XVI. On the quantities of heat developed in the condensation of the vapour of water, and in that of alcohol

Count Benjamin Rumford

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do not think it beneath the notice of your Journal, I will propose to the sagacity of your readers to discover. I know that it is rather out of fashion to offer these sort of questions to the public, though it was very common in the beginning of the last century, and was, I believe, attended with much advantage to science, by producing a widely extended emulation: even the questions yearly proposed in *The Ladies' Diary* are, I am persuaded, very advantageous to the studious in mathematics.

The question I propose is this:

Of any cube number under a million give the figure of the unit, the two last figures, and the number of places, instantly and without any aid of writing to name its cube root. For example, let the cube 438976 be the number whose root is to be named. Given, the two first figures 43, the last figure 6, the number of places six. The root is to be immediately named.

Should the ingenuity of some of your correspondents not find out the very simple method of doing this, I will with great pleasure communicate it to you for insertion when required.

I do not pretend that there is much use in this, but it may be an object of curiosity to some of your numerous readers.

I am, sirs, your obedient servant,

H. C. ENGLEFIELD.

To Messrs. Nicholson and Tilloch.

XVI. *On the Quantities of Heat developed in the Condensation of the Vapour of Water, and in that of Alcohol.* By BENJAMIN Count RUMFORD*.

§ 1. *Of the Quantity of Heat developed in the Condensation of the Vapour of Water.*

HAVING filled the calorimeter and placed it on its stand, a current of vapour was introduced into the serpentine through a cork placed in the lower aperture of the serpentine. This cork having been perforated with a hole two lines in diameter, in the direction of its axis, a small cork (two lines in diameter and two in height) was fitted into it, and four other holes about a line in diameter, pierced horizontally through the sides of the large cork at two lines below its upper extremity, and communicating with the hole two lines in diameter in the axis of this cork, afforded a passage to the vapour, to admit of its entering by four small channels horizontally into the serpentine.

As the apertures of these small channels were higher than the level of the flat bottom of the serpentine, the water which re-

* This paper was read before the French Institute as a supplement to the Count's Inquiry into the Heat developed by Combustion. *Vide Phil. Mag.* vol. xlii. p. 296.

sulted from the condensation of this vapour, did not prevent the vapour from continuing to flow through these passages.

This vapour came from a long-necked matrass containing distilled water, which was put on a portable stove placed in a chimney at some distance from the calorimeter; and in order to stop all direct communication of heat between the stove and the calorimeter, the former was masked by plates, and the tube which conducted the vapour to the calorimeter was well covered with flannel.

The cold water which filled the calorimeter was of a lower temperature than that of the chamber by 6° of Fahrenheit and when the thermometer of the calorimeter announced an augmentation of temperature by 12° of Fahrenheit, an end was put to the experiment.

The water produced by the condensation of the vapour in the serpentine was carefully weighed; and from its quantity, as well as from the heat communicated to the calorimeter, the heat developed by the vapour in its condensation was determined.

As a small part of the heat communicated to the calorimeter proceeded from the cooling of the water condensed in the serpentine, after the vapour had been changed into water, an account was kept of this heat. It was supposed that the water at the moment of condensation was at the temperature of 212° F. being that of boiling water; and it was determined by calculation, what part of the heat communicated to the calorimeter must have been owing to this boiling water.

In making this calculation, no account was taken of the difference in the capacity of water for heat, which depends on its temperature: this is but imperfectly known; and besides, the correction which would have been the result, could not but have been very small.

The following are the details and results of two experiments made on the 21st of January 1812.

Number of Experiments.	Temperature of the Room.	State of the Calorimeter (equal in capacity for Heat to 2781 Grammes of Water.)			Quantity of Vapour condensed into Water in the Serpentine.	Result.	
		Temperature at the Beginning of the Experiment.	Temperature at the End of the Experiment.	Elevation of its Temperature.		Quantity of Water which may be heated 1° F. with the Heat developed in the Condensation of 1 lb. of Vapour.	
1	61°	55°	$67\frac{1}{2}$	$12\frac{1}{2}$	grammes. 29.61	lbs. 1029.3	
2	$62\frac{1}{4}^{\circ}$	$57\frac{1}{4}^{\circ}$	$67\frac{1}{2}$	$10\frac{1}{2}$	24.4	1052.3	
Mean Result						1040.8	

By expressing the mean result of these two experiments in the way employed by Mr. Watt and others, I shall say that 1040 degrees of heat (Fahrenheit) are liberated in the condensation of steam, and that consequently this very quantity of heat is employed and rendered latent when the water, already at the temperature of boiling water, is changed into steam.

The duration of each of these two experiments was from ten to eleven minutes, and I had boiled the water some time in the matrass (to drive out the air which it contained) before I directed the steam from it into the serpentine of the calorimeter.

As the results of these experiments have been very uniform, and as they agree very well with the latter experiments made by Mr. Watt with a view to determine the same question, I have not thought it necessary to repeat them.

I have besides been very much occupied with the following branch of my inquiries.

§ II. *Of the Quantity of Heat developed in the Condensation of the Vapour of Alcohol.*

As chemists are not agreed as to the state of the elements of the water which exist in alcohol, I thought that, by determining with precision the quantity of heat which is developed, we should be better able to form conjectures as to the state of the water, if it be at all times found in this inflammable liquid.

The results of the experiments which I made with alcohol are less regular than those of the experiments made with water, as might have been expected; but they have nevertheless been sufficiently uniform to establish a fact, which will be regarded without doubt as very curious and important.

As the vapour which is extricated from spirit of wine when boiled, varies a little with the intensity of the fire used in boiling it, I took care to note the time which was taken in every experiment, in order to be able to judge, by comparing the quantity of vapour condensed, with the time employed to form it, of the intensity of the heat employed to boil the liquid.

In the following table we shall see the details and results of five experiments made on the same day (January 21, 1812) with alcohol of different degrees of strength. The capacity of the calorimeter was always equal to that of 2781 grammes of water, and the thermometer employed was that of Fahrenheit.

TABLE.

TABLE.

Number of Experiments.	Specific Gravity of the Alcohol employed.	Time employed in the Experiment.	Temperature of the Apartment.	State of the Calorimeter.			Quantity of Alcohol condensed in the Calorimeter.	Result.
				Temperature at the Beginning.	Temperature at the End.	Elevation of its Temperature.		
			<i>min</i>				<i>gram.</i>	
1	85342	7	61°	54½°	68½°	14½°	69.86	499.54
2	85342	5	61°	56°	66½°	10½°	52.21	476.83
3	84714	8	60½°	55½°	65½°	10°	48.82	500.03
4	81763	4½	61°	56°	66½°	10½°	56.61	479.92
5	85342	6½	64°	57°	71½°	14½°	71.31	499.65

On determining, by calculation, the quantity of water which may be heated *one degree*, by the heat developed in the combustion of one pound of this vapour, I took care to keep an account of the difference between the capacity of water for heat and that of alcohol, when I determined how much heat should have been communicated to the calorimeter by the alcohol, and produced by the condensation of the steam, by being cooled in the worm.

In order to prove the state of the elements of the water which exist in the steam of alcohol, it must be shown how much water these elements ought to form.

We shall select the experiment which was made with alcohol of the specific gravity of 81763, and which contained the least water. The quantity of steam condensed in this experiment was 56.61 grammes.

In 100 parts of this alcohol there were
91.79 parts of pure alcohol of Lowitz, and
8.21 parts of water.

Consequently there were in the 56.61 grammes of alcohol condensed in the calorimeter,

51.962 grammes of alcohol of Lowitz, and
4.648 of water.

Now, as M. de Saussure has shown that there are 47 parts of water in 100 parts of alcohol of Lowitz, there must have been 24.422 grammes of water in the 51.962 grammes of alcohol of Lowitz, which were condensed in the calorimeter.

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If to this quantity of water ($=24.422$ grammes) we add the 4.648 grammes which were found mixed with 51.962 grammes of alcohol of Lowitz, in order to compose the 56.61 grammes of alcohol employed in the experiment, we shall have 29.07 grammes of water which ought to have existed, ready formed either in the common state of water, or in some other state, in the 56.61 grammes of alcohol condensed in the calorimeter.

But the condensation of 29.07 grammes of steam into liquid water ought to have of themselves furnished more heat than we had in the experiment in question, in the condensation of these 29.07 grammes of elements of water, with 27.57 grammes of carbon and hydrogen, which concur, with these elements, in forming the steam of the alcohol which was condensed.

If we apply a similar calculation to the results of the experiments made with alcohol which contained more water, the result of the inquiry will be still more striking.

In the experiment No. 5. the alcohol employed was of the specific gravity of 85324 : consequently 100 parts of this alcohol were composed of 77.88 parts of alcohol of Lowitz, and 22.12 water.

And in the experiment 71.31 grammes of vapour of alcohol were condensed.

There were therefore in these 71.31 grammes of condensed alcohol,

55.688 grammes of alcohol of Lowitz, and
 15.622 grammes of water.

In the 55.688 grammes of alcohol of Lowitz there were 26.102 grammes of water, according to the analysis of M. de Saussure; and this last quantity of water ($=26.012$ grammes) added to the quantity found above, viz. 15.622 grammes, makes 41.727 grammes of water which ought to have existed, either as steam or otherwise, in the 71.31 grammes of alcoholic vapour condensed in the calorimeter, in the experiment in question.

In order to simplify our calculation, and to render our comparisons more striking, we shall show how much pure water, in vapour, ought to have been sufficient to furnish, in its condensation, the same quantity of heat which was furnished by the condensation of 71.31 grammes of alcoholic vapour, in the experiment in question.

In this experiment the temperature of the calorimeter was raised to $11\frac{1}{2}$ degrees of Fahrenheit.

In the second experiment, made with the steam of pure water, the temperature of the same calorimeter was raised $10\frac{1}{2}$ degrees of Fahrenheit; with the heat developed in the condensation of 24.4 grammes of this vapour.

Conse-

Consequently the temperature of the calorimeter must have been elevated to $14\frac{1}{2}$ degrees of Fahrenheit, with the heat which must have been developed in the condensation of 33·695 grammes of steam from pure water.

Now as the hydrogen and the oxygen forming the elements of 41·727 grammes of water, which are found to form constituent parts of the 71·31 grammes of vapour of alcohol condensed in the experiment in question, only furnished in their condensation the same quantity of heat as 33·695 grammes of steam of pure water should have furnished, it is clearly proved, in my opinion, that these elements are not so united as to form water, so long as they concur in the formation of alcohol.

I have discovered that the vapour of sulphuric ether furnishes about one half less of heat in its condensation than that of alcohol, and consequently one fourth only of what is furnished by the steam of water of equal weight; but having been interrupted by an accident in the course of my experiments with ether, I am desirous of finishing them before I publish the results.*

XVII. *Proceedings of Learned Societies.*

ROYAL SOCIETY.

Jan. 20. **T**HE President in the Chair. Sir H. Davy communicated, in a letter to the President, a long paper from Paris, on a new gas discovered in that city by M. Courtois, a manufacturer of saltpetre. It appears that this gas was discovered above two years ago; but such is the deplorable state of scientific men in France, that no account of it was published till the arrival of our English philosopher there. M. Courtois communicated his discovery to Clement and Desormes, who made some experiments with the gas, and latterly M. Gay Lussac has devoted his attention to an examination of its history and properties. Mean time Sir Humphry has made a great number of experiments on it, and would have made several more had he not wanted the necessary apparatus in Paris. M. Courtois was led to the discovery by observing how rapidly his metal pots were corroded in preparing the different kinds of sea-weed, which he used for making carbonate of soda. When the soda is extracted from the sea-weed, the new gas is easily disengaged; by pouring strong sulphuric acid on the residuum, at

* In a subsequent number we shall give the learned author's "Inquiries into the Capacity for Heat, or the calorific Power of various Liquids," as being connected with the foregoing memoir.—EDITORS.