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Assembling and Using a Simple, Low-Cost, Vacuum Filtration Apparatus That Operates without Electricity or Running Water

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Supporting Information

ABSTRACT: A simple, energy-saving vacuum filtration apparatus was successfully devised and applied in both a teaching laboratory for chemistry experiments undertaken by students and a scientific research laboratory. Compared with a conventional vacuum filtration apparatus, such as a mechanical vacuum pump, water-circulating vacuum pump, or water aspirator, the novel vacuum filtration apparatus exhibits many obvious advantages: portability, no need of a laboratory setting, energy-saving, cost-effectiveness, facilitating manipulation anytime and anywhere, and a very good filtration effect in the absence of electricity and running water. An air control valve plays a key part in this system. It can hold back outside air to decrease the pressure inside the suction flask by exerting a continual pull on the hand-held pump, and achieves the same filtration effect as a water-circulating vacuum pump. The vacuum filtration apparatus is suitable for different volumes and various liquid−solid mixtures, including organic and inorganic compounds; therefore, it has great potential for wide application.

KEYWORDS: *High School/Introductory Chemistry, Organic Chemistry, Interdisciplinary/Multidisciplinary, Inorganic Chemistry, First-Year Undergraduate/General, Second-Year Undergraduate, Laboratory Equipment/Apparatus, Green Chemistry, Hands-On Learning/Manipulatives*

INTRODUCTION

Vacuum filtration as a technique of separating and purifying various liquid−solid mixtures has been widely applied in all types of laboratories to perform teaching and scientific research tasks, especially for chemistry teaching laboratories. According to different properties and different volumes of liquid−solid mixtures, various vacuum filtration devices have been reported in the literature,[1−10] such as semi-, micro- and small-scale hot filtration apparatuses, which are easy, safe, fast, and contamination-free and can avoid the loss of crystals in sample transfers.[1,2] Low-temperature filtration of strong hygroscopic crystals, low-boiling solvents, or inert atmosphere have also been presented in terms of the properties of liquid−solid mixtures.[6,7] However, most vacuum filtration apparatuses can be operated only in the presence of electrical energy or running water. Ideally, there should be one vacuum pump or one aspirator for each student, or each team of students, in a chemistry laboratory. Vacuum filtration for this large group of students would require a tremendous investment in either a mechanical vacuum pump, water aspirator, or water-circulating vacuum pump. Additionally, these vacuum sources lack portability, might possibly take up valuable space, and will certainly consume vast amounts of running water and electrical energy.[1−8] Therefore, based on the above issues, we devised a novel, simple, low-cost, energy-saving vacuum filtration apparatus.

ASSEMBLY AND OPERATING PRINCIPLE OF THE VACUUM FILTRATION APPARATUS

The vacuum filtration apparatus consists of five parts:

1. A Büchner funnel
2. An air control valve, which consists of four parts (see Figure 1C)
3. A hand-held pump from a cupping jar kit
4. Latex tubing, vacuum hose, or rubber tubing with appropriate diameter and length
5. A suction flask

The five parts are assembled as shown in Figure 1A, and the air control valve is assembled as shown in Figure 1C.

Note that parts a and b of the air control valve (Figure 1C) come from a part of a cupping jar kit (see the Supporting Information); parts c and d (Figure 1C) come from a 1000 μL plastic pipette tip, which is cut into two parts to be suited for the diameters of parts a and b. The total cost of the hand-held pump and the air control valve is not more than $3.00 in China.

In order to establish and maintain a vacuum, both the hand-held pump and the air control valve work in tandem. The hand-held pump in Figure 1A only eliminates air inside the suction flask when pulled, but the pump cannot hold a vacuum. The air control valve can hold a vacuum after the hand-held pump is pulled. The operating principle is that when the hand-held

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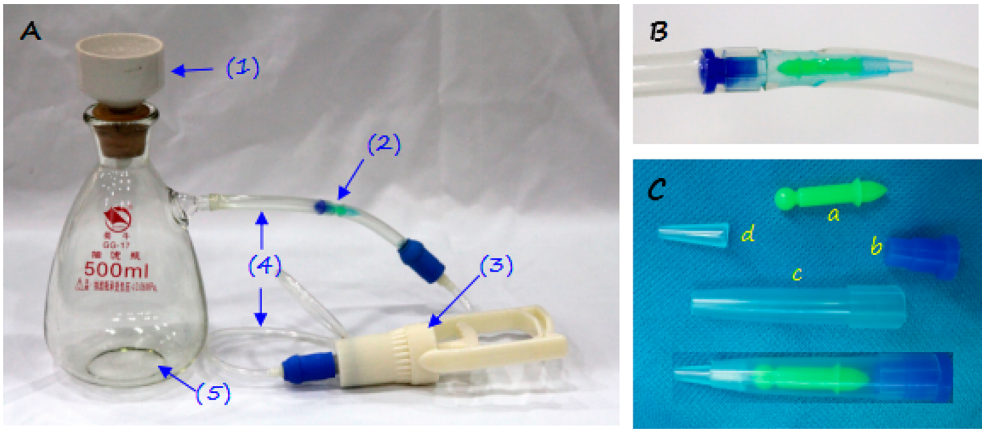

Figure 1. (A) The vacuum filtration apparatus has five elements: (1) Büchner funnel; (2) air control valve; (3) hand-held pump; (4) vacuum tubing; (5) suction flask. (B) Air control valve connected with tubing. (C) Air control valve components individually (parts a, b, c, and d) and assembled. (See the text and the Supporting Information for more details.)

pump is pulled, a vacuum is formed because the tapered end of part a in Figure 1B is nearer the suction flask and is forced by the pressure outside of the flask to block the small hole in the cap of part b; thus, no air enters the suction flask from the vacuum hose, allowing the suction flask to hold a higher vacuum. Moreover, when the hand-held pump is pulled once, the pressure in the suction flask reaches 0.05 MPa, as measured by a pressure gauge; when pulled many times, the pressure is gradually lowered and can achieve the same filtration effect as that using a circulation water vacuum pump. Therefore, this design of the air control valve is of great significance for a novel vacuum filtration apparatus.

APPLICATION OF THE VACUUM FILTRATION APPARATUS

This system has been effectively applied to the vacuum filtration of various liquid–solid mixtures dissolved in deionized water or organic solvents, including organic and inorganic compounds (e.g., potassium dichromate, sodium and aluminum sulfate, acetylsalicylic acid, ethylene diamine tetraacetic acid (EDTA), nano-zinc oxide, cyclodextrin, acetanilide, D-mannitol, acrylamide, calcium acetate, pentaerythritol, and ferrous sulfate) as well as other liquid–solid mixtures. Therefore, this novel vacuum filtration apparatus has a broad application potential for the separation and purification of organic and inorganic substances, and can be introduced into high school classrooms, field trips, undergraduate-led experiments, and scientific research laboratories. The overall filtration process and examples of partly filtrated samples using this novel vacuum filtration apparatus can be seen in the video and photographs of the Supporting Information.

IN SUMMARY

A simple, highly effective, low-cost, energy-saving vacuum filtration apparatus has been successfully devised and can be used with students learning chemistry (see the notes for instructors in the Supporting Information), in other disciplines, and in scientific research laboratories. The vacuum filtration apparatus requires no electricity or running water for the entire filtration process, and the apparatus exhibits many advantages, such as portability, energy-saving, cost-effectiveness, safety, facilitating manipulation anytime and anywhere, and highly effective filtration. Additionally, it is well suited to vacuum filtration for various organic and inorganic compounds with different volumes.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.5b00997.

Notes for instructors for assembly and use of apparatus (PDF, DOC)

Photograph A of partly filtrated samples in deionized water (PDF)

Photograph B of partly filtrated samples in organic solution or deionized water (PDF)

Video of filtration process (AVI)

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Notes

The authors declare no competing financial interest.

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