

BUILDING EXERCISES TO DEVELOP CALCULATION CAPACITY FOR THE 11TH GRADE STUDENTS IN TEACHING THE TOPIC “SULFUR AND SULFUR COMPOUNDS” IN HIGH SCHOOL

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Calculation capacity is one of the specific competencies that need to be developed for students, formed mainly in teaching Mathematics and other subjects, including Chemistry. The development of calculation capacity can be accomplished by different methods. One of the effective measures is using exercises in teaching chemistry. In this paper, a procedure for constructing and application of the exercise “Sulfur and sulfur compounds” in order to develop calculation capacity for high school students will be presented.

Keywords: Calculation capacity; chemistry exercises; Sulfur and sulfur compounds; high school; students.

1. Introduction

The overall general education program provides a system of competencies that need to be developed for students, including general competencies (self-control and self-study, communication and cooperation, problem-solving and creativity), and specific competencies (language ability, computing ability, natural and social inquiry capacity, technological ability, informatics ability, aesthetic ability, physical ability). Thus, calculation capacity is one of the specific competencies that need to be developed for high school students (Ministry of Education and Training, 2018). There have been many research projects on developing computing capacity in teaching Mathematics (Nguyen Duong Hoang, Nguyen Danh Ngon, 2019; Pham Nguyen Hong Ngu, Phan Ba Le Hien, 2018). The issue of developing this capacity in teaching other subjects such as Chemistry has not been fully investigated. In practical teaching, chemistry exercises play a very important role, which is both the purpose, the content and the effective teaching method. Chemistry exercises not only provide students with knowledge, a path to knowledge but also brings the joy of discovery, exploration and detection of finding the answer, giving learners the excitement of awareness (Nguyen Ngoc Quang, 1994; Ministry of Education and Training, Department of Secondary Education, 2007). Chemistry

exercises have been used in teaching chemistry to formulate and to develop students' competencies such as problem solving and creativity, self-study, experimentation, perception and thinking, general thinking ability, collaborative problem-solving ability, etc. However, there are very few published researches using chemistry exercises to develop calculation competence for students in high schools (Tran Thi Hue, Nguyen Duc Dung, 2018; Nguyen Thi Phuong Lien et al., 2020; Pham Thi Tinh, Vu Thi Thu Hoai, 2019; Nguyen Tri Ngan, 2018).

In this article, the construction of exercises in the section “Sulfur and sulfur compounds” for grade 11 students in order to develop their calculation ability will be presented.

2. Research contents

2.1. Calculation competency

Competence is defined as the capacity to respond to individual, or societal, demands in order to perform an activity or complete a given task, which has been much mentioned in theoretical and practical fields. There are different views on the concept of competence. According to the 2018 General Education Program, competence is an individual attribute that is formed and developed through inherent qualities and through learning and training, which allows people to mobilize the synthesis of knowledge, skills and other personal attributes such as excitement, belief, etc. to successfully perform a certain type of activity, achieving the desired results under specific conditions (Ministry of Education and Training, 2018).

There are also many different views on calculation competency. For students, calculation competence is not only reflected in the understanding of numbers and calculations, but also in the ability to do calculations on pieces of paper, do mental calculations or technology usage (Mohammad Aliakbari, Elham Faraji, 2011). However, starting with the concept of capacity, calculation capacity is a person's intellectual capacity against problems, numbers, etc. in specific, goal-oriented and highly oriented exercises that require the mobilization of thinking ability, logical and proficient use of formulas and calculations to achieve the purpose of the exercise and put it into practice.

Competence of an individual is understood as a combination of all three contents: Knowledge, skills and attitudes. However, it is necessary to consider independently the structure of calculation capacity in teaching chemistry in order to specify the content that is necessary for the learner. On the theoretical basis to form the calculation capacity in teaching chemistry, combined with the survey of the teaching practice, investigated the computational activities of students in learning chemistry in grade 11, consulted chemistry teachers at high schools in Nghe An province, the manifestations and levels of assessment of chemical calculation ability of high school students have been formulated as Table 1.

Table 1: Manifestations and evaluation levels of chemical calculation ability

| Criteria | Manifestations | Evaluation levels | | |
|--------------------------|------------------------|-------------------------|------------------------|----------------------|
| | | Level 1 | Level 2 | Level 3 |
| 1. Identify knowledge of | Identify knowledge and | Incorrectly identifying | Correct but incomplete | Correct and complete |

| Criteria | Manifestations | Evaluation levels | | |
|--|---|---|--|--|
| | | <i>Level 1</i> | <i>Level 2</i> | <i>Level 3</i> |
| chemistry related to the exercise: concepts, chemical properties, etc. | concepts related to chemical problems to be solved. | knowledge and concepts related to exercises. | identification of knowledge and concepts related to the exercise. | identification of knowledge and concepts related to the exercise. |
| 2. Proficient in using chemical language, mathematical calculations, calculation tools, etc. | <ul style="list-style-type: none"> - Effectively use chemical language in solving exercises. - Proficient in using arithmetic operations, calculation tools, etc. to solve chemistry exercises. | <ul style="list-style-type: none"> - There are still many limitations in using the language of chemistry in problem solving - Understand how to apply arithmetic operations, tools, ... but not yet proficient. | <ul style="list-style-type: none"> - Relatively proficient in applying the language of chemistry to solve problems. - Relatively proficient in applying arithmetic operations, tools, etc. | <ul style="list-style-type: none"> - Proficient in applying the language of chemistry to solve problems. - Proficient in the application of arithmetic operations, tools, etc. |
| 3. Reasonable application of laws, rules, etc. to solve chemistry exercises | Be aware of and apply the laws, rules, etc. to solve chemistry exercises. | <ul style="list-style-type: none"> - Rarely apply the laws, rules, etc. to solve chemistry exercises. | <ul style="list-style-type: none"> - Having applied but not yet mastered the laws, rules, etc. to solve chemistry exercises. | Proficiently apply laws, rules, etc. to solve chemistry exercises. |
| 4. Set up a diagram to solve chemistry exercises. | Generalizing, modeling exercises through diagrams, graphs, etc. and solving chemical problems using established models. | Cannot express the given exercise in the form of symbols, diagrams, etc. | Able to model exercises in the form of symbols, diagrams, etc. but there are still a few flaws. | Model the given exercise in the form of symbols, diagrams, etc., and provide the appropriate solution. |
| 5. Propose a suitable solution method, be able to interpret the obtained results. | <ul style="list-style-type: none"> - Propose a suitable solution. - Discuss and interpret the results. | <ul style="list-style-type: none"> - Proposing inappropriate solutions. - Unable to solve the problem. | <ul style="list-style-type: none"> - Proposing appropriate solution methods under the guidance of teachers. | <ul style="list-style-type: none"> - Self-propose a suitable solution. - Discuss and interpret the results. |

| Criteria | Manifestations | Evaluation levels | | |
|----------|----------------|-------------------|---|---------|
| | | Level 1 | Level 2 | Level 3 |
| | | | - Provide comments on the obtained results. | |

In which, level 1 corresponds to a “not achieved”, the score range from 0 to 1 point. Meanwhile, level 2 corresponds to the level of “achieved”, which is rated above 1 point and up to 2 points. Level 3 corresponds to the level of “good and very good”, which is rated above 2 points and up to 3 points.

2.2. Chemistry exercises to develop students' calculation competency

Exercise is a category of teaching theory. For teachers, exercises are the element to control the teaching process. Meanwhile for students, an assignment is a task to be performed, a part of the learning content. For Chemistry subject, students have to use their own knowledge, skills and experience to complete assigned exercises (Bernd Meier, Nguyen Van Cuong, 2014).

Competency development orientation exercises focus on applying separate and different understandings to solve a new issue for learners, which is associated with life. It also helps students to gradually form and develop their capacity, helping teachers and educational administrators to evaluate the students' ability and to understand the level of qualification of the teaching process (Le Dinh Trung, Phan Thi Thanh Hoi, 2016).

The selection and construction of chemistry exercises to develop students' calculation competency need ensure the following principles:

- Ensure the training program's objective, requirements to be achieved and orientation to develop students' competence.
- Ensure the development of the components of calculation competency.
- Ensure the accuracy and scientificity of the knowledge of chemistry and other related sciences.
- Ensure systematic, logical.

The formation of chemistry exercises to develop students' calculation competency is carried out according to the following procedure:

Step 1: Identify the purpose of the exercises: The purpose of the exercises on the topic of sulfur and sulfur compounds is to consolidate knowledge and develop calculation capacity for students.

Step 2: Identify the content of the exercises: The content of the exercises should cover the knowledge of the topic “Sulfur and sulfur compounds”.

Step 3: Determine the types of exercises.

Step 4: Gather information to compose a system of exercises: The collection of information is done through textbooks, exercise books, reference books and documents related to the system of exercises to be formulated.

Step 5: Implement the construction of a system of chemistry exercises.

Step 6: Forming the answers, the explanation for the solutions, check the correctness, the scientific nature of the solution, style of expression and presentation, etc.

according to the oriented criteria for the development of the calculation capacity of the exercises.

Step 7: Conduct testing and tweaking: The constructed exercises need to be tested and edited to ensure the accuracy, correctness, the scientific nature of knowledge and skills, to be suitable for students and meet the educational goals of Chemistry in high schools.

In the topic “Sulfur and sulfur compounds”, the following 07 types of exercises can be proposed: (1) Sulfur single substance reacts with metals; (2) Sulphate salt precipitation reaction; (3) Sulfur dioxide reacts with alkaline solutions; (4) Sulfur dioxide reacts with strong oxidizing agent; (5) The issue of strong acidity of dilute H₂SO₄; (6) Oxidising properties of concentrated H₂SO₄ solutions; (7) Oleum - The dilution of the solution. In the next section, corresponding to each type of exercise mentioned above, an illustrative exercise will be proposed and analyzed.

a. Sulfur element reacts with metals

The proposed exercise is as follows: Heat a mixture of 4.8 grams of Mg powder and 3.2 grams of S powder in a vacuum sealed vessel. After a while, the mass of the solid obtained is:

- A. 8.0 g. B. 11.2 g. C. 5.6 g. D. 4.8 g.

Solution instructions: Two cases are possible: (1) Mg is left in excess, S is a limiting reagent (complete reaction); (2) Both Mg and S are left in excess (incomplete reaction). Since all substances are solids before and after the reaction, the mass of the substances must be the same, according to the law of conservation of mass. Therefore, the law of conservation of mass will be applied to solve this problem as follows: $m_{\text{solid}} = m_{\text{Mg}} + m_{\text{S}} = 4.8 + 3.2 = 8.0$ (g). This shows that answer A is correct.

Manifestations of calculation competency through this example are:

- The analysis is done based on the relevant chemistry knowledge and the given data.
- Applying the law of conservation of mass and select the appropriate method to solve the chemical problem.

b. Sulphate salt precipitation reaction

The proposed exercise is as follows: Slowly add Ba(NO₃)₂ solution to 30 ml of K₂SO₄ 1M solution until the mass of the precipitate starts to remain constant. The volume of Ba(NO₃)₂ solution used was 50 ml. What is the concentration of the Ba(NO₃)₂ solution?

- A. 0.03 M. B. 0.06 M. C. 0.05 M. D. 0.015 M.

Solution instructions: This problem is related to the exchange reaction of salt which involves the formation of a precipitate. When the mass of the precipitate starts to remain constant, it stops meaning that the reactants are considered sufficient. The chemical equation for the reaction is as follows:



The reaction is until the precipitate remains unchanged, that is, K₂SO₄ has been the limiting reagent.

$$\begin{aligned} n_{\text{Ba}(\text{NO}_3)_2} &= n_{\text{K}_2\text{SO}_4} = 0.03 \cdot 1 = 0.03 \text{ (mol)} \\ \Rightarrow C_{M(\text{Ba}(\text{NO}_3)_2)} &= \frac{0.03}{0.5} = 0.06 \text{ M} \end{aligned}$$

Therefore, answer B is correct.

Manifestations of calculation competency through this example are:

- Apply chemical knowledge about the chemical properties of salt.
- Use the learned formula.
- Use appropriate formulas to solve chemistry problems.

c. Sulfur dioxide reacts with alkaline solutions

The proposed exercise is as follows: 2.479 liters of SO_2 under standard conditions were completely absorbed into 150 ml of NaOH 1M solution to obtain solution Y. What is the mass of salt in solution Y?

- A. 11.5 g. B. 12.6 g. C. 10.4 g. D. 9.6 g.

Solution instructions: As an acid oxide, when SO_2 reacts with a base solution, it will produce acidic salts or neutral salts depending on the amount of reactants. The following cases can be distinguished:

$$T = \frac{n_{\text{NaOH}}}{n_{\text{SO}_2}}$$

$$\rightarrow \begin{cases} +T \leq 1 \rightarrow \text{forming NaHSO}_3 (T < 1 \rightarrow \text{excess SO}_2): \text{SO}_2 + \text{NaOH} \rightarrow \text{NaHSO}_3 \\ +1 < T < 2 \rightarrow \text{forming} \begin{cases} \text{Na}_2\text{SO}_3 \\ \text{NaHSO}_3 \end{cases} \rightarrow \begin{cases} \text{SO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_3 + 2\text{H}_2\text{O} \\ \text{SO}_2 + \text{NaOH} \rightarrow \text{NaHSO}_3 \end{cases} \\ +T \geq 2 \rightarrow \text{forming Na}_2\text{SO}_3 (T > 1 \rightarrow \text{excess NaOH}): \text{SO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_3 + 2\text{H}_2\text{O} \end{cases}$$

When solving problems of this type, the law of conservation of mass and conservation of elements can be applied, as follows:

$$T = \frac{0.15}{0.1} = 1.5 \rightarrow \text{forming two salts} \begin{cases} \text{Na}_2\text{SO}_3 \\ \text{NaHSO}_3 \end{cases}$$

Conservation of element S: $n_{\text{NaHSO}_3} + n_{\text{Na}_2\text{SO}_3} = n_{\text{SO}_2}$ (*)

Conservation of element Na: $n_{\text{NaHSO}_3} + 2n_{\text{Na}_2\text{SO}_3} = n_{\text{NaOH}}$ (**)

From (*), (**), draw: $n_{\text{NaHSO}_3} = 0.05$; $n_{\text{Na}_2\text{SO}_3} = 0.05$

\Rightarrow Salt mass: $m = 0.05 \times 104 + 0.05 \times 126 = 11.5$ (g). Therefore, answer A is correct.

Manifestations of calculation competency through this example are:

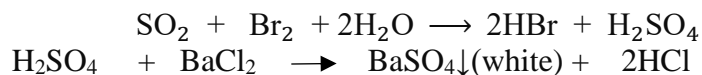
- Identify chemistry knowledge related to exercises to solve the assignments.
- Recommend suitable solution.

d. Sulfur dioxide reacts with strong oxidizing agent

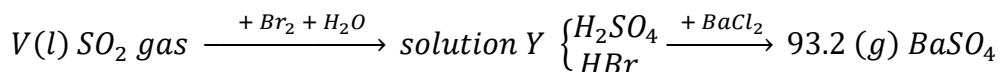
The proposed exercise is as follows: Absorb V liters of SO_2 (SATP - Standard Ambient Temperature and Pressure) with a sufficient amount of Br_2 solution to obtain solution Y. An excess amount of BaCl_2 solution was added to solution Y to obtain 93.2 grams of a white precipitate. The value of V is?

- A. 89.6. B. 99.2. C. 9.0. D. 9.9.

Solution instructions: SO_2 is a reducing agent when reacting with strong oxidizing agents such as KMnO_4 solution, Br_2 solution, etc. Thus, the reaction that occurs in the given problem is as follows:



Dealing with this issue, the law of conservation of elements, conservation of electrons, conservation of mass can be applied, whose diagram is as below:



Conservation of element S:

$$n_{\text{SO}_2} = n_{\text{H}_2\text{SO}_4} = n_{\text{BaSO}_4} = \frac{93.2}{233} = 0.4 \text{ (mol)}$$

$$V_{\text{SO}_2} = 0.4 \times 24.79 = 9.916 \text{ (l)}$$

Answer D is correct.

Manifestations of calculation competency through this example are:

- Identify the chemistry knowledge relevant to the exercise.
- Draw a diagram to solve the chemistry problem.
- Apply the law of conservation of elements, the calculation formula and choose the appropriate solution method to solve the chemistry problem.

e. The issue of strong acidity of dilute H₂SO₄

The proposed exercise is as follows: Completely dissolve 6.48 grams of mixture X consisting of Mg and metal M, which are of equal mass, in excess dilute H₂SO₄ solution to obtain solution Y and 0.315 mol H₂. The metal M is:

A. Ca. B. Al. C. Fe. D. Cu.

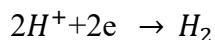
Solution instructions: The dilute solution of H₂SO₄ is a strong acid, so it has all the general chemical properties of an acid. With this type of exercise, the laws of conservation of mass, conservation of electrons, and conservation of elements can be applied.

Let k be the valence of the metal M.

$$m_{\text{Mg}} = m_{\text{M}} = \frac{6.48}{2} = 3.24 \text{ (g)}$$

$$n_{\text{Mg}} = \frac{3.24}{24} = 0.135 \text{ (mol)}$$

Oxidation and reduction processes:



Apply the law of conservation of electrons:

$$\Rightarrow 2 \cdot n_{\text{Mg}} + k \cdot n_{\text{M}} = 2 \cdot n_{\text{H}_2}$$

$$\Rightarrow n_{\text{M}} = \frac{2 \cdot 0.135 - 2 \cdot 0.315}{k} = \frac{0.36}{k}$$

$$\Rightarrow \text{M} = \frac{3.24}{\frac{0.36}{k}} = 9k \Rightarrow \begin{cases} k=3 \\ \text{M}=27(\text{Al}) \end{cases}$$

Answer B is correct.

Manifestations of calculation competency through this example are:

- Identify the chemistry knowledge relevant to the exercise.
- Apply the law of conservation of electrons to solve chemical problems.
- Proposing a suitable solution for the exercise.

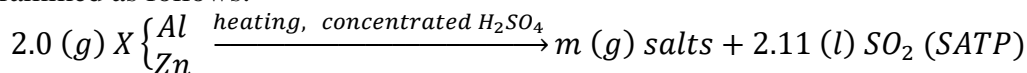
f. Oxidising properties of concentrated H₂SO₄ solutions

The proposed exercise is as follows: Completely dissolve 2.0 g of metal mixture X consists of Al, Zn by hot, concentrated H₂SO₄ solution. The result is solution Y and 2.11

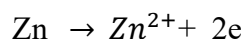
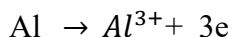
liters of SO_2 released (at SATP and is the only reduction product). After careful draining of solution Y, the resulting solid will be heated at a suitable temperature and time (to ensure complete removal of water) to obtain m (g) of anhydrous sulphate salt. The value of m is:

- A. 11.03. B. 10.16. C. 11.06. D. 10.33.

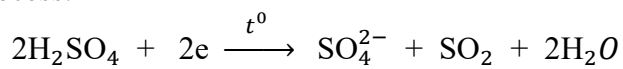
Solution instructions: Concentrated H_2SO_4 has strong oxidizing properties, reacts with most metals (except Au, Pt, etc.), many nonmetals such as C, P, S, etc., and compounds such as FeO, H_2S , etc. In those reactions, the S atom is reduced to a lower oxidation number. To solve exercises in this section, it is necessary to flexibly apply the laws of conservation of electrons, of mass, of elements, etc. The problem can be diagrammed as follows:



Oxidation process:



Reducing process:



$$n_{\text{SO}_4^{2-}} = n_{\text{SO}_2} = \frac{2.11}{24.79} \approx 0.085 \text{ (mol)}$$

Applying the law of conservation of mass, we have:

$$m_{\text{salts}} = m = m_{\text{metal ion}} + m_{\text{SO}_4^{2-}} = 2 + 0.085 \times 96 = 10.16 \text{ (g)}$$

Answer B is correct.

Manifestations of calculation competency through this example are:

- Identify the knowledge relevant to the exercise.
- Apply the law of conservation of mass and choose the optimal solution.

g. Oleum - The dilution of the solution

The proposed exercise is as follows: 38.7 grams of $\text{H}_2\text{SO}_4 \cdot 2\text{SO}_3$ oleum is added to 100 grams of 30% H_2SO_4 solution. A solution of X was obtained. What is the percent concentration of H_2SO_4 in X?

- A. 67.77%. B. 53.43%. C. 74.10%. D. 32.23%.

Solution instructions: Consider $\text{H}_2\text{SO}_4 \cdot 2\text{SO}_3$ to be a solution of H_2SO_4 whose concentration is: $\frac{98.3}{98+2.80} \cdot 100\% = 114\%$

Adding oleum to the H_2SO_4 solution is considered to be mixing two solutions of H_2SO_4 with different concentrations. Therefore, diagonal diagrams can be used to solve this type of exercise, as follows:

$$\begin{array}{ccc} 38.7 \text{ (g) } \text{H}_2\text{SO}_4 \cdot 2\text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4 \text{ (114\%)} & \begin{array}{c} \nearrow \\ \searrow \end{array} & \begin{array}{c} a - 30 \\ a \\ 114 - a \end{array} \\ 100 \text{ (g) } & \text{H}_2\text{SO}_4 \text{ (30\%)} & \\ \Rightarrow \frac{38,7}{100} = \frac{a - 30}{114 - a} & \Rightarrow a = 53.43\% & \end{array}$$

Answer B is correct.

Manifestations of calculation competency through this example are:

- Learn how to create diagrams to solve chemistry problems.

- Choose the appropriate method to solve the chemistry problem.

2.3. Pedagogical Experiments

The purpose of the pedagogical experiment is to evaluate the effectiveness of using exercises to develop students' calculation competency through teaching sulfur and sulfur compounds in grade 11 in high school. Pedagogical experiments were conducted at two schools: Dien Chau 3 High School (Experimental class: 41 students; Control class: 40 students) and Dien Chau 4 High School (Experimental class: 41 students; Control class: 42 students) in Dien Chau district, Nghe An province. The results of the assessment through the test are shown in Figure 1 and Table 2.

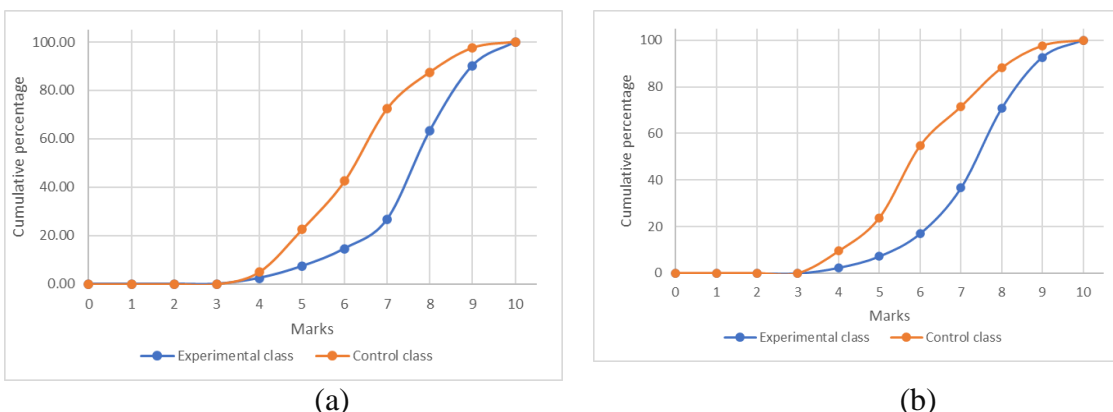


Fig. 1: Cumulative test score for students in Dien Chau 3 High School a) and Dien Chau 4 High School (b)

Table 2: Descriptive statistics for Experimental class and Control class in Dien Chau 3 High School and Dien Chau 4 High School

| High school | Dien Chau 3 | | Dien Chau 4 | |
|--------------------------------------|--------------------|---------------|--------------------|---------------|
| Class | Experimental class | Control class | Experimental class | Control class |
| Mod | 8 | 7 | 8 | 6 |
| The average point (\bar{X}) | 7.951 | 6.725 | 7.731 | 6.547 |
| Standard Deviation (SD) | 1.395 | 1.449 | 1.3788 | 1.533 |
| P-value (Independent-Samples T-Test) | 0.000109 | | 0.000196 | |
| Coefficient of Variation (V, %) | 17.54 | 21.54 | 17.83 | 23.41 |

Some comments obtained from the pedagogical experiments:

- The graph of the cumulative lines of the experimental class is always to the right and bottom of the cumulative lines of the control class.

- The standard deviation of the experimental class is smaller than the control class has demonstrated the smaller dispersion of the score around the average value of the experimental class, and the learning quality of the experimental class is more uniform than that of the control class.

- The experimental coefficient of variation V is between 10% and 30% (with average fluctuations). Therefore, the obtained results are reliable.

- The average score of students in experimental class is higher than that of students in control class. The P-value is less than 0.05, demonstrating that the difference between the experimental and control class results is statistically significant.

Based on the pedagogical experiment results and through the processing of the obtained data, quality of learning of students in experimental classes was higher than that of the control class. That shows the effectiveness of using the exercise system in developing calculation capacity for students in high school.

3. Conclusion

Chemistry exercises hold an important position in teaching Chemistry in high schools. The rational and flexible use of exercises in teaching contributes to the development of students' ability in general and calculation capacity in particular.

The theoretical basis of capacity, calculation capacity, process of building chemistry exercises towards capacity development for students have been presented in a general way in the article. The system of exercises "Sulfur and sulfur compounds" has been built and used in the process of pedagogical experiments. The results of pedagogical experiments initially show the effectiveness of using exercises in developing calculation capacity for high school students.

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TÓM TẮT

XÂY DỰNG HỆ THỐNG BÀI TẬP NHẪM PHÁT TRIỂN NĂNG LỰC TÍNH TOÁN CHO HỌC SINH TRONG DẠY HỌC PHẦN “SULFUR VÀ HỢP CHẤT SULFUR” LỚP 11 TRUNG HỌC PHỔ THÔNG

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Năng lực tính toán là một trong những năng lực đặc thù cần phát triển cho học sinh, được hình thành chủ yếu trong dạy học môn Toán và môn số môn học khác, trong đó có Hóa học. Việc phát triển năng lực tính toán có thể được thực hiện bằng nhiều biện pháp khác nhau. Một trong những biện pháp hữu hiệu là sử dụng bài tập trong dạy học hóa học. Nội dung bài báo trình bày quy trình xây dựng và sử dụng bài tập phần “Sulfur và hợp chất sulfur” nhằm phát triển năng lực tính toán cho học sinh trung học phổ thông.

Từ khóa: Năng lực tính toán; bài tập hóa học; Sulfur và hợp chất sulfur; trung học phổ thông; học sinh.