A simple microscale gas generation apparatus
Sencillo aparato de generación de gas para los experimentos de microescala

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Abstract

This article presents a new safe, cheap and attractive microscale gas generation method that is expected to find place in the primary and secondary schools. Microscale gas generation apparatus consists of plastic syringe, Beral pipette and small plastic or glass test tube on a stand. The pipette has a role of a chemical reactor, which generates gas and delivers it into a test tube where reaction takes place. Gas generation is based on chemical reaction between liquid substance, which is inserted with syringe and needle into the pipette bulb with liquid or solid substance previously placed in it. A large number of interesting and vivid microscale experiments can be performed using this kind of apparatus and many gases can be generated.

Key words: *gases, gas generation, microscale experimentation, chemical experiments, chemical education.*

Resumen

En este artículo se presenta una alternativa fácil, segura y económica a microescala para la generación de gases, que se espera encuentre aplicación en las escuelas primarias y secundarias. El dispositivo para la generación de gases consiste en una jeringa de plástico, pipeta Beral y un pequeño tubo de ensayo de vidrio o de plástico colocado sobre un soporte. La pipeta tiene función de un reactor químico, en el que se genera el gas, y después se lleva a un tubo de ensayo donde tiene lugar la reacción. La generación del gas se basa en la reacción química entre la sustancia líquida, que se inserta con una jeringa en el bulbo de la pipeta Beral y la sustancia líquida o sólida previamente depositada en la pipeta. Un gran número de experimentos interesantes y vívidos se pueden realizar utilizando este tipo de dispositivo y también muchos gases pueden ser generados.

Palabras clave: *gases, generación de gas, la experimentación a microescala, experimentos químicos,la educación química.*

INTRODUCTION

Microscale chemistry which has become more popular describes numerous methods for chemical experimentation with small amounts of chemicals and miniature apparatus. Microscale apparatus are easier for construction and even more efficient than the conventional ones which are still used today. Microscale chemistry due to its benefits: saves time for preparation, reduces waste, costs less, requires shorter experimental time improves laboratory skills and most of all it is safer. Microscale experiments are very attractive nowadays. A wide spectrum microscale experiments which are described in the literature (El-Marsafy et al., 2011) are available on the Internet as well.

A contribution to the development of new methods for microscale gas generation has been given by many chemists, famous in the field of microscale experimentation with gases. Hubert Alyea, introduced safe gas generation using syringes (Alyea, 1992). Professor Viktor Obendrauf, proposed many methods for gas generation in a test tube with syringe for reactant introduction and another syringe for gas collection (Obendrauf, 1994, 1995, 1996, 2005, Goodwin, 2009). Bruce Mattson, independently and together with his co-workers, contributed with their ideas (Mattson et al, 1996, 1997, 2007). The three important methods: construction of a small-scale and low-cost gas apparatus (Kvittingen and Verley, 2004), a novel microscale gas generator (Wang et al, 2003) and method using plastic Petri dishes (Edith Muller-Carrera and Rivero-Muller, 2010) give inspiration for more simple and applicative gas generation ideas.

Experiments, which are part of the education in chemistry, could be divided as: demonstration experiments and demonstrated by the teacher and hands-on experiments performed by the students. Gas generation experiments are now, mainly, demonstration experiments, for one class or group of students. Due to the high cost and fragile nature of the traditional apparatuses (made of glass) demonstration experiments are limited.

The purpose of the presented microscale gas generation method is partly or full replacement of demonstration gas experiments with hands-on ones. These kind of experiments are attractive because of theirs advantages. This makes chemistry more popular as experimental science, wide opened for new researches in the field of education and for improving and enriching the education process.

METHODOLOGY

Materials and chemicals:

Materials (Fig. 1): plastic test tube (12 mm/75 mm) (**a**), gypsum stand (**b**) Beral pipette (**c**), 2 mL syringe (**d**), hypodermic needle (1.2 mm/40 mm) (**e**), small plastic spoon or tweezers (**f**), scissors (**g**), transparent sticky tape (**h**) and pliers (**i**).

Chemicals: 50 mg calcium carbide (with the size of a rice grain), 1 mL deionized water, potassium permanganate aqueous solution (0.005 mol/L) and 1 mL hydrochloric acid aqueous solution (2 mol/L).

Figure 1. Materials for apparatus assembling

Experimental part:

Microscale gas generation apparatus, which is proposed in this article, is an improved version of the Cost effective microscale gas generation apparatus published by M. Najdoski and S. Stojkovikj (M. Najdoski and S. Stojkovikj, 2010). It consists of a Beral pipette, plastic test tube and syringe with a hypodermic needle. The apparatus assembling starts with making a small section in the pipet bulb using scissors (Fig. 2).

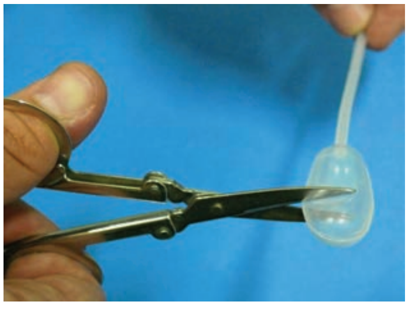

Figure 2. Making a small section in the pipette bulb

The hypodermic needle is carefully inserted into pipet bulb near its stem and needle's sharp end is cut off using pliers as shown on Fig. 3.

Figure 3. Cutting hypodermic needle's sharp tip

One piece of the solid reagent is inserted through the section. Pipet's small section is then closed using transparent sticky (Fig. 4) or insulation tape.

Figure 4. Pipette assembled as gas generation reactor

Both pipette (reactor) and the test tube are set together with a sticky tape. Pipette's stem is bent and then inserted in the test tube which is filled with the reagent for about $^1/_3$ of its volume. The hypodermic needle is attached on the syringe which is filled with liquid reagent. Assembled apparatus can be placed on a stand as shown on Fig. 5 or it can be held in hands whilst performing the experiment.

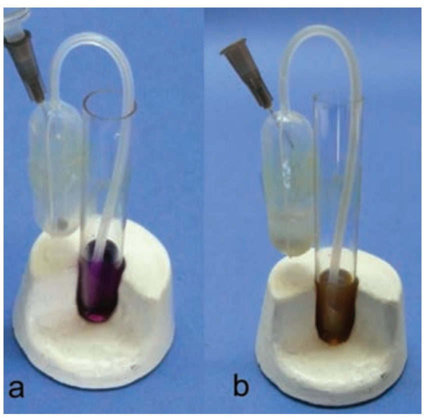

Figure 5. Assembled apparatus set on a stand

RESULTS AND DISCUSSION

Ethyne gas generation which is described in this article is based on a chemical reaction between calcium carbide as solid reagent (placed in the pipette bulb) and water as liquid reagent (in the syringe). The water is carefully inserted in the pipette bulb, drop by drop, in order to obtain small flow of generated gas (bubble by bubble).

The chemical equation for the gas generation chemical reaction is well known:

$$CaC_2(s) + 2H_2O(l) \longrightarrow C_2H_2(g) + Ca(OH)_2(s)$$

An aqueous solution of potassium permanganate and hydrochloric acid is used in the test tube for reaction with ethyne. In one or two minutes after the contact of the gas with the violet solution a color change into brown can be observed (Fig. 5). The reaction is based on ethyne oxidative cleavage with strong oxidizing reagents in acidic media producing carboxylic acid and carbon dioxide which is characteristic for terminal alkynes. The reaction is described with the following chemical equation:

$$3C_2H_2(g) + 8KMnO_4(aq) + 8HCl(aq)) \longrightarrow 3HCOOH(aq) + 3CO_2(g) + 8MnO_2(s) + 8KCl(aq) + 4H_2O(l)$$

Safety tips

Due to the fact that ethyne is highly flammable and explosive gas, there is a potential explosion danger and a special attention is required during experimentation. Only a small amount of calcium carbide must be used. In order to avoid uncontrolled ethyne generation its storage must be in dry place away from water and moisture.

The students must be careful when handling the hypodermic needle and its sharp tip must be cut off with pliers.

CONCLUSIONS

The proposed novel gas generation apparatus provides conditions for hands-on experimentation. This idea involves students in the process of experimentation and makes them active participants in the educational process. This should produce inventive students with increased motivation for learning chemistry. The described method has all advantages that come with the microscale chemistry. The proposed idea for microscale gas generation described in this article provides more productive and vivid method of experimentation which should partially substitute some of the demonstration experiments to a certain extend and increases the chemical education quality.

Using this microscale gas generation apparatus many gases like: carbon dioxide, chlorine, oxygen, nitrogen, hydrogen, ammonia, sulfur dioxide, nitrogen oxides, halogen hydrides(?), hydrogen cyanide and some hydrides can be obtained by using the known chemical reactions (M. Najdoski and S. Stojkovikj, 2010, Edith Muller-Carrera and Rivero-Muller, 2010).

This microscale method was introduced to students, with a positive impact on their knowledge, improving their attention and curiosity. The results showed that this microscale gas generation method confirmed the expected practical usage, safety, simplicity and experimentalist's individuality during experimentation.

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