Chemistry Formulas

This document was created by the Guide to IJSO team — a student-led initiative dedicated to supporting Junior Science Olympiad aspirants around the world. It contains a carefully curated and organized collection of essential formulas commonly used in chemistry, covering key topics relevant to the IJSO level preparation.

1. Atomic structure

No. of protons = Z

No. of neutrons = A-Z

With Z = atomic number, A = mass number

Average atomic mass $A = \sum \alpha_i A_i$, where α_i is the relative abundance of the isotope with mass number A_i

2. Stoichiometry

For compound $A_a B_b C_c$ ..., the molar mass is $\mu = aA_A + bA_B + cA_C$, with A_X being the atomic masses.

Number of moles $n = \nu = \frac{m}{\mu}$

Number of moles $n = \nu = \frac{N}{N_A}$

Purity $p = \frac{m_{pure}}{m_{sample}}$ (usually expressed as a percentage)

Percent concentration $c = \frac{m_{solute}}{m_{sample}}$ (usually expressed as a percentage)

Molar concentration $c = \frac{\nu_{solute}}{V_{solution}}$

Percent yield $\eta = \frac{\text{obtained quantity}}{\text{maximum theoretical quantity}}$ (usually expressed as a percentage)

Molar fraction $\chi_i = \frac{\nu_i}{\nu_{total}}$

3. Thermochemistry

Specific heat capacity $c = \frac{Q}{m\Delta t}$

Molar heat capacity $c = \frac{Q}{\nu\Delta t}$

Latent heat $L = \lambda = \frac{Q}{m}$

Molar phase change heat (phase change enthalpy) $\Delta H = \frac{Q}{\nu}$

Ideal gas law $pV = \nu RT$

$T(K) = t(°C) + 273.15 \approx t(°C) + 273$

Partial pressure $p_i = \chi_i P$

Partial pressure obeys the ideal gas law, $p_i V = \nu_i RT$

Reaction enthalpy $\Delta_r H = \sum_{products} \Delta_f H - \sum_{reactants} \Delta_f H$

4. Chemical Kinetics

Average reaction rate with respect to substance A, $v = \frac{\Delta[A]}{\Delta t}$

Rate law $v = k[A]^a[B]^b[C]^c$ ..., A, B, C,… are the reactants, a, b, c,…are the partial reaction orders, a+b+c+… is the total reaction order

Integrated rate laws:

- Zeroth order reaction $[A] = [A]_0 - kt$
- First order reaction $[A] = [A]_0 e^{-kt}$
- Second order reaction $\frac{1}{[A]} = \frac{1}{[A]_0} + kt$

Half-lives:

- Zeroth order $t_{1/2} = \frac{[A]_0}{2k}$
- First order $t_{1/2} = \frac{\ln(2)}{k}$
- Second order $t_{1/2} = \frac{1}{k[A]_0}$

Radioactive decays follow a first order kinetic.

Enthalpy change $\Delta_r H = E_{a1} - E_{a2}$ with $E_{a1,2}$ being the activation energies in the forward and reverse reactions.

Arrhenius law, $k = Ae^{-\frac{E_a}{RT}}$

5. Chemical equilibrium

Considering $aA + bB \rightarrow cC + dD$

Equilibrium constants:

- $K_C = \frac{[D]^d[C]^c}{[A]^a[B]^b}$
- For gas phase reactions, $K_P = \frac{p_D^d p_C^c}{p_A^a p_D^d}$
- $K_X = \frac{\chi_D^d \chi_C^c}{\chi_A^a \chi_B^b}$

$K_C = (RT)^{-\Delta\nu} K_P = \left(\frac{p}{RT}\right)^{\Delta\nu} K_X$ for gas phase reactions

$K_a = \frac{[H^+][A^-]}{[HA]}$

$K_b = \frac{[HO^-][BH^+]}{[B]}$

$pK_a = -\log K_a$

$pK_b = -\log K_b$

$pH = -\log[H^+]$

$\mathrm{pOH} = -\log[\mathrm{HO^-}]$

$[\mathrm{H^+}][\mathrm{HO}]^- = K_W = 10^{-14}$

$\mathrm{pH} + \mathrm{pOH} = 14$

$[\mathrm{H^+}] \approx \sqrt{K_a c}$

$[\mathrm{HO^-}] \approx \sqrt{K_b c}$

For $M_m N_n$, $K_s = [M^{n+}]^m [N^{m+}]^n$

$\mathrm{p}K_s = -\log K_s$

$S = \sqrt[m+n]{\frac{K_s}{m^m n^n}}$

6. Electrochemistry

$E^0_{\mathrm{cell}} = E^0_{\mathrm{red,cathode}} + E^0_{\mathrm{ox,anode}} = E^0_{\mathrm{red,cathode}} - E^0_{\mathrm{red,anode}}$

Because the given potentials are usually reduction potentials, we can write: $E_{\mathrm{cell}} = E_{\mathrm{cat}} - E_{\mathrm{an}}$, however you should keep in mind to check if the potentials given are for reduction or oxidation half reactions

Nernst equation $E = E^0 - \frac{RT}{nF}\ln(Q)$, where Q is the reaction quotient (defined similarly to the equilibrium constant, but for any state of the system, not for the equilibrium state).

Faraday's law of electrolysis $m = \frac{\mu I}{nF} t$ (easily derivable from the stoichiometry of the electrolysis reaction and from $I = \frac{q}{t}$)

7. Other formulas

The Beer-Lambert law, $A = \log\left(\frac{I_0}{I}\right) = \varepsilon c l$

Radioactive decay (first order kinetic), $N = N_0 e^{-\lambda t}$

Activity (no. of decays per unit time) $A = A_0 e^{-\lambda t}$