Figure 1.1: A schematic diagram of a shock tunnel

I represents the initial shock into an equilibrium test gas.
R represents the reflected shock with an equilibrium nozzle reservoir behind it.
S represents the standing shock on a wedge in a nonequilibrium test gas.
e denotes equilibrium conditions
f denotes frozen conditions
r denotes relaxing conditions
Figure 2.1: Vibrational transition probabilities for $H_2$ at 5000K and 1 atm.
Figure 2.2: Vibrational level population distribution for $N_2$ at 1 atm and $Y = 3000K$. The translational temperature varies from 4000 to 800K. The two curves just below $T = 1000K$ correspond to values of $-3\times10^5$ and $-3\times10^6$ Ks$^{-1}$ for $\frac{dT}{dt}$, respectively.
Figure 2.3: Vibrational temperature (Y) vs reservoir pressure ($P_o$) at a reservoir temperature $T_o = 4500K$ and area ratio $A/A^* = 32$. Theory: ○ experimental value of Y from Hurle et al. (1964) reinterpreted according to MacDonald (1972).
Figure 2.4: Vibrational temperature ($Y$) vs reservoir temperature ($T_o$) at $P_o = 50$ atm and area ratio $A/A^* = 8$. --- Theory; • experimental value of $Y$ from Hurle et al. (1964) reinterpreted according to MacDonald (1972).
Figure 2.5: Time evolution of vibrational level populations of $H_2$ at 5000K and 1 atm with no dissociation. —— V-T transitions only, --- V-T and V-V transitions. The populations were in a Boltzmann distribution at 300K.
Figure 2.6: Time evolution of vibrational level populations of $H_2$ at 5000K and 1 atm with no recombination. --- V-T transitions only, --- V-T and V-V transitions. The populations were in a Boltzmann distribution at 10000K.
Figure 2.7: Time evolution of vibrational level populations of $\text{H}_2$ at 5000K and 10 atm with dissociation. Half the atom population is also plotted. —— V-T transitions only, —— V-T and V-V transitions. The populations were in a Boltzmann distribution at 300K.
Figure 2.8: Time evolution of vibrational level populations of H₂ at 5000K and 10 atm with recombination. Half the atom population is also plotted. —— V-T transitions only, —— V-T and V-V transitions. The populations were in Boltzmann distribution at 10000K. The mole fraction of H₂ was 10⁻⁸.
Figure 2.9: Variation of initial dissociation rate of H₂ with mole fraction of H₂ in Ar at 5000K and 1 atm. — V-T transitions only, — V-T and V-V transitions, — V-T and V-V transitions with q equal to 100, — V-T transitions only, with equal normalised V-T transition probabilities for H₂-H₂ and H₂-Ar collisions.
Figure 2.10: Vibrational excitation rates of $\text{H}_2$. The straight line is the experimental value of Kiefer and Lutz (1966b). Results of four shocks in 5 torr initial pressure of $\text{H}_2$ at 300K are plotted. The slowest rate for each shock is for V-T transitions only. The effect of V-V transitions is shown by varying $q$. 
Figure 2.11: Vibrational excitation rates of N₂. The straight line is the experimental value of Appleton (1967). Results of four shocks in 5 torr initial pressure of N₂ at 300K are plotted. The slowest rate for each shock is for V-T transitions only. The effect of V-V transitions is shown by varying q.
Figure 2.12: Dissociation rate coefficient $k_d$ of $H_2$. For comparison the experimental value of $k_d$ given by Breshears and Bird (1973a) is shown. Results of three shocks in 5 torr initial pressure of $H_2$ at 300K are plotted. The effect of V-V transitions is shown by varying $q$. 
Figure 2.13: Vibrational de-excitation rates of H₂. The straight line is the experimental value of Kiefer and Lutz (1966b). The reservoir conditions are 3000K and 50 atm. The rates for V-T transitions only, V-T and V-V transitions and V-T and V-V transitions with q equal to 10 are seen to be nearly identical.
Figure 2.14: Vibrational and translational temperature along the nozzle. The reservoir conditions are 3000K and 50 atm.——calculations using Lordi et al. (1966), ——— V-T transitions only, ——— V-T and V-V transitions.
Figure 2.15a: Atom mass fraction, vibrational and translational temperature along the nozzle --- calculations using Lordi et al. (1966), V-T transitions only, V-T and V-V transitions. The reservoir conditions are 5000K and 200 atm.
Figure 2.15b: Atom mass fraction, vibrational and translational temperature along the nozzle. The reservoir conditions are 6000K and 200 atm.
Figure 2.15c: Atom mass fraction, vibrational and translational temperature along the nozzle. The reservoir conditions are 7000K and 200 atm.
Figure 2.16: Comparison between the vibrational equilibrium energy, per mole, of the SHO and the MO representation of N$_2$ for temperatures up to 15000K. —— MO, —— SHO, and —— RT.
Figure 3.1: Range of temperature and inert gas dilution of different dissociation rate measurements.
Figure 3.2: Ratio of equilibrium to initial density as a function of shock speed for two driver conditions. Curve I, 2700 lb/in², curve II, 10500 lb/in² diaphragm burst pressure. ——— Calculated, • measured.
-5100 Å calibration for the white light interferogram.

Figure 3.3: Three time-resolved interferograms of nitrogen dissociation behind a shock.

- **a** 4.80 km sec$^{-1}$, 31 torr, 298.2K.
- **b** 5.60 km sec$^{-1}$, 19 torr, 298.2K.
- **c** 7.31 km sec$^{-1}$, 5 torr, 300.2K.
Figure 3.4: Calculated and measured fringe shift in the relaxation zone for three shock speeds: • 4.80 km sec\(^{-1}\), 31 torr; ■ 5.60 km sec\(^{-1}\), 19 torr; ▲ 7.31 km sec\(^{-1}\), 5 torr. Calculated curves according to Hanson and Baganoff (1972) ---, Appleton et al. (1968) ______, equations 3.2-11 and 12 ______.
Figure 3.5a: Pre-exponential factor for the rate coefficient $k_d^{\text{N}_2}$ versus temperature; □ Hanson and Baganoff (1972), ○ present, △ Cary (1966), ▼ Appleton et al. (1968), ● Byron (1966). The error bars indicate authors' estimated uncertainties. Edge-hatching delineates regions in which 3 or more but not all, authors agree, or that if only 2 authors cover the range, they agree. Cross-hatching indicates where all authors agree. The numbers indicate how many authors agree in the region.
Figure 3.5b: Pre-exponential factor for the rate coefficient $k_d^N$ versus temperature.
Figure 3.6: Primary shock speed in T2 versus initial shock tube pressure of nitrogen for four operating conditions
A. He driver, $p_b = 6800$ psi, $\lambda_p = 37$
B. He driver, $p_b = 3600$ psi, $\lambda_p = 29$
C. He driver, $p_b = 1700$ psi, $\lambda_p = 14$
D. Ar driver, $p_b = 6800$ psi, $\lambda_p = 37$. 
Figure 3.7: Pitot pressure probe and results of an axial Pitot pressure survey. The nozzle stagnation conditions are $T_0 = 4400K$ and $P_0 = 227$ atm.

- △ 13 deg nozzle
- ■ 15 deg nozzle
- ◇ 14 deg nozzle
Nozzle stagnation condition = B2

Nozzle stagnation condition = C1

Figure 3.8: Static pressure variation with time, measured from shock reflection in the shock tube.

Vertical scale:  Stagnation pressure - 35 atm/div
                Static pressure        - 0.143 psi/div

Horizontal scale:  Time, increasing from right to left - 100 μsec/div
Figure 3.9: Calculated and measured shock angle on a 35° wedge for the range of stagnation temperature \( T_0 \). --- represents a free-hand fit to the calculated points □. The time, after shock reflection, of each measured interferogram is indicated: • 500 μsec, ▲ 350 μsec, ■ 300 μsec, ◇ 225 μsec ▼ 200 μsec. ● represents the ratio of vibrational de-excitation rate to excitation rate used in the calculations. The error bar of 300K for \( T_0 \), above 4500K, is considered to be pessimistic.
Figure 3.10: Calculated and measured shock angle on a 39° wedge for the range of stagnation temperature $T_0$. The description is the same as Figure 3.9.
Figure 3.11: Calculated and measured shock angle on a 41° wedge for the range of stagnation temperature $T_0'$. The description is the same as Figure 3.9.