INFLUENCE OF THERMODYNAMIC ARROW OF TIMEON ENTROPY

Abstract

This study assessed the influence of thermodynamic arrow of time on entropy for boiled cooling water (physical process), the universe and the air (natural process). This was done by determining the entropies of boiled water, the universe and air. This was achieved by using 1.5 litres of pure water, a 2 liter electric kettle, a digital thermometer, a digital weighing scale and a stop watch.The entropy values of boiled water as it was cooling, was in negatives, that of the universe was in negatives and positives and that of air (natural process) was positive.This showed that for any physical process, (boiled cooling water and the universe) thermodynamic arrow of time does not influence entropy in the positive direction while as for a natural process (air), thermodynamic arrow of time influences entropy in the positive direction. The boiledcooling water was a non-spontaneous process, the universe was both non-spontaneous and spontaneous and the air was a spontaneous process. The study has shown that thermodynamic arrow of time influences only entropies of natural process in the forward direction but for the physical process, the entropy can be influenced both backwards and forwardwise.

Keywords: Influence, Thermodynamic, Arrow of time, Entropy.

INTRODUCTION

Arrow of time, also called time's arrow, is the concept positing the "one-way direction" or "asymmetry" of time (Reichenbach, 1956). It was developed in 1927 by the British astrophysicist Arthur Eddington, and is an unsolved general physics question (Hawking, 1996). This direction, according to Eddington, could be determined by studying the organization of atoms, molecules, bodies, and might be drawn upon a four-dimensional relativistic map of the world ("a solid block of paper") (Weinert, 2005),

Physical processes at the microscopic level are believed to be either entirely or mostly time-symmetric: if the direction of time were to reverse, the theoretical statements that describe them would remain true. Yet at the macroscopic level it often appears that this is not the case: there is an obvious direction (or flow) of time.

In the book, the Nature of the Physical World (Eddington, 1928), which helped to popularize the concept, Eddington stated, let us draw an arrow arbitrarily, if as we follow the arrow we find more and more of the random element in the state of the world, then the arrow is pointing towards the future, if the random element decreases, the arrow points towards the past. That is the only distinction known to physicists (Callender, 2011). This follows at once if our fundamental contention is admitted that the introduction of randomness is the only thing which cannot be undone. I shall use the phrase 'time's arrow' to express this one-way property of time which has no analogue in space. Eddington then gives three points to note about this arrow:it is vividly recognized by consciousness, it is equally insisted on by our reasoning faculty, which tells us that a reversal of the arrow would render the external world nonsensical and it makes no appearance in physical science except in the study of organization of a number of individuals.

According to Eddington the arrow indicates the direction of progressive increase of the random element following a lengthy argument upon the nature of thermodynamics; he concludes that, so far as physics is concerned, time's arrow is a property of entropy alone

Thermodynamic arrow of time and entropy

Thermodynamic arrow of time is the time that confirms that entropy of any process/system must increase as time of existence of that process/system increases. Thermodynamic arrow of time is given by the Second Law of Thermodynamics, which says that in an isolated system, entropy tends to increase with time (Clausius, 1850).

$$\Delta S \geq \int \frac{dQ}{T^{'}}$$

where ΔS is the entropy of the system, dQ is the infinitesimal heat exchanged of the system with the environment, being positive when it is introduced into the system, and $T^{'}$ is the temperature of the system.

Entropy can be thought of as a measure of microscopic disorder, implying that the Second Law of thermodynamics asserts that time is asymmetrical with respect to the amount of order in an isolated system. As time increases, a system statistically becomes more disordered (Price, 2013), . This asymmetry is used empirically in distinguishing between the future and the past, though measuring entropy does not accurately measure time (Davies, 2006).
In an open system, entropy can locally decrease with time: living systems decrease their entropy by expenditure of energy at the expense ofenvironmental entropy increase (Albert,2000)

Though the second law of thermodynamics is statistical, physicists assert otherwise. According to Sir Alfred Brian Pippard, "there is thus no justification for the view, often glibly repeated, that the second law of thermodynamics is only statistically true, in the sense that microscopic violations repeatedly occur, but never violations of any serious magnitud. On the contrary, no evidence has ever been presented that the Second Law breaks down under any circumstances." (McN, 1951). The Second Law is universal and seems to accurately describe the overall trend in real systems toward higher entropy (Ayala & Arp, 2009).

METHODOLGY

Materials

In this experiment, theoretical predictions of Newton's law of cooling and the second law of thermodynamics were being tested, the following materials were used; a 2 liter electric kettle, a digital thermometer, a digital weighing scale and a stop watch.

Experimental Procedures

1.5 liters of 520 grams of pure water was put in an electric kettle and then boiled to 100^0 C. The kettle was carefully placed on top of a thick layer of dry papersplaced on a table. The thick layer of papers acted as an insulation between the table and the kettle, making the universe consisting of only two parts, the water and the air.When the kettle was placed on the table, its initial temperature θ_0 at $t = 0$ minutes was measured and recorded.

The stopwatch was started and the temperature of water in the kettle was measured every after a minute for a period of 20 minutes. The temperature change, ΔT of boiled water for the time interval was calculated by subtracting the previous temperature value of boiled water from the current value.The amount of heat for water, q_{water}, at a particular change in temperature was calculated using;

$$q_{water} = \left(m \times 4.182 \frac{j\,0}{g} C \right) \times \Delta T$$

where m is the mass of water .

After converting the temperature of water to Kelvins at the respective minute time, the entropy of water, ΔS_{water},was calculated as;

$$\Delta S_{water} = mc_p \int_{T_0}^{T_f} \frac{dT}{T} = mc_p \ln\left(\frac{T_f}{T_0} \right)$$

where, T_0 is 272 K and T_f is the temperature change of boiled cooling water at a particular minute.

while asafter converting, 29^0C the temperature of air into Kelvin, the entropy of air, ΔS_{air}, was also calculated

The entropy of the universe, $\Delta S_{universe}$, was calculated using,

$$\Delta S_{universe} = \Delta S_{water} + \Delta S_{air}$$

and the free energy change, ΔG_{water}, of water was calculated using;

$$\Delta G_{water} = -T_m \Delta S_{universe}$$

where, T_m, is the measured temperature of water at a particular minute. Using Newton's law of cooling, the calculated temperature at a particular time, t , T_c was obtained according to;

$$T_c = T_s + (T_m - T_s)e^{-kt}$$

after which we get;

$$\ln\left(\frac{T_c - T_s}{T_m - T_s}\right) = -kt$$

$\ln\left(\frac{T_c - T_s}{T_m - T_s}\right) = -kt$, was calculated at various times, t, in minutes.

RESULTS AND DISCUSSION

The results of temperature of water at different times (minutes), change in temperature, heat of water, heat of air, entropy of water, entropy of air, entropy of the universe and the free energy change of boiled water, are given in tale 1.

Table 1: Process values

Time (minutes)	**Measured temp (T_m)of water(°C)**	**Temperature change of water (°C)**	q_{water} **(J)**	q_{air} **(J)**	ΔS_{water} **(J/K)**	ΔS_{air}**(J/K)**	$\Delta S_{universe}$**(J /K)**	ΔG_{water} **(J)**	**In**($\frac{Tc-Ts}{T_m-T_S}$)	**Calculated temp(T_c)of water (°C)**
0	89	-1	-217.4	217.4	-7.60	0.72	-6.88	612.3	0	89
1	88	-2	-434.7	434.7	-1.20	1.44	0.24	-21.1	-0.017	86
2	86	-2	-434.7	434.7	-1.21	1.44	0.23	-19.8	-0.051	83
3	84	-1	-217.4	217.4	-7.61	0.72	-6.89	578.8	-0.087	81
4	83	-1	-217.4	217.4	-7.61	0.72	-6.89	571.9	-0.105	79
5	82	-2	-434.7	434.7	-1.22	1.44	0.22	-18.0	-0.124	77
6	80	-1	-217.4	217.4	-7.62	0.72	-6.90	552.0	-0.163	74
7	79	-1	-217.4	217.4	-7.62	0.72	-6.90	545.1	-0.182	73
8	78	-2	-434.7	434.7	-1.24	1.44	0.20	-15.6	-0.203	71
9	76	-1	-217.4	217.4	-7.62	1.44	-6.90	528.4	-0.244	69
10	75	-1	-217.4	217.4	-7.62	1.44	-6.90	517.5	-0.266	67
11	74	-2	-434.7	434.7	-1.25	1.44	0.19	-14.1	-0.288	65
12	72	-2	-434.7	434.7	-1.26	1.44	0.18	-13.0	-0.333	63

13	70	-2	-434.7	434.7	-1.27	1.44	0.17	-11.9	-0.381	61
14	68	-2	-434.7	434.7	-1.27	1.44	0.17	-1.6	-0.431	59
15	66	-2	-434.7	434.7	-1.28	1.44	0.16	-10.6	-0.483	57
16	64	-2	-434.7	434.7	-1.29	1.44	0.15	-9.6	-0.539	55
17	62	-2	-434.7	434.7	-1.30	1.44	0.14	-8.7	-0.598	53
18	60	-1	-217.4	217.4	-7.65	0.72	-6.93	415.8	-0.660	51
19	59	-1	-217.4	217.4	-7.65	0.72	-6.73	408.9	-0.693	50
20	58	-3	-652.1	652.1	-1.97	2.16	0.19	-1.0	-0.727	49

The variation of entropies of the boiled water, universe and the air, with time are preseted in figure 1. As seen in the figure, the entropy of boiled cooling water, the universe and the air, were never uniform from the one minute time to the eleventh minute time. The entropy of boiled cooling water was the least and in negatives followed by that of the universe, also in negatives with a few at the 0 J/K mark. The entropy of air, a natural process within this very time interval was a bove 0 J/K and less than 1 J/K. From the tweleveth minute to the sevententh minute, the entropy value of airwas constant while those of boiled cooling water and and the universe were changing within just a range of 1 J/K.

The universe is treated as an isolated system whose entropy must either increase or be constant with respect to time while as for a closed system of which boiled cooling water in the kettle was, its intropy is supposed to decrease but be not less than zero since it exchanges energy to and from the universe. The boiled cooling water’s entropy was decreesing with decressing temperature since its temperature was reducing leading to reduction in the collision of water molecules. It has been observed that the entropy of the universe was always greater than that of the boiled cooling water (system) at the same time interval and at the same temperature. This is because, at the same time, the boiled cooling water was at a higher temperature than the universe making the universe observe heat from the boiling cooling water. Air being taken as an open system, influenced by the universe, its entropy is seen to be greater than zero, which is a must according to the second law of thermodynamics. Hence, with air, its thermodynamic arrow of time is influenced by entropy.

Thermodynamic arrow of time works on the principle of forwardness and as a result, it only influences entropy of any system foward and not backward.

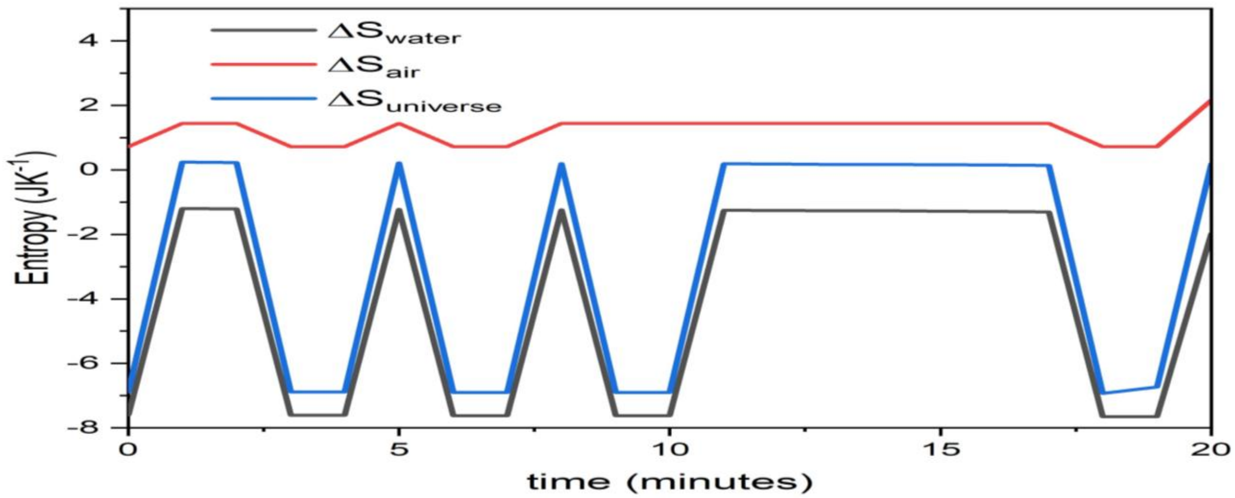

Figure 1: Variation of entropies with time

The entropy of water ranged from-1.20 J/K to -7.65 J/K, for the universe it ranged from 0.24J/K to -6.90 J/K and that of the air ranged between 0.72 J/K to 2.16 J/K. The change in temperature of the boiled cooling water was in between -1^0 Cand -3 ^{0} C within the 20 minutes time interval.

The variation of free energy change of boiled wateris shown in figure 2. It was observed that the Gibbs free energy change of boiled water was highest at the 0 minute time, 612.3 J and least at the 1 minute time, -21.1 J. Between the second minute time and the eleventh minute time, the change in the Gibbs free energy was non uniform withvalues ranging from positive to negative and negative to positive (spontaneous and non-spontaneous),hence proving that the process was neither exergonic nor endothermic. Between the eleventh and the seventh minute, the Gibbs free energy was almost uniform, at zero, as if the system had attained its state of equilibrium. The influence of thermodynamic arrow of time on the boiled cooling water was evident because any change in the temperature of the water brought a change in the Gibbs free energy.

Gibbs free energy of boiled cooling water did not decrease uniformly which violets the second law of thermodynamics in relation to free energy change of any material below 373.15 K (Wright, 2001). This shows that the free energy change of boiled water's arrow of thermodynamics is not influenced by entropy the way it is supposed to be (Grandy, 2008).

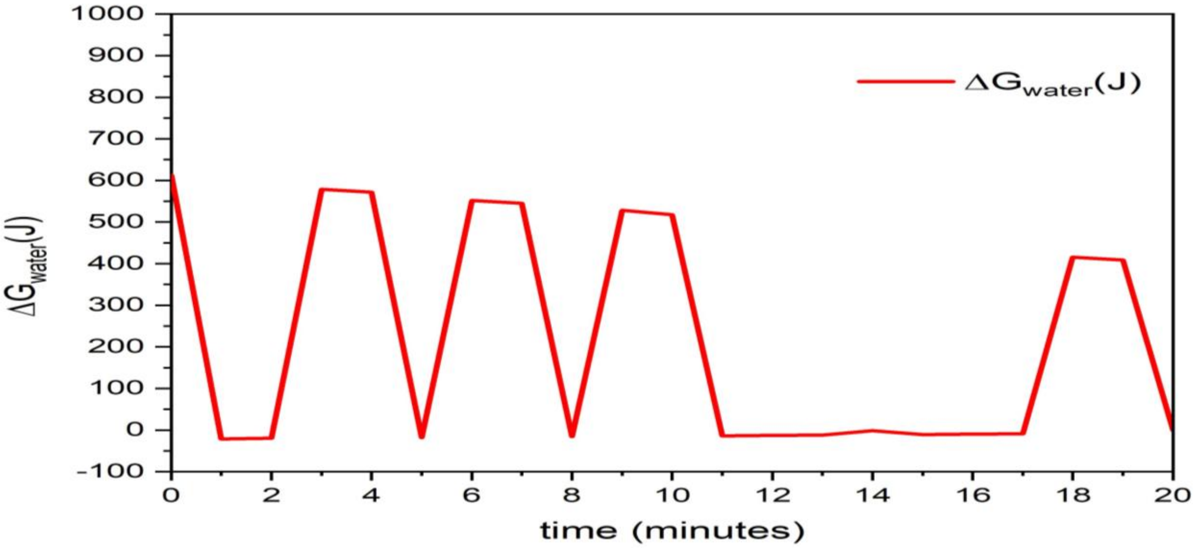

Figure 2: Variation of the free energy of boiled water with time.

For $In\frac{(Tc-Ts)}{(Tm-Ts)}$ against time, the slope obtained is negative. This clearly asserts that Newtons law of cooling is in direction with thermodynamic arrow of time, hence, having influence on entropy. Figure 3 clearly shows that the temperature of the boiled water keeps on reducing and there is uniform decree for both calculated and measured temperature of the boiledwater, as time increases, which confirms that thermodynamic arrow of time influences entropy for any natural process (Galant, 2003). confirms that thermodynamic arrow of time influences entropy for any natural process.

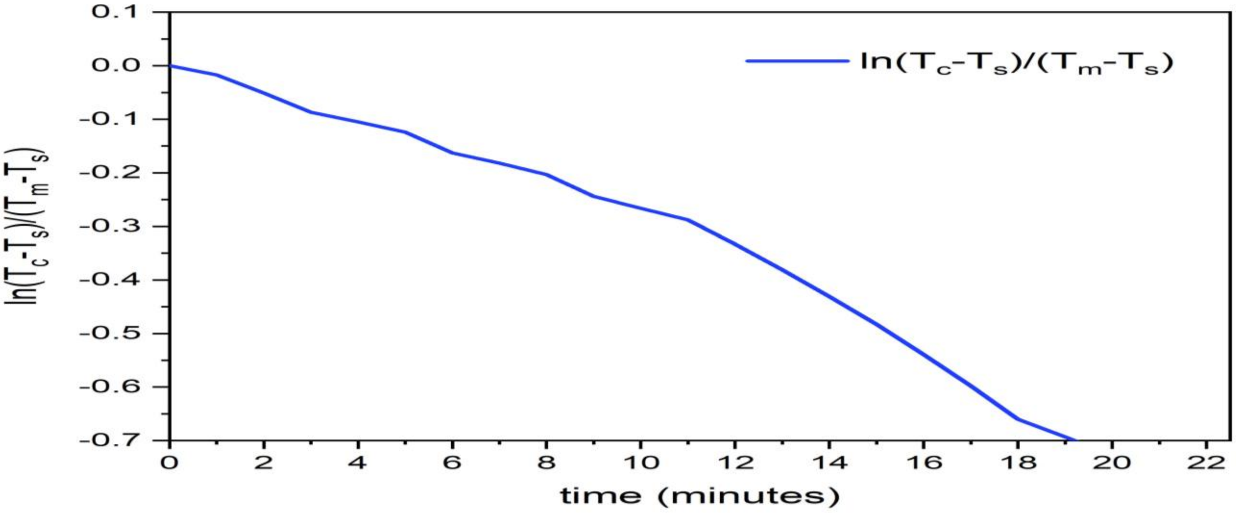

Figure 3: Variation of $In\frac{(Tc-Ts)}{(Tm-Ts)}$ with time

CONCLUSIONS

The thermodynamic arrow of time greatly influences entropy. The results indicate that the entopy of the universe is greater than that of the system for the same temperature at the same time. The entropy of air from the study was always greater than that of the boiled cooling water(closed system) and the universe at any time at the same temperature. Generally thermodynamic arrow of time greatly influences entropy at any particular time at a certain temperature. For a physical process,entropy is influenced backwards and forwardwise and for a natural process, entropy is influenced only forwardwise.

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