

Law of Mass Action

On the basis of observation of many equilibrium reaction two Norwegian chemist

Cato Maximilian Guldberg and Peter Waage suggested a relationship between rate of reaction and concentration of reaction

It states that

the rate of chemical reaction is directly proportional to the product of the molar concent

rate of the reaction at
constant temperature



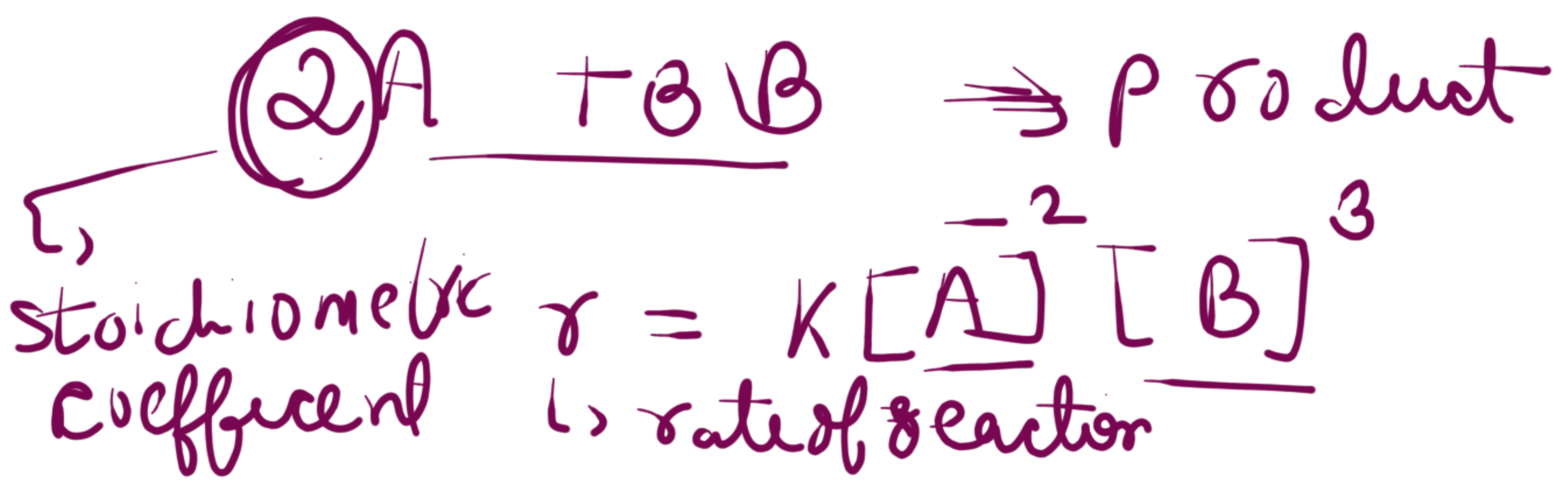
$$\underline{r} \propto \underline{[A][B]}$$

[Molar concentration
no. of moles per litre)

$$\Rightarrow \underline{r} = \underline{K} \underline{[A]} \underline{[B]}$$

K = rate constant
= velocity constant

ex

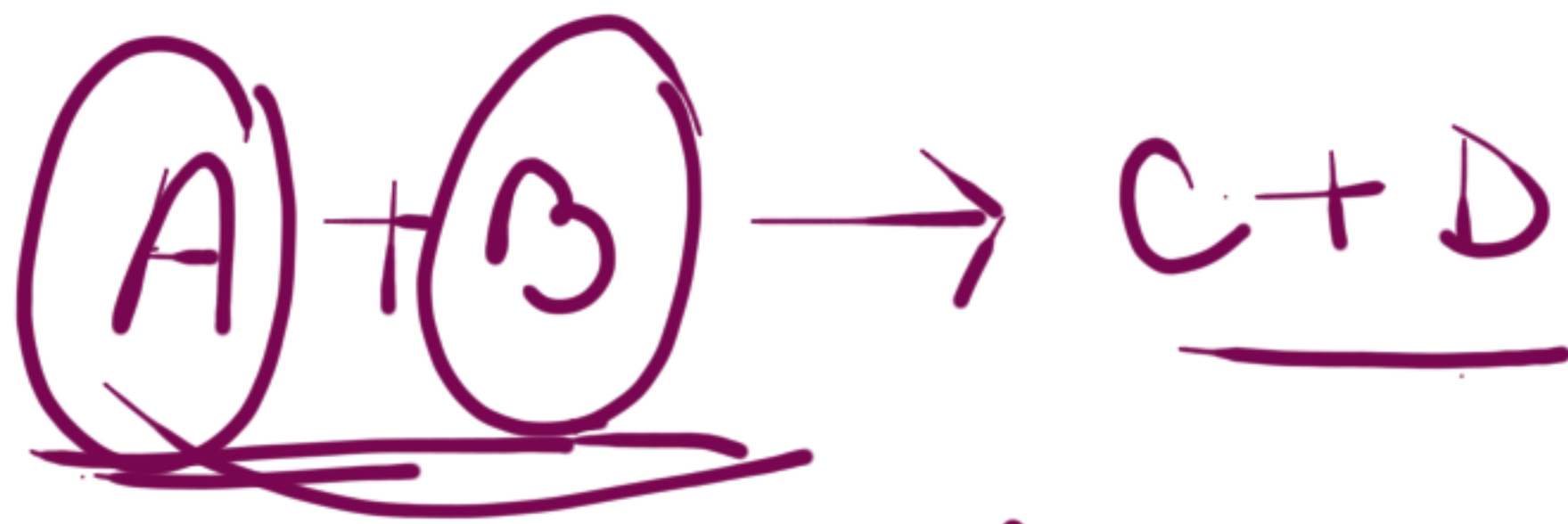


Law of Chemical Equilibrium

Let us consider a simple reversible reaction



The Forward Reaction

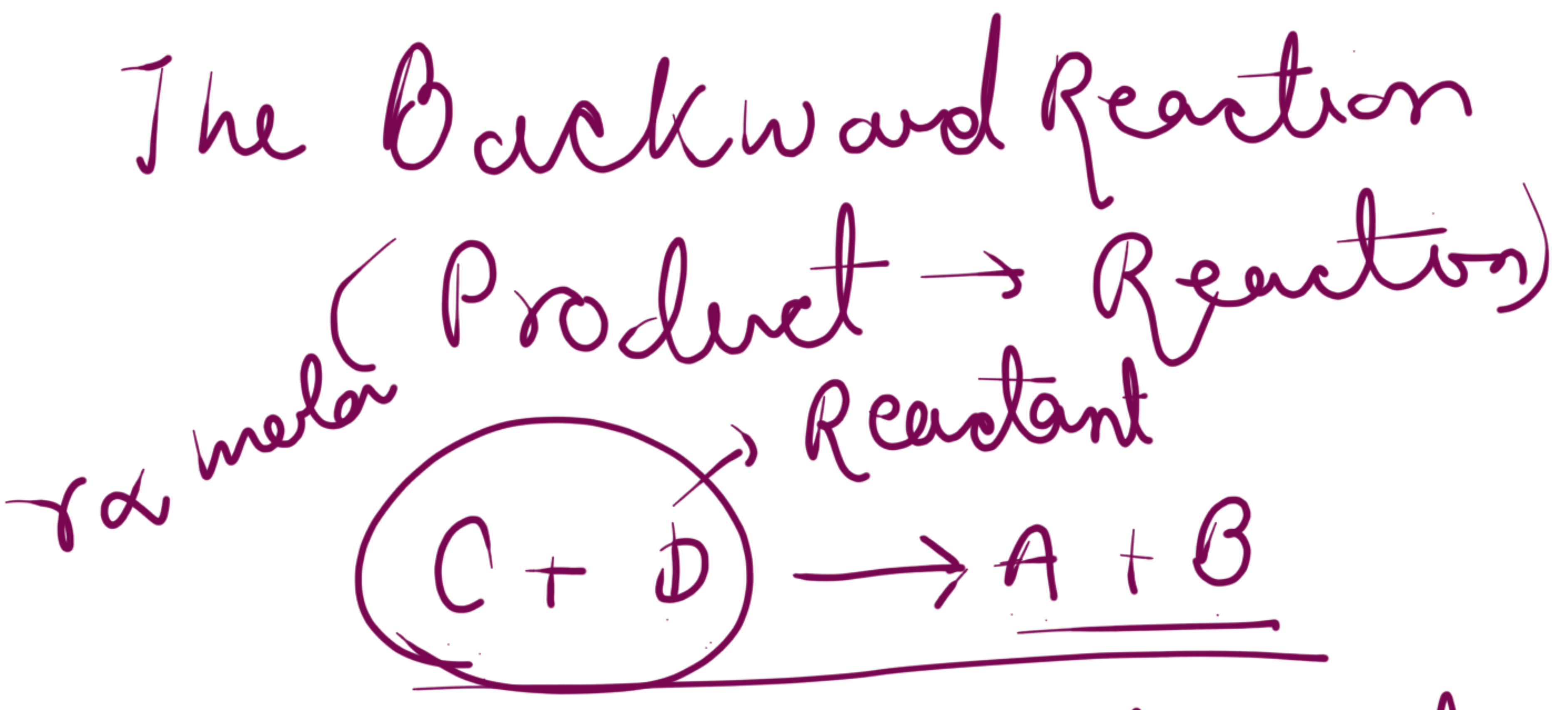


Rate of forward Reaction

$$r = k_f \underline{[A][B]} \quad \text{①}$$

k_f = rate constant for forward reaction

$[A]$ & $[B]$ are molar concentration of A and B



Rate of backward reaction

$$r = K_b [C] [D]$$

K_b = rate constant of backward reaction

At equilibrium

Rate of backward reaction = Rate of forward reaction

$$\Rightarrow K_b [C] [D] = K_f [A] [B]$$

$$\Rightarrow \frac{[C][D]}{[A][B]} = \frac{K_f}{K_b}$$

$$\Rightarrow K_c = \frac{[C][D]}{[A][B]}$$

K_c = equilibrium constant

$$K_c = \frac{K_f}{K_b} \rightarrow \text{Rate constant for forward}$$



Rate constant for backward

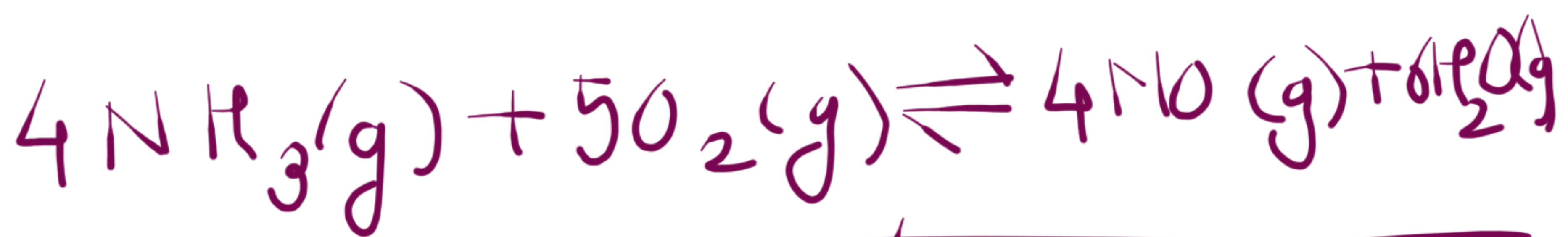


$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

$$\frac{[A]^a [B]^b}{[C]^c [D]^d}$$

The equilibrium constant is ratio between the product of molar concentration of the reaction with each raise to power with each its stoichiometric coefficient

Ex



$$K_c = \frac{[\text{NO}]^4 [\text{H}_2\text{O}]^6}{[\text{NH}_3]^4 [\text{O}_2]^5}$$

Equilibrium Constant in Gaseous System



$$K_p = \frac{(P_C)^c (P_D)^d}{(P_A)^a (P_B)^b}$$

P_A, P_B, P_C, P_D are partial pressures of A, B, C, D

Note :- K_p is not always equal to K_c

✓✓✓

Relationship between K_p & K_c

For the Reaction



$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b} \quad \text{--- (I)}$$

$$K_p = \frac{(P_C)^c (P_D)^d}{(P_A)^a (P_B)^b} \quad \text{--- (II)}$$

According to Ideal Gas

$$\underline{P} \underline{V} = \underline{n} \underline{R} \underline{T}$$

$$\Rightarrow P = \frac{n}{V} RT$$

$$\frac{n}{V} = \frac{\text{no of moles}}{\text{volume}} = C$$

$$P = CRT$$

$$\Rightarrow P = [gas] RT$$

$$P_A = [A] RT$$

$$P_B = [B]RT$$

$$P_C = [C]RT$$

$$P_D = [D]RT$$

$$K_p = \frac{P_C^c P_D^d}{P_A^a P_B^b}$$

$$K_p = \frac{([C]RT)^c ([D]RT)^d}{([A]RT)^a ([B]RT)^b}$$

$$K_p = \frac{[C]^c (RT)^c [D]^d (RT)^d}{[A]^a (RT)^a [B]^b (RT)^b}$$

$$K_p = \frac{[C]^c [D]^d}{[A]^a [B]^b} \frac{(RT)^{c+d}}{(RT)^{a+b}}$$

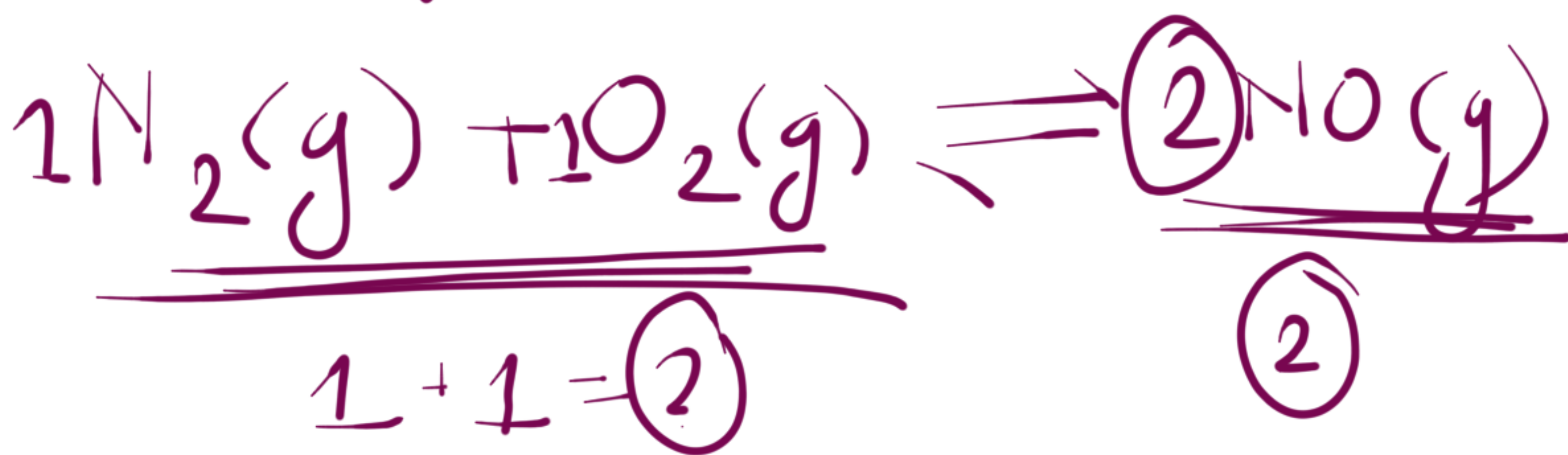
$$K_p = K_c (RT)^{\underline{(c+d)} - \underline{(a+b)}}$$

$$K_p = K_c (RT)^{\Delta n}$$

$$\Delta n = (c + d) - (a + b)$$

Unit of Equilibrium Constant

1) When the total number of moles of product is equal to mole of reactant



$K = \text{no unit}$

$$K = \frac{[NO]^2}{[N_2][O_2]}$$

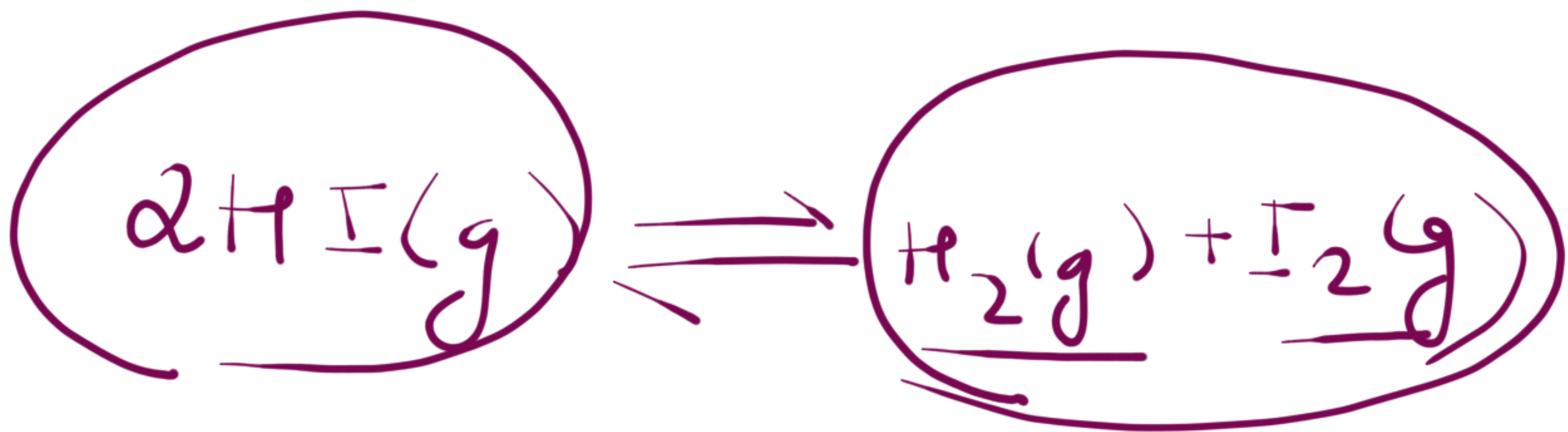
molar concentration

$$\text{unit mol/L} = \underline{\text{mol L}^{-1}}$$

$$K = \frac{(\text{mol L}^{-1})^2}{(\text{mol L}^{-1})(\text{mol L}^{-1})}$$

$$= \frac{\text{mol}^2 \text{L}^{-2}}{\text{mol}^2 \text{L}^{-2}} = 1$$

$K = \text{no unit}$



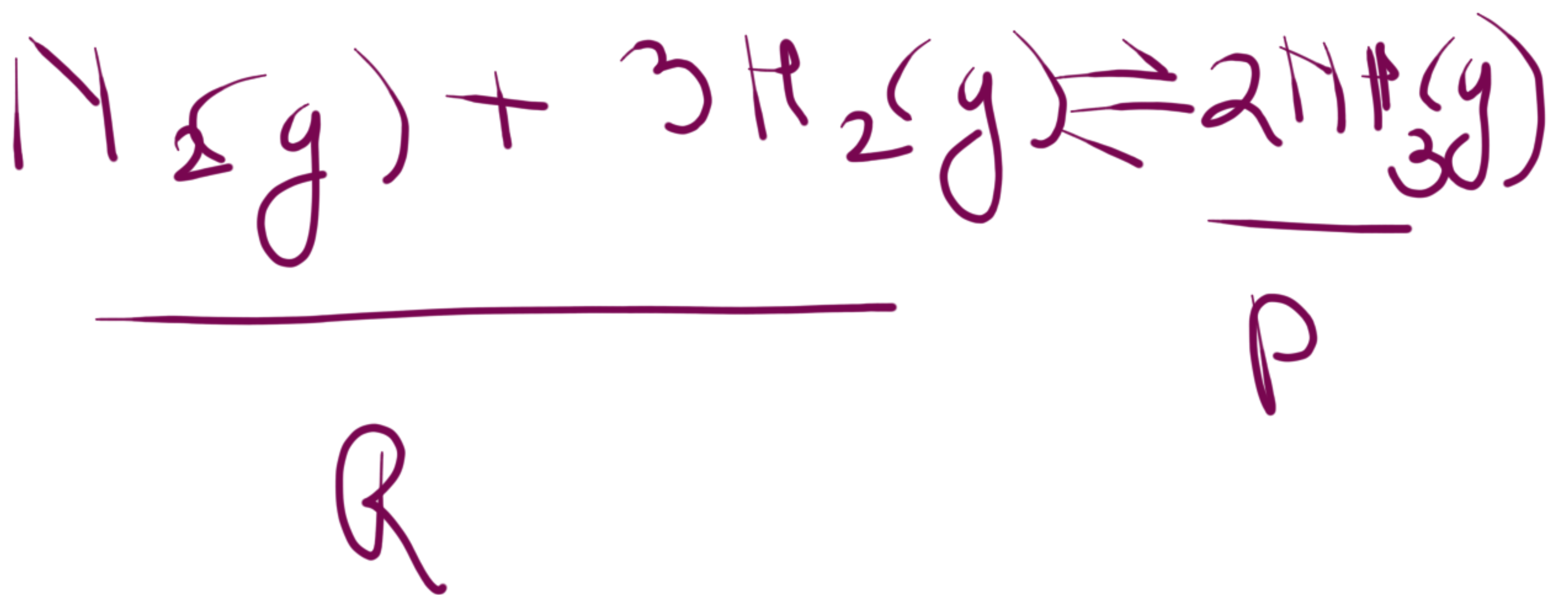
$$K = ?$$

$$K_c = \frac{[\text{H}_2][\text{I}_2]}{[\text{HI}]^2}$$

$$= \frac{\text{mol L}^{-1} \times \text{mol L}^{-1}}{(\text{mol L}^{-1})^2}$$

$$= \frac{\cancel{\text{mol}^2} \cancel{\text{L}^{-2}}}{\cancel{\text{mol}^2} \cancel{\text{L}^{-2}}}$$

$$= 1 \quad \text{— no unit}$$



$$K_c = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3}$$

$$= \frac{(\text{mol L}^{-1})^2}{(\text{mol L}^{-1})(\text{mol L}^{-1})^3}$$

$$= \frac{\text{mol}^2 \text{L}^{-2}}{\text{mol}^1 \text{L}^{-1} \times \text{mol}^3 \text{L}^{-3}}$$

$$= \frac{\text{mol}^2 \text{L}^{-2}}{\text{mol}^4 \text{L}^{-4}} = \text{mol}^{-2} \text{L}^2$$

$$= m\omega L^{2-4} \quad -2-(-4)$$

$$= m\omega L^{-2} \quad -2+4$$

$$= m\omega L^2$$