Measuring accommodation coefficients using laser-induced incandescence

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This study presents thermal accommodation coefficients between soot and different gases. The dependence of these values on the molecular mass of the gas is investigated.

Introduction

Laser-induced incandescence has recently been used to measure thermal accommodation coefficients, α_T. Although most experiments carried out to date provide soot/air or soot/flame-gas accommodation coefficients, a recent study [1] presents α_T values between soot and four other gases. The present study expands this data to include more gases and explores the relationship between α_T and the molecular mass of the gas.

Theory

Although the physics of gas-surface interactions is highly complex and not fully understood, several phenomenological models accurately describe the dependence of α_T on different parameters, the most important being the ratio of the molecular mass of the gas and the atomic mass of the surface atoms, $\mu = m_g/m_a$. The earliest and most robust model was proposed by Baule [2, 3], who predicted α_T based on the kinetic energy transferred when a moving rigid sphere representing a gas molecule collides with a stationary rigid sphere representing a surface atom,

$$\alpha_T = \frac{2.4\,\mu}{(1+\mu)^2}. \qquad (1)$$

This model is physical only if $\mu < 1$, since the surface atom could not otherwise back-scatter the gas molecule. If $\mu > 1$, lattice forces between multiple surface atoms help repel incident gas molecules. Burke and Hollenback [4] suggest that m_a can be adjusted to account for these lattice forces.

Experimental Apparatus

Soot is extracted at a height of 52 mm above a Gülder burner operating at conditions described in [5], and is induced into a motive gas in the venturi section of a mini-eductor resulting in dilution ratios between 30:1 and 100:1. The mixture flows into a closed chamber where two-color laser-induced incandescence is carried out. The thermal accommodation coefficient is then calculated from the effective temperature time-decay following the procedure described in [5].

Results

Values of α_T between soot and different gases are plotted in Fig. 1. The accommodation coefficient increases with increasing m_g for monatomic gases as predicted by Baule theory, but decreases for diatomic gases. Figure 2 shows the monatomic gas data plotted with Eq. (1) assuming an effective atomic surface mass of 119 amu, determined by least-squares fit. Although the general trend of the data agrees with the Baule model, Eq. (1) is not a good fit to the data if m_s is constant. A better fit is found by letting m_s be a function of m_a, which is consistent with the theory proposed in [3]. Values of m_s were solved by fitting Eq. (1) to the experimentally-measured α_T values for monatomic gases, and were found to be a hyperbolic function of m_a, as shown in Fig. 2.

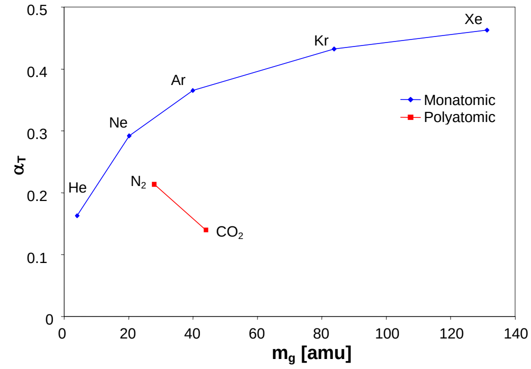

Fig. 1: Experimentally-determined values of α_T between soot and different gases.

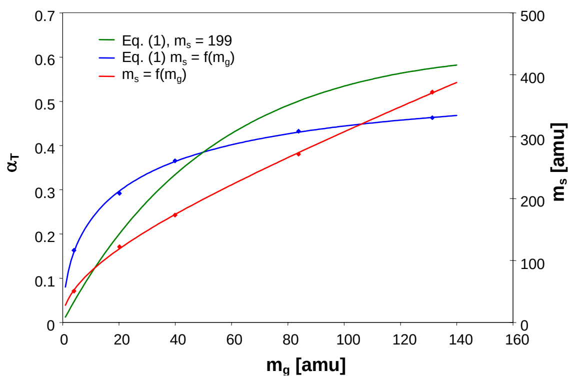

Fig. 2: Comparison of Baule theory to experimentally determined α_T values for monatomic gases.

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International Discussion Meeting and Workshop 2006: Laser-induced Incandescence, Quantitative interpretation, modelling, application