

5.3 Gas laws

Ideal gas

Joule's law	$U = U(T)$	(5.55)	U internal energy T temperature
Boyle's law	$pV _T = \text{constant}$	(5.56)	p pressure V volume
Equation of state (Ideal gas law)	$pV = nRT$	(5.57)	n number of moles R molar gas constant
Adiabatic equations	$pV^\gamma = \text{constant}$	(5.58)	γ ratio of heat capacities (C_p/C_V) ΔW work done on system
	$TV^{(\gamma-1)} = \text{constant}$	(5.59)	
	$T^\gamma p^{(1-\gamma)} = \text{constant}$	(5.60)	
	$\Delta W = \frac{1}{\gamma-1}(p_2V_2 - p_1V_1)$	(5.61)	
Internal energy	$U = \frac{nRT}{\gamma-1}$	(5.62)	ΔQ heat supplied to system 1,2 initial and final states
Reversible isothermal expansion	$\Delta Q = nRT \ln(V_2/V_1)$	(5.63)	
Joule expansion ^a	$\Delta S = nR \ln(V_2/V_1)$	(5.64)	ΔS change in entropy of the system

^aSince $\Delta Q = 0$ for a Joule expansion, ΔS is due entirely to irreversibility. Because entropy is a function of state it has the same value as for the reversible isothermal expansion, where $\Delta S = \Delta Q/T$.

Virial expansion

Virial expansion	$pV = RT \left(1 + \frac{B_2(T)}{V} + \frac{B_3(T)}{V^2} + \dots \right)$	(5.65)	p pressure V volume R molar gas constant T temperature B_i virial coefficients
Boyle temperature	$B_2(T_B) = 0$	(5.66)	T_B Boyle temperature



Van der Waals gas

Equation of state	$\left(p + \frac{a}{V_m^2}\right)(V_m - b) = RT$	(5.67)	p pressure V_m molar volume R molar gas constant T temperature a, b van der Waals' constants
Critical point	$T_c = 8a/(27Rb)$	(5.68)	T_c critical temperature
	$p_c = a/(27b^2)$	(5.69)	p_c critical pressure
	$V_{mc} = 3b$	(5.70)	V_{mc} critical molar volume
Reduced equation of state	$\left(p_r + \frac{3}{V_r^2}\right)(3V_r - 1) = 8T_r$	(5.71)	$p_r = p/p_c$ $V_r = V_m/V_{mc}$ $T_r = T/T_c$

Dieterici gas

Equation of state	$p = \frac{RT}{V_m - b'} \exp\left(\frac{-a'}{RTV_m}\right)$	(5.72)	p pressure V_m molar volume R molar gas constant T temperature a', b' Dieterici's constants
Critical point	$T_c = a'/(4Rb')$	(5.73)	T_c critical temperature
	$p_c = a'/(4b'^2e^2)$	(5.74)	p_c critical pressure
	$V_{mc} = 2b'$	(5.75)	V_{mc} critical molar volume
Reduced equation of state	$p_r = \frac{T_r}{2V_r - 1} \exp\left(2 - \frac{2}{V_r T_r}\right)$	(5.76)	$p_r = p/p_c$ $V_r = V_m/V_{mc}$ $T_r = T/T_c$

