CHAPTER 4

Figures

These figures are from

Understanding the properties of matter

by Michael de Podesta.

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Figure 4.1. A schematic illustration of the motion of molecules in a gas. The molecules are shown as a central darkly-shaded region, where the electron charge density is high, and a peripheral lightly-shaded region. Although there is no electronic charge in this peripheral region, the electric field there will significantly affect the motion of any other molecules that enter that region. Notice that on average, the distance between the molecules is large compared with the extent of their region of influence. The arrows indicate the velocities of the molecules. Notice that the velocities are randomly oriented and that the length of the velocity vectors is varied, indicating that the molecules have a wide range of speeds.

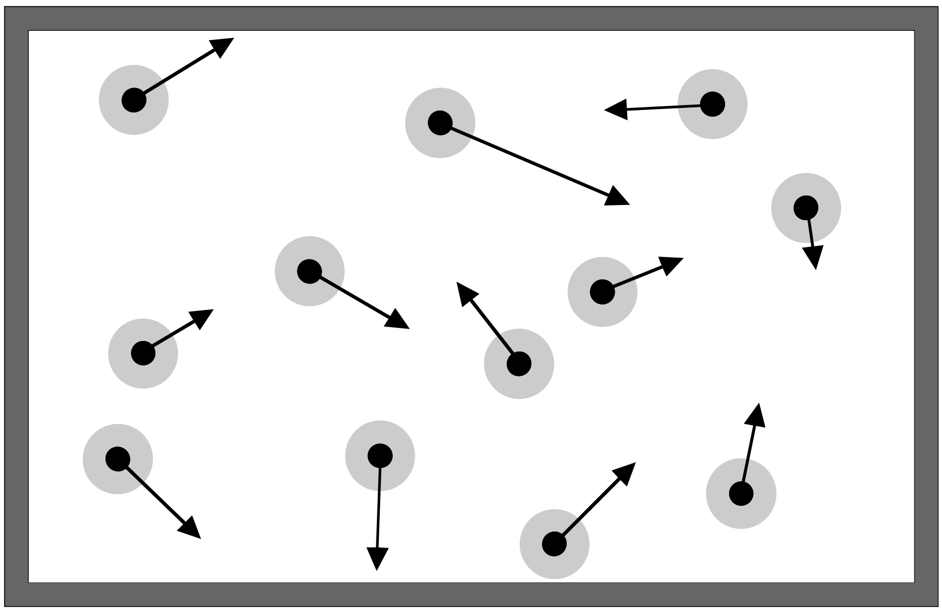

Figure 4.2 The molecule S is alone in a box travelling with a kinetic energy which is the same as the average kinetic energy of all the molecules that will eventually inhabit the box.

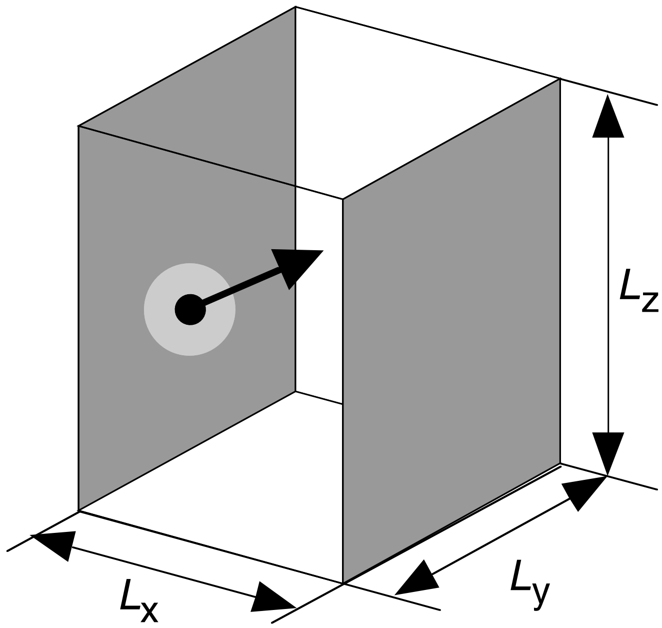

Figure 4.3 An elastic collision with the wall imparts momentum to the wall. (a) and (b) show a molecule before and after such a collision.

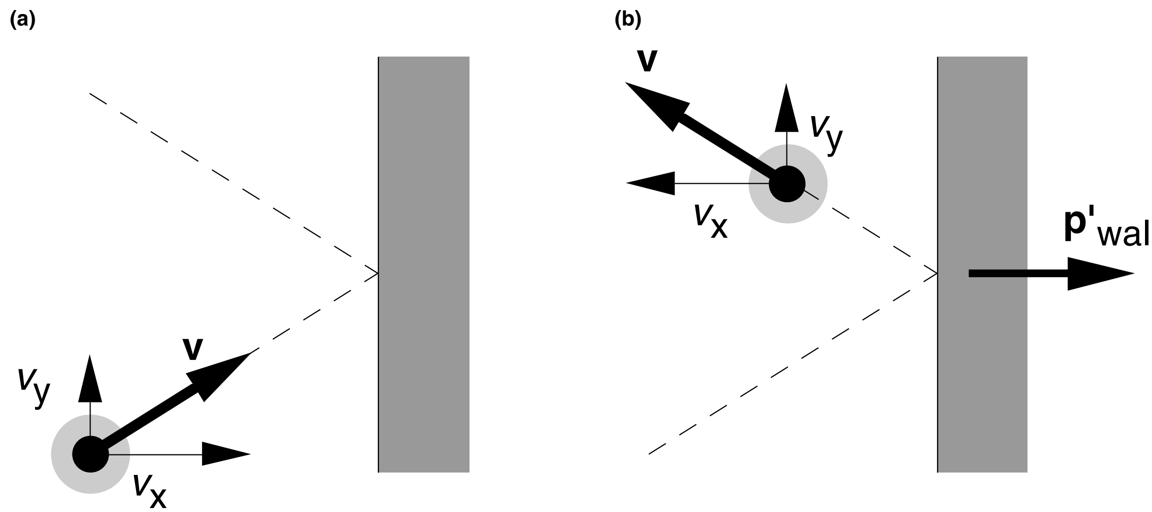

Figure 4.4. When a molecule hits a wall, what really happens is that it sticks to the wall for a short while (typically 10^{-12} s), and eventually leaves the wall and rejoins the gas with no 'memory' of the trajectory with which it hit the wall. It sticks to the wall because the wall is made of molecules with which it will have some kind of interaction. The figure shows (a) the approach to the wall, (b) the adsorption on the wall and (c) the escape from the wall. On each molecule, the area shaded grey indicates the region in which the molecule interacts strongly with neighbouring molecules.

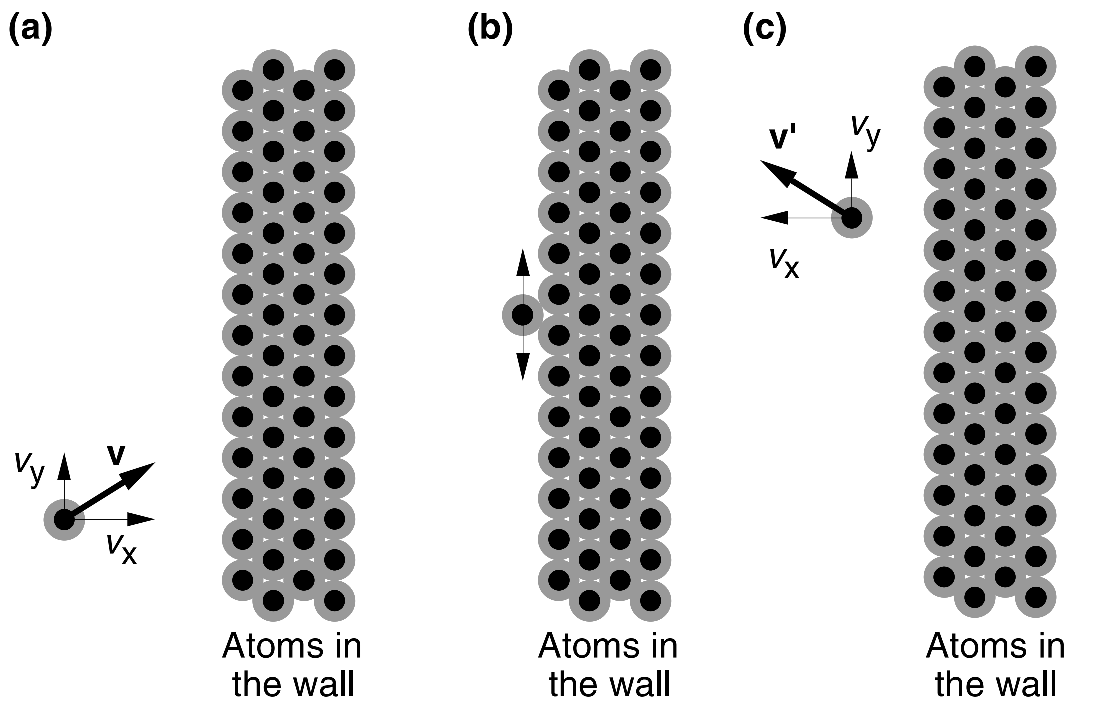

Figure 4.5 When there is more than one molecule in the box, a 'representative' molecule can no longer travel freely across the box and bounce from side to side in a time $2L_x/v_x$

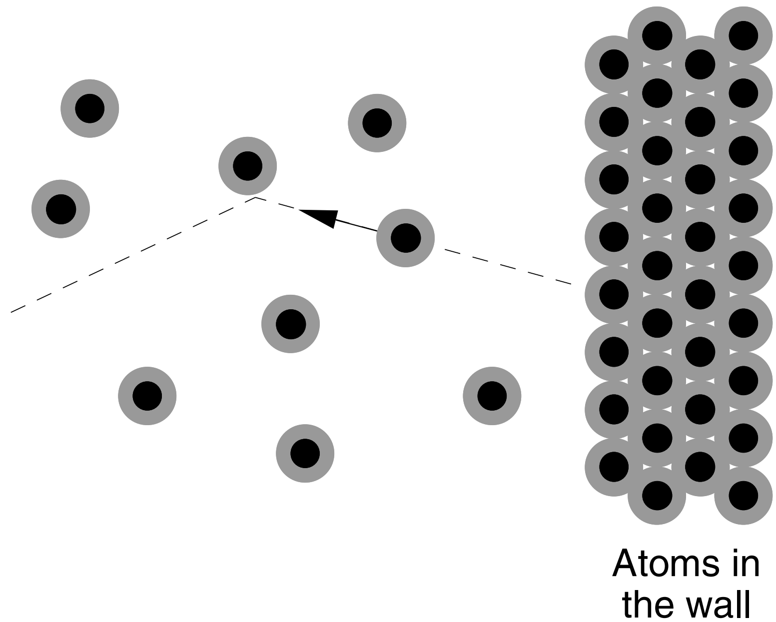

Figure 4.6 The general form of the Maxwell speed distribution curve for a gas (Equation 4.31)

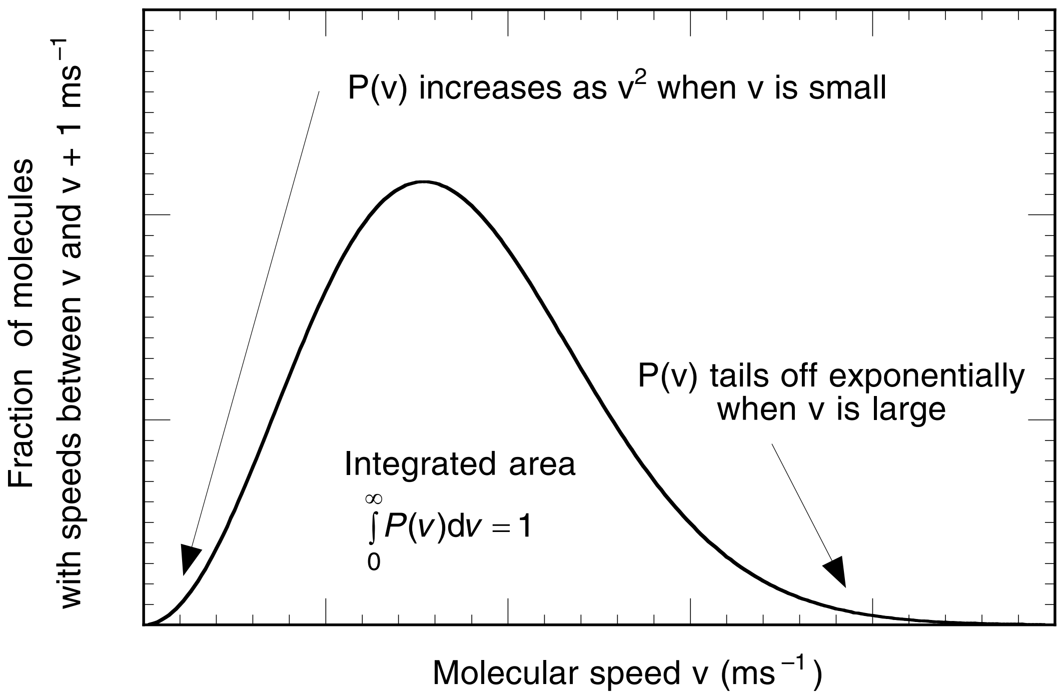

Figure 4.7 Three curves showing the Maxwell distribution of molecular speeds in nitrogen gas and hydrogen. The vertical axis is the probability $P(v)$ that a molecule has a speed between v and $v + 1\ \mathrm{ms}^{-1}$. Two of the curves show the distribution for nitrogen at temperatures of 100 K and 1000 K. Notice that the peak of the curves shifts to higher speeds at higher temperatures. The third curve is for hydrogen at 100 K. Notice that because of the low mass of hydrogen compared with nitrogen, the curve is similar to the curve for nitrogen at 1000 K.

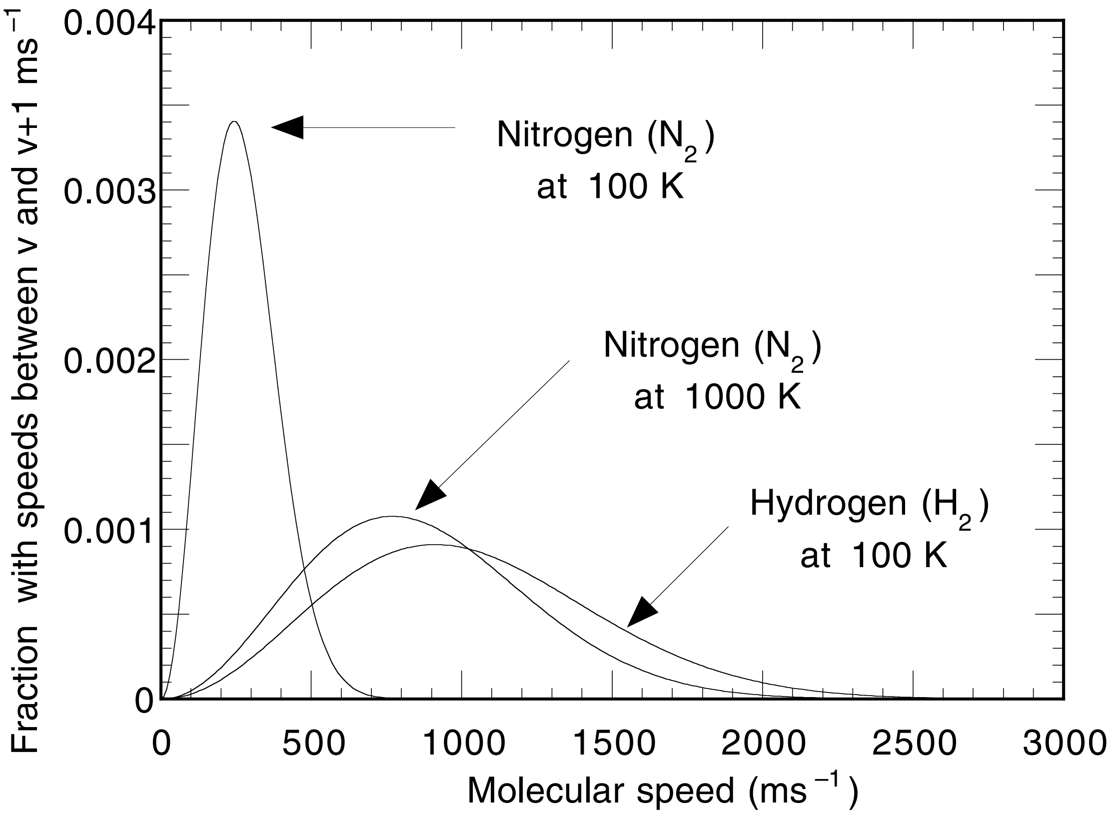

Figure 4.8 Illustration of the special speeds relevant to the Maxwell speed distribution curve. The curve shown refers to nitrogen molecules at a temperature of 1000 K (approximately 730 °C). Notice the three speeds shown are all near the peak of the curve, but differ significantly from each other.

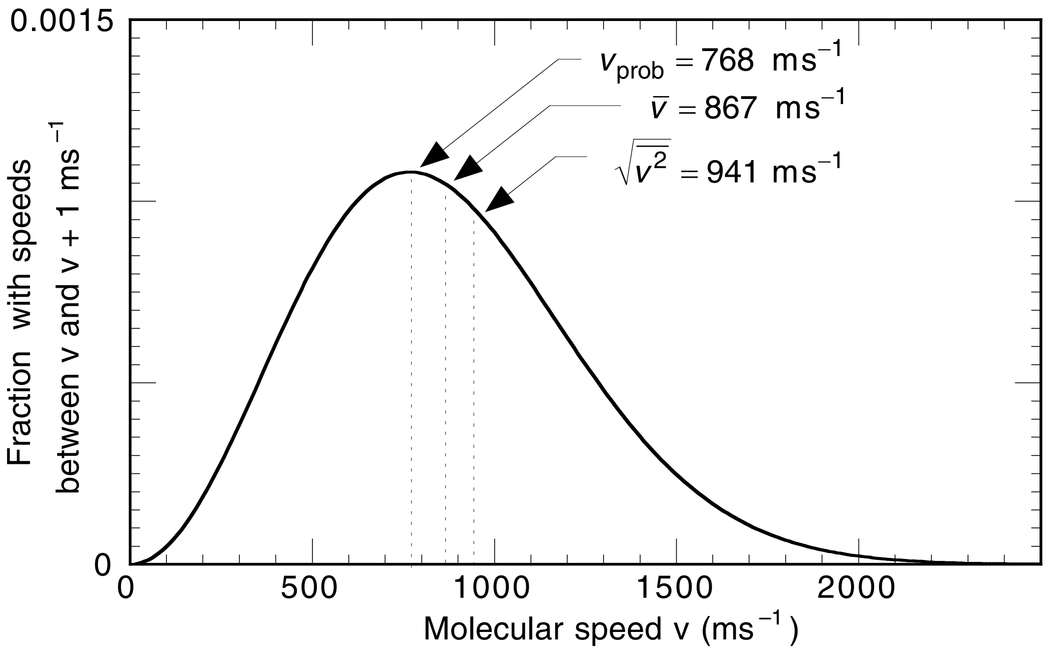

Figure 4.9 A method for making an approximation for the mean free path for fast-moving molecules. A molecule travels on average a distance λ before colliding with another molecule. If the other molecules are effectively stationary while M travels through the gas then there must on average be no other molecules whose centres lie within a volume $\pi a^2 \lambda$.

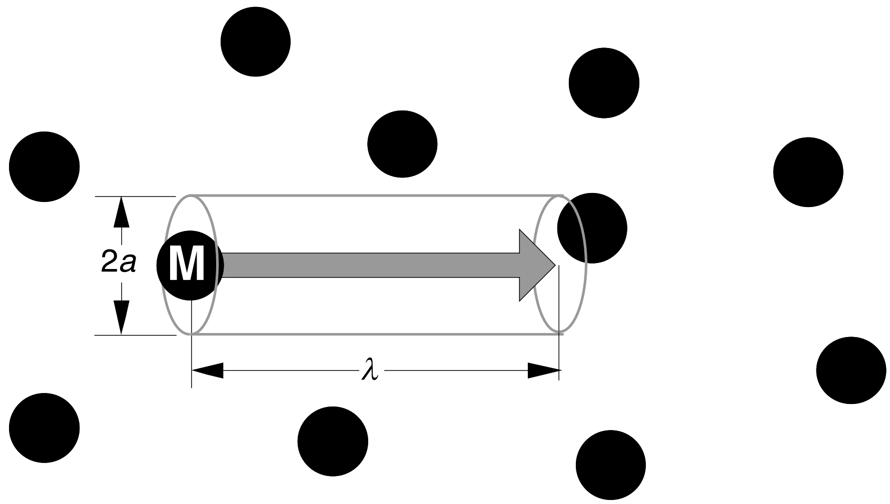

Figure 4.10 A method for making an approximation for the mean free path for slow moving molecules. A stationary molecule C presents a cross-sectional area $\pi(a/2)^2$ to other moving molecules. If the centre of other molecules pass within an area πa^2 around the centre of C there will a collision.

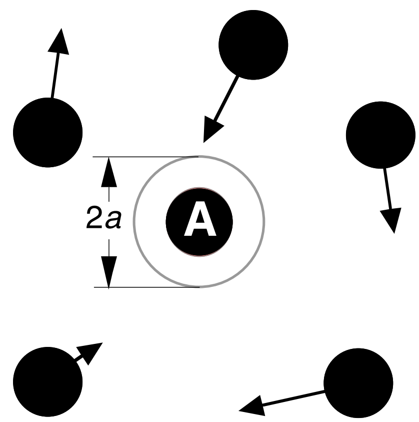

Figure 4.11 The variation of the mean free path λ of molecules as a function of the speed of the molecules expressed as fraction of the mean speed in units of $1/n\pi a^2$. The figure indicates the limiting behaviour of λ for low-speed molecules, high-speed molecules, and the average value for all molecules, λ_{mfp}. Also shown is a qualitative indication of the distribution of molecular speeds (Figures 4.6, 4.7 & 4.8)

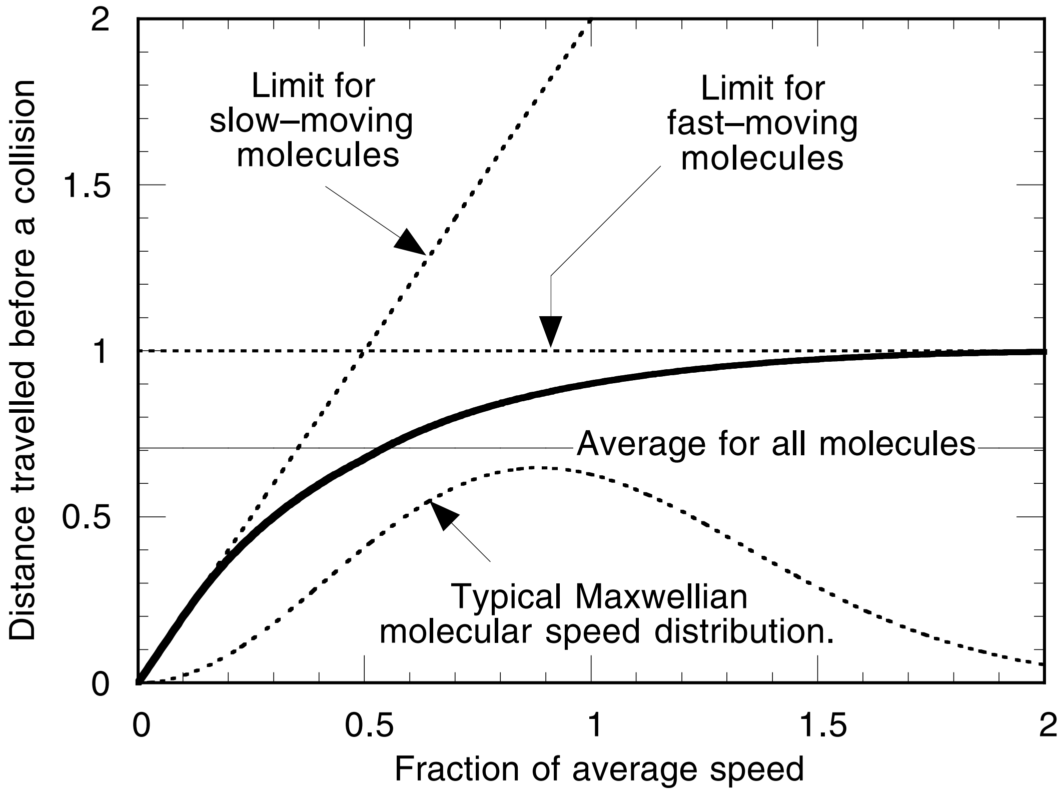

Figure 4.12 Molecular interactions are sometimes poorly modelled by the hard sphere approach used in determining the mean free path of a molecule λ_{mfp}. Each of the following cases shows a molecule A colliding with a stationary molecule B.

(a) In the hard sphere approach, A would completely 'miss' B.

(b) This shows the effect of long-range attractive interactions between molecules (grey region). If A is moving slowly, interactions such as this produce quite different results from those envisioned in (a).

(c) This shows how the same collision as in (b) might be affected if molecule A were moving more quickly. Notice the deviation of A's trajectory is less than in (b).