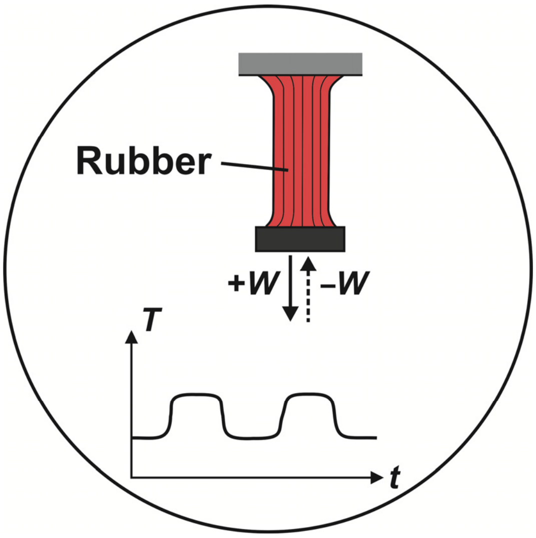
Temperature as Function of Time in Expanding Rubber



Equipment

rubber band (e.g. 3 x 20 x 50 mm)
  with thermocouple
chart recorder
two cables

Chemicals:

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Safety:

It is recommended to wear safety glasses. One should make sure that the rubber band does not tear or snap back.

Procedure

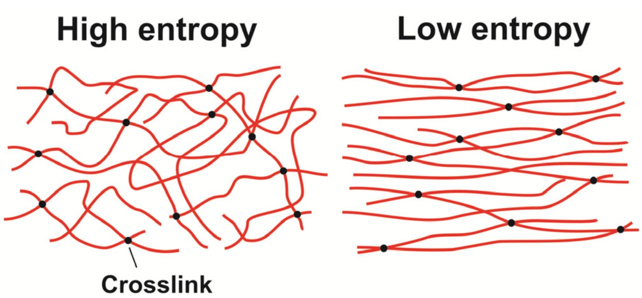
First, the thermocouple is connected to the chart recorder using the cables. Subsequently, the zero position of the chart recorder is adjusted to the center of the paper (50 %) and the rubber band is expanded and then relaxed several times. The measuring range has to be chosen according to the thermocouple used, the paper advance should be about 250 mm/min.

Observation:

During expansion the temperature rises whereas the temperature sinks again when the rubber band is allowed to contract. This temperature change can be observed no matter how often the experiment is repeated. The plot of T against t resembles a square wave.

Explanation:

The effect of increasing entropy on rubber is different to that on most substances: Whereas solids, liquids and gases usually expand with rising temperature, rubber contracts when heated. Inversely, a substance such as rubber that contracts when entropy is added to it will become warmer when expanded. When the rubber is allowed to contract exactly the opposite will happen. Therefore, a rubber band that is expanded and then relaxed, will become warm at first and then cold again. The energy expended at the beginning is retrievable. The process is reversible. Entropy is scarcely generated because the band is exactly as cool at the end as it was at the beginning.



The unusual behavior of rubber is caused by its molecular structure. Rubber consists of very long chains of polymerized molecules. The random-length chains are held together by weak intermolecular forces but are also joined at irregular intervals by covalent disulfide bonds (crosslinks). The crosslinks produced by vulcanization prevents the polymer chains from moving independently (such as, for example, the individual noodles in a heap of spaghetti would do). In the unstressed state, the chains are folded and wildly tangled up. If one stretches the rubber, the messy tangles line up to a certain degree; the disorder and therefore the entropy decreases. The excess entropy is transferred to the environment what causes the observed increase in temperature. When the rubber band relaxes, the polymer chains curl up again; the required entropy is “soaked up” from the environment what is the cause for the decrease in temperature. The experiment demonstrates the entropic character of rubber elasticity.

Supplement:

from: Alex Seeley, www.physlink.com

The experiment can be adapted in a simplified manner to everyday life: One touches a broad rubber band with the upper lip, which is very sensitive to changes in temperature and after waiting a short while for equalization of temperature, the band is stretched quickly and powerfully and immediately pressed again against the upper lip. It feels noticeably warm. When the stretched band is allowed to contract to its original length and then quickly pressed against the upper lip there is a noticeable cooling.

Disposal:

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