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## A3_2: Can a drinking glass be filled with water by a human by exhaling into it?


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**Abstract**
The following discussion is a brief investigation into whether it is reasonable to expect a human breathing into a glass under normal conditions to be able to fill it with the water from his/her breath. It finds that using this process it takes more than a day to fill a glass and would not be possible without cooling the glass regularly.


**Introduction**

The phenomenon of condensation is often seen; in the formation of clouds or on mirrors or panes of glass (especially in poorly heated student houses). The question is whether or not this can be useful on a small scale, as well as the large scales of the atmosphere, in the production of water. The test case of someone breathing into a glass in order to fill it with water is presented and discussed in the following article.

**Discussion**

Firstly, a typical human breath is considered. According to Gessner et al. (2001) [1], the mean temperature of a survey sample of 8 random people's breaths (after leaving their lungs) was 29°C and the mean relative humidity was 88%. A typical tidal volume of 500ml=$5\text{x}10^{-4}\text{m}^3$ is used [2].

Knowing these facts it is possible to calculate the partial pressure of the water leaving the lungs. This is because the saturated vapour pressure of a substance follows the Clausius-Clapeyron relation:

$$\ln\left(\frac{P_{sat}}{P_0}\right) = \frac{l}{R}\left(\frac{1}{T_0} - \frac{1}{T}\right), (1)$$

where $P_{sat}$ is saturated vapour Pressure, $T$ is Temperature, $l$ is latent heat of vaporisation [3], $R$ is the gas constant and the reference pressure and temperature used were those of the normal boiling point: $P0$=1atm, $T0$=373K. Inputting $T$=302K into equation (1) gives a saturated vapour pressure for the exhaled breath of 0.0458atm.

Perry's Chemical Engineers' Handbook [4] defines the relative humidity as:

$$\varphi = \frac{P_{partial}}{P_{sat}} \times 100\%, (2)$$

where $P_{partial}$ is the partial pressure of the water. So the partial pressure of the water in exhaled breath at 302K is 0.0403atm. Inputting this as the saturated vapour pressure, $P_{sat}$, in equation (1) gives a temperature of 300K; for temperatures at or below this value the water in the breath will condense.

This creates a problem for the idea of condensing a large volume of water into the glass as the condensation of the water releases the latent heat of the water onto the surface of the glass. The glass will then quickly heat up making it more difficult to condense a significant amount of water. Once the glass reaches 300K in the above situation, no more water will condense onto the glass.

How long would this take? Taking the mass of a standard drinking glass, 0.3kg, the heat energy required to raise the temperature would be:

$$\Delta Q = mc\Delta T = mc(T_f - T_i), (3)$$

where $c$=840$\text{Jkg}^{-1}\text{K}^{-1}$ [5] is the specific heat for glass. If it is assumed that the glass begins at temperature, $T_i$=293K, then a $\Delta T$ of 7K is needed to reach $T_f$=300K; point at which no more water will condense. This gives a corresponding $\Delta Q$=1764J.

Given that the partial pressure of the water in the exhaled breath composes 4.03% of the pressure we can give the concentration of the water in the breath as 4.03% of the total molecules, which in turn is given by the ideal gas equation:

$$n = \frac{PV}{RT}. (4)$$

Using the atmospheric pressure, the temperature given by Gessner et al., $T$=302K and the tidal volume above gives $n$=0.0201mol for the total exhaled breath and $8.10\times10^{-4}$mol for just the water content. This amount of water has mass, $m=1.46\times10^{-5}$kg. The heating this provides is given by:

$$\Delta Q = ml. (5)$$

This gives a corresponding $\Delta Q$ of 33J per breath. So, it would take the water content of about 54 breaths to heat the glass to the temperature at which no more water will condense onto the glass.

There are other factors that would affect the temperature of the glass, such as heating provided by the water as it cools after it has condensed and heat transport away from the glass by the surrounding air. These however, would be negligible when compared with a constant heating from the condensation of the water.

The measured volume of the aforementioned glass is 300ml=$3\times10^{-4}$m$^3$, and taking the density of the water [6], $\rho$=995.7kgm$^{-3}$, the mass of water needed to fill the glass is 0.299kg; about 20500 breaths. This is about 380 times the amount that would condense onto the glass before it was heated by the water to the temperature at which the vapour would be in equilibrium with the condensed water.

Unless the glass was cooled, it can therefore be concluded that less than 1ml of water would condense from breathing before no more condensation would be able to take place. It is also worth noting that this number of breaths would take more than a day to complete considering that the normal respiratory rate is 12 breaths per minute [7].

**Conclusion**

In summary, this discussion looked into the factors affecting the condensation of water from human breath into a glass. It can be concluded that by this method it would take more than a day to fill a glass as 20500 breaths are needed. It would not be possible without cooling the glass regularly as each breath gives an energy $\Delta Q$ of 33J to the glass causing it to heat above 300K in 54 breaths; the temperature at which no more water will condense onto the glass.

There are also other effects that would be more difficult to model. The amount of the water that would actually come into contact with the glass is difficult to model as much of it would diffuse into the surrounding air. Also, the amount of evaporation from the glass into the surrounding air would depend on the humidity of the air during the process. These are both factors that would make the process longer and/or less likely to be possible.

**References**

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[2] http://www.brianmac.co.uk/spirometer.htm 22/10/12.

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