Variorum Multi- Disciplinary e-Research Journal
Vol.-01, Issue-III, February 2011

Experimental Determination of the Faraday Constant and Avogadro Number by electrochemical method

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Abstract:

Diverse experimental techniques were used to determine the faraday constant and Avogadro Number. These methods depend upon different properties of a single particle. In this study, a simple electrochemical method is used to determine the faraday constant and Avogadro number considering accuracy and time. An electrolysis of $AgNO_3$ was carried out by using 0.1 M solution of $AgNO_3$ as an electrolyte and silver electrodes. A 2 volt D.C. source was used. The amount of silver deposited at cathode at the end of 1500 seconds was measured.

Keywords: faraday constant, Avogadro number, electrochemical method, electrolyte, D.C. source.

Introduction:

Avogadro's hypothesis, "equal volumes of different gases under identical temperature and pressure conditions contain the same number of molecules" was postulated in 1811[1]. Avogadro made no quantitative estimates of neither of the above mentioned constants. The first actual estimate of the number of molecules in one cubic centimeter of a gas under standard conditions was made in 1865 by Loschmidt, the Austrian physical chemist[2]. He estimated the volume of a single molecule using the kinetic theory of gases and density of liquid air. The term Avogadro constant was first used by Perrin who identified the number of molecules in a gram molecular weight of a substance. Perrin's determination of the Avogadro's constant was based on measuring the distribution of colloidal particles of identical sizes (monodisperse) in a vertical column under isothermal conditions under the influence of gravity [3]. Even Counting of α particles, Black-Body Radiation concepts were used to find these constants. The most accurate method to date has been the one in which X-ray diffraction method is used to measure the microscopic density of a Silicon unit cell. The macroscopic density of the crystal is also precisely

ISSN 0976-9714

Variorum Multi- Disciplinary e-Research Journal
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measured using highly sophisticated methods. Avogadro number determined from this method is accurate to better than one part per million.

Most of the methods explained above need most sophisticated instruments like X-ray diffraction spectrometer, G.M. counter. In most of the colleges, these instruments may not be available. Hence in order to understand the basic concept of electrochemistry, Faraday's laws of electrolysis and determination of these constants, electrochemical method is useful. Recently, many researchers[4-11] have focused on the subject of determining Avogadro's number. In this work, an electrolysis experiment found in the literature[12] has been modified.

Materials and Method

A 2.5 volt D.C. source, an ammeter, two silver electrodes and 0.1 M $AgNO_3$ solution (as electrolyte) were used for electrolysis.

When direct current passes through this solution, following reactions take place.

At one Ag electrode (Anode), oxidation takes place

$Ag(s) \rightarrow Ag^+ (aq) + e^-$

At another Ag electrode (cathode) reduction takes place

$Ag^+ (aq) + e^- \rightarrow Ag(s)$

The mass of the cathode electrode before electrolysis and after electrolysis are m_1 and m_2 respectively. The differences $(m_2 - m_1)$ represent quantity of silver deposited on the cathode. The electrical charge that flows through the system during electrolysis Q can be calculated by using following equation

$$\mathbf{Q = I \times t} \qquad \text{---- (1)}$$

The charge carried by a mole of electrons is the Faraday. It is known from electrochemical studies, being determined from the charge that is required to deposit one gram atomic weight of a mono-positive metal ion (such as silver from a solution of silver nitrate) at the cathode. The value of Faraday constant (F) can be calculated by using following equation

$$\mathbf{F = Q.\,M / n.\,m} \qquad \text{---- (2)}$$

Where

F = Faraday's constant

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M = the atomic weight of the metal

n = the number of electrons transfer during half reaction

Q = the electrical charge that flows through the system during electrolysis.

The ratio of Faraday constant (F) to the charge carried by an electron gives the Avogadro Number (N_0).

$$\mathbf{N_0 = F/q_e} \qquad \text{----- (3)}$$

Where qe **= Charge carried by a electron = 1.602 xl0 $^{-19}$ C**.

Experimental Procedure

The silver electrodes were cleaned with dilute solution of acetic acid and then dried. The weight of dried silver electrode (cathode) was noted (m_1). Both the electrodes then dipped in a beaker containing 0.1 M $AgNo_3$. A current of 0.160 ampere was passed through this solution for 1500 s. After 1500 s, the silver cathode was again weighed (m_2). The difference (m_2 –m_1) gave the amount of silver deposited at cathode during electrolysis (m). The experiment was repeated 5 times.

Results and Discussion

The experimental results obtained from 5 trials were used to calculate Faraday Constant (F) and Avogadro's Number (N_0).

Table 1: Results of Electrolysis Experiment

Parameters	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**
Electrolysis time(t) in s	**1500**	**1500**	**1500**	**1500**	**1500**
Current(I) in ampere	**0.160**	**0.160**	**0.160**	**0.160**	**0.160**
Mass increase in cathode(m) in g	**0.265**	**0.264**	**0.265**	**0.266**	**0.265**
Faraday	**9.770 X 10^4**	**9.807 X 10^4**	**9.770 X10^4**	**9.733 X 10^4**	**9.770 X 10^4**

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constant(F) in C mol^{-1} electron^{-1}					
Avogadro's Number in atoms mol^{-1}	**6.098 X 10^{23}**	**6.122 X 10^{23}**	**6.098 X 10^{23}**	**6.075 X 10^{23}**	**6.098 X 10^{23}**

Average Experimental value of Avogadro's Number = 6.098 X 10^{23} atoms mol^{-1}

Average Experimental value of Faraday Constant = 9.770 X 10^{4} C mol^{-1} electron^{-1}

Accuracy and Precision of the Method

The average experimental value of Avogadro number **(6.098 X 10^{23} atoms mol^{-1})** was found to be in good agreement with the accepted Avogadro number i.e.
6.02 x 10^{23}. The standard deviation of this result was ± 0.0468 x 10^{23} and the percent error was 1.26 %.

The average experimental value of Faraday constant (**9.770 X 10^{4} C mol^{-1} electron^{-1}**) was found to be in good agreement with the standard Faraday Constant i.e **9.6487 X 10^{4} C mol^{-1} electron^{-1}**. The standard deviation of this result was ± 0.0233 x 10^{4} and the percent error was 1.26 %.

Conclusion

Practical work is an effective way of learning and reinforcing theoretical concepts in science. Teachers who make effective use of practical work and experiments often find that students learn better. Through practical work, teaching is enhanced and becomes more interesting both for the learner and the teacher. Science learning, to be of maximum value, includes observing, asking questions about why things happen in the way they do, and evaluating. Learners should be encouraged to plan, measure, record, look for patterns, voice and debate their findings and ideas, and all these can be enhanced through experimentation. Science does not have to use expensive or complex resources. It can be taught in the simplest fashion using empty tins, spirit burners, a few test tubes, plastic drink bottles and materials from home.

ISSN 0976-9714

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Cooking food and washing dirt off clothes are everyday examples of science in action, examples to which all learners can relate. Scientific practical work by using everyday materials, published sources of ideas and a little common sense can be fun for both students and teachers and results in a deeper understanding of science than theoretical lessons alone.

There are several methods described in the literature for determination of Faraday constant as well as Avogadro's number. However, there is no well known and easy method of determining the Avogadro's number and Faraday constant. Hence the above mentioned method was developed which can be performed in any science laboratory.

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Acknowledgement

Author is thankful to Dr. Usha Mukundan, Principal, R.J. College, Ghatkopar (Mumbai) and Prof. Raghu Pillai, Head of Physics Dept, R.J. College Ghatkopar(Mumbai) for their kind co-operation.