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Original Research Article

Exploration of Electrolyte Ionization Activities with a Self-made Instrument and the Student Evaluation

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Abstract: In this paper, a chemical experimental instrument was designed with a sing-chip computer. By using this instrument, the teachers instructed the students to deeply and comprehensively explore the ionization of electrolytes through the processing and analysis of the experimental data, which allow the latter to profoundly understand the factors influencing the ionization of electrolytes, the variations during ionization process, and the concept of ionization. Besides, based on the evaluation of the students' exploration activities, the teachers can further improve their experimental and core attainments in chemistry.

Keywords: Ionization, Electrolyte; Experimental Instrument; Self-made Instrument

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1. Introduction

Ionization is the process that an electrolyte dissociates into oppositely charged and freely mobile ions in an aqueous or molten state. In the basic theories of chemistry in high school, electrolyte ionization, occupying an important position, is the basic theory for students to understand and cognize the existential state and the movement of matters in the solution, and it occupies an important position in chemistry. [1] Some students might have certain misconceptions about electrolytes, and believe that electrolytes can only be dissociated under the condition of electrification. The theory teaching might lead to failures in the concept construction and theoretical understanding. Relying on homework, students might only vaguely know electrolytes, but cannot associate electrolytes to how particles are present in solution, leading to the difficulty in solve various subsequent questions. Specifically, "the ionization of weak electrolyte" is a very important link in the three equilibrium theories of aqueous solution, and it is very difficult for students to understand and master it. The experimental exploration of this paper allows students to master the ionization of strong electrolytes/weak electrolytes/non-electrolytes, the influence of temperature on electrolyte ionization, the ionization during the dilution of glacial acetic acid, the ionization of electrolytes during chemical reactions, etc., gaining in-depth understandings on the concepts of acids, bases, salts and electrolyte ionization.

Electrolyte solutions transmit current through the migration of positive and negative ions. However, in weak electrolyte solutions, only the ionized part undertakes the task of transmitting electrons. The experiment was designed to distinguish strong electrolytes, weak electrolytes and non-electrolytes by measuring the ionic conductivities of aqueous solutions, and to explore the influence of temperature on electrolyte ionization, the effect of water polarization on ionization, the ionization of ions in chemical reactions, etc. [2]

In the experimental teaching of high school, most chemistry teachers represent the concepts with the process of adding hydrochloric acid and acetic acid solutions (same volume and same concentration) in a small beaker, connecting the conductive device, and observing the brightness of the bulb. The method can display the ionization of the electrolyte, but cannot effectively quantize the ionization. However, the instruments for conductivity test are generally expensive, and generally cost thousands to hundreds of thousands CNY. It is quite difficult to find a simple test instrument. Targeting this problem, we successfully developed a high-sensitivity, low-cost analytical testing instrument. Using the self-made instrument, we can guide students in scientific exploration, and design a scale to evaluate their exploration activities, so as to discover shortcomings, develop advantages, better guide them, and improve their core attainments in chemistry.

2. Experimental Research Method

For this instrument, a microampere ammeter was designed with a single chip microcomputer and an operational amplifier, as shown in Fig. 1-3. Specifications of the Microcontroller: STC15W401AS (model), DC 5 V (power supply voltage), 8-channel 10-bit

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ADC, package pin S0P28. Specifications of the Voltage Regulator Chip: LM1117-3.3V. The Current Detection Resistor: 5 Ω Chip Resistor. Operational Amplifier: LM358DR was used to form a differential amplifier circuit, which amplifies the voltage across the current-sensing resistor, with the magnification factor of 20 times.

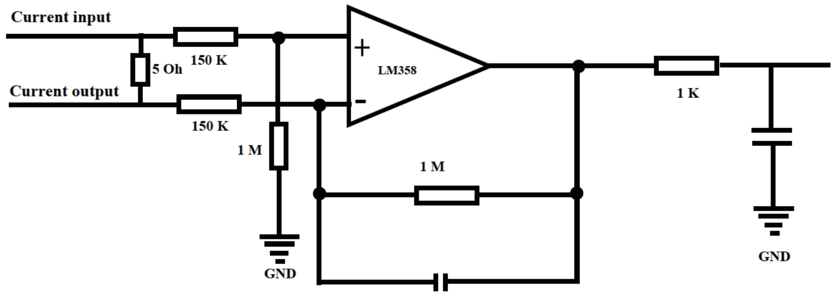

Fig. 1 Schematic Diagram of the Instrument

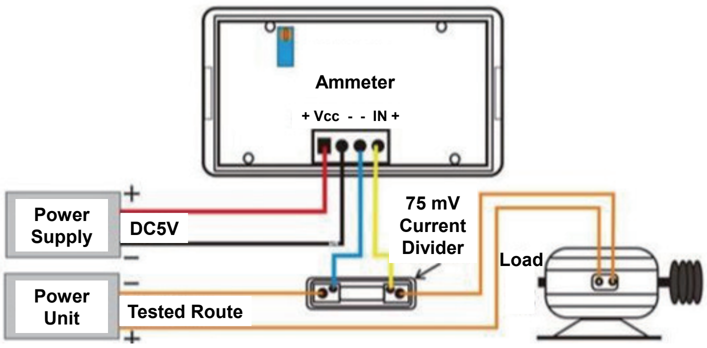

Fig. 2 Circuit Diagram of the Operational Amplifier

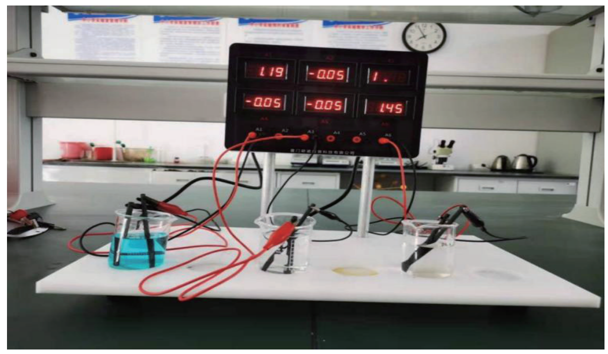

Fig.3 Physical map of set-up

With the rapid development of microelectronics technology, the continuous updating of ultra-large-scale integrated circuits, and especially the popularization of single-chip microcomputers, the measurement and control instrument, apparatus and technology have been developed and innovated accordingly. A digital ammeter, characterized by high precision, simple measurement, easy-to-read data, and strong utility, is to digitize the measured analog current through A/D conversion. The conversion of analog quantity into digital quantity requires an AD converter, which digitizes the input voltage (U) instead of the current (I). First, convert the current (I) of the measured circuit into a voltage (U), and then connect the circuit in series with a sampling resistance (R; 100 ohms). In the Figure, the supply voltage is 5 V DC, the supply unit is one required for testing the electrolyte, and its voltage and current can be adjusted according to different electrolytes. The Load refers to that required to test the electrolyte current, as certain voltages and currents are required to test the ionization equilibrium of the electrolytes. Complete the current-to-voltage conversion (U; U=IR). The A/D converter converts the analog voltage (U) into a digital quantity and sends it to the single-chip microcomputer, which then reads, stores, analyzes and calculates the data and obtains the current result. Finally, the single-chip microcomputer communicates with the liquid crystal display to display the current. A 16-bit A/D converter was selected to reduce the measurement error to less than or equal to 0.01 mA. In the design of the peripheral circuit, we used a new anti-interference set and utilized graphite as the electrodes to achieve high-precision, high-reliability, and low-cost test and analysis of electrolyte ionization. Specifically, the design idea of the anti-interference circuit is that diodes are used to suppress the reverse current at the measurement inlet and outlet of the milliammeter and then to return the ammeter to zero without affecting the test results.

3. Research Process

The students were guided to carry out exploration activities. Specifically, use six sets of test instruments to assemble the electrolyte ionization test instrument, and conduct conductivity tests on hydrochloric acid, acetic acid, deionized water, sodium hydroxide, ammonia water, and gasoline; conduct conductivity tests in the process of adding deionized water to glacial acetic acid, during the acetic acid warming process, and in the process of dilute sulfuric acid reaction with barium hydroxide.

3.1 Research on the Ionization Behaviors of Electrolytes and Weak Electrolytes

On the basis of studying chemical equilibrium theories and understanding the environment in which ionization and ion reaction occur in electrolytes, the teachers want to further strengthen the concepts of strong and weak electrolytes in students, and expect them to understand the ionization equilibrium of weak electrolytes, the influences of concentration, temperature and other conditions on ionization equilibrium and ionization Equilibrium constant. Therefore, we designed the conductivity experiment with 0.1 mol/L HCl solution and 0.1 mol/L CH3COOH solution, as shown in Fig. 4.

The method often used by middle school chemistry teachers is to test ionization behaviors with light bulbs connected in series. However, it is generally difficult to achieve an obvious phenomenon with the method, especially in the concentration of 0.1 mol/L, which leads to the difficulty in the experimental teaching. [3] By using the ammeter prepared with the single-chip microcomputer can we express the difference between strong and weak electrolytes intuitively. The current in acetic acid is significantly smaller than that in hydrochloric acid. The decrease of the current with time is mainly caused by polarization. With the extension of time, the current value will show a stable state. It will allow the students to intuitively understand the ionization of strong and weak electrolytes in aqueous solutions.

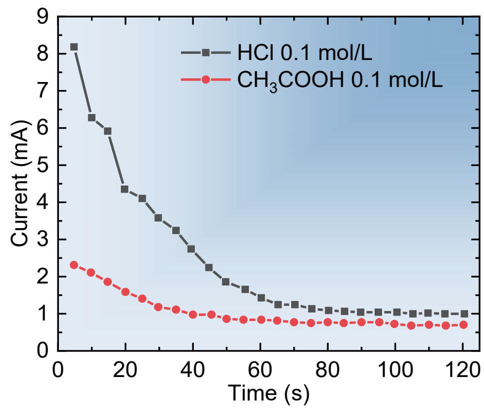

Fig. 4 HCl and CH_3COOH Current Method for On-current Measurement

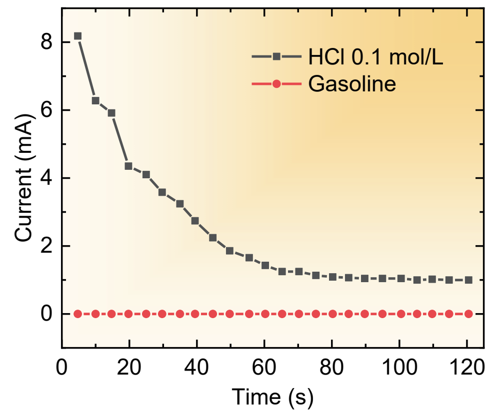

Fig. 5 On-circuit Current Measured by Hydrochloric Acid and Gasoline Galvanometry

3.2 Electrolytes and Non-electrolytes

Definition of Electrolyte: It refers to a compound that can conduct electricity in an aqueous solution or in a molten state. The Definition of Non-electrolyte: It refers to a compound that does not conduct electricity in an aqueous solution or in a molten state. It is determined that gasoline cannot conduct electricity, but experimental verification is required. Fig. 5 shows the hydrochloric acid and gasoline galvanometry in measuring the ionization.

This experiment can fully help students understand the difference between electrolyte and non-electrolyte. A non-electrolyte has zero conductivity, while an electrolyte conducts electricity in aqueous solution. The distinctive difference between the two is directly shown in the curves.

3.3 Identification of Electrolyte Conductivity Variations with Concentration

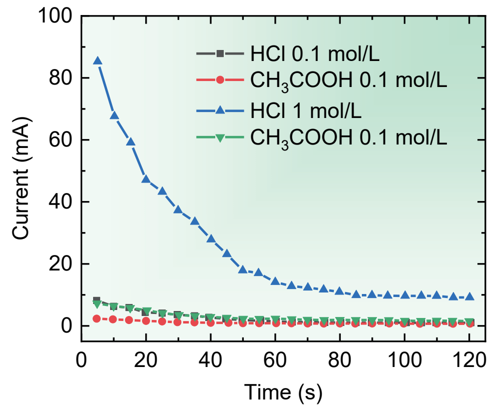

Fig. 6 On-current Measurement of HCl and CH_3COOH at Different Concentrations by Galvanometry

Electrolytes in large quantities are incompletely dissociated at higher concentrations. Therefore, the ionization of acetic acid is weakened at higher concentrations, resulting in a 3-fold increase in the conductivity of acetic acid when the concentration is increased by 10 times, which hydrochloric acid, as a strong electrolyte, has the conductivity increased nearly by 10 times when its concentration is increased by 10 times, as shown in Fig. 6. This experiment fully reflects the change of ionization balance of strong and weak electrolytes during ionization.

3.4 Current Changes during Glacial Acetic Acid Dilution

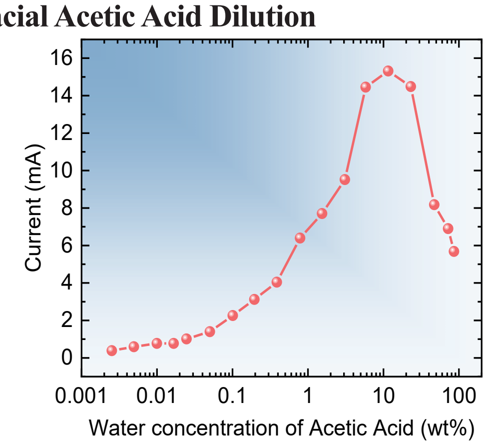

Fig. 7 Current of Acetic Acid Solution Varying with Water Concentration

The experiment of testing the conductivity change of glacial acetic acid during the dilution with water at a constant temperature is a hot topic in the education of electrolyte ionization. We chose this experiment to carry out the analysis and test with the self-made chemical instrument. At a certain temperature, in the process of diluting glacial acetic acid with water, the conductivity curve of the measured solution increases with the concentration of added water, as shown in Fig. 7. The current measured in glacial acetic acid is very weak; at the initial diluting stage, the current increases very rapidly, and the presence of trace water leads to a rapid increase in current, indicating that the acetic acid molecules are rapidly ionized, producing cations and anions and resulting in a rapid increase in current. When the current reaches a certain value, it decreases, suggesting that the concentration of ions in the solution begins to decline. In the late diluting stage, the declining trend slows down, showing that the ionization equilibrium of the acetic acid molecules changed, resulting in little change in the current. [4]

3.5 Test of Sulfuric Acid and Barium Hydroxide Reaction

Traditionally, the reaction between barium hydroxide solution and dilute sulfuric acid is mainly monitored through the brightness changes of the light bulbs, which reflect the ion changes during the double decomposition reaction, but the event effect is less than satisfactory. Therefore, the use of our ammeter to monitor the conductivity change of the reaction has the advantages of simple operation, obvious demonstration effect, and good experimental reproducibility, and has a good teaching effect in helping students understand the essence of the double decomposition reaction.

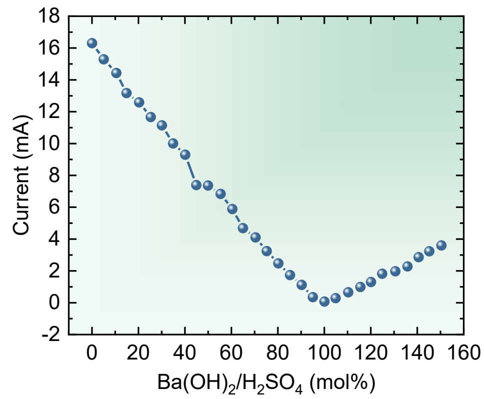

Fig. 8 Changes in the Conductivity of H_2SO_4 Solution Added with $Ba(OH)_2$ Solution Drops

The conductivity of an electrolyte solution mainly depends on the ion migration rate and migration number in the solution. The ion migration rate is related to the nature of ions (including ionic radius, degree of ion hydration, electric charge, etc.), the nature of the solvent and the potential of the electric field. Besides, ion migration rate and migration number are affected by factors such as ion concentration and temperature. Sulfuric acid solution is characterized by good conductivity, and double decomposition reaction occurs when $Ba(OH)_2$ is dripped into H_2SO_4 solution: $Ba(OH)_2$+ H_2SO_4= Ba SO_4↓+2H_2O; since barium sulfate is insoluble in water, the reaction results in significant reductions of OH^-, SO_4^{2-}, Ba^{2+} and H^+ ions, showing a certain linear relationship. Therefore, as shown in Fig. 8, there is a straight drop in current, and the current increases with the increase of barium hydroxide after approaching 0 point. The inflection point indicates the end of the reaction, and it effectively reflects the reaction process with clear experimental phenomenon.

3.6 The Relationship between Weak Electrolyte Ionization and Temperature

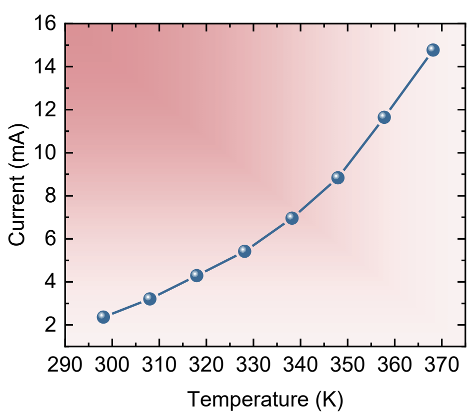

Fig. 9 Current Variation of 0.1 mol/L Acetic Acid Solution during the Warming Processing

It can be seen from the Fig. 8 that as the temperature increases, the current of the acetic acid solution increases gradually. Because acetic acid is a weak electrolyte, and the ionization process is an endothermic reaction, the increase of temperature promotes ionization, and leads to more ionized H^+ and CH_3COO^-, the rise of the ion concentration, and growth of the current. [5]

4. Project Achievement

Electrolyte ionization experiments were carried out by using an ammeter controlled by a single chip microcomputer, so as to systematically explore the ionization of strong and weak electrolytes as well as electrolyte and non-electrolytes, the change of electrolyte conductivity with concentration, the current change during the dilution of glacial acetic acid, the test of sulfuric acid and barium hydroxide reaction, and the relationship between the ionization of a weak electrolyte and temperature. The experiments with our self-made experimental instrument intuitively and reliably reflect the physical and chemical changes of electrolyte ionization, reaction, physical properties, etc., and the instrument provides a good teaching platform for experimental teaching and learning in high school chemistry.

Project Innovations and Advantages:

(1) Innovatively use a single chip microcomputer for current testing in electrolyte ionization experiments.

(2) Systematically study various factors influencing electrolyte ionization, and monitor the process of chemical experiments.

(3) The instrument has the advantages of simple operation, high test accuracy, reliable performance, and relatively good cost performance.

5. Teaching Evaluation

As shown in Table 1, an evaluation form was designed to evaluate students' exploration activities from the perspectives of experimental attitude, experimental skills, experimental knowledge, and experimental attainment. Based on the evaluation, teachers can carry forward the merits and improve the shortcomings, so as to improve the students' experimental exploration in chemistry as well as their core attainments in chemistry.

Table 1 Scientific Exploration Classroom Evaluation Form

Item	Experimental Attitude (10 Points)	Experimental Skills (40 Points)	Experimental Knowledge (40 Points)	Attainment in Chemistry (10 Points)
Dimension	Preparation before class, purpose of experiment, principle of experiment, safety of experiment, resource conservation, environmental protection awareness	Experiment design, operating specifications, accurate records, collaboration, active participation, communication and discussion	Experimental data processing, completion of experimental reports, interpretation of experimental phenomena, understanding of experimental principles	Macroscopic identification and microscopic analysis, concept of change and thought of balance, evidence reasoning and model cognition, experimental exploration and innovative consciousness, scientific spirit and social responsibility
	Each dimension is divided into four levels (excellent, good, medium, and poor), which account for about a quarter of each item, and are directly scored.			
Student Self-Assessment				
Group Assessment				
General Evaluation by Teacher				

6. Conclusion

The teachers and students have studied together and practiced continuously. With the self-made chemical experimental instrument, the teachers guided students to carry out the experimental explorations, allowing them to experience the fun of scientific exploration, master the research ideas, and learn scientific research methods. An assessment form is used to evaluate the efficiency of students' scientific exploration, and based on the feedback, teachers can further improve the quality of teaching as well as students' research ability and core attainments, and cultivate more and better developers and socialist successor.

References:

[1] Ye Peipei. Teaching design of "electrolyte ionization" based on particle view [J]. Education in Chemistry, 2020, 55-59.

[2] Zhao Kun. Experimental Improvement on Determination of Ionization Equilibrium Constant of Weak Electrolyte [J]. Guangzhou Chemical Industry, 2014, 42(9): 106-107.

[3] Li Jingbo. A self-made device for the comparison of electrolytic solution conductivity [J]. Experiment Teaching and Apparatus, 2017, 12: 51-52.

[4] Luo Yifang & Wu Wenzhong. Theoretical Analysis and Demonstration of Conductivity Changes during Dilution of Glacial Acetic Acid [J]. Education in Chemistry, 2019, 11:70-74.

[5] Wei Yating, Xu Pingping, Su Wenting, Li Rongqing, Lin Cui & Zheng Liuping. The Application of Hand-Held Technology in the Teaching of Weak Electrolyte Ionization Equilibrium [J]. Journal of Xiamen University (Natural Science), 2008,47: 228-230.

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