FORMULAS FOR LIFE

All formulas you'll ever need

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A helpful tool for scientific studies

Contents

1 Statistics

1.1 Mean

1.1.1 Arithmetic mean

$$\overline{x} = \sum_{i=1}^{n} \frac{x_i}{N}$$

1.1.2 Geometric mean

$$\overline{x} = (\prod_{i=1}^{n} x_i)^{\frac{1}{n}}$$

1.1.3 Harmonic mean

$$\overline{x} = n(\sum_{i=1}^{n} \frac{1}{x_i}^{-1})$$

1.2 Standard Deviation

1.2.1 Absolute

$$s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{N-1}}$$

1.2.2 Relative

$$RSD = \frac{s}{\overline{x}}$$

2 Pure Physics

3 Pure Chemistry

3.1 Concentration

3.1.1 Molarity

$$M = \frac{n}{V}$$

3.1.2 Mole

4 Thermodynamics

4.1 Perfect gases

4.1.1 State equation

$$pV = nRT$$
$$pV_m = RT$$

4.1.2 Properties

Molar mass

$$d_{gas} \cdot V_m = MW$$

Boyle's law

$$p_1V_1 = p_2V_2$$

Charle's law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Gay-Lussac's Law

$$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$

4.2 Real gases

4.2.1 Virial equation

$$pV_m = RT\left(1 + \frac{B}{V_m} + \frac{C}{V_m^2} + \dots\right)$$

4.2.2 van der Waals equation

$$p = \frac{nRT}{V - nb} - a\left(\frac{n}{V}\right)^2$$
$$p = \frac{nRT}{V_m - b} - a\left(\frac{1}{V_m}\right)^2$$

4.3 Internal Energy

$$dU = \delta w + \delta q$$
$$dU = TdS - pdV$$

4.4 Entalphy

$$H = U + pV$$

4.4.1 T dependence

Pure substance

$$\Delta H(T_2) = \Delta H(T_1) + \int_{T_1}^{T_2} C_p dT.$$

Chemical reaction

$$\Delta(T_2) = \Delta H_r T_1 = \Delta C_p(T_2 - T_1)$$
$$\Delta C_p = [cC_{p,C} + dC_{p,D}] - [aC_{p,A} + bC_{p,B}]$$

4.5 Entropy

$$\Delta S_{TOT} \geq 0$$
$$\Delta S = \frac{q}{T} \implies \Delta S = \int_i^f \frac{q_{rev}}{T}$$

For an ideal gas it can be simplified:

$$\Delta S = nC_m \ln\left(\frac{T_f}{T_i}\right) + nR\ln\left(\frac{V_f}{V_i}\right)$$

4.5.1 T dependence

Constant pressure

$$\Delta S = S(T_f) - S(T_i) = C_p \int_i^f \frac{dT}{T} = C_p \ln\left(\frac{T_f}{T_i}\right)$$

Constant volume

$$\Delta S = S(T_f) - S(T_i) = C_v \int_i^f \frac{dT}{T} = C_v \ln\left(\frac{T_f}{T_i}\right)$$

4.6 Isothermal Transformations

4.6.1 Free expansion

$$\Delta T = 0 \implies \Delta U = 0 \implies q = w$$
$$w = q = -p_{ext}\Delta V = 0$$
$$\Delta H = \Delta PV \text{ (0 for perfect gas)}$$
$$\Delta S = nR\ln(\frac{V_f}{V_i}) \quad \Delta S' = 0 \quad \Delta S_{tot} = \Delta S$$

4.6.2 Expansion vs. p_{ext}

$$\Delta T = 0 \implies \Delta U = 0 \implies q = w$$
$$w = q = -p_{ext}\Delta V$$
$$\Delta H = \Delta PV \text{ (0 for perfect gas)}$$
$$\Delta S = nR\ln(\frac{V_f}{V_i}) \quad \Delta S' = \frac{-q_{sistema}}{T} \quad \Delta S_{tot} = \Delta S + \Delta S'$$

4.6.3 Reversible expansion

$$\Delta T = 0 \implies \Delta U = 0 \implies q = w$$
$$q = w = -nRT\ln(\frac{V_f}{V_i})$$
$$\Delta H = \Delta PV \text{ (0 for perfect gas)}$$
$$\Delta S = nR\ln(\frac{V_f}{V_i}) \quad \Delta S' = -nR\ln(\frac{V_f}{V_i}) \implies \Delta S_{tot} = 0$$

4.7 Adiabatic Transformations

$$dU = dw$$
$$C_v dT = -pdV$$
$$w_{Adiabatic} = nC_{V,m}\Delta T$$
For an adiabatic process is also true that:
$$\gamma = \frac{C_{p,m}}{C_{V,m}} = \frac{C_p}{C_V} \quad P_1(V_1)_\gamma = P_2(V_2)^\gamma$$

4.7.1 Reversible process

$$C_V dT = \frac{-nRT}{V}dV$$
$$\int_{T_1}^{T_2} \frac{C_V dT}{T} = -nR\int_{T_1}^{T_2} \frac{dV}{V}$$
$$C_V \ln\left(\frac{T_1}{T_2}\right) = -R\ln\frac{V_2}{V_1}$$
$$\frac{T_2}{T_1} = \left[\frac{V_2}{V_1}\right]^{-\frac{R}{C_V}}$$

4.7.2 Irreversible

Take P as constant
$$\int_{T_1}^{T_2} CvdT = -p\int_{V_1}^{V_2} dV$$
Assuming $C_V = cost$
$$C_V\Delta T = -p\Delta V$$

4.7.3 Free expansion

$$q = 0,\ w = -p_{ext}\Delta V = 0 \implies \Delta U = 0$$
$$\Delta H =$$
$$\Delta S = nR\ln(\frac{V_f}{V_i}) \quad \Delta S' = 0 \quad \Delta S_{tot} = 0$$

4.7.4 Expansion vs. p_{ext}

$$q = 0 \implies \Delta U = w$$
$$\Delta U = nC_{V,m}\Delta T = w = -p_{ext}\Delta V$$
$$\Delta T = -\frac{p_{ext}\Delta V}{nC_{v,m}}$$
$$\Delta H = V\Delta p$$
$$\Delta S = nC_{V,m}\ln(\frac{T_f}{T_i}) + nR\ln(\frac{V_f}{V_i})$$
$$\Delta S' = 0 \implies \Delta S_{TOT} = \Delta S$$

4.7.5 Reversible expansion

$$q = 0 \implies \Delta U = w$$
$$\Delta U = nC_{V,m}\Delta T$$
$$\Delta S = \Delta S' = \Delta_{tot} = 0$$

4.8 Isobaric transformations

4.8.1 Reversible

$$q = \Delta H = nC_{p,m}\Delta T$$
$$w = -pdV$$
$$\Delta S = nC_{p,m}\ln(\frac{T_f}{T_i}) \quad \Delta S' = -nC_{p,m}\ln\frac{V_f}{V_i}$$
$$\implies \Delta S_{TOT} = 0$$

4.9 Thermodynamic cycles

$$\Delta U = 0,\ \Delta S = 0.$$

4.9.1 Carnot cycle

There is 4 stage (ABCD):

AB Reversible Isothermal expansion

$$\Delta U = 0 \implies q_{AB} = -w_{AB}$$
$$w_{AB} = -q_{AB} = -nRT_h\ln\left(\frac{V_B}{V_A}\right)$$

BC Reversible Adiabatic Expansion

$$q_{BC} = 0 \implies \Delta U_{BC} = w_{BC}$$
$$w_{BC} = nC_{V,m}(T_C - T_h)$$

CD Reversible Isothermal compression

$$\Delta U = 0 \implies q_{CD} = -w_{CD}$$
$$w_{CD} = -q_{CD} = -nRT_h\ln\left(\frac{V_D}{V_C}\right)$$

DA Reversible Adiabatic compression

$$q_{DA} = 0 \implies \Delta U_{DA} = w_{DA}$$
$$w_{DA} = nC_{V,m}(T_C - T_h)$$

5 Radiations

5.1 Bragg Equation

$$n\lambda = 2d_{hkl} \sin\theta$$