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A simple method for comparing the properties of gases and liquids using a decompressible container

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Abstract

This work reports a simple way to compare the properties of gases and liquids using a decompressible container. Since a decompressible container provides unfamiliar pressure conditions, using this apparatus is a fun and useful way to demonstrate the properties of gases and liquids by comparing them with each other.

Introduction

Comparing the differing properties of gases and liquids is an important aspect of understanding the nature of matter for upper primary and secondary students [1] and also preservice teachers [2]. According to the kinetic theory of matter, the gas particles move fast and are able to spread out because the gas particles have enough energy to break away from the intermolecular attractions while the liquid particles move freely but are not able to break away from the intermolecular attractions because they do not have enough energy.

To demonstrate these properties, most school science focuses on the difference of compressibility between gases and liquids [3]. Figure 1 is the representative experiment usually used in school science [3]. In this experiment, students are asked to compress water and air in syringes and compare the different properties of the two. This experiment, however, can only show how much gases or liquids can be compressed, primarily focusing on the different intermolecular distances between the molecules. In this experiment it is difficult to also show another representative feature, which is that gases always take the whole space while liquids keep their volume. Thus, in this study, as an additional experiment, we designed an experiment that can simply compare the properties of gases and liquids using a decompressible container.

Apparatus: decompressible container

A decompressible cylindrical container is a piece of equipment where the air can be taken out of the container at room temperature and atmospheric pressure. It has a pumping bar that allows the air to go only one way, which causes the air to be removed (see figure 2). Food preservation decompression boxes[3], which are transparent containers

[3] We can obtain this apparatus in an online-shop by using keywords 'vacuum food containers' or 'vacuum food container pump'. This apparatus can be made referring to various video clips that provide how to make a vacuum pump.

with good visibility inside, can be also used as this apparatus.

A decompressible container has some advantages over the use of syringes in terms of learning the properties of gases and liquids. First of all, this equipment creates a condition of decompression, which is a novel situation. A decompressible container allows students to observe an unfamiliar phenomenon that is different from everyday experience. In addition, this equipment is straightforward to use even for primary school students as well as for secondary school students. The air can be taken out easily by pumping the bar many times. These features of the decompressible container allow many kinds of experiments related to air pressure to be designed, considering simply measuring the air pressure through the barometric sensor equipped in a smartphone [4].

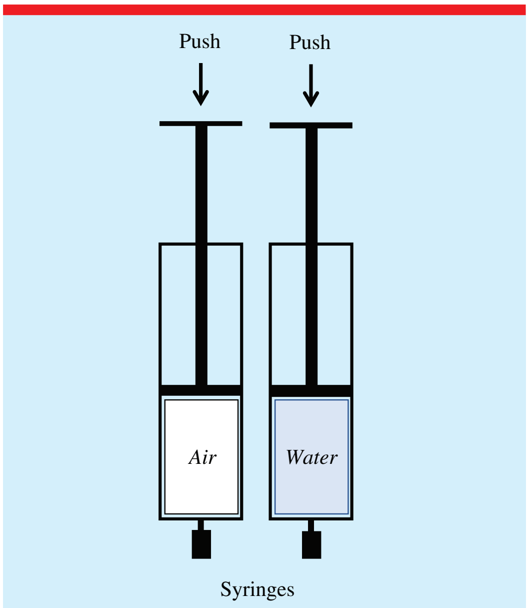

Figure 1. The comparative experiment to compress water and air in syringes.

Design of the approach

Setting for the experiment

We put two small plastic zipper bags of the same size into the container, one containing air and one containing water. To minimise the elastic force of the plastic bags, the bags contain only small amounts of air and water. The bags were also tightly sealed so that they would not open during the experiment to prevent air inflow and outflow.

Process of the experiment

Decompressing process. When we created the decompressed condition (shown in figure 3), the bag containing the air expanded while the bag containing the water retained its same volume and shape.

Why did the bag with air in it expand? This resulted from maintaining the equilibrium of the air pressures between the inside and outside of the bag. In the microscopic view, there are many collisions between the air particles and the wall of the bag both inside and outside the bag. The number of collisions per area inside the bag is larger than the number of collisions per area outside. In this unbalanced condition, the effect of the gap between air pressures causes the boundary to move until the two air pressures are the same, which is the equilibrium state. It is for this reason that the air in the bag expands: the property of gases is that all gas particles fill the whole space.

So why then does the bag with water in it keep the same shape and volume? This results from the strong intermolecular forces among the water molecules and gravity. If there is not sufficient energy to break the intermolecular bonds, liquids keep the same volume. The surface of water in a cup is flat for this same reason. The shape of water is determined only by the shape of the container and gravity.

Back to the initial state. When we push the button on the cover of the container (shown (b) of figure 2), the process is reversed. The expanded air shrinks to its initial state while the water in the zipper bag is still the same. This is because the gas particles move freely in the whole system with collisions, while the liquids particles move freely but keep closer distances among the particles.

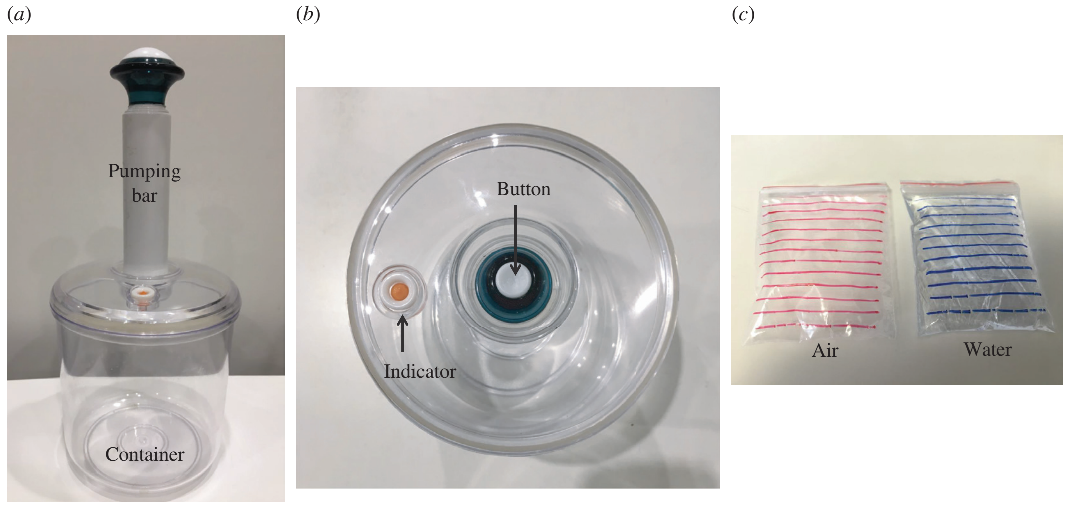

Figure 2. The apparatus for the experiment: (a) the main piece of equipment consists of a pumping bar (ϕ 30 mm $\times$ 140–230 mm), a container (ϕ 130 mm $\times$ 120 mm) and a cover (ϕ 130 mm $\times$ 20 mm); (b) a view of the top side of the container cover, which has a button and an indicator. Pushing the button allows the outside air to come into the container. The indicator gives a rough indication of the air pressure in the container; (c) the small coloured zipper bags (50 mm $\times$ 70 mm), one containing air (red) and one containing water (blue).

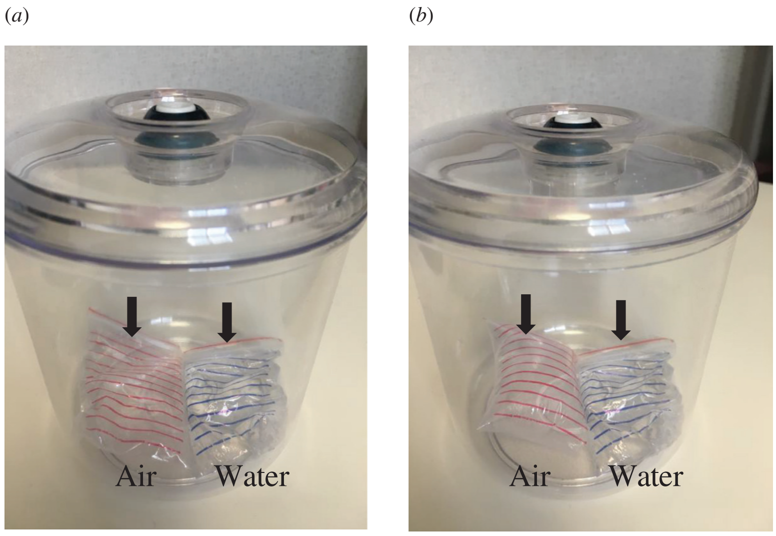

Figure 3. The bags filled with air and water during the experiment in their (a) original and (b) decompressed conditions.

Conclusion

The decompressible container is a useful and simple apparatus that can be used to compare the properties of gases and liquids. The common experiment using syringes can only compare the compressibility between the two states of matter, while the approach presented here highlights the two states' different properties in terms of energy and intermolecular forces, which can be crucial criteria for comparing gases and liquids. As an additional experiment that compares the properties of gases and liquids, this approach provides a condition that may be unfamiliar to students and that is a fun and useful way to explore the properties of gases and liquids.

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