



Fig. 8 Prandtl number for carbon-dioxide air mixtures

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DISCUSSION

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It would be of interest to know the exact procedure followed and ranges covered in the statistical analysis of the available transport property data to obtain the corresponding force constants, since variations can considerably change their values, and thus the extrapolated property values. Furthermore, extrapolation of these properties to high temperatures by kinetic theory is not always found to be as accurate as use of the simpler Sutherland equation.

In view of this situation, it would be appreciated to have the authors' estimate of the reliability of the trend of Prandtl number with temperature for the pure gases, as shown in Fig. 8. A continual decrease to above 1500 deg K is shown for CO₂, and possibly to 1100 or 1200 deg K for air. This trend seems to disagree with the authors' Table I for CO₂, and with Vines' data and Glassman's extrapolated data for air.

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Fig. 3 only compares the experimental measurements of Vines [32]⁵ with the NBS tabulation. The latter used an equation of Keyes for temperatures above 600 deg K. In Table 7 other values for the range 600-1200 deg C are given.

The data of columns (1) and (4) are based upon experimental measurements, while columns (3), (5), (6) represent calculated values based upon experimental data which do not in all cases fall in this temperature range. The data of column (6) are those calculated by the Keyes formula [34] and the Vines measurements are given in column (7).

One conclusion is evident, that the values calculated by the

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⁵ Numbers in brackets from [26 to 35] designate References at end of discussion.

Table 7 Thermal conductivity of air

| T, deg C | 10 ⁵ k(1) ^a | 10 ⁵ k(2) ^a | 10 ⁵ k(3) ^a | 10 ⁵ k(4) ^a | 10 ⁵ k(5) ^a | 10 ⁵ k(6) ^a | 10 ⁵ k(7) ^a |
|----------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|
| 600 | 14.65 | 14.88 | ... | ... | ... | 14.68 | ... |
| 626.85 | ... | ... | ... | 14.85 | ... | ... | ... |
| 648.89 | ... | ... | ... | ... | 15.18 | ... | ... |
| 700 | 15.64 | 16.05 | ... | ... | ... | 15.84 | ... |
| 704.44 | ... | ... | ... | ... | 15.76 | ... | ... |
| 726.85 | ... | ... | ... | 15.94 | ... | ... | ... |
| 760 | ... | ... | ... | ... | 16.42 | ... | 16.7 |
| 800 | 16.64 | 16.69 | 16.0 | ... | ... | 16.94 | ... |
| 815.56 | ... | ... | ... | ... | 17.00 | ... | ... |
| 826.85 | ... | ... | ... | 16.98 | ... | ... | ... |
| 871.11 | ... | ... | ... | ... | ... | 17.58 | ... |
| 900 | 17.52 | 17.69 | ... | ... | ... | 17.98 | 18.4 |
| 926.85 | ... | ... | ... | 17.97 | 18.20 | ... | ... |
| 982.22 | ... | ... | ... | ... | 18.78 | ... | ... |
| 1000 | 18.29 | 17.90 | 18.2 | ... | ... | 18.98 | ... |
| 1026.85 | ... | ... | ... | 18.91 | ... | ... | ... |
| 1037.78 | ... | ... | ... | ... | 19.44 | ... | ... |
| 1093.33 | ... | ... | ... | ... | 20.02 | ... | ... |
| 1100 | (18.89) | ... | ... | ... | ... | ... | ... |
| 1126.85 | ... | ... | ... | 19.81 | ... | ... | ... |
| 1200 | (19.63) | ... | 20.2 | ... | ... | ... | ... |

^a Data sources for column 1: (1), [26]; (2), [27]; (3), [28]; (4), [29]; (5), [30]; (6), [31]; (7), [32].

Keyes formula are somewhat large at the higher temperatures and that more probable values would be 18.1 ± 0.2 at 1000 deg C and 20.1 ± 0.4 at 1200 deg C. Below about 750 deg C the Keyes formula should be accurate. The experimental data of Vines also seem a little high as compared with other values, a deduction also confirmed by analysis of the carbon dioxide data below.

Several sets of data for carbon dioxide have been omitted from Fig. 4. Two of the more significant sets are listed below:

| T, deg C | 10 ⁵ k[33] | 10 ⁵ k[26] | T, deg C | 10 ⁵ k[33] | 10 ⁵ k[26] |
|-------------|-----------------------|-----------------------|-------------|-----------------------|-----------------------|
| 300 | 9.1 | 9.59 | 900 | 18.1 | 18.36 |
| 400 | 10.9 | 11.34 | 1000 | 19.1 | 19.46 |
| 500 | 12.6 | 12.96 | 1100 | ... | (20.47) |
| 600 | 14.1 | 14.47 | 1200 | ... | (21.39) |
| 700 | 15.6 | 15.87 | 1300 | ... | (22.24) |
| 800 | 17.0 | 17.17 | | | |

The tabulation of Keyes [34] to 1000 deg C has not been added as the data are extrapolated above 300 deg C and quite serious errors result, the value quoted at 1000 deg C being 26.89. Also omitted here are values of Lenoir [30] which are given in British units for even Fahrenheit temperatures. At 760 deg C Lenoir quotes 16.96 which may be compared with the experimental value of 17.5 of Vines. At the highest temperature (982.2 deg C) Lenoir quotes 20.10; i.e., intermediate between (26), (33), and Vines. In Table 7, column (8), are values recommended by Rothman and Bromley [33] while column (26) gives data calculated from an equation of Stops [26]. The writer has found that below some 400 deg C this equation can lead to error but that the higher temperature values are satisfactory, as can be deduced by comparison at 1000 deg C with the experimental value of 19.5. Values calculated above this limit of measurement are enclosed in parentheses.

If these data are plotted in Fig. 4 two curves are found which lie below the thick line. In fact, the molecular parameters leading to the black line appear to be a very satisfactory choice as values indicated thereby fall nicely between those of Vines [7], on one hand, and those of Stops [26] and of Rothman and Bromley [33], on the other hand. The data for carbon dioxide may therefore be regarded as quite accurate.

The use of an intermolecular potential should be justified by comparison with experiment, if at all possible. Kliibanov,

Pomerantsev, et al. [35], measured the diffusion coefficient of these mixtures to 1500 deg K and a comparison of their data with that predicted by the Lennard-Jones potential function would be interesting.

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Authors' Closure

The data analyzed for determining the force constants for both air and carbon dioxide are presented by the sources listed in Table 4. In both cases the highest temperature is 1173 deg K (Vines' data). The results of Rothman and Bromley and Stops were not included in the carbon-dioxide analysis since only the smooth curves were available. The statistical analysis is carried out in the following manner: Successive values of ϵ/k are chosen and for each ϵ/k a σ is calculated for each experimental value of λ , thus giving a set of σ 's. The ϵ/k associated with the set of σ 's having the least-square per cent deviation from the average σ for that set is taken along with the average σ as being the best set of force constants.

The reliability of the conductivity calculations can be only as good as the scatter of the experimental data which are analyzed to give the average force constants. This, for both air and carbon dioxide, is approximately 1 to 3 per cent at 300 deg K and 10 per cent at 750 deg K. Since the calculated conductivity results are average values from a large number of investigations, one will find trends in the calculated Prandtl number as mentioned in the discussion of C. F. Bonilla. The maximum difference in the CO₂ results, Fig. 1, and the calculated results, Fig. 8, is 3 per cent.