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)	
	$TV^{(\gamma-1)} = \text{constant}$	(5.59)	γ ratio of heat capacities (C_p/C_V)
	$T^\gamma p^{(1-\gamma)} = \text{constant}$	(5.60)	ΔW work done on system
	$\Delta W = \frac{1}{\gamma-1}(p_2V_2 - p_1V_1)$	(5.61)	
Internal energy	$U = \frac{nRT}{\gamma-1}$	(5.62)	
Reversible isothermal expansion	$\Delta Q = nRT\ln(V_2/V_1)$	(5.63)	ΔQ heat supplied to system 1,2 initial and final states
Joule expansion[a]	$\Delta S = nR\ln(V_2/V_1)$	(5.64)	ΔS change in entropy of the system

[a]Since $\Delta Q = 0$ 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	$pV = RT\left(1 + \frac{B_2(T)}{V} + \frac{B_3(T)}{V^2} + \cdots\right)$	(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	$$\left(p+\frac{a}{V_{\rm m}^2}\right)(V_{\rm m}-b)=RT$$	(5.67)	p pressure $V_{\rm m}$ molar volume R molar gas constant T temperature a,b van der Waals' constants
Critical point	$T_{\rm c}=8a/(27Rb)$ $p_{\rm c}=a/(27b^2)$ $V_{\rm mc}=3b$	(5.68) (5.69) (5.70)	$T_{\rm c}$ critical temperature $p_{\rm c}$ critical pressure $V_{\rm mc}$ critical molar volume
Reduced equation of state	$$\left(p_{\rm r}+\frac{3}{V_{\rm r}^2}\right)(3V_{\rm r}-1)=8T_{\rm r}$$	(5.71)	$p_{\rm r}=p/p_{\rm c}$ $V_{\rm r}=V_{\rm m}/V_{\rm mc}$ $T_{\rm r}=T/T_{\rm c}$

Dieterici gas

Equation of state	$$p=\frac{RT}{V_{\rm m}-b'}\exp\left(\frac{-a'}{RTV_{\rm m}}\right)$$	(5.72)	p pressure $V_{\rm m}$ molar volume R molar gas constant T temperature a',b' Dieterici's constants
Critical point	$T_{\rm c}=a'/(4Rb')$ $p_{\rm c}=a'/(4b'^2{\rm e}^2)$ $V_{\rm mc}=2b'$	(5.73) (5.74) (5.75)	$T_{\rm c}$ critical temperature $p_{\rm c}$ critical pressure $V_{\rm mc}$ critical molar volume e $=2.71828\ldots$
Reduced equation of state	$$p_{\rm r}=\frac{T_{\rm r}}{2V_{\rm r}-1}\exp\left(2-\frac{2}{V_{\rm r}T_{\rm r}}\right)$$	(5.76)	$p_{\rm r}=p/p_{\rm c}$ $V_{\rm r}=V_{\rm m}/V_{\rm mc}$ $T_{\rm r}=T/T_{\rm c}$