

Drinking Duck

Equipment:

duck
beaker
possibly support
bell jar (optionally: (relatively rigid) transparent plastic bag))
possibly lifting gear

Chemicals:

water

Procedure and observation:

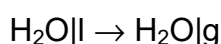
The beaker is filled with water and the felt of the duck's head is wetted. After a while, the duck begins to "drink" periodically, i.e. it slowly swings back and forth, dips its beak into the water, backs up again and after a few oscillations restarts the game.

After repeated "drinking" the bell jar is placed over the duck and the beaker. After a while the duck stands still. When the bell jar is removed the duck will begin to "drink" again.

By means of an appropriate equipment the movement of the duck can be utilized to lift up a weight.

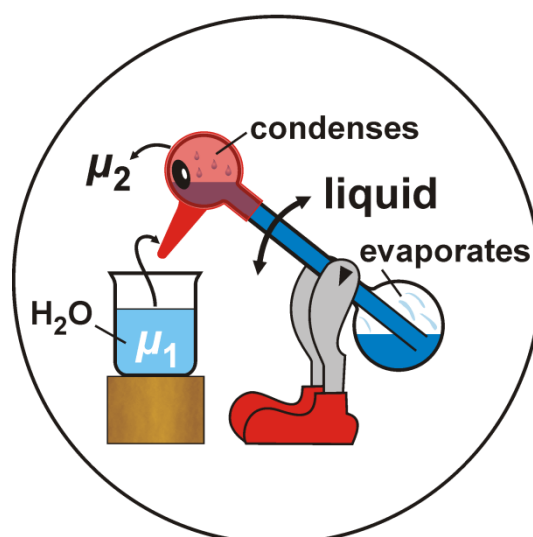
Explanation:

Technically, the "drinking duck" is a kind of "matter engine" which utilizes the difference between the chemical potentials of liquid water (μ_1) and water vapor in the air (μ_2). Due to the phenomenon of mass action the chemical potential of water vapor strongly diluted in air is lowered below that of liquid water and the evaporation process

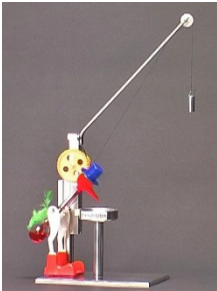


can take place spontaneously.

The flow of vapor from the felt into the ambient air caused by the potential gradient, $\mu_1 \rightarrow \mu_2$, is coupled with an entropy flow. The vapor transports approximately three times more entropy than was previously contained in the liquid water. Therefore, the wet felt cools down and entropy begins to flow off from the interior of the head, thereby cooling it inside compared to the body. Some of the vapor of the internal liquid (with a very low boiling point) condenses and the reduced pressure forces the liquid to rise up in the tube thereby gradually changing the centre of gravity of the duck. Finally, the duck tips over and tilts into the water. At this moment the lower end of the tube comes out of contact with the liquid surface, part of the liquid drains back into the body and the vapor pressure in head and body is equalized. The bird returns to its upright position and the "game" can start again. As long as the head of the duck remains wet the process of "drinking" will recur periodically.



When the bell jar is placed over the duck and the beaker the chemical potentials of water and (saturated) water vapor will become equal and therefore, the potential difference necessary for the “drive” is zero. The duck stops drinking. Instead of a bell jar, a (relatively rigid) transparent plastic bag can be used.



The use of the drinking duck in the lifting gear proves that it is in fact a matter engine. For a lossless machine working between two reservoirs with fixed potentials μ_1 and μ_2 the energy W can be utilized (negative sign!) when the amount of matter n is transferred from μ_1 (the higher potential of liquid water) to μ_2 (the lower potential of water vapor in ambient air):

$$W = n(\mu_2 - \mu_1).$$