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P2_5 The Burning of the Sistine Chapel

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Abstract

The celebration of Pentecost involves burning a candle across a 50 day period, so we thought about the idea of a single candle using all of the oxygen in a sealed room. We decided to investigate how massive a candle we would need to use all of the oxygen in the Sistine Chapel, and how much the temperature changes from this. Using a paraffin wax candle, we found the required mass of the candle to be 985 kg, and the total temperature increase to be 3830 K.

Introduction

After Easter Friday until the Christian feast day of Pentecost, a candle is placed by the altar to represent the Resurrection. With a candle being in a room for so long we considered how this would affect the oxygen levels if the room were sealed.

In this paper we investigated how massive a paraffin wax candle is needed to use all of the oxygen in the Sistine Chapel, and how much the temperature would change from this. We chose the Sistine Chapel due it being the most iconic chapel in the world, and chose a paraffin wax candle because it is the most common type of candle [1].

We assumed the Sistine Chapel to be an isolated system (thermally isolated and sealed to be airtight to ensure a constant volume of air), the air within the chapel to be an ideal gas, and the shape of the room to be approximately a cuboid. Due to the system being thermally isolated we ignored the burn rate of the candle. We also assumed an average carbon chain length of 30 for paraffin wax [2] and the candle to burn with complete combustion.

Method

From the volume of the Sistine Chapel, 11,345 m^3(calculated from its dimensions [3]), we calculated the total moles of oxygen (assuming the initial state is at Standard Temperature and Pressure (STP) we can convert from litres to moles by 22.4 L/mol [4], and the percentage of oxygen in the air being 21.0 percent [5]) to be 106,000 moles.

Creating an equation for the combustion of paraffin wax based on an example equation for complete combustion [6],

$$2C_{30}H_{62} + 91O_2 \rightarrow 60CO_2 + 62H_2O, \qquad (1)$$

we can find the amount of wax needed to fuel the flame for all the oxygen in the room to be used. This gave us a ratio of 2 moles of wax for every 91 moles of oxygen, and thus 2330 moles of wax.

With the molar mass of the wax being 423 g/mol [7], we calculated the required mass of the candle to be 985 kg.

Multiplying the heat of combustion, 42.0×10^6 J/kg [8], by the mass of wax, we get the total energy of combustion, Q to be 41.0×10^9 J.

Next we calculated the final mass of the air in the room, considering the gaseous products of the chemical reaction, Eq. (1), are of higher mass than the gaseous reactants. Starting with the initial mass of air in the room, 13900 kg, $m_{\mathrm{air,i}}$, which we calculated using the density of air [9] and the volume of the room. Using the ratios of the numbers of moles of the molecules in Eq. (1), and multiplying by their respective molar masses (O_2 = 32 g/mol, CO_2 = 44 g/mol, H_2O = 18 g/mol [7]) we calculated the masses of each molecule species with

$$m_{\mathrm{air,i}} - m_{\mathrm{O_2}} + m_{\mathrm{CO_2}} + m_{\mathrm{H_2O}} = m_{\mathrm{air,f}}, \qquad (2)$$

(where $m_{\mathrm{O_2}}$ is the mass of oxygen in the room before the candle is lit, 3400 kg,
$m_{\mathrm{CO_2}}$ is the mass of CO_2 in the room after burning, 3080 kg,
$m_{\mathrm{H_2O}}$ is the mass of H_2O in the room after burning, 1300 kg,
and $m_{\mathrm{air,f}}$ is the total mass of air in the room after burning). With $m_{\mathrm{air,f}}$ found to be 14900 kg.

Finally, using a rearranged heat equation for ΔT [10],

$$Q = m_{\mathrm{air,f}} c \Delta T, \qquad (3)$$

(where Q is heat energy, c is specific heat of air at constant volume, ΔT is the total change in temperature of the system), we found ΔT to be 3830 K, where c is 0.718 kJ/(kg$\cdot K$)[11].

Conclusion

In this report we investigated how much wax would be required for a candle to use all of the oxygen in the Sistine Chapel, and how much the temperature would increase by if it were an isolated system.

We calculated the total mass of wax required to be 985 kg, which is undoubtedly larger than a regular sized candle. But considering the amount of oxygen present in the Sistine Chapel this seems quite reasonable.

We also found the temperature to increase by 3830 K, meaning the final temperature inside the Sistine Chapel to be greater than the surface temperature of the red giant star Aldebaran [12].

References

[1] `http://candles.org/elements-of-a-candle/wax/` [Accessed 21 October 2018]

[2] `https://preview.tinyurl.com/waxformula` [Accessed 21 October 2018]

[3] `https://en.wikipedia.org/wiki/Sistine_Chapel` [Accessed 21 October 2018]

[4] `http://hyperphysics.phy-astr.gsu.edu/hbase/Kinetic/idegas.html` [Accessed 21 October 2018]

[5] `https://en.wikipedia.org/wiki/Atmosphere_of_Earth` [Accessed 27 October 2018]

[6] `https://preview.tinyurl.com/bbcbitesizechemistry` [Accessed 19 November 2018]

[7] `https://preview.tinyurl.com/molecularweight` [Accessed 22 October 2018]

[8] `https://en.wikipedia.org/wiki/Paraffin_wax#Properties` [Accessed 22 October 2018]

[9] `https://www.engineersedge.com/calculators/air-density.htm` [Accessed 27 October 2018]

[10] P. A. Tipler, *Physics for scientists and engineers, sixth edition*, p.566-569.

[11] `https://preview.tinyurl.com/waxheatcapacity` [Accessed 22 October 2018]

[12] `https://www.space.com/22026-aldebaran.html` [Accessed 27 October 2018]