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A1_10 As much use as a chocolate teapot

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Abstract

This paper tackles the age old insult of 'You're as much use as a chocolate teapot!', showing that a chocolate teapot is in fact useful and can boil water when taken to an altitude of 50,000-55,000 feet. This is found by using the Clausius-Clapeyron method and atmospheric physics.

Introduction

Being told that you're as much use as a chocolate teapot is something which many find offensive, however there must be some way to make a chocolate teapot become useful! By using the fact that as altitude increases, pressure decreases and therefore the boiling point of water decreases from 100 ^{o}C. This physics will be explored to find at what altitude water will boil before the chocolate teapot melts, therefore making the teapot useful!

Theory and Method

A liquid will boil at the temperature at which its vapour pressure is equal to the gas above it. So, by using the fact that as pressure decreases so does the temperature at which a liquid boils and applying this to the chocolate teapot situation, a pressure can be calculated where water will boil at a low enough temperature to keep the chocolate solid.

On Earth, pressure decreases with increasing altitude. By using the Clausius-Clapeyron [1] equation (equation 1), the altitude at which water will boil before the melting temperature of chocolate can be found.

$$\ln \frac{P_2}{P_1} = -\frac{\Delta H}{R}(\frac{1}{T_2} - \frac{1}{T_1}), \tag{1}$$

In equation 1, P_1 and P_2 (Pa) are the pressure at sea level and pressure at the point where water will boil at the melting point of chocolate respectively, ΔH is the molar heat of vaporisation (40.8×10^3 J mol^{-1} for water [2]), R is the gas constant (8.314 J K^{-1} mol^{-1}) and T_1 and T_2 (K) are the boiling temperature at sea level (100 ^{o}C) and boiling point of chocolate respectively.

This equation can be rearranged to find the pressure at which water will boil at the temperature the chocolate starts to melt, shown in equation 2 below.

$$\ln(P_2) = -\frac{\Delta H}{R}(\frac{1}{T_2} - \frac{1}{T_1}) + \ln(P_1), \tag{2}$$

Once this has been calculated, it can be used to find the altitude in Earth's atmosphere where this pressure is present and this is the height where the teapot becomes useful as the water in it will boil without the teapot melting.

In this situation, it is assumed that the water must be heated by a heating element from inside of the teapot and the heating is even and uniform

throughout the water and on the edges of the teapot.

Results and Discussion

As there are different types of chocolate (i.e. milk and dark chocolate), this method has been applied to both milk and dark chocolate. This is because milk is the most popular chocolate, but dark has a higher melting point and will therefore become useful at a higher pressure and therefore lower altitude. The melting points of milk and dark chocolate are 42.5 ^{o}C and 46 ^{o}C respectively [3]. For milk chocolate, the pressure at which water will boil at 42.5 ^{o}C is found to be 0.09 atm, while the value found for dark chocolate is 0.11 atm, which is the expected result which was explained previously.

The altitude to pressure conversion table [4] shows that a pressure of 0.09 atm is found at around 55,000 feet, whilst 0.11 atm is the pressure at around 50,000 feet. Both of these altitudes are beyond the cruising altitude of commercial airlines (33,000 - 42,000 feet [5]), but most military planes, including the Stealth Bomber [6], fly at around 50,000 feet and Concord routinely flew at 60,000 feet [7] as the lack of air pressure means there is less air resistance and a faster cruising speed can be reached. However, as planes are pressurised, the water would not have the chance to boil at the lower temperature, so a high-altitude balloon could be utilised to transport the chocolate teapot and remain at the pressure of the altitude it requires to become useful enough to boil the water it contains.

Conclusions

After finding that water will boil at the melting temperatures of milk and dark chocolate when at very low pressures, it is found that a chocolate teapot is only useful on a depressurised Concorde flight or on a high-altitude balloon. Overall, a chocolate teapot is not exactly useful to the average person. Maybe instead of chocolate, a different kind of confectionery could be made into a teapot, like boiled sweets which have a much higher melting point than chocolate.

Overall, if a person is ever told that they are 'as useful as a chocolate teapot', they should take offence... unless they are piloting a Stealth Bomber or Concorde!

References

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