5.3 Gas laws

Ideal gas

Joule's law	$U = U(T)$	(5.55)	U T	internal energy temperature
Boyle's law	$pV\|_T = \text{constant}$	(5.56)	p V	pressure volume
Equation of state (Ideal gas law)	$pV = nRT$	(5.57)	n R	number of moles 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
	$\Delta W = \dfrac{1}{\gamma-1}(p_2V_2 - p_1V_1)$	(5.61)		
Internal energy	$U = \dfrac{nRT}{\gamma-1}$	(5.62)		
Reversible isothermal expansion	$\Delta Q = nRT\ln(V_2/V_1)$	(5.63)	ΔQ 1,2	heat supplied to system 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	$pV = RT\left(1 + \dfrac{B_2(T)}{V} + \dfrac{B_3(T)}{V^2} + \cdots\right)$	(5.65)	p V R T B_i	pressure volume molar gas constant temperature virial coefficients
Boyle temperature	$B_2(T_\mathrm{B}) = 0$	(5.66)	T_B	Boyle temperature

Van der Waals gas

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

Dieterici gas

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