es interesante para que el docente explore esta diversidad y aclare qué le compete a la ciencia para diferenciarla de las creencias y las preconcepciones.

Otra forma de dirigir la propuesta presentada, podría ser situando al alumno en los comienzos de la vida en la tierra, planteando como situación problema: cómo se llega a la diversidad que hoy se observa. A partir de ello se pueden indagar los mecanismos evolutivos desde distintas posturas: DARWIN, LAMARCK, neutralismos, equilibrios puntuados, de forma tal, que ayuden a realizar conexiones con nuevas estructuras conceptuales.

Una recomendación adicional es, que se debe tener especial cuidado en reforzar las explicaciones científicas sobre el origen de la vida como un proceso natural en la tierra, y en segundo lugar, explicar porqué no se forma vida espontáneamente en épocas recientes. Como toda teoría científica, dado el tiempo y las condiciones definidas para su origen, la vida debería originarse nuevamente para que la teoría sea válida, aunque sea imposible de concretar porque las condiciones del universo variaron enormemente. Se dejan de lado así, teorías que sugieren un origen extraterrestre de la vida (por ejemplo, que fue "sembrada" por otros seres inteligentes, o que las primeras células llegaron a la tierra en un asteroide u otro cuerpo estelar que colisionó con ella) y explicaciones que se apoyan en la creación de la vida por un ser superior.

CONCLUSIONES

- Se reconoce la necesidad de implementar nuevas estrategias con los estudiantes para desarrollar la comprensión como una meta superadora a la reproducción de la información.
- El desarrollo de aprendizajes comprensivos implica siempre interacción, comunicación y co-construcción del conocimiento.
- Existe un marco teórico y unas estrategias presentadas por el modelo de EpC, las cuales pueden optimizar los resultados de la enseñanza en términos de la comprensión.
- Una buena selección de los tópicos generativos, tanto el marco conceptual, como las estrategias son necesarias.
- Hay que presentar y posibilitar un amplio repertorio de desempeños asociados a la indagación científica, potenciando los procesos de comprensión a partir de lo que el alumno ya sabe.
- Es importante a la hora de definir un tópico generativo considerar su significado, la motivación que despierta y la posibilidad de integración conceptual.
- Los tópicos generativos permiten abordar un tema desde varios enfoques tendientes a enseñar formas de pensamiento.

AGRADECIMIENTOS

Se agradece a la Agencia Córdoba Ciencia por haber apoyado este trabajo mediante un subsidio.

BIBLIOGRAFÍA

BLYTHE, T. y COLABORADORES, *La enseñanza para la comprensión*, Guía para el docente, Paidós, Buenos Aires, 1999, 35-42.

CIRIGLIANO, G y VILLAVERDE, A., *Dinámica de grupos y educación*, Humanitas, Buenos Aires, 1968, 185-190.

GALLINO, M., FERRERO, M.T. y CAMPANER, G., Estrategias de apoyo y seguimiento en la implementación de programas de capacitación docente en ciencias naturales, *II Congreso Iberoamericano de Educación en Ciencias Experimentales*, Argentina, 2000, T2-029.

GARDNER, H., *La educación de la mente y el conocimiento de las disciplinas*, Paidós, Barcelona, 2000, 133-153.

GARDNER, H., KORNHABER, M., WAKE, W, *Inteligencia. Múltiples perspectivas*, Aique, 2000, 174-187.

GARDNER, H., *La mente no escolarizada*, 2ª edición, Paidós, Barcelona, 1997, 23-38.

GARDNER, H., *La nueva ciencia de la mente*, Paidós, Barcelona, 1987.

PERKINS, D., ¿Qué es la comprensión?, en STONE WISKE, M., *La enseñanza para la comprensión*, Paidós, Buenos Aires, 1999, 34-56.

STONE WISKE, M., *La enseñanza para la comprensión*, Paidós, Buenos Aires, 1999, 23-30.

TISHMAN, S., PERKINS, D., JAY, E., *Un aula para pensar. Aprender y enseñar en una cultura de pensamiento*, Aique. Buenos Aires, 1996, 18-37.

VALEIRAS, N., La perspectiva histórica como un aporte a la construcción del concepto el origen de la vida, *Pensamiento Educativo*, 2002, 30, 197-221.

WALTERS, J y GARDNER, H., The development and education of intelligences, en *Essays on the intellect*, Curriculum Development Associates/ Association for Supervision and curriculum Development, Washington, DC, 1985, 1-21.

Received 05.09.2003 / **Approved** 06.07.2004

Computer-based experiment: determining the Avogadro's number through electrolysis process

Experimento en computador para determinar el número del Avogadro a través del proceso de electrólisis

D. AMRANI, P. PARADIS, A. HENAULT AND D. PIOTTE

University of Québec, Ecole de Technologie Supérieure - Service des Enseignements Généraux
1100, rue Notre-dame Ouest Montreal (QC) H3C 1K3, Canada
damrani@seg.etsmtl.ca

Abstract

A laboratory experiment to optimize hydrogen volume, with respect to atmospheric pressure, for determining Avogadro's number (N_A), is described. The method is based on the use of a computer-controlled data acquisition and an electrolysis apparatus. This work involved adapting a classic physical chemistry experiment to using modern data acquisition analysis system. Hydrogen volumes used to obtain accurate values of N_A were found to be in the range of 7 to 30 mL. The determined Avogadro's numbers were equal or less than (≤) 2% compared to accepted values. The procedure was described and the results were presented and discussed.

Key words: *electrolysis; computer-cased laboratory; pressure; volume; Avogadro's number; datastudio software; science workshop interface and sensor.*

Resumen

Se describe un experimento de laboratorio para optimizar el volumen de hidrógeno, con respecto a la presión atmosférica, para determinar el número de Avogadro. El método está basado en el uso de una computadora y un aparato de electrólisis. Este trabajo involucra un experimento clásico de físico química, utilizando un sistema de análisis moderno de adquisición de datos. Los volúmenes de hidrógeno para obtener valores exactos de N_A estuvieron entre 7 y 30 mL. Los valores del número del Avogadro determinados eran iguales o menores (≤) a 2% comparando con los valores aceptables.

Palabras clave: *electrólisis; laboratorio computarizado; presión; volumen; número de Avogadro; software de datastudio; interfaz y sensor para taller de ciencias.*

INTRODUCTION

To implement a laboratory experiment for students at our school, employing computer-controlled data acquisition, we have used suitable devices, which were able to do accurate measurements. Avogadro's number (N_A) was estimated by means of Hoffman electrolysis apparatus (Hoffman electrolysis 2001) and a current sensor (Current sensor 1999) interfaced with a computer using Datastudio Program (Data studio 2001). The software allowed the collection and display of real-time data of electric charge due to water electrolysis.

Optimum hydrogen volume (H_2) that could be used, with respect to atmospheric pressure (P_1), for calculating N_A with an error varying between 0.01 to 2% of accepted value, was investigated. Hydrogen volumes and atmospheric pressures considered in this study were ranging from 4 to 30 mL and 96.0 to 105.0 KPa, respectively.

Temperature of the laboratory and total charge (Q) obtained by data acquisition system, for each experiment, were recorded. The height (h), between the liquid (Na_2SO_4 solution) level, which is in contact with atmospheric pressure and hydrogen level touching the solution, was measured accurately three times and the average value was taken.

It was found that, in the range of H_2 volume from 7 to 30 mL and atmospheric pressure from 96.0 to 105.0 KPa, the average calculated Avogadro's number was in the interval of 0.01 to 2% of the accepted value, 6.022 x 10^{23}. Each experiment was repeated three times and the average value of N_A taken with an error of ± 0.4.

This work presents a precision, student laboratory experiment of water electrolysis, based on computer assisted data acquisition, to computerize Avogadro's number. Results were presented and discussed.

Theory

Avogadro's number can be determined in several ways. This laboratory experiment was using Hoffman electrolysis apparatus, a power supply delivering 24 V and Science Workshop interface 750 with a current sensor and Datastudio software incorporated in a computer.

The electrolysis of the solution is described by the following reactions. (http://chemed.chem.purdue/demos/moviessheets/20.2html)

a) At negative electrode (cathode).

$2\ H_2O\ (l) + 2\ e^- \rightarrow\ H_2\ (g) + 2\ OH^-$

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

b) At positive electrode (anode).

$2\ SO_4^{2-}\ (aq) \rightarrow\ S_2O_8\ (aq) + 2\ e^-$

$2\ H_2O\ (l) \rightarrow\ O_2\ (g) + 4\ H^+\ (aq) + 4\ e^-$

Combining the two half reactions so that electrons are conserved, we obtain the following equations.

$6\ H_2O\ (l) \rightarrow\ 2\ H_2\ (g) + O_2\ (g) + 4\ H^+\ (aq) + 4\ OH^-\ (aq)$

OR

$2\ H_2O\ (l) \rightarrow\ 2\ H_2\ (g) + O_2\ (g)$

The produced, hydrogen and oxygen are both considered as ideal gases. Therefore, the relation PV = nRT could be applied to these gases. Two gases coexist in the gaseous phase: hydrogen (H_2) and water vapour (H_2O). The vapour pressure of water is described by Antoine's Equation.

(Lauge 's Handbook,1995, Notes de cours,2000)

$$\log P^0_{H_2O} = 10.23 - \frac{1750.286}{(t + 235)} \quad (1)$$

P^0 is the vapour pressure of water in PASCAL,

t represents the temperature in degree Celsius

The total pressure above the solution is the sum of partial pressures.

$$P_t = P_{H_2} + P^0_{H_2O} \quad (2)$$

The difference of pressure between two points separated by a height (h), between the solution level, which is in contact with atmospheric pressure and the H_2 level communicating with the liquid, is given by.

$$P_2 = P_t = P_1 + \rho_{liquid}\, gh \quad (3)$$

liquid is the volume density of liquid = 1000 kg.m^{-3},

g represents the acceleration of gravity = 9.381 m.s^{-2},

h is the height between P_1 (atmospheric pressure) and P_2 (hydrogen pressure and water vapour pressure) , in m.

Substituting equations (1) and (3) in equation (2), we obtain the equation describing the hydrogen pressure (P_{H2}).

$$P_{H_2} = P_t - P^0_{H_2O} \quad (4)$$

The total charge is determined by Datastudio software. The charge represents the area under the curve of current versus time and is described by

$$\text{Charge} = \int_0^t I\,dt \quad (5)$$

From the equations described previously, we could derive expressions for e/K_B and N_A.

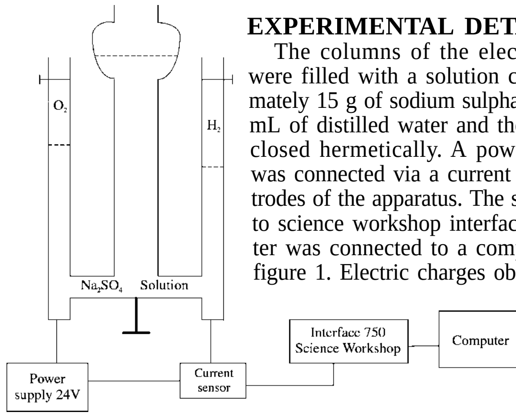
$$e/K_B = \frac{QT}{2P_{H_2}V} \quad (6)$$

Where e is the electron charge (=1.6 x 10^{-19} C) , K_B is the Boatmann's constant (= 1.3806 x 10^{-23} J.s), Q is the total charge in C, T represents the temperature in Kelvin, P_{H2} pressure due to hydrogen gas , in Pa and V is the volume of H_2 in m^3.

Avogadro's number is given by

$$N_A = \frac{R}{K_B} \quad (7)$$

Where N_A represents Avogadro's, R is the gas constant = 8.31 and K_B is Boltzmann's constant.



EXPERIMENTAL DETAILS

The columns of the electrolysis apparatus were filled with a solution containing approximately 15 g of sodium sulphate (Na_2SO_4) in 200 mL of distilled water and then the valves were closed hermetically. A power source of 24 V was connected via a current sensor to the electrodes of the apparatus. The sensor was attached to science workshop interface 750 and this latter was connected to a computer, as shown in figure 1. Electric charges obtained through water electrolysis, by Datastudio software, were recorded for each volume of H_2, from 4 to 30 mL.

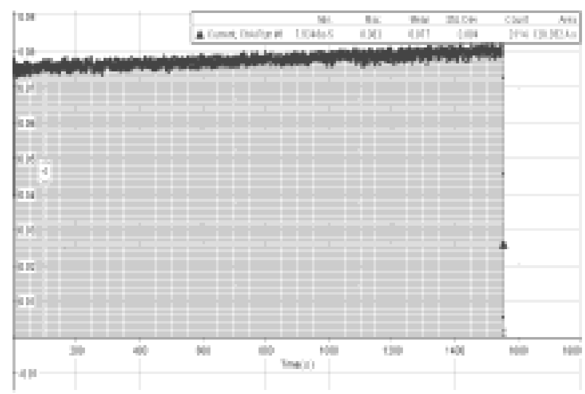


Figure 2. Graph of electrical charge of water electrolysis

A typical graphic representing electric charge of electrolysis was given in figure 2. The height between the liquid, which is in contact with the atmospheric pressure and the level of H_2 in contact with the solution, was measure accurately for each volume, as illustrated in figure 3. Room temperature and atmospheric pressure from 96.0 to 105.0 KPa were taken to perform the calculation of Avogadro's number.

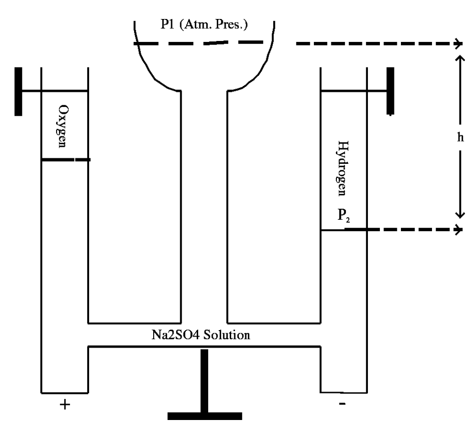


Figure 3. Hoffman electrolysis apparatus

To study the reproducibility of computed Avogadro's number, each experiment was repeated three times and the average value was taken.

RESULTS AND DISCUSSION

The experiments were performed in the physics laboratory at the Higher School of Technology, University of Quebec. N_A was calculated using equation (7). The average value of three measurements was recorded with an error of ± 0.04.

Experimental results were shown in figures 4 and 5, where the difference between estimated and accepted values of N_A was plotted as a function of hydrogen volume, with variable atmospheric pressures.

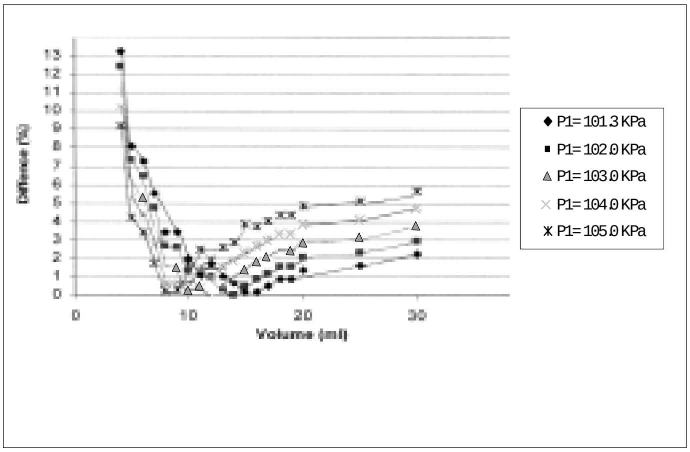


Figure 4. Difference between experimental and theoretical values of N_A versus volume of H_2

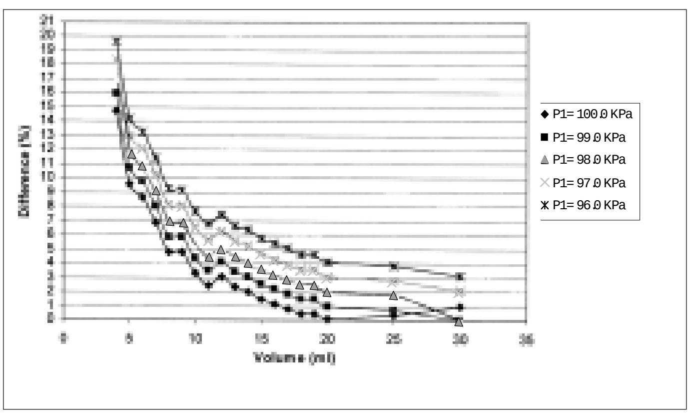


Figure 5. Difference between experimental and theoretical values of N_A versus volume of H_2

As can be shown in figure 4, the error between experimental and theoretical value of N_A decreased to less than 1% and then increased, as the volume of hydrogen increased, for atmospheric pressure range 101.3 to 105.0 KPa. Where as in figure 5, in the interval of 100.0 to 98.0 KPa, the difference between calculated and accepted value of Avogadro's number deceased exponentially as the volume of H_2 increased. For pressure 97.0 and 96.0 KPa, the difference between measured and accepted value of N_A decreased up to 2.1% and 3.1%, respectively; as the hydrogen volume increased.

The results of hydrogen volumes, which were necessary to obtain Avogadro's numbers = 2% compared to accepted values, were given in table 1. The variation within the three measured values of N_A for each volume was ± 0.04, the reproducibility of obtained results was satisfied.

Table1. Range of hydrogen volume to calculate accurate Avogadro's number

Atmospheric pressure (KPa)	Range of hydrogen volume (mL)
101.3	10 - 25
102.0	10 - 20
103.0	8 - 16
104.0	8 - 14
105.0	7 - 12
100.0	14 - 30
99.0	17 - 30
98.0	20 - 30
97.0	/
96.0	/

CONCLUSIONS

The experimental results are very satisfying, being in excellent agreement with the theoretical value of Avogadro's number. This laboratory experiment can be very interesting learning tool for introductory chemistry students. Teachers and students using computer controlled data acquisition system and Hoffman electrolysis apparatus could work with hydrogen volumes, from 7-30 mL with an error ⩽ 2% between calculated an accepted value of Avogadro's number.

ACKNOWLEDGEMENTS

The authors would like to thank the administration authorities of É.T.S. for their help and encouragement to implement new laboratories, in the physics laboratory, based on the use of computer–aided data acquisition.

BIBLIOGRAPHY

Current sensor CI-6556 Science workshop, *PASCO Scientific*, USA, 1999.

Hoffman electrolysis apparatus, *Boreal Laboratories LTD catalogue*, Ontario, Canada, 2001.

Lange's Handbook of chemistry, thirteen editions, editor: JOHN A. DEAN, McGraw-Hill Book Company, 1985.

Notes de cours CHM101 S.E.G., *École de Technologie Supérieure, University of Quebec,* Montreal, Canada, 2000.

Data studio Software 1.7.2 a Tool for Science Workshop, *PASCO Scientific*, USA, 2001.

http://chemed.chem.purdue.edu/demos/moviesheets/20.2html

Received 09.02.2004 / **Approved** 15.09.2004