

LXV. THE TRACES OF COMBUSTIBLE GASES IN HUMAN EXPIRED AIR.

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THE stimulus to the present investigation was furnished by the observations of Campbell [1929], who showed that the gases present in the peritoneal cavities of animals may contain as much hydrogen (produced by intestinal putrefaction) as corresponds to a tension of the order of 20 mm. Hg. Some of this hydrogen must dissolve in the blood and later diffuse through the lungs into the expired air. The object of the experiments herein recorded has been to determine the extent to which such a transfer of hydrogen or other combustible gas takes place in the human subject, in order to decide whether this constitutes a factor necessary to be taken into consideration in the calculation of the total respiratory exchange from observations carried out with an open circuit respiration chamber. In using such an apparatus the volume of the ingoing air is calculated from the percentage of nitrogen in the outgoing air, the total amount of nitrogen being assumed to be unaltered during its passage through the chamber. But any hydrogen given off from the subject would be returned as unabsorbable gas, *i.e.* nitrogen, in the analysis of the outgoing air and would influence the calculation of the volume of air entering the chamber and so of the respiratory exchange of the subject.

The possibility of carrying out such an investigation depended on the circumstance that there was available the gas analysis apparatus accurate to 0.001 % already described by Krogh [1920]. In using such an apparatus for the estimation of minute traces of combustible gases, two points of technique must be carefully observed. Firstly, the solubility of oxygen and nitrogen in the potash solution used for the CO₂ absorption becomes a factor of very significant magnitude: in order to avoid errors from this source, it is usual to keep this potash solution saturated with air at the temperature of the apparatus, but this restricts the use of the apparatus to the analysis of gas mixtures not differing very appreciably in composition from atmospheric air. Then, secondly, it has already been shown [Krogh, 1919] that pure atmospheric air itself shows a just measurable diminution in volume amounting to about 0.0005 cc. for each minute of exposure to the hot platinum wire of the combustion pipette—an effect that cannot be due to the presence of combustible gases in the atmosphere as it can be repeatedly obtained with the same sample of air. This means that there will never be an absolutely final end-point to a

combustion analysis; when all the combustible gases present have been burned, a further slight diminution of volume will always be obtainable on continuing the combustion. The diminution of volume due to this effect in pure air becomes added to that due to the burning of any combustible gases that may be present. These considerations led to the adoption of the following technique.

In order to have the maximum amount of hydrogen for measurement we analysed not the expired air as directly collected but air that had been re-breathed until its hydrogen tension had come into equilibrium with that in the blood. A simple closed circuit was used consisting of a pair of respiratory valves, a tower of loosely packed soda-lime and a Douglas bag. Into the latter there were drawn through a cotton-wool filter about 5 l. of outside air and to this was added enough oxygen from a cylinder to cover the estimated needs of the subject during the experiment. In this way the composition of the air in the bag at the end of the rebreathing period did not differ greatly from that of the atmosphere, and solubility errors did not enter into the analysis. It was found convenient to observe the volume of air in the bag by attaching a sheet of metal to its upper surface and connecting this by a thread to a simple lever: in this way it was easy to see the point at which all the added oxygen had been used up by the subject, which was the point at which the rebreathing was stopped. To ensure that the results were not being affected by possible contaminating traces of combustible gases, both the air and the oxygen used were passed slowly through about 6 cm. of red-hot wire-form CuO before being collected in the bag. As a further precaution in each experiment a control sample of air was withdrawn from the bag for analysis before the oxygen was added. It was also proved that the rubber lining of the bag did not give off any appreciable amount of combustible gas to air stored within it. Lastly, in order to avoid any possible formation of hydrogen by the action of moisture on oxidisable metals, no metal parts other than the heavily nickel-plated valves were used in the respiration circuit. Every effort was made to carry out the analyses as uniformly as possible. In all cases after a preliminary absorption of any CO₂ present the gas was passed to and fro for 6 minutes (in three carefully measured periods of 2 minutes) over the platinum wire of the combustion pipette heated to dull redness. After measurement of the resulting contraction a second CO₂ absorption was carried out.

Table I contains the results of duplicate determinations made in this way on control samples of atmospheric air collected and treated as mentioned in each case. It will be seen that these data confirm the former statement that in pure air for each minute of exposure to the hot wire shrinkage occurs to the extent of about 0.001 % of the original volume, but that the volume of the potash-absorbable product apparently formed is always less than twice the contraction on combustion. This indicates that, whatever its explanation, the phenomenon cannot be due to the presence of traces of carbon monoxide in the air analysed and this is confirmed by the observation that the effect

is equally well obtained with air that has been passed over red-hot copper oxide.

Table I. *Control combustions with atmospheric air.*

Date	Material analysed	× 0.01 % of volume taken for analysis (50 cc.)	
		Contraction on 6 mins. combustion	Subsequently absorbed by KOH
3. v	Filtered outside air	0.50	0.85
		0.35	0.80
7. v	Air after exposure to red-hot CuO	0.50	0.50
		0.50	0.65
10. v	Filtered outside air	0.40	1.10
		0.50	0.90
10. v	Air after storage in Douglas bag 6.5 hours	0.70	0.75
		0.65	0.75
13. v	Air after storage in Douglas bag 3 days	0.80	1.00
		0.65	1.00
15. v	Filtered laboratory air	0.55	0.65
		0.25	0.55
19. v	Filtered outside air	0.50	0.55
1. vi	Filtered outside air	0.45	0.75
4. vi	Air from compressed air supply after exposure to red-hot CuO	0.50	0.85

Table II. *Analyses of rebreathed air.*

Date	Experiment and subject	× 0.01 % of volume taken for analysis (50 cc.)			
		Contraction on 6 mins. combustion	Subsequently absorbed by KOH	H ₂	CH ₄
30. iv	Filtered air + 5 l. O ₂ . Rebreathed 15 mins. Subject P.	1.00	1.20	0.25	0.10
		1.00	0.65		
2. v	Filtered air + 5 l. O ₂ . Rebreathed 15 mins. Subject N.	1.20	1.35	(?)	0.55
		1.50	1.40		
15. v	Air + 5 l. O ₂ passed over red-hot CuO. Rebreathed 15 mins. Subject R.	4.75	0.90	2.80	0.00
		4.55	0.70		
18. v	Air + 5 l. O ₂ passed over red-hot CuO. Rebreathed 15 mins. Subject P.	1.90	1.20	0.25	0.55
		2.00	1.00		
31. v	Air + 6 l. O ₂ passed over red-hot CuO. Rebreathed 15 mins. Subject R.	4.00	1.20	1.85	0.35
		3.90	1.00		
4. vi	7.5 l. air + 20 l. O ₂ all passed over red-hot CuO. Rebreathed 63 mins. Subject P.	2.15	1.45	0.30	0.60
		1.15 (?)	1.35		

Turning now to the analyses of the rebreathed air recorded in Table II, it will be seen at once that the contractions on combustion and the subsequent amounts of absorption by potash are invariably larger than with atmospheric air, indicating that traces of combustible gases are in fact expired by the human subject. The subjects used for these observations were all examined in the absorptive period either in the middle of the morning (Exps. 1, 2 and 4) or after lunch (remaining experiments). That these traces of expired combustible gases do not consist of carbon monoxide derived from tobacco smoke is evident from the fact that the highest figures were obtained with the subject R. who is a non-smoker. Prolongation of the rebreathing period from

15 minutes to 63 minutes as in the last experiment recorded led to no significant increase in the amount of combustible gas collected.

In the last two columns of Table II the amounts of combustible gases in the rebreathed air have been calculated on the assumption that they consist of hydrogen and methane only. In making this calculation the contraction on combustion and subsequent absorption by potash obtained on the same day with a control sample of atmospheric air, collected as mentioned from the Douglas bag just before each experiment, were subtracted from the corresponding data obtained with the rebreathed air.

In order to determine approximately the rate at which these gases are given off from the body, let us take the highest percentage of combustible gas obtained, namely the $2.80 \times 0.01\%$ from the experiment of 15. v. This appears to be made up entirely of hydrogen. This percentage corresponds to a tension in moist air at body temperature of approximately 0.2 mm. Hg. Taking this as the same as the tension of hydrogen in the mixed venous blood, and assuming an average rate of blood flow through the lungs of 5 l. per minute and a solubility of hydrogen in blood equal to that in water under the same conditions, the amount of hydrogen carried to the lungs per minute works out to be 0.02 cc. But during a respiratory experiment on a human subject about 60 l. of air pass through the chamber per minute, so that if the blood gave off the whole of its hydrogen while passing through the lungs this would add only 1 part of inert gas to 3×10^6 parts of outgoing air—a change in composition that is about one-thirtieth of the smallest detectable by the most accurate technique yet devised. We may conclude with certainty, therefore, that, whatever may be the exact nature of these traces of combustible gases in human expired air, even if they were produced at 10 times the maximum rate here observed, they would be quite without influence on the results of the most accurate respiratory experiments that have so far been made.

SUMMARY.

1. The slight shrinkage in volume when pure atmospheric air is submitted to combustion analysis is confirmed. This effect cannot be due to the presence of traces of ordinary combustible gases as it is obtained in air that has been passed over red-hot copper oxide.

2. Air that has been rebreathed by a human subject contains traces of combustible gases in amounts that indicate a rate of production of about 0.02 cc. per minute. This is far too small to be of significance in determinations of total respiratory exchange.

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