Bulletin of the Chemists and Technologists of Macedonia, Vol. **23**, No. 2, pp. 197–200 (2004)
GHTMDD – 453
ISSN 0350 – 0136
Received: May 4, 2004
UDC: 371.388 : 532.71
Accepted: May 31, 2004

Education

TRANSPORT PHENOMENA. A MARATHON EXPERIMENT ON A TRANSPORT OF OXYGEN THROUGH WATER: AN EXAMPLE OF A RESEARCH EXPERIMENT ON GAS→LIQUID OSMOSIS

Vladimir M. Petruševski, Marina Monković

Institute of Chemistry, Faculty of Natural Sciences and Mathematics, Ss Cyril and Methodius University, P.O. Box 162, MK-1001 Skopje, Republic of Macedonia
vladop@iunona.pmf.ukim.edu.

A graduated cylinder filled with NO is placed under water. The water level in the cylinder slowly increases, until (after ≈ 1 month) it is practically filled with water. There appears to be a steady transfer of oxygen from the air through the water and NO is consumed in a chemical reaction with O_2. The experiment is a nice demonstration for gas-through-liquid osmosis (water is semipermeable to oxygen), and an effective example of marathon experiments.

Key words: marathon experiments; osmosis; semipermeable medium; nitric oxide; oxygen; water

INTRODUCTION

Marathon experiments (or marathons) are known [1] as long-period (yet, often attractive) experiments. Whether they should be considered as *demonstrations* or just experiments is mainly a matter of choice, for if a demonstration is an experiment that is to serve during (at most) a lesson period then obviously marathons are just lengthy experiments. If the previous restriction on the duration is cancelled and a 'relaxed' definition of a demonstration is adopted, marathons might be considered as *corridor demonstrations* or *exhibition demonstrations*.

Marathons are by no means unimportant, despite that the time period needed for a completion of such an experiment might vary from few days to many months or even years (like in supermarathons [2]). In the general and physical chemistry courses many important phenomena (diffusion and osmosis [3, 4], spontaneous distillation [2], effusion in liquids [5], chemical waves [6, 7] etc.) can often be presented as long-period (i.e. marathon) experiments.

The present demonstration deals in fact with a transport of oxygen through water, which is possible due to the fact that oxygen is slightly soluble in water (≈ 3 parts of oxygen gas in 100 parts of liquid water, at room temperature), and may therefore be considered as a peculiar type of gas→liquid osmosis.

THE DEMONSTRATION: FIRST IDEAS

In one of our earlier papers [8] NO gas was used for a fast and simple determination of the oxygen content in the air. Precisely measured volumes of NO and air were mixed under water, and after few minutes the final volume was read, thus enabling a surprisingly accurate method for determination of the oxygen content. Historically, part of the credit for that demonstration should go to J. Priestley, for it was he who used NO gas in a so-called "goodness-of-air" test (i.e. in a qualitative test whether a gas sample contains oxygen). Anyway, the offered method [8] was really simple, ef-

fective, and in few minutes everything was completed (accurately, as mentioned).

What if the NO gas was to be kept for a longer period under water? Water, it is known, always contains some dissolved oxygen. Is it possible that this oxygen could react with NO? If yes, what will the duration of the experiment be: hours, days, months?

That is how the very idea for this marathon was born. A graduated cylinder filled with NO gas should be placed (mouth down, of course) under water and the gas volume will be read in a certain period. The result will indicate whether the first idea was correct or wrong. The experiment will therefore be a *research experiment*, because the results are not known in advance (but also the demonstration seems to be a novel one).

EXPERIMENTAL SETUP

A water-filled graduated cylinder was clamped on a stand, its open end (‘mouth’) being immersed in a pneumatic trough filled with water. The cylinder is then almost filled with NO (a fast method for generation of pure NO gas is given elsewhere [8]). This is actually the setup for the experiment (cf. Fig. 1). The value for the volume of water here is considered as a 'zero value'.

The water level in the cylinder was then monitored during ≈ 1 month period. The results and conclusions are summarized in the following heading.

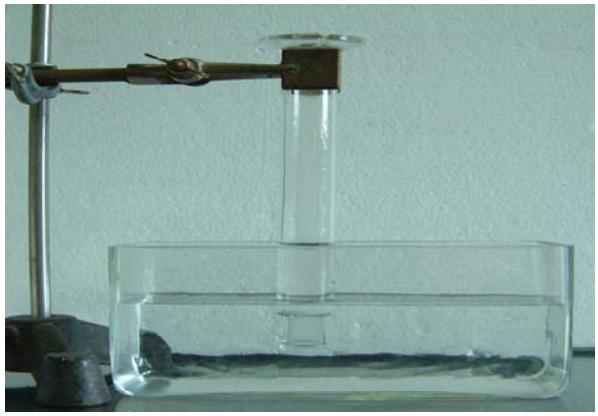

Fig. 1. Experimental setup
(the 'zero value' volume of water is seen)

RESULTS AND DISCUSSION

Water slowly enters the graduated cylinder (cf. Fig. 2) and after ≈ 1 month the cylinder is almost filled. The quantitative results are given in Fig. 3.

These results are in complete agreement with our a priori expectations, and can be interpreted in the following way: oxygen from the air is dissolved in water. This dissolved oxygen reacts with NO and, in the presence of water, gives HNO_3 and HNO_2:

$$2NO(g) + O_2(aq) + H_2O(l) = HNO_3(aq) + HNO_2(aq) \quad (1)$$

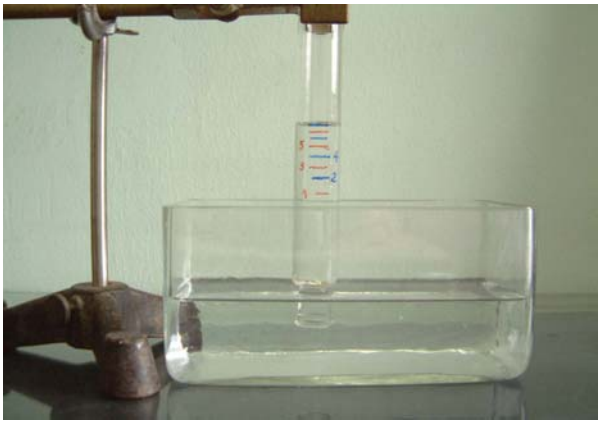

Fig. 2. After eight days, water level in the cylinder is much higher

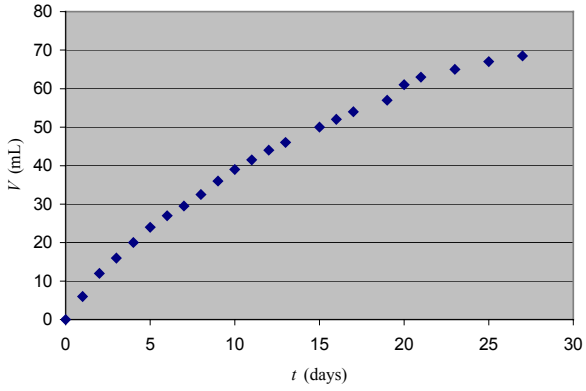

Fig. 3. Variation of volume of water in the cylinder with time

Since both acids are water soluble, the water level in the cylinder increases. The steady in-flow of oxygen from the atmosphere prevents depletion of the dissolved oxygen. The process continues at practically constant rate (the minor attenuation trend seen in Fig. 3 might easily be explained as a result of the increasing water level in the cylinder, thus affecting the time necessary for diffusion of the dissolved oxygen). The minor scatter of (some of) the points may be easily explained as result of experimental errors and/or temperature variations. Indeed, since the experiment was not performed under isothermal conditions, one understands that the higher the temperature, the less oxygen is dissolved in water.

A parallel experiment in which freshly boiled distilled water was used (allowing for virtually no dissolved oxygen in the very beginning of the experiment) gave practically the same result. The process, however, was slower in the start (some time is needed for the air oxygen to dissolve in the water in the trough and to diffuse to the NO/H_2O boundary surface).

Isn't it possible that another explanation is also feasible? NO which is slightly water soluble might simply 'escape' from the cylinder (due to its slight solubility) in the water and from here in the atmosphere, where it will eventually react with oxygen?

To give a proper answer to this question, we used the same experimental setup, but the cylinder was filled with C_3H_8/C_4H_{10} mixture (used for cigarette lighters). There is no chemical reaction possible in the latter case. However, this mixture could also escape due to its slight solubility in water, if the alternative mechanism was feasible. After one month, the water level in the cylinder filled with the alkane mixture was exactly the same, thus strongly suggesting that in the case of NO too this alternative based on 'gas-through-water escaping' is much less probable.

We are, thus, left with the first alternative as the only feasible one. However, one must agree that in this case we are dealing with a gas transfer (i.e. oxygen) through a semipermeable medium (i.e. water). The process can, in short, be described as an example of a gas→liquid osmosis (this is the basic mechanism) followed with chemical reaction at the boundary surface in the cylinder (cf. Eq. 1), which eliminates some NO. Consequently the quantity of NO gas reduces, thus decreasing its volume and giving rise to a nice marathon demonstration (and we also believe, a novel one) of transport phenomena.

SAFETY TIPS

Nitric oxide is poisonous gas! Gas generation should preferably be done in a hood. It might be a good idea to the first fill bottle reservoir with it, and use the gas later. All details concerning generation and handling of NO gas (including few more safety remarks) are given elsewhere [8].

LITERATURE

[1] G. Fowles, *Lecture Experiments in Chemistry*, Fifth Edition, G. Bell & Sons Ltd., London, 1959, pp. 2–5.

[2] V. M. Petruševski, M. Z. Najdoski, *Chem. Educator,* **6**, 91–94 (2001).

[3] В. Н. Верховскиј, Техника и методика хемијског експеримента у школи, књига II, Завод за издавање уџбеника СР Србије, Београд, 1965, стр. 147–160.

[4] J. Herak, *Opća i anorganska kemija. Pokusi*, Školska knjiga, Zagreb, 1968, str. 147–148.

[5] V. M. Petruševski, M. Monković, M. Najdoski, Alternative Demonstrations of Slow Processes. III: A Demonstration and Video Clip Showing Effusion in Liquids, *Chem. Educator*, submitted for publication.

[6] M. Najdoski, R. Aleksovska, V. M. Petruševski, An Alternative Demonstration of Chemical Waves: A Video Clip of a One-Dimensional Wave in the Iodate–Arsenite System, *Chem. Educator,* **6**, 319–320 (2001).

[7] V. M. Petruševski, M. Monković, M. Najdoski, Alternative Demonstrations of Slow Processes. II: A Video Clip of One-Dimensional Waves in the Hypochlorite–Iodide–Water System, *Chem. Educator,* **9**, 39–41 (2004).

[8] M. Najdoski, V. M. Petruševski, A Novel Experiment for Fast and Simple Determination of the Oxygen Content in the Air, *J. Chem. Education,* **77**, 1447–1448 (2000).

Р е з и м е

ТРАНСПОРТНИ ФЕНОМЕНИ. МАРАТОНСКИ ЕКСПЕРИМЕНТ ЗА ТРАНСПОРТ НА КИСЛОРОД НИЗ ВОДА: ПРИМЕР НА ИСТРАЖУВАЧКИ ЕКСПЕРИМЕНТ ЗА ОСМОЗА ОД ТИПОТ ГАС→ТЕЧНОСТ

Владимир М. Петрушевски, Марина Монковиќ

Институт за хемија, Природно-математички факултет, Универзитет „Св. Кирил и Методиј", п. фах 162, МК-1001 Скопје, Република Македонија
vladop@iunona.pmf.ukim.edu.mk

Клучни зборови: маратонски експерименти; осмоза; семипермеабилен медиум; азот-моноксид; кислород; вода

Градуиран цилиндар полн со NO се поставува под вода. Нивото на водата во цилиндарот бавно се зголемува, додека (по околу еден месец) цилиндарот не е практично целосно исполнет со вода. Се покажува дека доаѓа до постојан трансфер на кислород од воздухот преку водата, што доведува до трошење на моноксидот на азот при реакција со кислородот. Ова е убава демонстрација на осмоза од типот гас→течност (водата е семипермеабилен медиум за кислородот) и ефектен пример на маратонски експеримент.