1.3 The perfect gas law - a thermal equation of state

As already stated above the perfect gas is a limiting case which strictly hols only for $p = 0$ bar where repulsive or attractive forces between particles are always negligible. Famous scientists have contributed to its equation of state by experimental findings:

- Boyle's law (at const. n, T): $p \propto 1/V$
- Charles's laws (at const. n, p or at const. n, V): $V \propto T$ resp. $p \propto T$
- Avogadro's principle (at const. p, T): $V \propto n$

Combined one finds:

$$p\, V = n\, R\, T \tag{1.3}$$

- n = number of particles in moles; 1 mol = 6.022×10^{23} molecules
- R = gas constant = 8.314 J/(mol K)
- V_m = molar volume of perfect gas = V/n = 22.414 $\mathrm{dm^3 mol^{-1}}$
- Determination of R: a) evaluation of perfect gas law at low pressure, b) measurement of the speed of sound and extrapolation to $p = 0$ bar

The partial pressures p_i of perfect gas mixtures just add up, i.e.

$$p_{tot} = \sum_i p_i = \sum_i x_i\, p_{tot} = \sum_i \frac{n_i}{n_{tot}} \frac{n_{tot} RT}{V_{tot}} = \sum_i n_i \frac{R\,T}{V_{tot}} \tag{1.4}$$

Here the first equals sign holds for any gas while the second equals sign only holds for a perfect gas. $x_i = n_i/n_{tot}$ is the fraction of component type i in the mixture.
This equation reflects Dalton's law: "The pressure exerted by a mixture of gases is the sum of the pressures that each one would exert if it occupied the container ALONE" (only valid for perfect gases).
A second law which has been found experimentally holds for the (inner) energy U of a perfect gas:

$$U = \frac{3}{2}\, n\, R\, T \tag{1.5}$$

This equation reflects that neither repulsive nor attractive forces act on the molecules; so the energy cannot depend on the distance between particles, i.e. on the volume V, and according to the perfect gas equation not on the pressure p correspondingly.