namely 47%. An indicator of numeration ability obtaining the highest percent is an indicator using numbers and symbols related to mathematics in everyday life of 80%. As for the suggestion of this study to do observations with a larger scale or more significant number of students, it can also be done to students at colleges or schools on other chemistry topics.

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