Determination of the Ratio of the two Specific Heats of Gases by Kundt's Tube Method

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Abstract.

The main principle of the experiment is based upon the determination of the velocity of sound through gases by observing the wave-length of sound given out by the telephone whose frequency has been determined by the preliminary experiment with dry air. The ratio of the two specific heats λ is determined from this by the help of the following simple formula

$U = nL = \sqrt{\frac{P.\lambda}{\rho}}.\ \therefore \lambda = \frac{L^2 n^2 \rho}{P}$, where U is the velocity of sound, L the wave-length, n frequency, P pressure and ρ the density. The percentage of error on repitition of the same experiment is 0·045.

The result obtained for CH_3 CHO is 1·145 which agrees with the result 1·140 obtained by Muller. The following are the experimental results of the ratio of the two specific heats of gases:

CH_3CHO	at	30°C	1·145
$C_2H_5CH_2OH$	at	110°C	1·272
(CH_3) CHOH	at	110°C	1·590
$CH_3(CH_2)^3$ CH_3	at	40°. 2 C	1·382
C_5H_{10}	at	43°C	1·432

1. *Description of the Method.*

In this experiment the ratio of the two specific heats of gases is determined from the velocity of sound through the gases at our disposal. The velocity of sound U is given by the following equation :

$U = \sqrt{\frac{dP}{d\rho}}$ where P is the pressure and ρ the density.

We know PV^{λ} to be constant, where λ is the ratio of two specific heats of gases and V the volume,

$$\text{or } P = c\rho^{\lambda} \text{ or } \frac{dP}{d\rho} = \lambda c \rho^{\lambda - 1} = \lambda \frac{P}{\rho}. \quad (i)$$

$$\therefore U = \sqrt{\frac{P.\lambda}{\rho}} \text{ from } eqn.\ (i)$$

U_0 the velocity of sound at O°C and U_t at t°C are given by

$$U_0 = \sqrt{\frac{P.\lambda}{\rho_0}} = \sqrt{\frac{13{\cdot}6 \times 76 \times 981 \times 1{\cdot}41}{0{\cdot}00129}} = 33160 \text{ c.m. per sec. for}$$

air at N. T. P.

$$U_t = \sqrt{\frac{P.\lambda}{\rho_t}} = \sqrt{\frac{P.\lambda T_t}{\rho_0 T_0}} \text{ or } \frac{U_t}{U_0} = \sqrt{\frac{T_t}{T_0}}$$

$$\therefore U_t = U_0 \sqrt{\frac{273 + t}{273}}$$

$$= U_0(1 + 0{\cdot}00184t)$$

$$= 33160 + 60{\cdot}9t \text{ c.m. per sec.}$$

And we know that $U = nL = \sqrt{\frac{P.\lambda}{\rho}}$ $\therefore \lambda = \frac{L^2 n^2 \rho}{P}$

where L = wave length and n = frequency.

The velocity of sound in different gases is determined by Kundt's tube method. A telephone is fixed at one end of the tube and the other end is closed with a rubber stopper through which passes a narrow glass tube with a piece of cork at the end used as a piston. At the other end of the narrow glass tube sound is heard through a rubber tubing.

Fleming's three-electrode Thermionic Valve is used to produce alternating current from the direct E.M.F. The frequency of alternation n is given by the equation

$$n=\frac{1}{2\pi}\sqrt{\frac{1}{CL}-\frac{R^2}{4L^2}}$$

where C is the capacity of the condenser, L the self-inductance and R the ohmic resistance of the coil.

The induction coil of the telephone is inductively coupled with that of the thermionic valve. The frequency of the sound waves given out by the telephone is determined from the velocity of sound in dry air and the velocity of sound in other gases is deduced from this value.

The glass tube used for obtaining sound waves is placed in a brass box filled with oil having boiling point 140°C., the temperature of which can be maintained constant at any required value. The ends of the glass tube outside the box are also heated by electric current passing through nickel wire uniformly coiled round the two pieces of wider glass tubes in which the ends lie. The temperature of the ends is maintained at the same temperature as inside by adjusting the rheostat. The telephone used is of ebonite frame and with varnished diaphgram so as not to be acted on by gases. An ebonite collar is fixed with the frame of the telephone so that it can be fixed with the end of the glass tube and pulled out when required.

The frequency of sound waves given out by the telephone through air at the room-temperature is determined in the following way. The ends of the glass tube are closed with rubber stoppers and the air inside is exhausted to a pressure of about 1 cm. of Hg then the tube is filled with dry air passing very slowly through several long-tubes filled with $Ca\ Cl_2$ and lastly through strong H_2SO_4. Then the stoppers are pulled out and at one end the telephone is fixed and through the other end the piston is allowed to pass through the stopper. Then by slowly moving the piston the points of maximum augmentation of sound are noticed and several readings are taken for each point of maximum augmentation of sound or by a preliminary experiment first the nubmer of half waves containing in the tube is determined and then readings are noted only for the 1st point R_1 and the last point R_2 of max. augmentation of sound and then the average value is taken. The vapour at our disposal is allowed to pass through the evacuated tube and then the stop-cock is closed and again the tube is evacuated and then vapour is allowed to pass through the tube. This process is carried on 2 or 3 times in order to be sure that there is no mixture of air inside the tube. Then the same process is carried on as in the case of air but the following precautions are taken. While moving the piston it is quite likely that air will mix with the gas. In order to avoid this error the readings for R_1 and R_2 are determined separately by allowing fresh gas to pass through the tube each time and while taking observation the piston is placed approximately at the pt. R_1 or R_2 which has been determined by preliminary experiment. With each gas the experiment is repeated several times and the average value is taken because it is not possible to take more readings at the same time since air will mix with the gas while moving the piston.

2. *Experimental Results.*

Experiments with dry air.

Temp.	R_1 Mean of 10 Readings.	R_2	N Number of half waves.	Value of half wave-length.	Frequency.
100°C.	5·42 cm.	72·41 cm.	6	11·165 cm.	1757·7
14°.30.	7·07	74·79	7	9·674	1760·10
14°.3C.	7·02	74·66	7	9·663	1760·36
15°.0.	9·80	77·50	7	9·672	1761·8
					Mean value of n =1760·0

Experiment with Acetaldehyde, CH_3CHO at 30°C.

	R_1 (mean of 5 readings).	R_2 (mean of 5 readings).	Number of half waves.	Value of half wave-length.
I	7·03	72·75	9	7·304 cm.
II	7·28	73·00	9	7·301 ,,

$$\lambda = 22 \times \frac{273 \times (14{\cdot}6)^2 \times (1760)^2 \times 0{\cdot}000089}{303 \times 76 \times 14{\cdot}59 \times 981}$$

$= 1{\cdot}145.$

Experiment with Normal Propyl alcohol, $C_2H_5CH_2OH$ at 110°C.

	R_1 (mean of 5 readings)	R_2 (mean of 5 readings)	N	L/2
I	3·50	33·20	4	7·42 cm.
II	3·50	33·2	4	7·42 ,,

$\lambda = 1{\cdot}272$

Experiment with Iso-propyl alcohol, $(CH_3)_2CH\ OH$ at 110°C.

	R_1	R_2	N	L/2
I	3·34	44·91	5	8·314 cm.
II	3·36	44·89	5	8·306 „

$\lambda=1{\cdot}590.$

Experiment with dry air.

Temp.	R_1 (mean of 10 readings)	R_2 (mean of 10 readings)	N	L/2	Frequency.
14°·5C.	10·27	74·78	7	9·215 cm.	1847·15
14°·5C.	9·98	74·48	7	9·210	1848·15
15°·1C.	9·79	74·39	7	9·228	1847·10
13°·85C.	9·87	74·50	7	9·232	1847·0
					Mean value of n =1846

Experiment with Pentane, $CH_3(CH_2)_3\ CH_3$ at 40°·2C.

	R_1 (mean value)	R_2 (mean value)	N	L/2
I	6·45 cm.	79·45	12	6·083 cm.
II	7·0	79·80	12	6·066
III	6·77	79·8	12	6·086
IV	6·0	79·04	12	6·087
V	6·35	79·0	12	6·054
VI	6·0	78·85	12	6·066
VII	5·95	78·5	12	6·045
VIII	6·73	79·8	12	6·090
				Mean value of L =12·144 cm.

$\lambda=1{\cdot}382.$

Experiments with Amylene, $C_5 H_{10}$ at 43°C.

	R_1 (mean value)	R_2 (mean value)	N	L/2
I	6·7	82·0	12	6·275 cm.
II	6·93	76·62	11	6·331 ,,

$\lambda = 1{\cdot}432$.

The percentage of error on repetition of the same experiment is 0·045. The result obtained for $CH_3\,CHO$ is 1·145 which agrees with the result 1·14 obtained by Müller.

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