

# THE LAST WORD

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## The Heaven/Hell problem



What will happen to us when we die has always been a matter of concern. Believers in the Word of God see beyond this terrestrial life three places where our souls will go: Hell, where we will suffer forever to pay for all earthly sins; Purgatory, where we will be cleansed (by fire!) for minor faults; and Heaven, where we will enjoy the vision of God's glory and be happy forever and ever. Among the matters of exceptional concern to scientists are answers to the questions: What is Hell? What does it look like? How are the damned souls tortured? What are the temperatures of Heaven and Hell? Is Heaven hotter than Hell?

One author (1) who asserts that Heaven is hotter than Hell cites two verses (2), applies some equations, and ends up with a temperature of 525 °C for Heaven and 444.6 °C for Hell. He considered these two scriptural facts: "Moreover the light of the Moon shall be as the light of the Sun and the light of the Sun shall be seven fold as the light of seven days" (2a), and "But the fearful, and unbelieving, and the abominable, and murderers, and whoremongers, and sorcerers, and idolaters, and all liars, shall have their part in the lake which burneth with fire and brimstone" (2b). On the other hand, Healey (3) shows some experimental data to demonstrate that Hell is hotter than Heaven. To the best of our knowledge, this conclusion

seems more reliable than the reverse.

In his analysis Healey considers a damned soul similar in shape and size to a living creature. The literature is full of different arguments. Some consider souls visible and sweet (Tennyson, "In Memoriam"), others like a sentimental wife (Richard Le Gallienne, "The Decadent to His Soul"), and still others pale, gentle, and naked (Hadrian, "Ad Animam Suam"). Others go further and speculate about the material of which a soul is made; Lawrence ("Apocalypse") says it is made of organic material (he doesn't define what kind of material); Goncharov ("Oblomov") claims that it is made of crystal; Lindsay ("Every Soul is a Circus") considers a soul like a circus; and Longfellow ("The Spanish Student") sees a soul like a musical instrument, a vague description that Thoreau clarifies when he says that a human soul is a silent harp ("Journal," Aug. 10, 1938). If we believe Thoreau, a soul would weigh about 20 kilograms. If we believe Le Gallienne it would weigh three times as much and if Lindsay is right, it would weigh several hundred kilograms. To give the last word on this problem, we carried out an experiment in our sophisticated high-pressure laboratory and have concluded that a soul is made of spirit-like material (see any good handbook for definition and formula) and weighs  $0.1660312 \pm 0.0000001$  grams. This value has been determined by carefully comparing the weight of living and dead creatures and taking into account all the biological phenomena of the dying process. Thus, we consider it correct. Even though the authors named above might be right, and a soul be like a harp, a wife, or a circus, God could have made it as light as he or she wanted. Remember that, "Those things which are impossible with men, are possible to God" (2c).

What Hell is, what it looks like, and how the damned souls are tortured have also been matters of dispute. We cite here some important references. According to the great English poet Lord Byron,  
No ear can hear nor tongue can tell  
The tortures of the inward hell.  
"Heaven and Hell" by Isaac Watts reads in part:  
There is a dreadful hell  
And everlasting pains;  
Where sinners must with devils dwell  
In darkness, fire, and chains.  
Milton, in "Paradise Lost," says more:  
A dungeon horrible on all sides 'round  
As one great furnace flam'd those flames  
No light, but rather darkness visible,  
Serv'd only to discover sights of woe  
Regions of sorrow, doleful shades, where  
peace  
And rest can never dwell, hope never  
comes  
That comes to all, but torture without end.  
"Emblems" by Francis Quarles reads:

I see a brimstone sea of boiling fire,  
And fiends, with knotted whips of flaming  
wire  
Torturing poor souls, that gnash their teeth  
in vain,  
And gnaw their flame-tormented tongues  
for pain.  
And there is more in the Koran, in  
Shakespeare, in Dante . . .

In our experiments we went further. We wished to solve the whole problem once and for all and give the scientific world good, reliable data to do its own calculations and draw its own conclusions. One of my students took some data on the spot and then reproduced the atmosphere of Hell in our lab (Table 1).

A correct analysis must begin with the fundamental equation of vapor-liquid equilibria: the fugacity of each component in both phases is the same.

$$f_s^V = f_s^L \quad f_B^V = f_B^L \quad (1)$$

where  $f$  stands for fugacity,  $V$  for vapor,  $L$  for liquid,  $s$  for soul, and  $B$  for brimstone.

From thermodynamics we know that for the situation under study:

$$Y_s \phi_s P_{HL} = X_s H_{sB}$$

$$Y_B \phi_B P_{HL} = X_B \gamma_B f_B^\circ \quad (2)$$

Here,  $Y$  and  $X$  represent the compositions in the vapor and liquid phase,  $\phi$  is the fugacity coefficient,  $P_{HL}$  the total pressure in Hell,  $\gamma$  is the activity coefficient, and  $f^\circ$  the standard-state fugacity.

### Notation

- $f_B^\circ$  = Standard state fugacity for brimstone (atm)
- $f_B^V, f_B^L$  = Fugacity of brimstone in the vapor phase and in lake (atm)
- $f_s^V, f_s^L$  = Fugacity of soul in the vapor phase and in lake (atm)
- $H_{sB}$  = Henry's constant for soul in brimstone (atm/mol fraction)
- $n_B$  = Moles of brimstone in lake
- $n_{sL}$  = Moles of souls in lake
- $n_{sV}$  = Moles of souls above lake
- $n_V$  = Total number of moles above lake
- $P_B$  = Vapor pressure of brimstone (mm Hg)
- $P_{HL}$  = Pressure in Hell (atm)
- $T_{HL}$  = Temperature of Hell (K)
- $x_B, x_s$  = Mole fraction of brimstone and souls in lake
- $Y_B, Y_s$  = Mole fraction of brimstone and souls above lake
- $\phi_B, \phi_s$  = Fugacity coefficient of brimstone and soul
- $\gamma_B$  = Activity coefficient of brimstone

Based on information in Table 1 we can write as an approximation:

$$X_s \rightarrow 1 \quad \phi_2 = \phi_B \approx 1.0$$

$$\gamma_B \approx 1.0 \quad f_B^\circ \approx P_B^\circ \quad (3)$$

and  $PV = nRT$ , valid for the vapor over the lake. Therefore, Equations 2 reduce to the nonlinear equation

$$7.6 \times 10^4 = 10^{7.5 - 3500/T_{HL}} \quad (4)$$

which was solved using a sophisticated routine available on our high-speed IBM 1620 computer. Convergence was reached after approximately three hours of CPU time, and we obtained:

$$T_{HL} = 1336.293 \text{ K}$$

The temperature of Heaven, as calculated in *Applied Optics* (1), is 798.15 K. It is clear then, when one compares these values, that Hell is hotter than Heaven (Table 2). We should mention here that the value 798.15 K was calculated based on radiative equilibrium. Such an approach involves some assumptions as to the nature of the atmosphere in Heaven, which we have failed to check for now. We are carrying out some experiments to accurately determine the temperature of Heaven and the effect of the assumptions on the given value.

Now we recalculate the solubility  $X_s$  (assumed  $\approx$  zero in a first approximation) as:

$$X_s = \frac{Y_s P_{HL}}{H_{sB}}$$

**Table 2. Calculated data for Hell, Heaven, and souls**

Characteristics	Values
Temperature of Heaven (1)	798.15 K
Temperature of Hell	1336.293 K
Souls in lake	$8.820601 \times 10^8$
Solubility of souls in brimstone at Hell temperature	$3.213402 \times 10^{-5}$
Probability of a soul being in the lake	1 in $10^9$

where

$$Y_s = \frac{n_{sV}}{n_V} = \frac{\text{moles of souls above lake}}{\text{total number of moles above lake}}$$

$$n_{sV} = \left( \frac{\text{number of souls wandering above lake}}{\text{Satan's number}} \right)$$

(Satan's number is equal to  $6.023 \times 10^{23}$  and corresponds to the number of souls per mole of souls. This number is not equivalent to Avogadro's number, which is used on earth for material things like atoms or molecules.)

$$n_{sV} = \frac{3.0115 \times 10^{19}}{6.023 \times 10^{23}} = 5 \times 10^{-5}$$

$$n_V = \frac{P_{HL} V_{cave}}{R \times T_{HL}} = \frac{100 \times 14.01385 \times 10^{12}}{0.08206 \times 1336.293}$$

$$Y_s = \frac{5 \times 10^{-5}}{1.277981 \times 10^{13}} = 3.912421 \times 10^{-18}$$

So finally  
 $X_s =$

$$\frac{3.912421 \times 10^{-18} \times 100}{100 - 0.5(1336.293) + (1336.293)^2 \times 10^{-3}}$$

$$X_s = 3.213402 \times 10^{-5}$$

Therefore, for the purpose of the results, the approximations introduced above are considered correct.

The volume of the lake is  $4.4 \times 10^8 \text{ m}^3$  (see Table 1); the density of sulfur approximately  $2.0 \text{ g/cm}^3$ ; its atomic weight 32.06 (4). Thus, moles of brimstone in the lake,  $n_B$ , are:

$$n_B = \frac{4.4 \times 10^{14} \times 2.0}{32.06} = 2.744853 \times 10^{13}$$

and the moles of souls in the lake are:

$$n_{sL} = \frac{X_s n_B}{1 - X_s} = \frac{(2.744853 \times 10^{13}) \times (3.213402 \times 10^{-5})}{(1 - 3.213402 \times 10^{-5})}$$

$$n_{sL} = 8.820601 \times 10^8$$

The probability of being in the lake is of the order of one in  $10^9$ !

In conclusion, we can say that with this work we have notably improved the knowledge of Hell and souls. However, there are many aspects to be analyzed by those investigators who want to participate in this kind of research. Among these matters, thermodynamic properties of a soul, entropy changes in Hell, chemical reactions between souls, and a rigorous study of conditions in Heaven are of interest. Do not hesitate to go to Heaven or Hell for some challenging research!

### Acknowledgment

I would like to thank my student Sergio Rojas, for his help in performing the experiments and in preparing this problem. I don't believe he went to Hell, but, like the good student he is, he produced data that convinced me that he had actually gone.

### References

- (1) *Applied Optics* **1972**, 11, A 14. Quoted in Weber, R. L. "A Random Walk in Science"; Crane-Russak Co., Inc.: New York, 1973.
- (2) (a) Isaiah 30:26; (b) Revelations 21:8; (c) Luke 18:27.
- (3) Healy, *J. Irr. Results* **1979**, 25(4), 17.
- (4) Perry's Handbook.

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**Table 1. Experimental data obtained in Hell and the laboratory**

Characteristics	Value
Shape of the lake	Approximately circular
Area of the lake ( $\text{m}^2$ )	$2 \times 10^6$
Volume of the lake ( $\text{m}^3$ )	$4.4 \times 10^8$
Volume of the cave ( $\text{m}^3$ ) (over the lake)	$14.01385 \times 10^9$
Number of souls wandering in the cave (counted) <sup>a</sup>	$3.0115 \times 10^{19}$
Pressure in Hell (atm)	100
Henry's constant for soul in brimstone (atm/mol fraction, range $800 < T < 1500$ )	$H_{sB} = 100 - 0.5 T + 10^{-3} T^2$
Vapor pressure of brimstone in mm Hg (range $500 < T < 2000$ )	$\log P_B - 7.5 - 3500/T$
Weight of a soul (g)	0.1660312
Solubility of soul in brimstone at room temperature	Practically insoluble
Methods of torture in Hell	There are 352 methods, but all of them are carried out under fire.
Frequency of torture	Once in a while.

<sup>a</sup> This number is similar to that given by Healey for the total number of damned souls, which is approximately  $2.9 \times 10^{19}$ .