



A Comparative Analysis of the Contents of “Acid-Base Neutralization Titration” in the New and Old Editions of the Textbook Published by People’s Education Press Based on Core Competencies in China

Ma, Xiao-Li

College of Chemistry and Molecular Science,
Henan University, Kaifeng 475001, China

Hu, Wei-Ping

College of Chemistry and Molecular Science,
Henan University, Kaifeng 475001, China

ABSTRACT

In the new edition of the high school chemistry textbook, published by People’s Education Press in China in 2019, the knowledge of “Acid-Base Neutralization Titration” is extracted as an independent class hour from the content of “The Application of pH” in the old edition textbook published in 2004. Based on the idea of Chinese core competencies in chemistry, the contents of “Acid-Base Neutralization Titration” in the 2019 edition and the 2004 edition of Chinese high school chemistry textbooks are compared and analyzed in this paper. It is found that the new edition of textbook is optimized in many aspects, for example, a variety of columns are set up, exercises are simplified, and the content is more concise and organized. At the same time, some suggestions are presented about the approaches to cultivating students’ core competencies and the improvement of calculation method of the examples in the new edition of textbooks.

Keywords: Core competencies, Acid-base neutralization titration, Quantitative analysis, Teaching suggestions

With the promulgation of the “Chemistry Curriculum Standards for Senior High Schools (2017 edition)” (hereinafter referred to as the new curriculum standards), the chemistry textbooks used in Chinese high schools have also been revised accordingly. Acid-base neutralization titration experiment, which is the only titration method introduced, is also one of the most important quantitative experiments in high school chemistry^[1]. The knowledge of “Acid-Base Neutralization Titration” not only involves the mastery of the basic principles and concepts of acid-base balance, but also includes the cultivation of experimental operations and skill^[2]. In the new edition, the content of “Acid-Base Neutralization Titration” is independent as a single class, and classified as a mandatory experiment in the new curriculum standards, which proves its importance in high school chemistry. For teachers, making good use of the knowledge of this course can not only impart titration knowledge to students, but also deepen students’ understanding of quantitative analysis, expand the depth and breadth of students’ knowledge of the whole chemistry discipline, and cultivate students’ core competencies in chemistry.

The “Acid-Base Neutralization Titration” knowledge in the textbook published by People’s Education Press in 2019 (hereinafter referred to as the new edition) and in 2004 (hereinafter referred to as the old edition) is analyzed in this paper. So that teachers can better understand the difference between the new and old edition, make better use of the new edition in the teaching process, and develop students’ core competencies in chemistry.

CONCEPT ANALYSIS

In quantitative analysis, in order to ensure the accuracy of the measurement, the number of reserved digits in the experimental data processing is not arbitrary, but should be determined according to the accuracy of the instrument and the analysis method. Significant figure is the number used to represent the size of the value and reflect the accuracy of the measurement. The number of significant figures directly affects the relative error in quantitative analysis, which is composed of the accurate digits and one estimated digit with uncertainty^[3]. In data processing, the number of significant figures in each measured value may vary because of different measuring instruments, so it is necessary to modify the significant figures of the calculated results according to the rules of half adjust. The rounding of numbers generally adopts the rule of “Round half to even” according to Chinese national standard. According to this principle, the rounding decision depends on the digit immediately preceding the 5. If the preceding digit is even, the number is rounded down. If the preceding digit is odd, the number is rounded up. When adding or subtracting several data, the number of significant figures should be determined by the data with the least number of decimal places. The other data should be rounded to match that number. In the case of data multiplication and division, the number of significant figures shall be determined according to the minimum number of significant figures in the data.

THE COMPARISON OF TEXTBOOK CONTENTS FROM THE PERSPECTIVE OF CORE COMPETENCIES

Since the implementation of the new curriculum standards, there has been an increasing recognition of the importance of cultivating students’ core competencies. The five core competencies of macroscopic identification and microscopic analysis, concept of change and balance thinking, evidence reasoning and pattern cognition, scientific inquiry and innovative thinking, as well as scientific spirit and social responsibility are condensed in the new curriculum standards in high school chemistry, which conforms to the trend of the reform and development of world education, as well as the needs of national development^[4]. The updating direction of textbook is also an important guide for teachers and students. Many changes have been made in the new edition.

Column Settings

The arrangement of textbook columns is an important reflection of the principles underlying textbook compilation and serves as a crucial means of realizing the objectives of the curriculum^[5]. Through various forms of column setting, students can establish a scientific learning style and rigorous learning attitude. After comparing the old and new editions, it can be found that the column of “Acid-Base Neutralization Titration” has great differences, and the relationship between the type and quantity of column settings is shown in Table 1.

Table 1: Comparison of column types and numbers in “Acid-Base Neutralization Titration” in the new and old editions

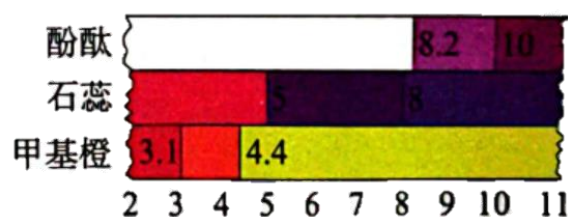
	Old edition		New edition		
Column composition	Data; Practical Activity		Data Card; Method Index; Experimental Activities		
Number of columns	1	1	1	1	1
Total number of columns	2		3		

As shown in Table 1, the types of columns in the new edition are more diverse. The setting of “Qualitative Analysis and Quantitative Analysis” column can help students master scientific methods, summarize experiment types, establish qualitative experiment and quantitative experiment models, and cultivate students’ core competencies of evidence reasoning and model cognition.

At the same time, the content of the new edition columns has been optimized accordingly. For example, there are obvious differences in the “Color-changing range of acid-base indicators” column between the new and old editions. In the new edition, the table of color transition ranges of indicators has been replaced by the illustration of color transition ranges of indicators. As a result, the color changes and different color transition ranges of methyl orange, litmus, and phenolphthalein indicators are accurately and visually demonstrated by this approach.

指示剂	变色范围 (pH)	颜色	
		酸性	碱性
甲基橙	3.1~4.4	红	黄
石蕊	5.0~8.0	红	蓝
酚酞	8.2~10.0	无	红

(a) Table of color transition ranges of indicators in old edition.



(b) Illustration of color transition ranges of indicators in new edition

Fig .1: Changes of “Data Card” in new and old editions

Exercise Setting

Exercise is one of the most important components in the textbook. By doing exercises, students can develop their problem-solving ability and promote the transfer of chemical knowledge^[6]. Furthermore, exercises provide guidance for students to learn the textbook. In the new edition, the “Review and Enhancement” section has been added at the end of each chapter, instead of an exercise section after section in the previous edition of optional Chemistry 4 textbook. This section helps students to assess their understanding of the chapter’s knowledge and provides both teachers and students with directions and ideas for learning. Students do exercises and then reinforce their understanding by reviewing the entire chapter, which aligns with their cognitive and psychological development.

As for the exercise contents of this section, the comparison and analysis of the questions in the new and old editions are shown in Table 2. In the new edition, although the total number of exercises in this section has been decreased, the proportion of exercises related to “Acid-Base Neutralization Titration” has been increased from 27.27% to 42.86% in the section “Ionization of Water and pH of Solution”. At the same time, in the “Review and Improvement” part of the new edition, two exercises related to titration also has been set up. It shows that the status of “Acid-Base Neutralization Titration” knowledge has been greatly promoted in new edition.

Table 2: The comparison of the number of exercises in sections and chapters on “Acid-Base Neutralization Titration” in the new and old editions

	Section exercises	Related to acid-base titration	Proportion	Chapter exercises	Related to acid-base titration	Proportion
New edition	7	3	42.86%	10	2	20%
Old edition	11	3	27.27%	—	—	—

Content Setting

Comparative Analysis of Text Content:

Through the analysis of columns and exercises, it can be found that the new edition has been optimized in many aspects. For the text contents in “Acid-Base Neutralization Titration”, most of the differences between the new and old editions are in the expression of individual terms. As shown in Table 3, compared with the old edition, the terms of the new edition are more concise and more convenient for students to understand. Table 3 Comparison of the contents of “Acid-Base Neutralization Titration” between the new and old editions

Textbook edition	Old edition	New edition
Content	When the acid-base neutralization reaction is complete, As the percentage of acid-base neutralization increases	As the acid-base neutralization reaction proceeds
	Using the quantitative relationship between acid and base expressed in the chemical equation, it can be calculated that...	It can be calculated that...
	When approaching the end point of the titration (pH=7), a very small amount (0.04ml, about a drop) of a base or acid can cause a sudden change in solution pH	When approaching the end of the titration, a very small amount of base or acid will cause a sudden change in the pH of the solution

In addition to some differences in language expression, the biggest changes in content between the new and old editions are reflected in the calculation process of the example section on “Acid-Base Neutralization Titration”. The comparison of the problem-solving process ideas in the new and old editions is shown in Figure 2. From the comparison, it can be seen that the reasoning process in the new edition is clearer and more concise. Based on stoichiometric relationship of acid-base neutralization titration, a calculation model for calculating the concentration of base, $c(\text{NaOH}) = \frac{c(\text{HCl}) \cdot V[\text{HCl}(\text{aq})]}{V[\text{NaOH}(\text{aq})]}$, has been built. Students’ core competencies of

evidence reasoning and pattern cognition is better established through such reasoning presentation process. However, the accuracy of the calculation method of this example in the new edition is still in doubt.

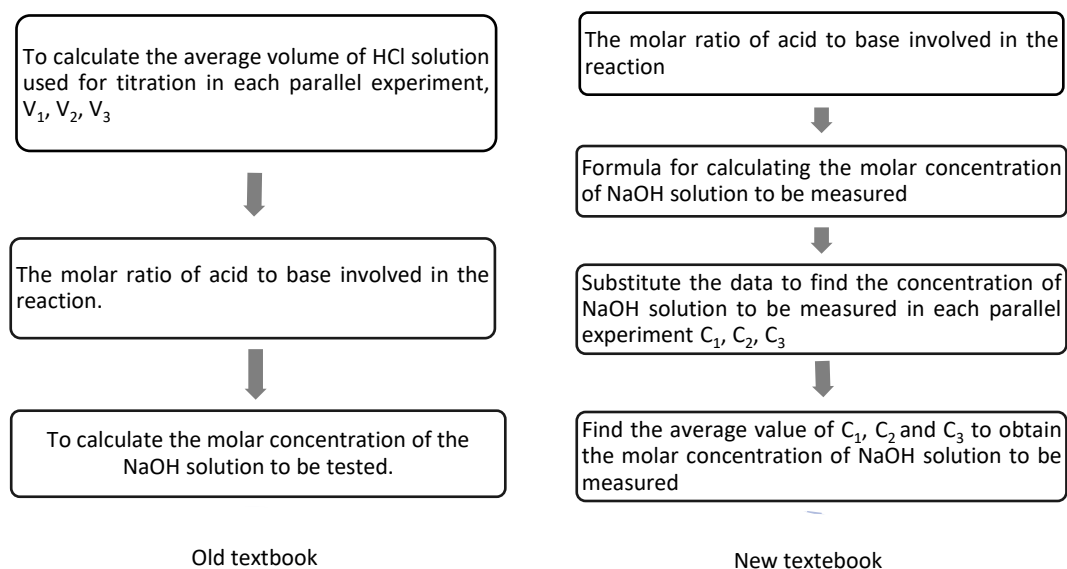


Fig. 2: Comparison of calculation process of examples in new and old editions

The principle of acid-base neutralization titration is $H^+ + OH^- = H_2O$. Using this stoichiometric relationship between acid and base, we can get the equivalent relationship of $c(HCl) \cdot V[HCl(aq)] = c(NaOH) \cdot V[NaOH(aq)]$, so as to calculate the concentration of the base in the problem. Considering the existence of random errors in measurement, three parallel experiments are set in the new and old editions. However, there are obvious differences in the treatment of the results of parallel experiments. In the old edition, the average value of the three determination results for $V[NaOH(aq)]$ is first calculated. Then the average value is substituted into $c(NaOH) = \frac{c(HCl) \cdot V[HCl(aq)] \cdot n(NaOH)}{V[NaOH(aq)] \cdot n(HCl)}$, which is derived from the chemical equation. In the new edition, the equation $c(NaOH) = \frac{c(HCl) \cdot V[HCl(aq)]}{V[NaOH(aq)]}$ is derived from the chemical reaction equation. Then, each $V[NaOH(aq)]$ is substituted to calculate the value of $c(NaOH)$. Finally, the average value of the three $c(NaOH)$ values is taken. In the example, due to the clever setting of experimental data in the new and old editions, the results of the two calculation methods are the same. But in this type of problem under different data, different calculation methods may have different answers. Therefore, considering the rigor of the textbook, the author has the following opinions.

In scientific experiments, the accuracy of any measurement of a physical quantity has a certain limit. The last digit of the significant figure in the measurement is often estimated and is called the suspicious digit. In this example, the concentration of HCl solution and the volume of NaOH solution to be measured have been clearly given, as a result, the difference in the volume of titrant consumed during titration process is the source of random error in this problem. In the old edition, the example begins by computing the average volume of the consumed HCl ($\bar{V} = \frac{V_1 + V_2 + V_3}{3}$), and then the average value is substituted into the equivalent relationship to obtain

" $c(\text{NaOH}) = \frac{c(\text{HCl})}{V[\text{NaOH}(\text{aq})]} \times \frac{V_1 + V_2 + V_3}{3}$ ". This approach reduces the random error in the determination of $V[\text{HCl}(\text{aq})]$ by averaging the parallel measurements.

However, In the new edition, each measurement value with a suspicious digit (V_1 , V_2 , V_3) is individually substituted into the equivalence relationships derived from chemical equations. Then calculate the average of the data obtained, and obtain the equation " $c(\text{NaOH}) = \frac{1}{3} \left[\frac{c(\text{HCl}) \times V_1}{V[\text{NaOH}(\text{aq})]} + \frac{c(\text{HCl}) \times V_2}{V[\text{NaOH}(\text{aq})]} + \frac{c(\text{HCl}) \times V_3}{V[\text{NaOH}(\text{aq})]} \right]$ ". In this method the error caused by volume is transmitted to the concentration. Is this approach scientific? It is worth noting that the calculation method adopted in the new edition is step-by-step calculation, so the final equation " $c(\text{NaOH}) = \frac{1}{3} \left[\frac{c(\text{HCl}) \times V_1}{V[\text{NaOH}(\text{aq})]} + \frac{c(\text{HCl}) \times V_2}{V[\text{NaOH}(\text{aq})]} + \frac{c(\text{HCl}) \times V_3}{V[\text{NaOH}(\text{aq})]} \right]$ " from the new edition here cannot be directly simplified as " $c(\text{NaOH}) = \frac{c(\text{HCl})}{V[\text{NaOH}(\text{aq})]} \times \frac{V_1 + V_2 + V_3}{3}$ ". This means that the significant figures at every step in the calculation process of the new edition needs to be retained according to the calculation rules for significant figures.

The number of significant figures in the old edition depends firstly on the number of decimal places in V_1 , V_2 , and V_3 , then on the number of significant figures in $\bar{V}$, $c(\text{HCl})$, and $V[\text{NaOH}(\text{aq})]$. In the new edition, it depends firstly on the number of significant figures in $c(\text{HCl})$, $V[\text{NaOH}(\text{aq})]$ and V_1 , and then on the number of decimal places in the value of " $\frac{c(\text{HCl}) \times V_1}{V[\text{NaOH}(\text{aq})]}$ ". However, the numbers retained differently after half adjustment due to a different calculation sequence. For instance, if the values of " V_1 ", " V_2 ", and " V_3 " are determined as "26.80mL", "26.78mL", and "26.85mL" respectively, the results obtained from the new and old editions would be "0.1107mol/L" and "0.1106mol/L" respectively. It is evident that the outcomes differ. From the author's perspective, the methodology of data processing in the old edition is more scientific.

Comparative Analysis of "Practical Activity":

In the old edition, the "Practical Activity" column is classified under the "Application of pH" section. As a consequence, "Practical Activity" places greater emphasis on the subject of acidity and alkalinity. The new edition focuses on the acid-base neutralization titration process, and the column labeled "Experimental Activity" is titled "The Neutralization Titration of Strong Acid and Base".

Regarding the content of "Practical Activity", the comparison between the new and old editions is presented in Table 4. Because of the diverse themes, every aspect of the practice activities has been modified. For instance, in the section that introduces the techniques of using a burette, the conventional approach of starting with a specific initial reading has been replaced by a new method of counting from zero in the new edition.

Table 4: Comparison of experimental activities in different aspects of the new and old editions

content classification	Old edition	New edition
experimental objective	Practice measuring pH with a pH meter; Learn how to graphically process data;	Practice neutralization and titration operations; Master data analysis methods; Understand the principle of neutralization titration
experimental principle	Acid-base titration curve	-
experimental supply	About 0.1mol/L HCl solution; About 0.1mol/L NaOH solution; pH meter	0.1000mol/L HCl solution; A solution of NaOH around 0.1000 mol/L
Burette start reading	Keep the liquid level at a certain scale	Set the liquid level at the “0” scale
Experimental column	Experimental Purpose → Experimental Principle → Experimental Supplies → Experimental Instrument Instructions → Experimental Preview → Experimental Operation Tips → Experimental Requirements	Experiment Objective → Experiment Supplies → Experiment Procedure → Problem and Discussion

TEACHING SUGGESTIONS

Determination of the content of elements, ions, functional groups and other components in a substance is called quantitative analysis in chemistry^[7]. Quantitative analysis is an indispensable analytical method not only at the high school level, but also at every stage of chemistry. In the new curriculum standards, there are only two mandatory quantitative experiments—the preparation of solution with a specific molar concentration and the neutralization of strong acid and base.

When teaching this class, teachers should make full use of the textbook and conduct in-depth research on the textbook. Teachers should not only understand the updates of the textbook and grasp the trends of the new edition, but also understand why the updates are made and what the purposes of the updates are, so as to better integrate the research on the textbook into their teaching process. Teachers should make good use of the new edition through certain teaching design, reflect the updating direction of the new edition in the classroom, and provide students with the learning direction.

In the teaching process, teachers should make full use of the method guidance column of “Qualitative Analysis and Quantitative Analysis”, cultivate students’ chemistry thinking in the quantitative analysis. Such as, how to design experimental scheme in quantitative experiment; how to get more accurate experimental data, how to analyze the experimental data and how to reduce the measurement error in the experiment, which are particularly important for the cultivation of core disciplinary literacy of evidence reasoning and pattern cognition^[8]. Teachers should cultivate students’ core competencies in chemistry through the optimal design of classroom teaching. Through teaching design, students can understand the difference between qualitative analysis and quantitative analysis models. They can also experience the significance

of quantitative experiments in chemical research and establish corresponding cognitive model. This model enables them to effectively classify the knowledge they encounter.

The overall development of students should be focused on. Teachers should cultivate their innovative thinking, rigorous and critical scientific attitude, as well as a sense of social responsibility. The concept of “quantity” is extremely important both in the theoretical discipline of chemistry and in the application of chemistry in daily life. The “acid-base titration” as one of the most significant and fundamental methods in titration, conveys irreplaceable quantitative thinking to students. By engaging in the learning of this knowledge and in the recording and calculating of experimental data, students can develop innovative and truth-seeking spirit, and have comprehensive and accurate understanding of chemistry.

References

- [1] Mingsheng Wu, Xianjun Li. Teaching design of “Neutralization Titration” [J]. Journal of Chemical Education, 2008(06):19-21.
- [2] Chenxi Gu, Cheng Ping. Generation and Development of “Neutralization Titration” Knowledge and Its Teaching Value[J]. Journal of Chemical Education, 2021, 42(03):105-108.
- [3] Xinrui Zhang, Sa Wu, Renjun Chen, et al. Method for Determining Effective Number of Calculation Result Based on Uncertainty Analysis[J]. Environmental Technology, 2020, 38(05), 161-165+171.
- [4] Chongde Lin . Research on the core competencies of Chinese students[J]. Journal of Psychology and Behavior Research, 2017, 15(02), 145-154.
- [5] Shuang Li, Lihong Gong. A Study on Conversion of New and Old Chemistry Textbook Columns[J]. Teaching in Forest Region, 2020(06), 95-98.
- [6] Wenfa Yan, Yao Zhang, Yuan Ma. Context-based design of high school chemistry exercises: Taking exercises in the new edition of People’s Education Press textbooks as an example[J]. Chemistry Teaching, 2021(01), 85-89.
- [7] Jing Wang, Changlong Zheng. General Senior High School Textbook: Chemistry, Selective Compulsory 1[M]. Beijing: People’s Education Press. 2019, 67.
- [8] Jiangnan Wu. Research on Quantitative Experiment Teaching of High School Chemistry Based on Chemistry Core Competence[D]. East China Normal University. 2022.