Discrepant Balloons

Discrepant Event—Classroom Lessons

Introduction

Learn how to build a simple device to demonstrate the relationship between surface area and energy. Two identical balloons, inflated to different volumes, are connected. What will happen when the pathway is opened and air is allowed to flow between the two balloons? The outcome may surprise you . . . although it shouldn't!

Concepts

- Minimum energy state
- Mathematical models
- Observation and reasoning skills

Materials

Balloons, round, 2

Bottles, sport drink or water with pull top cap, 2

Electrical tape

Scissors

Safety Precautions

Care should be taken to avoid sharp edges when cutting the plastic bottles. If a balloon bursts, pieces may become projectiles. Wear chemical splash goggles or safety glasses. Follow all laboratory safety guidelines.

Preparation

1. Cut the top portion of water bottle about 1 cm below the cap (see Figure 1). Repeat with the second bottle.
2. Place the necks of the two bottles together and connect them together with electrical tape to make an air-tight seal. You should still be able to unscrew the caps (see Figure 2).
3. Stretch the neck of one balloon over one pull top and the neck of the second balloon over the other pull top (see Figure 3).

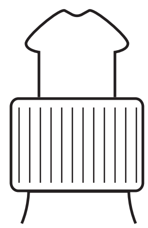


Figure 1.

Figure 2.

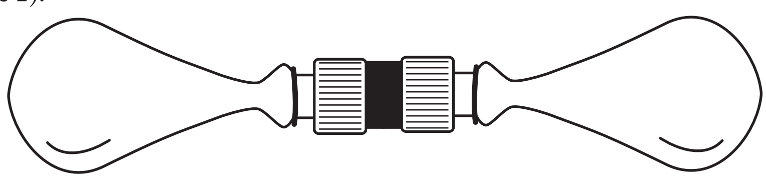


Figure 3.

Procedure

1. Pull both tops open.
2. Unscrew one bottle cap and blow through the open bottle neck three full breaths to inflate one balloon to about the size of a soccer ball.
3. Push the cap of the inflated balloon closed. *Note:* To keep the balloon from deflating while you are pushing the cap closed, use your finger to cover the inside hole of the bottle cap.
4. Screw the bottle cap back and unscrew the second cap.
5. Inflate the second balloon with only one full breath to inflate the second balloon to about the size of a softball.
6. Push the cap of the second balloon closed as in step 3.
7. Reconnect the second cap. The setup should now appear quite lopsided (see Figure 4).

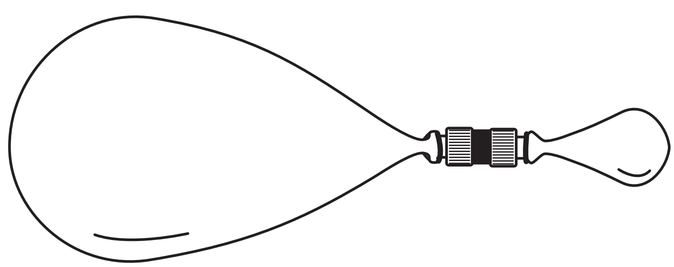


Figure 4.

8. Show the setup to the class and have them predict on paper what they think will happen when the clamp is opened and air is allowed to flow between the two balloons.

9. Pull the two bottle tops open and observe as the air from the less inflated balloon flows into the more inflated balloon, making it larger still.

Disposal

The entire apparatus may be stored for future use. Replace balloons as needed.

Tips

- When starting the demonstration, you may want to let the students decide for you which balloon to blow up bigger than the other or use a coin toss. That way, students will not think it is some kind of trick that works because of some unseen difference in the balloons.
- Do not blow up the balloons too far in advance, for the stretch tends to affect the rubber and diminish its elasticity over time. We have all experienced this effect—whenever a balloon that has been inflated for a few days is allowed to deflate, the thin, shriveled rubber bears little resemblance to the original uninflated balloon. If given enough time, the wilted balloon does seem to recuperate—at least partially.
- For an alternate set-up using one-hole rubber stoppers, glass tubing, rubber tubing, and a pinch clamp, see Figures 5–7. *Caution*: Care should be taken with the breaking and fire-polishing of glass tubing and with their insertion into the rubber stoppers.

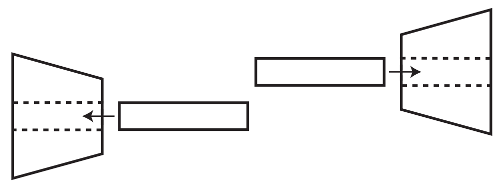


Figure 5.

Figure 6.

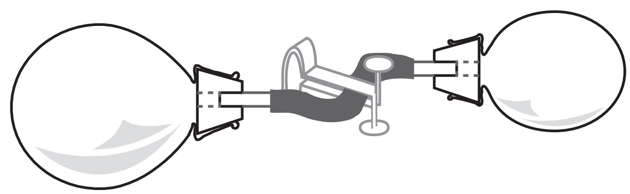


Figure 7.

Discussion

Counter-intuitive as it may seem, the air does not flow from the larger to the smaller to equalize the volumes, but instead, it flows from the smaller to the larger, increasing the size discrepancy! This demonstration is not new; it has been around for many years. But whereas most explanations point toward the molecular structure of rubber to account for this illogical phenomenon, such explanations are unnecessary and can even be considered misleading. The phenomenon is not unique to rubber; in fact, just about any stretchable membrane will work, including soap films. Furthermore, the results, though perhaps counter-intuitive, are in fact logical and completely predictable, given some well-known (though greatly underused) equations—mathematical, not chemical!

The fundamental equations for a sphere (most students learn these in 7th or 8th grade) are as follows.

$V = 4\pi r^3/3$, which can be rewritten to solve for the radius $r = \sqrt[3]{3V/4\pi}$

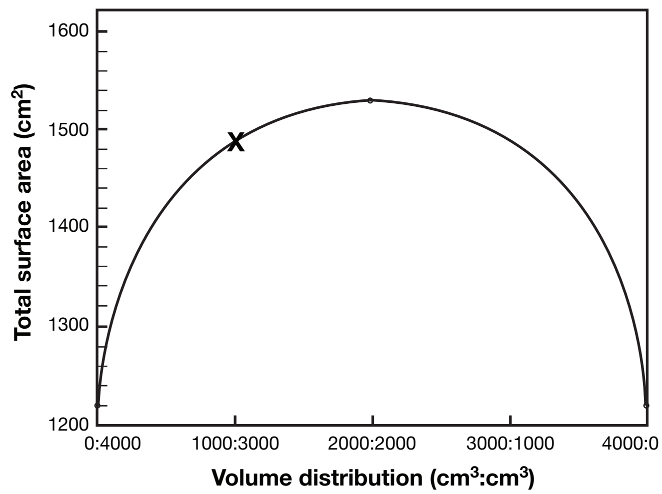
$SA = 4\pi r^2$ (SA = surface area)

Using these two equations, one can determine the radii and surface areas for spheres of the volumes found in Table 1.

V (cm^3)	r (cm)	SA (cm^2)
0	0	0
1000	6.20	483
2000	7.82	768
3000	8.95	1006
4000	9.85	1219

Table 1.

Assuming the balloons to be essentially spherical, it is now relatively easy to see why a 1,000 cm^3:3,000 cm^3 two-balloon configuration (with a total surface area of 1,489 cm2) would, if permitted, logically head toward the more lopsided 0 cm^3:4,000 cm^3 configuration (total SA = 1219 cm^2), and not toward the 2,000 cm^3:2,000 cm^3 configuration (total SA = 1536 cm^2). The graph shown may be thought of as a sort of potential energy "hill." A ball placed at point X would logically move away from symmetry, not toward it, and it would accelerate as it moves. It is worth pointing out that the air flow in the two-balloon system does in fact accelerate during the demonstration—starting off slow at first, then growing gradually faster as the surface area gradient becomes steeper.



Total surface area as a function of volume distribution of a two-balloon system containing 4000 cm^3 of gas.

That a balloon membrane or system of balloon membranes will assume a state of minimum surface area may very well be a function of its molecular networking, but it is certainly nothing neither unique nor remarkable. In essence, then, the outcome of this demonstration should be no more surprising than inflating a single balloon and then watching it deflate! Yet this demonstration is surprising. It catches most spectators off-guard. Even young children feel the balloons ought to "share" more equally. Perhaps this is because we are all to one degree or another believers in symmetry, and we automatically tend to equate symmetry with stability. This is easy to understand, for we see examples of stable symmetry over and over again throughout the natural world. (We also see many examples of stable asymmetry, but they are by their very nature not as noticeable in our mind's eye.) And there is nothing inherently wrong with the favoring of symmetry, as long as it in no way interferes with our powers of observation or narrows in scope our capacity for logical thought.

This two-balloon demonstration is indeed an eye-opener, but it opens our eyes not to any remarkable structuring in rubber, but to a remarkable bias in ourselves!

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, motions and forces, transfer of energy
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, motions and forces, conservation of energy and increase in disorder

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Discrepant Balloons* activity, presented by Bob Becker, is available in *Discrepant Event—Classroom Lessons*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Discrepant Balloons* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP6420	Balloons, Latex, 5″, Pkg/50
AP6011	Electrical Tape
AP8949	Scissors, Heavy-Duty

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.