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If Clouds Really Had Silver Linings

Evangeline Walker
The Centre for Interdisciplinary Science, University of Leicester
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Abstract
Considering the old adage, that every cloud has a silver lining, this paper considers what conditions would be required to produce clouds with enough silver content to class them as 'sterling', as well as the properties the resultant cloud would have, such as density and mass. Taking these results into account, the paper demonstrates, using the Earth as an analogue, the planet required to produce such a cloud would need a surface temperature of 2460K and an atmospheric density of 101872kgm^{-3} at the planet's surface.

Introduction

To consider how the theoretical silver clouds would be formed, it is important to consider the process of cloud formation conventionally. In its most basic form, cloud formation involves the cooling of water vapour contained in the air, causing the air to become saturated. To a certain point the water will condense into clouds of water droplets or ice crystals. Further cooling leading to an increased density, and thus weight of the vapour, causing rain or snow formation [1]. By taking the process into account, the temperatures which would be required for a silver-alloy to undergo this process can be found. As well as the properties of the cloud formed, and the implications of these as to a suitable planet for silver clouds to be sustained.

Cloud Properties

As silver is a soft material alone, it is often combined with other metals such as copper. As the properties of this alloy, which the cloud will be modelled as, depend on the relative proportions of the elements [2], the cloud will be taken as 92.5% silver to be considered 'sterling' in accordance with the UK standard [3]. Taking this into account it is possible to calculate the boiling point of the specific alloy (T_b), by using the boiling points of the relative proportions of the two metals [4].

$$T_b = (T_{b(silver)} \times 0.925) + (T_{b(copper)} \times 0.075)$$

$$T_{boiling} = (2430 \times 0.925) + (2830 \times 0.075)$$

$$T_{boiling} = 2460\ K$$

If this were the temperature required to form an alloy-vapour, then next the lower temperature at which the air would become saturated with the alloy must be considered, known as 'dew point temperature' for water saturation [5]. Whilst there is no equivalent for a silver alloy in air, by comparing how much lower the dew temperature of water is than its boiling temperature (331K and 373K respectively [5]), an approximation can be made for silver.

$$\frac{T_{boiling(water)} - T_{dew(water)}}{T_{boiling(water)}} \times 100 = 11\%$$

Using the same factor, the dew point temperature of the silver alloy would be 2189 K.

The next property to discuss of the theoretical cloud is its mass. Taking the cloud to be a cube with edges of approximately 1 km [6], its volume would be 1×10^{9}m^3. To find its mass the density of this cloud can be found by taking the densities of silver and copper in vapour form [4], and using the relative composition of these two metals within the cloud.

$$\rho_{total} = (\rho_{silver} \times 0.925) + (\rho_{copper} \times 0.075)$$

$$\rho_{total} = (8244 \times 0.925) + (7016 \times 0.075)$$

$$\rho_{total} = 8152\ kgm^{-3}$$

Therefore the mass of the cloud, taking its density and volume into account is $8.15x10^{12}$ kg.

The Planet of Silver Clouds

In order to create and maintain the silver cloud, the theoretical planet must have specific temperature and atmospheric properties. Firstly the temperature required to boil the alloy to create vapour can be considered as the planet's surface temperature, assuming the solid silver is found there. By assuming a distance away from the planet that the cloud would reside, the temperature gradient required for the 'silver dew temperature' to be reached can be found. Using the Earth as an example, 11 km has been selected for this distance, the average height of the troposphere in which many clouds reside [7].

$$\frac{dT}{dx} = \frac{T_{ground} - T_{dew}}{x}$$

$$\frac{dT}{dx} = \frac{2460 - 2189}{11 \times 10^3}$$

$$\frac{dT}{dx} = 0.02\ Km^{-1}$$

In order for the vapour to rise to the height of 11km, the atmospheric density must be of greater density than that of the silver-copper alloy which will make up the cloud, so that the component vapour-molecules of the cloud will rise. It is important to consider the density of the atmosphere at the surface of the planet. Even if this is greater than 8152 kgm^{-3}, it must be significantly greater so that it is likely decay as altitude increases will still accommodate the rise of the cloud up to 11 km.

Using a similar rationale to that used to determine the temperature gradient, by assuming that the density at 11km is equal to that of the silver cloud, and estimating a decay of density with increasing altitude, the required surface density of the atmosphere can be found. Using the Earth as an analogue, the density of the atmosphere decreases on average by 8.52 kgm^{-3} per meter [8]. Using this the planet would need a surface atmospheric density of 101872 kgm^{-3} to have a higher density over the entire distance the cloud components would travel, assuming the decay of density as altitude increased was the same as that of the Earth.

Considering the average density of the Earth's atmosphere at its surface is 1.217 kgm^{-3}, this highlights what a vast increase would be needed for silver-copper vapour to rise and form clouds at 11km high [9]. This being the highest value for the solar system planets also illustrates the unlikelihood of them being able to host silver clouds.

Conclusion

In order for a sterling silver cloud to be formed, a temperature of 2460 K is required to boil the alloy into a vapour form with a density of 8151 kgm^{-3}. Modelling the cloud as a cube of 1 km edges, its mass would be $8.15x10^{12}$ kg. The planetary conditions required to sustain such a cloud at a height of 11 km, would include a temperature gradient of 0.2 Km^{-1} and a surface atmospheric density of 101872 kgm^{-3}. As this model uses Earth as an analogue in terms of how quickly the density of the atmosphere decays as well as how high the cloud would be, it is difficult to extrapolate the results to other planets. However this simple model has illustrated the requirements for clouds made of silver.

References

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