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## A1\_6 There's No Point Crying over Spilled Milk

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### Abstract

This paper looks at the energy required to evaporate a pint of milk straight from the fridge. The values were found to be  $2.255 \times 10^8$  J for skimmed milk and  $2.224 \times 10^8$  J for whole milk which is approximately equal to the average person crying for 28.8 days for skimmed and 28.3 days for whole milk.

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### Introduction

“There’s no use crying over spilled milk” is a turn of phrase used when crying over something will not help fix a situation. We decided to take this in a literal sense and calculate whether the energy required to evaporate the spilled milk was equivalent to that expended by a human from crying. We looked at both skimmed and whole milk for the purpose of preference.

### Theory

In order to calculate the energy required to evaporate the milk we used the following equations [1]:

$$Q_1 = mc_m\Delta T \quad (1)$$

$$Q_2 = mL_m \quad (2)$$

Where  $Q_1$  is the energy to heat the milk to boiling point and  $Q_2$  is the energy required to change state,  $m$  is the mass of milk,  $c_m$  is the specific heat of milk,  $L_m$  is the latent heat of milk and  $\Delta T$  is the change in temperature. The first equation gives the energy required to heat the milk to boiling temperature and the second gives the heat required to transform the liquid milk

into a vapour. Since both of these are required to evaporate the milk, we added the two together:

$$Q = m(c_m\Delta T + L_m) \quad (3)$$

We assumed that the milk in question was a pint that came straight from a fridge and thus had a temperature of around 277.15 K [2]. Since the boiling point of milk is similar to that of water [3], we assumed the value of  $\Delta T$  to be 96 K. Using data available online [4], we found the specific heats of both skimmed and whole milk to be  $3977.5 \text{ J kg}^{-1} \text{ K}^{-1}$  and  $3935.6 \text{ J kg}^{-1} \text{ K}^{-1}$  respectively.

We then calculated the mass of the milk using the following equation:

$$m = \rho V \quad (4)$$

A pint of milk has a volume of 0.582 l. The densities of skimmed and whole milk were found to be  $1.036 \text{ kg l}^{-1}$  and  $1.033 \text{ kg l}^{-1}$  respectively [5]. Finally we calculated the latent heat of both milk types. The latent heat of a material depends on its water content by the following relationship [4]:

$$L = m_w L_w \quad (5)$$

where  $m_w$  is the mass of water and  $L_w$  is the latent heat of water, found to be  $2260 \text{ kJ kg}^{-1}$  [6]. We found the percentage of water in the two types of milk to be 90.84% for skimmed and 88.13% [7] for whole and multiplied this by the mass of a pint previously calculated. Once all of the variables had been found, we substituted them back into Equation (3) to give us the total amount of energy required.

### Results Discussion

We calculated that to entirely evaporate a spilled pint of milk from the fridge would require  $2.255 \times 10^8 \text{ J}$  for skimmed milk and  $2.224 \times 10^8 \text{ J}$  for whole milk under the assumption that not heat was lost to the surroundings. On average, the amount of energy expended by a human while crying is 1.3 calories a minute [8]; this equates to  $90.65 \text{ J s}^{-1}$ . We have assumed that this value was actually in kilocalories due to the terms often being mistakenly used interchangeably. Therefore the average person would have to cry for approximately 28.8 days for skimmed milk and 28.4 days for whole milk. In reality we would expect the energy required to evaporate the milk to be lower than calculated for several reasons:

- The ambient temperature of the surroundings would help the milk to heat up.
- Air breezes would transfer additional energy to the milk.
- The milk wouldn't have to reach boiling point before evaporating.

### Conclusion

We calculated the heat energy required to entirely evaporate a pint of spilled milk to be  $2.255 \times 10^8 \text{ J}$  for skimmed milk and  $2.224 \times 10^8 \text{ J}$  for whole milk. These values are maximums as in reality there are several factors which would aid the evaporation process. We then compared this to the energy expended by a human crying and

found this to be equivalent to the average person crying for approximately a month, however this energy could vary from person to person. We therefore suggest it is futile to cry over spilled milk.

### References

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