The Thermodynamics of a Rubber Band

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Topic

The first and second laws of thermodynamics

Time

1 hour

Safety

Please click on the safety icon to view the safety precautions. Adult supervision is necessary. When using the candle, be extremely careful not to burn the rubber band or other test samples.

Materials

balloon
matches
rubber band (the wider the better)
assortment of nylon thread and monofilament line
grease pencil
ruler
candle
ring stand and ring (or a nail in a wall or in another place to hang the rubber band and weight alongside the ruler)
fishing sinker or other heavy object that you can suspend from the rubber band to stretch it

Procedure

You will need a partner for Part B of this experiment.

Part A

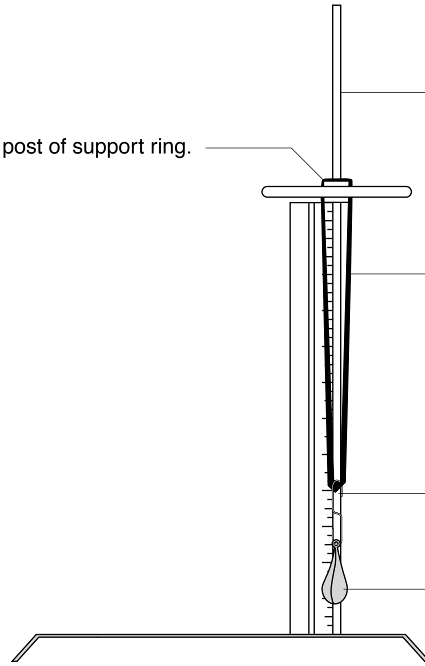
1. Hold an uninflated balloon to your lips and quickly stretch it. Make note on the data table of any change in temperature.
2. Keep the stretched balloon on your lips for 2 min; then allow it to relax. On the data table, note any change in temperature.

Data Table

Material	Observations	
	Stretched on lips	Relaxed after stretching
Balloon		
	Length with weight	Length after heating
Rubber band		
Monofilament line		
Thread		

PART B

1. Set up the ring stand as shown in the figure. Place the ruler on the stand as shown (or set up an alternative method for hanging and measuring the rubber band).



2. Place the rubber band so that it hangs unimpeded off the clamp on the ring. Attach the weight to the rubber band. Be sure that the rubber band is stretched by the weight.
3. Mark the ruler with the grease pencil even with the bottom of the rubber band. Record this length on the data table.
4. Light the candle. While your partner observes the rubber band and ruler, carefully move the flame around the rubber band. Keep the flame moving rapidly so as not to burn the rubber band. Observe what happens to the length of the rubber band. Record the results on the data table.
5. Repeat steps 2 to 4 with samples of nylon thread and monofilament line. Record all results on the data table.

One kind of change during which heat is given off is when matter forms crystals. Balloons, rubber bands, monofilament line, and nylon thread are all examples of polymer substances, which are made up of long chains of molecules and may exhibit a high degree of elasticity. When a polymer substance is in a relaxed state, the molecule chains are all mixed up in a disordered way. When an elastic polymer is stretched, these chains become more ordered, resulting in a sort of crystallization.

6. When you stretched the balloon against your lips, was heat given off or absorbed? Which driving force was dominating this change, the tendency toward lower energy or the tendency toward disorder? Explain why this happened.
7. When you relaxed the balloon on your lips, was heat given off or absorbed by the balloon? Which driving force dominated this change?

8. When you heated the stretched rubber band with the candle, what happened to its length? If adding heat to the rubber band should increase its tendency toward disorder, how was this reflected in the change that took place? Based on what you observed in the procedure with the balloon, do you think heat was absorbed or given off during this change?
9. Did the other polymer materials you tested behave similarly to the rubber band?
10. Unlike the materials you tested, most solid materials get longer or larger when you heat them. Explain why the rubber band does the opposite.

What's Going On

The stretched balloon gave off heat. The tendency toward lower energy dominated. Stretching the balloon orients the polymer chains, causing crystallization—a change to a lower energy state—so heat is given off. When the balloon relaxed, you should have felt it cool. This shows that it absorbed heat.

The tendency toward disorder dominated this change: As the balloon relaxed, its molecules became more disordered. The heated rubber band got shorter. Adding heat increased its tendency to become disordered. For a polymeric substance, this means a tendency to relax (its molecule chains becoming disoriented). Heating the stretched rubber band caused it to "try" to achieve a more relaxed (disordered) state. When the stretched balloon relaxed, it absorbed heat. Based on this finding, you could guess that the relaxing (shortening) rubber band also absorbed heat.

The monofilament line and the synthetic threads should exhibit similar behavior because they, too, are polymers. Heating a material increases its tendency to disorder. For most solids this means expanding. For many polymers (like the rubber band), however, in order to get more disorderly they must shrink to a more relaxed state. This is why the stretched rubber band shortens when the candle flame heats it.

Connections

There are two natural driving forces in the universe that govern the kinds of changes matter undergoes. The first of these is the tendency for all matter to attain its lowest energy level; the second is matter's tendency to reach its maximum level of disorder. When the tendency toward lower energy is strongest, changes that give off heat take place spontaneously and the substance heats up. When the tendency toward disorder is strongest, changes that absorb heat take place spontaneously and the substance cools.

Increasing the temperature of matter increases the motion of its molecules, making things more chaotic. So, we should be able to predict that if we increase a substance's temperature, we will increase its tendency toward disorder. In this experiment, you tested this prediction, observing changes in several different *polymer* substances.

Safety Precautions

READ AND COPY BEFORE STARTING ANY EXPERIMENT

Experimental science can be dangerous. Events can happen very quickly while you are performing an experiment. Things can spill, break, even catch fire. Basic safety procedures help prevent serious accidents. Be sure to follow additional safety precautions and adult supervision requirements for each experiment. If you are working in a lab or in the field, do not work alone.

This book assumes that you will read the safety precautions that follow, as well as those at the start of each experiment you perform, and that you will *remember* them. These precautions will not always be repeated in the instructions for the procedures. It is up to you to use good judgment and pay attention when performing potentially dangerous procedures. Just because the book does not always say "be careful with hot liquids" or "don't cut yourself with the knife" does not mean that you should be careless when simmering water or stripping an electrical wire. It *does* mean that when you see a special note to be careful, it is extremely important that you pay attention to it. If you ever have a question about whether a procedure or material is dangerous, stop to find out for sure that it is safe before continuing the experiment. To avoid accidents, always pay close attention to your work, take your time, and practice the general safety procedures listed below.

PREPARE

- Clear all surfaces before beginning work.
- Read through the whole experiment before you start.
- Identify hazardous procedures and anticipate dangers.

PROTECT YOURSELF

- Follow all directions step by step; do only one procedure at a time.
- Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eyewash, and first-aid kit.
- Make sure that there is adequate ventilation.
- Do not horseplay.
- Wear an apron and goggles.
- Do not wear contact lenses, open shoes, and loose clothing; do not wear your hair loose.
- Keep floor and work space neat, clean, and dry.
- Clean up spills immediately.
- Never eat, drink, or smoke in the laboratory or near the work space.
- Do not taste any substances tested unless expressly permitted to do so by a science teacher in charge.

USE EQUIPMENT WITH CARE

- Set up apparatus far from the edge of the desk.
- Use knives and other sharp or pointed instruments with caution; always cut away from yourself and others.
- Pull plugs, not cords, when inserting and removing electrical plugs.
- Don't use your mouth to pipette; use a suction bulb.
- Clean glassware before and after use.
- Check glassware for scratches, cracks, and sharp edges.
- Clean up broken glassware immediately.

- Do not use reflected sunlight to illuminate your microscope.
- Do not touch metal conductors.
- Use only low-voltage and low-current materials.
- Be careful when using stepstools, chairs, and ladders.

USING CHEMICALS

- Never taste or inhale chemicals.
- Label all bottles and apparatus containing chemicals.
- Read all labels carefully.
- Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves).
- Do not touch chemical solutions.
- Wash hands before and after using solutions.
- Wipe up spills thoroughly.

HEATING INSTRUCTIONS

- Use goggles, apron, and gloves when boiling liquids.
- Keep your face away from test tubes and beakers.
- Never leave heating apparatus unattended.
- Use safety tongs and heat-resistant mittens.
- Turn off hot plates, bunsen burners, and gas when you are done.
- Keep flammable substances away from heat.
- Have a fire extinguisher on hand.

WORKING WITH MICROORGANISMS

- Assume that all microorganisms are infectious; handle them with care.
- Sterilize all equipment being used to handle microorganisms.

GOING ON FIELD TRIPS

- Do not go on a field trip by yourself.
- Tell a responsible adult where you are going, and maintain that route.
- Know the area and its potential hazards, such as poisonous plants, deep water, and rapids.
- Dress for terrain and weather conditions (prepare for exposure to sun as well as to cold).
- Bring along a first-aid kit.
- Do not drink water or eat plants found in the wild.
- Use the buddy system; do not experiment outdoors alone.

FINISHING UP

- Thoroughly clean your work area and glassware.
- Be careful not to return chemicals or contaminated reagents to the wrong containers.
- Don't dispose of materials in the sink unless instructed to do so.
- Wash your hands thoroughly.
- Clean up all residue, and containerize it for proper disposal.
- Dispose of all chemicals according to local, state, and federal laws.

BE SAFETY-CONSCIOUS AT ALL TIMES