

Instructional Design of “General Methods for Studying Organic Compounds” Based on Real-life Scenarios - Elemental Composition and Material Structure of Nails

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Abstract. Protein is a necessary nutrient for human body. In common sense, most proteins are edible. Nails are important tissues of human body. Through the questionnaire of the main components of nails, cognitive conflict is established. Taking the content of the questionnaire and nails as the research carrier, students systematically analyzed, hypothesized and verified the elemental composition and structural characteristics of nails. Students understood the differences between nail protein and common edible protein structure. Through the extension after class, expand the understanding of the structure and use of keratin containing nails, hair and other substances. Assist students in improving their logical thinking skills in identifying, analyzing, and solving problems.

Keywords: protein; nail; project-based teaching; scientific inquiry.

1. Introduction

The course is the teaching content of Chapter 1 “Structural Characteristics and Research Methods of Organic Compounds” and Section 2 “General Methods for Studying Organic Compounds” in Fundamentals of Organic Chemistry^[1]. In the existing teaching design, in addition to the experiment of benzoic acid recrystallization, the general methods for studying organic compounds are mainly based on theoretical teaching^[2-4]. In the compulsory stage of high school chemistry, students focus on learning the composition, structure and properties of inorganic substances and typical organic compounds, and students have a certain understanding of chemical substances. Nails are selected as the research object to further enable students to have an in-depth understanding of the general methods of exploring chemical substances, cultivate students' ability to solve practical problems related to chemistry, and understand the important application and significance of chemistry in production and life.

2. Analysis of Teaching

2.1 Teaching Ideas and Innovations

Nails are important tissues in the human body, the main component of nails is protein, and nails, as research objects, are easy to obtain and non-toxic. By designing a questionnaire on the main components of nails, most students believed that the main components of nails were calcium carbonate and other substances with high hardness, which stimulated students' interest in exploring chemistry. Students use the knowledge they have learned to qualitatively and quantitatively detect the elemental composition of nails through combustion, concentrated sulfuric acid dehydration, pH test paper, lead acetate test paper and gas detection sensor, detect the structural characteristics of nails with hydrochloric acid, iodine water and newly produced copper hydroxide suspension, concentrated nitric acid and biuret reagent, and help students deeply understand the general methods and steps of studying organic compounds by consulting the literature on molecular weight, spectral analysis and microstructure of the main components of nails, and help students improve their ability

to comprehensively apply knowledge and enhance their ability of scientific inquiry and the formation of scientific concepts and systematic scientific methods.

2.2 Teaching Objectives of the Project

(1) The elemental composition of nails was systematically explored by the combustion-based detection of carbon and hydrogen, the dehydration of concentrated sulfuric acid for the detection of hydrogen and oxygen, the qualitative and quantitative detection of nitrogen and sulfur by pH test paper, lead acetate test paper and gas sensor. Master the general methods and steps of studying the composition of organic elements, and develop students' macro identification and micro analysis literacy.

(2) Through the experiment of fingernails with hydrochloric acid, iodine water, new copper hydroxide suspension and concentrated nitric acid, students are guided to use the biuret reagent to detect the protein structure of the compulsory biology course, be able to identify the peptide bonds in the protein structure of nails, master the general methods and steps of studying the structure of organic matter, and cultivate students' scientific spirit and innovation ability.

(3) Through literature review, students learned about the molecular weight and microstructure of nails, and knew that disulfide bonds are the main reason why nail proteins have a certain hardness. To improve students' ability of information extraction and integration, to appreciate the important role of chemistry in the development of life sciences and life and production, and to cultivate and develop the core literacy of chemistry with scientific spirit and social responsibility.

3. Teaching Process (Fig.1 Teaching design ideas)

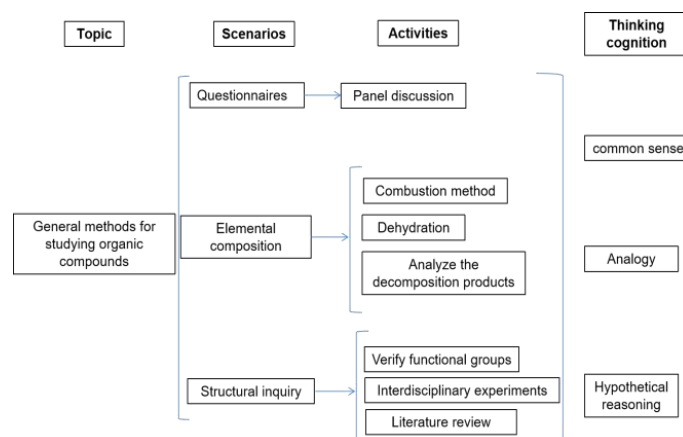


Fig.1 Teaching design ideas

3.1 Pre-Class Activities

A total of 216 votes were received for the survey of second-year high school students, as shown in Figure 2.

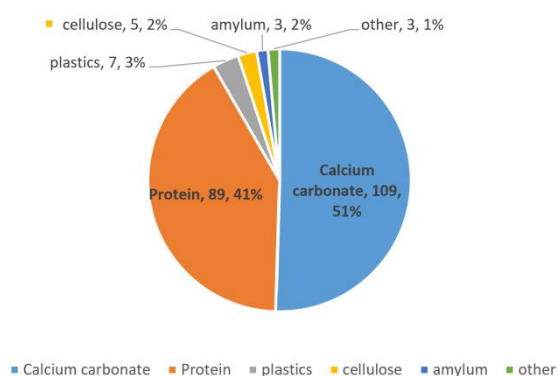


Fig.2 Questionnaire of nail components

As can be seen from Figure 1, there are as many as 109 votes that the main component of nails is calcium carbonate, accounting for more than half. Students tend to associate eggshells, marbles, etc., with calcium carbonate, which have a certain hardness, and it is difficult for them to associate nails with proteins. In chemistry and common sense, students' cognition is quite different, and real problem situations can help stimulate students' interest in learning chemistry knowledge.

3.2 Element Composition Verification

[Teacher] Elemental analysis is an important chemical analysis methods for studying the elemental composition of matter. When I studied inorganic substances in junior high school, I accumulated many qualitative analysis methods for determining the elemental composition of chemical substances. By understanding the characteristics of the chemical reaction that occurs in the substance and the properties of the product, the elemental composition of the substance is obtained.

[Teacher] Based on the questionnaire and the chemistry knowledge learned, how can [the teacher] prove the elemental composition and main components of the nails? The combustion method is one of the commonly used traditional methods to study the elemental composition of combustible substances. Design experiments and observe phenomena and draw conclusions.

[Student] Ignite the nails and observe the phenomena. The experiment is shown in Figure 3.

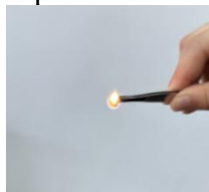


Fig.3 Nail burning experiment

[Student] Phenomena: Nails can be ignited, with black smoke and a pungent odor, and the residue after burning is black.

[Student] Conclusion: Nails contain carbon, possibly sulfur and nitrogen.

[Teacher] What other elements might be in the nails?

[Student] Concentrated sulfuric acid is dehydrated, which refers to the property of seizing hydrogen and oxygen atoms from a substance according to the ratio of hydrogen to oxygen in water molecules in a ratio of 2:1. Explore the reaction of concentrated sulfuric acid to the nail to verify whether the nail contains hydroxide.

[Teacher] Ask the students to wear gloves and take a little concentrated sulfuric acid on their fingernails and filter paper pieces as shown in Figure 4 to observe the phenomena.



Fig.4 Experiments with fingernails and paper with concentrated sulfuric acid

[Student] Phenomena: The filter paper gradually changes from white to dark brown, and the nails change from white to dark yellow.

[Student] Conclusion: Nails contain hydroxide.

[Teacher] Nails burning with a pungent odor, the preliminary judgment that the nails may contain sulfur and nitrogen, what other ways to verify the above judgment?

[Student] assumes that the pyrolysis of nails can produce acidic or alkaline gases, and that the gas can discolor the wet pH test paper, and if the pH test paper changes color, then use a gas detection sensor to quantitatively detect it, as shown in Figure 5.

[Student] After consulting the information^[5], lead acetate and sulfide are prone to black precipitate, and the volatile components of nails after pyrolysis can be detected with a test strip coated with lead acetate solution to observe whether there is a black precipitate. If black precipitation occurs, a gas detection sensor is used for quantitative detection. The experiment is shown in Figure 6.

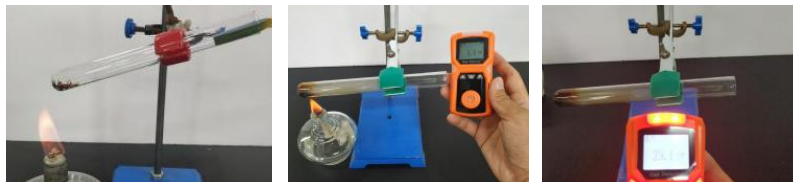


Fig.5 Verification experiment of nitrogen in fingernails

[Student] phenomena: The pH test paper is dark green and has a pH value of about 9. At the beginning of nail pyrolysis, the NH_3 sensor detected an NH_3 concentration of 1.1 mg/L at the mouth of the test tube. At the later stage of nail pyrolysis, the NH_3 sensor detected a rapid increase in NH_3 concentration to 29.1 mg/L near the test tube.

[Student] Conclusion: Nails contain nitrogen.

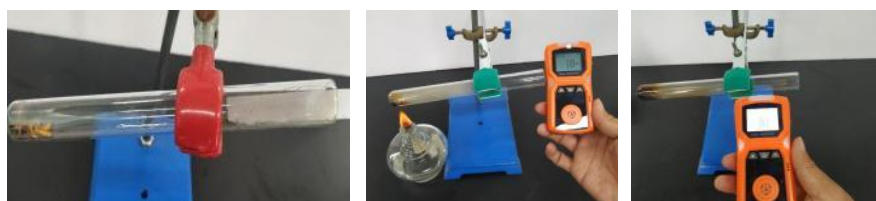


Fig.6 Verification experiment of sulfur in fingernails

[Student] Phenomena: The color of the filter paper strip coated with the lead acetate solution changes from white to gray. At the beginning of nail pyrolysis, the H_2S sensor detected that the H_2S concentration at the mouth of the test tube was 10mg/L. At the later stage of nail pyrolysis, the H_2S sensor detected a rapid rise in H_2S concentration to 51 mg/L near the test tube.

[Student] Conclusion: Nails contain sulfur.

[Teacher] Ask the students to summarize the types of elements that nail contains.

[Student] Through analysis, hypothesis, experimental verification, and testing, the types of elements contained in the nail are shown in Table 1 below.

Table 1. Composition of non-metallic elements of nails

Numbers	Phenomena	Elements
1	The nails burn and emit black smoke, and the residue is black	carbon
2	Burning nails have a pungent odor	sulfur and nitrogen
3	When the nails encounter concentrated sulfuric acid, they turn dark yellow in color	hydrogen and oxygen
4	The nail pyrolysis product turns the wet pH test paper dark green, and the NH_3 sensor shows 29.1 mg/L	nitrogen
5	The nail pyrolysis product caused the lead acetate test strip to turn gray from white, and the H_2S sensor showed 51mg/L	sulfur

3.3 Verification of material structure

[Teacher] The main elements that make up nails are C, H, O, S, N, etc., what are the main material structures in nails? Based on the student questionnaire, verify them one by one.

[Group 1] Obtaining the relative molecular weight of a substance is of medium significance for studying the composition and structure of an unknown substance. The relative molecular weights of the main components of nails were reviewed through literature review^[6]. This is shown in Table 2.

Table 2. Relative molecular weights of the appearance of African grey parrots

Numbers	Sample	Relative Molecular Weight
1	Remex	10500
2	Outer feathers	10500
4	Paw nails	15500
5	Scurf	15500
6	Mouth sheath	15500

[Group 1] The relative molecular weight of the main components of the nail is about 15500. Conclusion: The main components of nails belong to polymer compounds.

[Group 2] It is known that the molecular weight of carbonate cannot be in the tens of thousands. In order to further prove that the main component of the nail is not carbonate, hydrochloric acid can be used to react with the nail to observe whether there is gas production, as shown in Figure 7.

[Group 3] Starch is a polymer compound. It is known that starch turns blue when exposed to iodine water, assuming that the main component of the nail is starch, observe whether the nail appears blue after mixing with iodine water, as shown in Figure 8.

[Group 4] Cellulose is a polymer compound. Glucose mixed with a new copper hydroxide suspension and heated to produce a brick-red cuprous oxide precipitate. Assuming that the nail is cellulose, the cellulose is hydrolyzed by sulfuric acid to produce glucose, which is neutralized by adding sodium hydroxide solution, and then mixed with the new copper hydroxide suspension and heated, and the brick-red precipitate is observed, as shown in Figure 9.

[Group 5] Proteins are polymer compounds. The benzene ring group on the amino acid can react with concentrated nitric acid and appear yellow. Suppose the nail is a protein, and the protein is made up of amino acids with a phenylcyclic group on them. An experiment to investigate the reaction between the nail and concentrated nitric acid to see if the nail appears yellow, as shown in Figure 10.

[Group 6] The covalent bond formed by the carboxyl group of one amino acid and the amino group of another amino acid is called a peptide bond. In protein molecules, amino acids are linked together by peptide bonds to form peptide chains. Chapter 2 of the Biology Volume II (Compulsory) of the Renjiao Edition of High School “Molecules that Make Up Cells” uses biuret reagent to examine peptide bonds in proteins^[7]. Assuming that the nail is a protein, the protein must have a peptide bond. An experiment to explore the reaction of the biuret reagent with the nail is shown in Figure 11.

[Teachers] work in small groups to observe phenomena while doing experiments.



Fig.7 Experiments on nails (left), marble (right) and hydrochloric acid

[Group 2] Phenomenon: Nails mixed with hydrochloric acid without bubbles. Conclusion: The main component of nails is not carbonates.

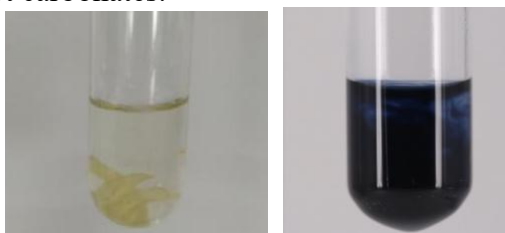


Fig.8 Experiments with nail and iodine (left) and starch with iodine (right)

[Group 3] Phenomenon: Nails do not appear blue when mixed with iodine water. Conclusion: The main component of nails is not starch.

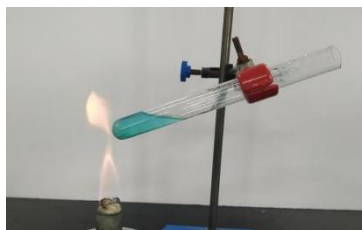


Fig.9 Experiments between fingernails and copper hydroxide suspension

[Group 4] Phenomenon: The treated nails were mixed with the new copper hydroxide suspension and heated without brick-red precipitation. Conclusion: The main component of nails is not cellulose.



Fig.10 Experiments on the reaction of nails and milk powder with concentrated nitric acid

[Group 5] Phenomenon: Nails appear yellow when they come into contact with concentrated nitric acid. Conclusion: The main component of nails is probably protein.



dried milk

fingernail

Fig.11 Experiments on nails and milk powder with biuret reagent

[Group 6] Phenomena: When the milk powder and nails were mixed with the biuret reagent, both tubes appeared purple. Conclusion: Nails contain multiple peptide bonds, and the main component of nails is proteins.

Figure 12 shows the Raman spectra analysis of cow hooves, and Figure12 shows the Raman spectrum in the range of wavenumbers 1800~300cm⁻¹[8]. Please derive the structural information present in keratin from the given Fourier Raman Spectra.

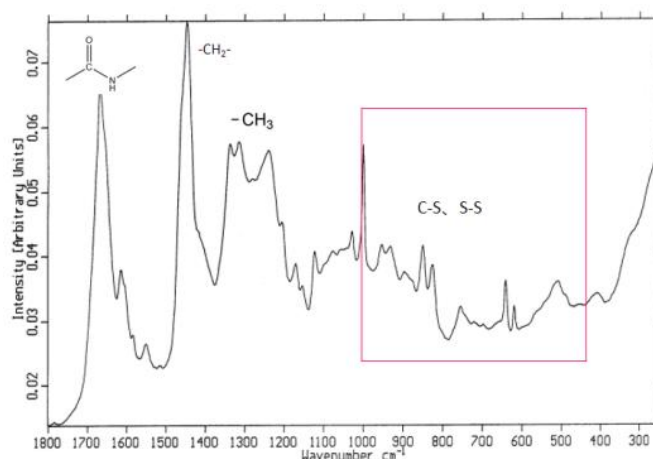


Fig.12 Fourier Rama Spectra

[Student] Keratin contains peptide bonds-CO-NH-, carbon-sulfur bonds, and disulfide bonds S-S.

[Teacher] After analysis, hypothesis and verification, the main component of nails is protein. In life, protein is often soft and edible, what is the essential difference between nail protein and daily consumption protein? The structure of proteins is complex, and it is easier to qualitatively analyze the basic structure of proteins at the secondary level, but it is more difficult to analyze the microstructure and quantification of proteins^[9,10].

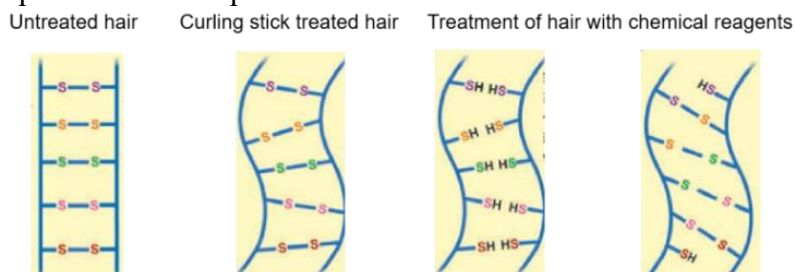


Fig.13 Basic principles of perm

[Teacher] Consulted the information^[11], the protein in the nail is keratin, because it contains a large number of disulfide bonds, it is hard, and it is inedible. Figure 13 shows a model of the structural changes of keratin in perming.

[Student] Nail keratin contains a large number of disulfide bonds, which is consistent with the fact that the products of nail combustion can cause a large amount of gray precipitation on the filter paper strip coated with the lead acetate solution, and the sensor detects a high concentration of hydrogen sulfide.

4. Summary

(1) Nails are an important carrier to stimulate students' interest in exploring the composition of material elements. Through the elemental analysis and structural analysis of the nail system using the knowledge learned, the nails are detected to contain C, H, O, S, N and other elements, and the nails contain peptide bonds, which improves the comprehensive ability of students to use disciplinary and interdisciplinary knowledge, and helps students form a systematic disciplinary cognitive methods. If students have a good foundation, they can also design and use high-precision instruments or complex chemical analysis methods to further explore the microscopic spatial structure of nails.

(2) The conflict between common sense and professional knowledge is an important thrust for exploring the microstructure. The keratin of nails contains a large number of disulfide bonds, which is the main reason why nails have a certain hardness, and also provides a theoretical basis for the application of keratin.

(3) The general methods of studying substances includes the process of separation and purification, determining the experimental formula, determining the molecular formula and structure, etc. Through the study of the composition and structure of nail elements, students' ability to understand and apply the connotation of material research methods is improved.

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