Demonstration Experiments

to the lecture

"Teaching Entropy with Fun"

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JOB FOUNDATION

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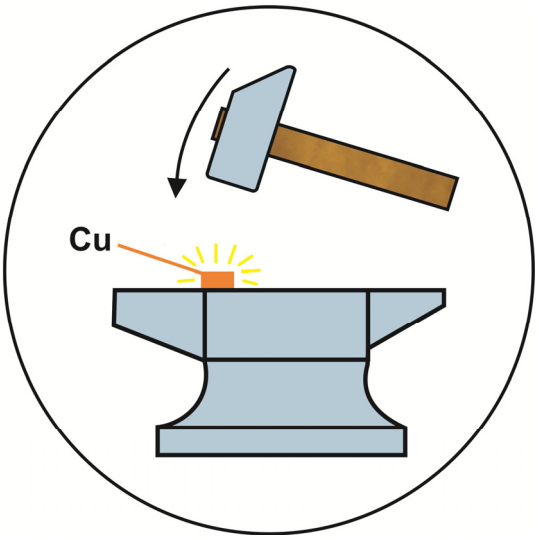
Heating of Metal by Forging



Equipment:

anvil
heavy sledgehammer
soft annealed piece of copper (having a volume of a few cubic centimeters) with handle

Chemicals:

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Safety:

Because hammers are notorious for causing thumb and finger injuries one should be very careful and wear protective gloves when working with this tool.

Procedure:

The piece of copper is put on the anvil and hit forcefully about 20 times with the sledgehammer.

Observation:

The piece of copper becomes so hot that it hisses when put into water.

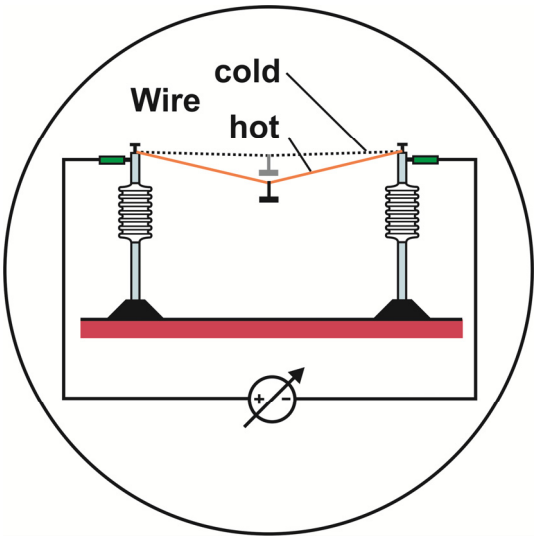
Explanation:

The atomic structure of the copper is permanently disturbed by hitting it with the hammer. As main effect of the entropy generated during the process the piece of copper becomes hot.

Disposal:

The piece of copper can be reused after annealing and quenching in water.

Expansion of a Wire Caused by Electric Current



Equipment:

power supply e.g. 25 V, 10 A
two isolating supports
resistance wire (thin)
e.g. constantan wire (600 × 0.4 mm ∅)
weight (10 to 20 g) e.g. big nut or
hook weight
two cables
“height indicator” e.g. glass rod in a stopper
with a hole

Chemicals

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Safety:

The wire should not be touched as long as the current flows through it.

Procedure:

Preparation: The thin wire is stretched between the two isolating supports the weight being located in the middle of the wire. The “height indicator” is placed below the weight. Subsequently, each of the isolating supports is connected by one of the cables with the power supply.
Procedure: First, the current is slowly increased. Subsequently, the current is decreased again.

Observation:

The weight in the middle of the wire sinks down slowly with increasing current. At higher current, the wire also begins to glow. If the current is decreased the weight moves upwards again. The movement of the weight can be observed especially clearly with the help of the shadows created by a lamp.

Explanation:

Entropy is generated by the electric current. As main effect of the increase in entropy the wire becomes warmer and finally begins to glow. But the increasing entropy also causes a side effect: The wire lengthens noticeably. The effect can be easily observed by the lowering of the weight. If the electric current is decreased again, also the entropy generated in the wire decreases; the wire gradually cools down and shrinks again.

Disposal:

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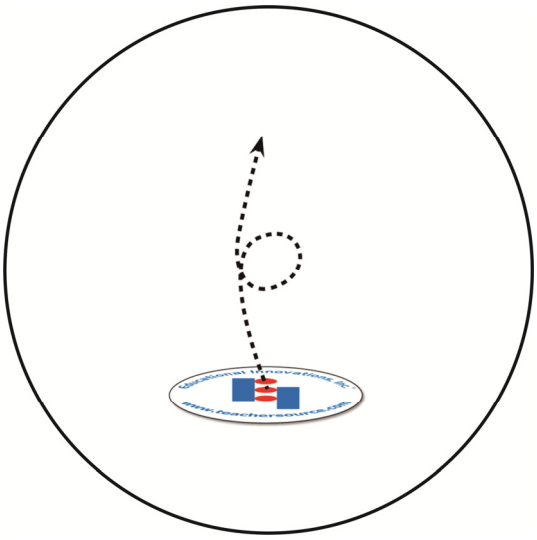
Bimetallic Jumping Disc



Equipment:

bimetallic jumping disc
(possibly cup with warm water)

Chemicals:

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Safety:

It is recommended to wear safety glasses.

Procedure:

First, the disc is warmed to about body temperature by rubbing it between the palm of one hand and the fingers of the other or by holding it, for example, against the outside of a cup of warm water. Then, it is “clicked” from its original convex shape to a concave shape. If the metal was warm enough, the disc will remain temporarily in this “inverted” position. Subsequently, the disc is quickly but carefully placed on a hard surface like a table.

Observation:

After a short while, the disc suddenly snaps back into its original shape with a loud click and jumps into the air.

Explanation:

The disc consists of two layers of different metals which are welded together (so-called “bi-metal”). When the entropy of the disc is increased, the two metals expand varyingly strong because of their rather different coefficients of thermal expansion and above a temperature of approximately 310 K the disc stays in the “inverted” position. When the disc cools down, the metals shrink again and the disc returns spontaneously to its original shape.
The same principle applies to a thermostat or a shunt-valve in a car.

Disposal:

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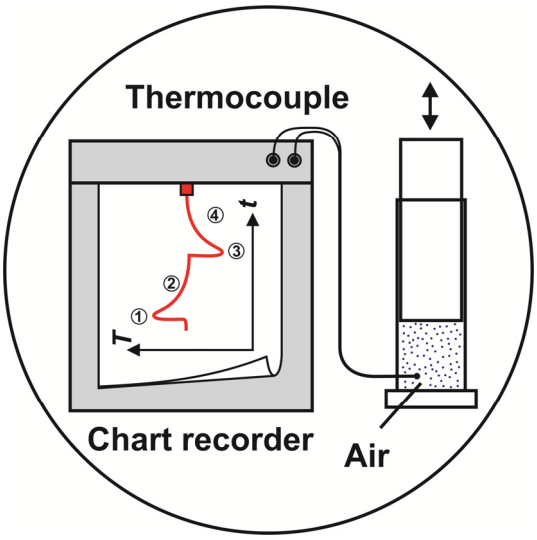
Source of supply:
for example Educational Innovations (http://www.teachersource.com)

Compression and Expansion of Air



Equipment:

plexiglass cylinder with piston sealed with o-ring and with implemented thermocouple
chart recorder
two cables

Chemicals:

silicone grease

Safety:

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Procedure:

The piston is greased with a bit of silicone grease and then wiped. The electric connections of the thermocouple are connected with the chart recorder by means of the cables. Subsequently, the zero position of the chart recorder is adjusted to the center of the paper (50 %). Then, the piston is quickly pressed into the cylinder. The piston is held down until the chart recorder deflection has returned to its original value. Subsequently, the piston is released. The measure range of the recorder has to be chosen according to the thermocouple used, the paper advance should be approximately 100 mm/min.

Observation:

The compression is characterized by an increase in temperature, the expansion, however, by a decrease in temperature.

Explication:

If air is compressed, the atoms become accelerated, the disorder and therefore the entropy increases and as a result the gas becomes warmer (phase 1). After a while, the gas cools down to its original value because it is not insulated from the cylinder walls and the entropy can flow out of the system into the environment (phase 2). The piston's expansion leads to further cooling (phase 3). Then, entropy begins to flow back from the environment into the system and the gas begins to warm up (phase 4). The more slowly this is done, the more the difference between the compression and expansion disappears.

Disposal:

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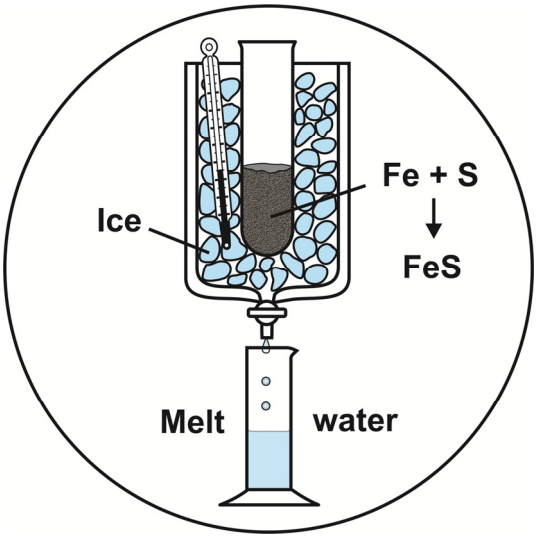
Ice Calorimeter



Equipment:

double-walled calorimetric vessel
large test tube
measuring cylinder calibrated in the unit of entropy (0.82 mL of melt water corresponds to the entropy of 1 J/K)
thermometer
mortar and pestle
sparkler
ring stand with clamp

Chemicals:

iron powder
sulfur powder
crushed ice

Safety:

sulfur powder (S):

H315
P302+352

iron sulfide (FeS):

H400
P273

Because of the generation of sulfur containing fumes during the reaction it is obligatory to work in a fume hood. It is also required to wear safety glasses and protective gloves.

Procedure:

Iron powder and sulfur powder is cautiously mixed in a mortar in the molar ratio 1:1. 22.0 g of the mixture (which corresponds to 1/4 mol FeS) are put into the test tube. Subsequently, the test tube and the thermometer (in the case of an electronic thermometer its temperature sensor) are placed in the calorimetric vessel filled with crushed ice. Before the reaction is started the stopcock of the vessel is opened to remove the water which was meanwhile produced. Then the stopcock is closed, the reaction of the Fe-S mixture is initiated with the help of a sparkler and the stopcock is opened again. The melt water produced during the reaction is collected in the graduated cylinder.

Observation:

The mixture reacts thereby glowing red. Part of the ice melts. The temperature in the calorimeter remains (almost) constant.

Explanation:

Iron reacts with sulfur to iron sulfide:

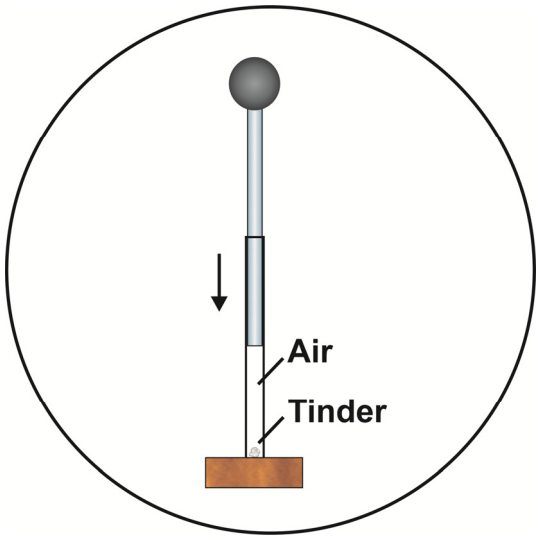
$$Fe|s + S|s \rightarrow FeS|s.$$

During the reaction a considerable amount of entropy is emitted. The volume of water collected in the graduated cylinder is indicative of this amount of entropy (0.82 mL of melt water corresponds to the unit of entropy).

Disposal:

The iron sulfide residue is collected in a special container for inorganic solids which is subsequently sent for proper disposal.

Fire Piston



Equipment:

fire piston consisting of lower piston, cylinder and upper piston
tweezer

Chemicals:

tinder e.g. cotton wool

Safety:

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Procedure:

A small piece of tinder e.g. cotton wool is poked with the aid of a tweezer into the hole in the lower piston. Subsequently, the cylinder is placed on the lower piston and the upper piston is pushed a few centimeters into the cylinder. Then, the upper piston is forced vigorously down.

Observation:

The piece of tinder ignites with a bright flash.

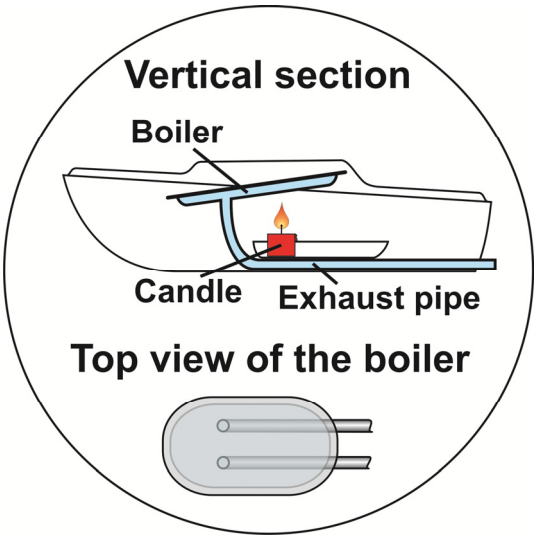
Explanation:

When a fixed mass of gas such as air is compressed rapidly it becomes glowingly hot (adiabatic compression). (If this compression is not done quickly enough the entropy has time to flow from the hot gas into the cold cylinder walls and the gas cools down.) This effect can be used to ignite a piece of tinder. Thereby, the air in the cylinder acts simultaneously as an oxidizer.
The same principle is utilized in diesel engines to ignite the fuel-air mixture in the cylinders of the engine.

Disposal:

The singed cotton wool can be discarded as household waste.

Pop-pop Steam Boat



Equipment:

pop-pop boat
big bowl, washtub, small pool or the like
candle
matches or lighter
plastic dropper

Chemicals:

water

Safety:

Because the boat will get hot one should not touch it during or shortly after its operating.

Procedure:

Using the plastic dropper, water is filled into one of the exhaust pipes of the boat until it flows out of the second pipe. The boat is put into the water in a bowl (or the like) carefully making sure that the water stays in the boiler and both exhaust pipes are under the water. The candle is placed into the holder and the wick is lighted. Subsequently, the holder is gently placed underneath the boiler.

Observation:

After a short while, the boat begins to move with the typical “popping” noise.

Explanation:

The pop-pop boat is powered by a very simple heat engine without moving parts. The candle heats the water in the boiler. When the water boils it creates a brief burst of steam which is expelled through the pipes in the rear of the boat and the boat moves forward in response to the jet of steam (phase 1). Upon leaving the boiler, some of the steam condenses in the cooler part of the pipes thereby creating a partial vacuum which refills the pipes and boiler with water (phase 2). The cycle can begin again.
The boiler consists of a small metal pan whose top is a slightly convex piece of very thin, springy metal that flexes with the expanding and contracting steam. The resulting rattle gives the pop-pop boat its name.

Disposal:

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