

Mecanismo e cinética

Hipótese do passo controlador

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Num mecanismo reacional constituído por vários passos elementares em série (ou consecutivos), em que um deles é muito mais lento que todos os outros, a velocidade de reacção global é determinada pela velocidade do passo mais lento

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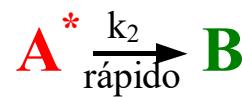
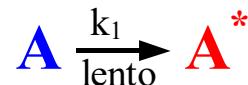
Exemplo:

Mecanismo e cinética

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Exemplo:

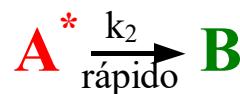
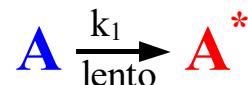


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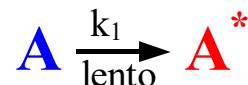
Velocidades absolutas dos passos elementares:

Mecanismo e cinética

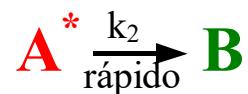
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Velocidades absolutas dos passos elementares:



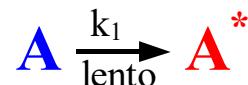
$$r_1 = k_1 C_A$$

Mecanismo e cinética

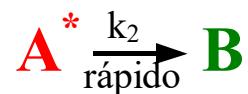
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Exemplo:



Velocidades absolutas dos passos elementares:



$$r_1 = k_1 C_A$$

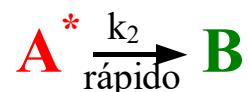
$$r_2 = k_2 C_{A^*}$$

Mecanismo e cinética

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Exemplo:



Velocidades absolutas dos passos elementares:

$$r_1 = k_1 C_A$$

$$r_2 = k_2 C_{A^*}$$

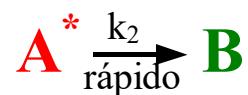
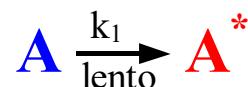
Velocidade global ($k_2 \gg k_1$):

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Exemplo:



Velocidades absolutas dos passos elementares:

$$r_1 = k_1 C_A$$

$$r_2 = k_2 C_{A^*}$$

Velocidade global ($k_2 \gg k_1$):

$$r_B = -r_A = k_1 C_A$$

Hipótese do estado pseudo-estacionário

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Num mecanismo reacional envolvendo **espécies intermediárias instáveis**, estas, enquanto a reacção decorre, devem encontrar-se num estado quase estacionário. Isto é, **a velocidade de formação deve ser igual à velocidade de consumo**. Nestas condições, **a velocidade de reacção relativa a estas espécies deve ser nula**.

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Exemplo 1: **Reacção envolvendo radicais livres**

Hipótese do estado pseudo-estacionário

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Exemplo 1: Reacção envolvendo radicais livres

Reacção global:



Hipótese do estado pseudo-estacionário

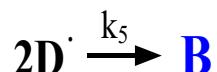
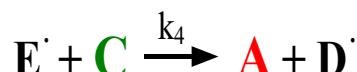
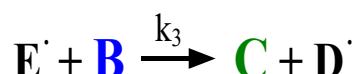
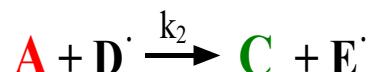
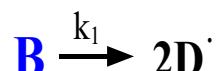
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Reacção global:



Mecanismo:



Hipótese do estado pseudo-estacionário

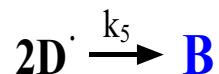
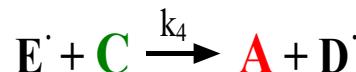
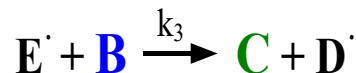
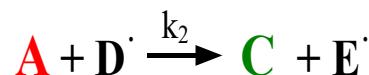
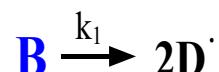
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Reacção global:



Mecanismo:



A velocidade de reacção relativa a uma espécie química é igual ao somatório das velocidades de reacção relativas a essa espécie química em todos os passos elementares

Hipótese do estado pseudo-estacionário

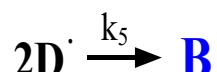
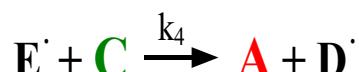
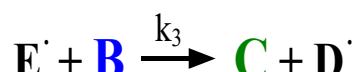
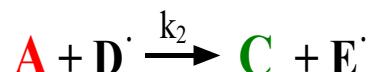
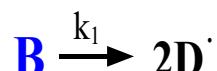
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Reacção global:



Mecanismo:



Hipótese do estado pseudo-estacionário

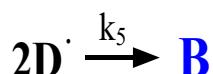
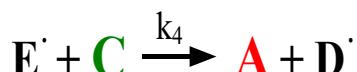
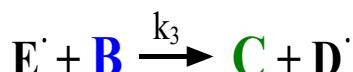
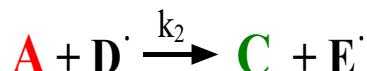
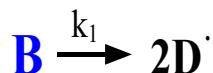
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Reacção global:



Mecanismo:



$$r_i = \sum_j r_{ij}$$

Espécie
química Reacção
elementar

Hipótese do estado pseudo-estacionário

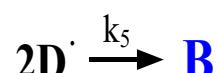
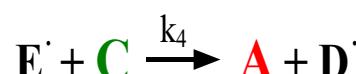
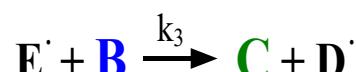
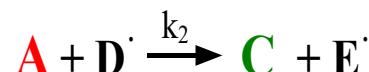
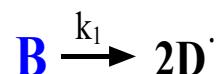
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Reacção global:



Mecanismo:



$$r_i = \sum_j r_{ij}$$

Espécie
química Reacção
elementar

$$r_{ij} = \frac{1}{V} \cdot \frac{dN_{ij}}{dt}$$

Hipótese do estado pseudo-estacionário

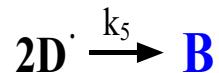
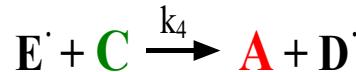
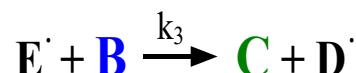
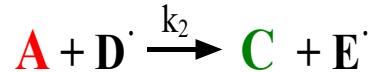
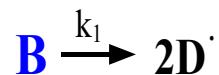
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Exemplo 1: Reacção envolvendo radicais livres

Reacção global:



Mecanismo:



$$r_j = \frac{1}{v_{ij}} \cdot \underbrace{\frac{1}{V} \cdot \frac{dN_{ij}}{dt}}_{r_{ij}}$$

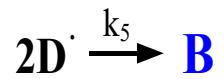
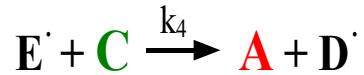
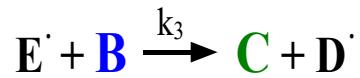
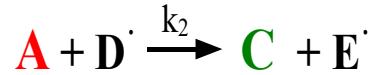
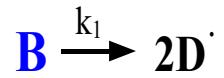
Espécie
química

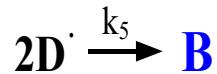
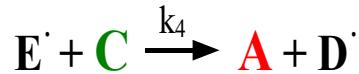
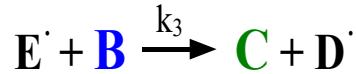
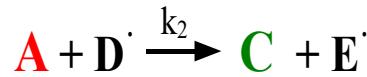
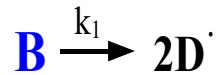
Coeficiente
estequiométrico da
espécie i no passo
elementar j

$$r_i = \sum_j r_{ij}$$

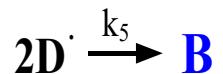
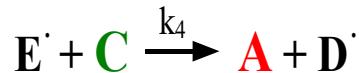
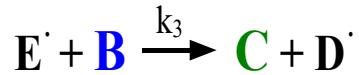
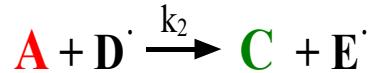
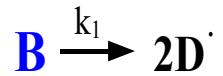
Reacção
elementar

$$r_{ij} = \frac{1}{V} \cdot \frac{dN_{ij}}{dt}$$



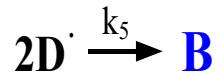
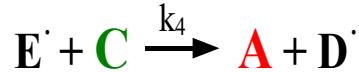
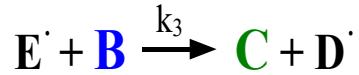
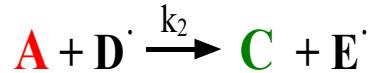
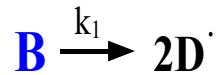


$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$



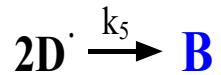
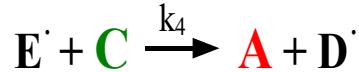
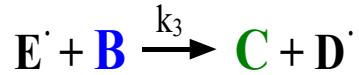
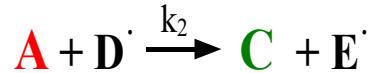
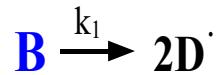
$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \quad \mathbf{r}_A = v_{A1} \mathbf{r}_1 + v_{A2} \mathbf{r}_2 + v_{A3} \mathbf{r}_3 + v_{A4} \mathbf{r}_4 + v_{A5} \mathbf{r}_5$$



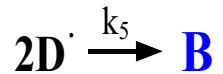
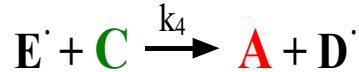
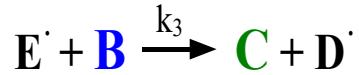
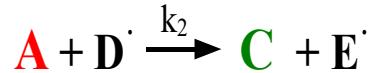
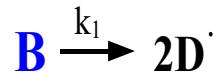
$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1 + v_{A2} \mathbf{r}_2 + v_{A3} \mathbf{r}_3 + v_{A4} \mathbf{r}_4 + v_{A5} \mathbf{r}_5}_0$$



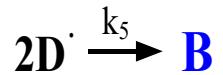
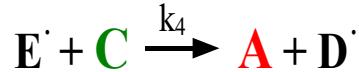
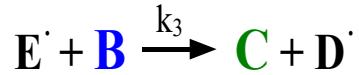
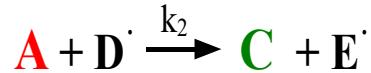
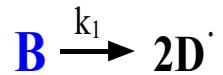
$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + v_{A3} \mathbf{r}_3 + v_{A4} \mathbf{r}_4 + v_{A5} \mathbf{r}_5$$



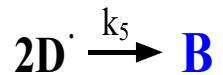
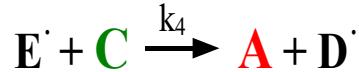
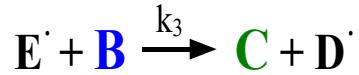
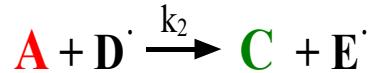
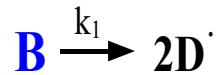
$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + v_{A4} \mathbf{r}_4 + v_{A5} \mathbf{r}_5$$



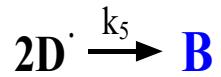
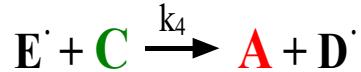
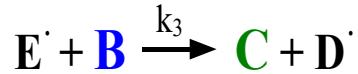
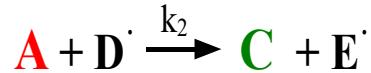
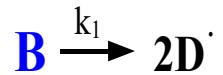
$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + v_{A5} \mathbf{r}_5$$



$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

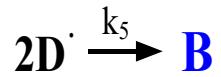
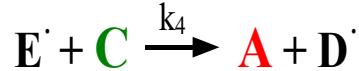
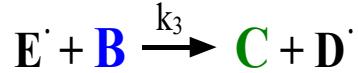
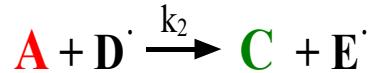
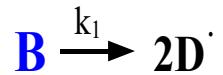
$$\therefore \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + \underbrace{v_{A5} \mathbf{r}_5}_0$$



$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \quad \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + \underbrace{v_{A5} \mathbf{r}_5}_0$$

$$\therefore \quad \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

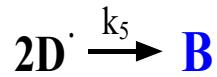
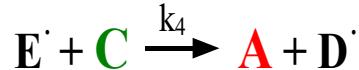
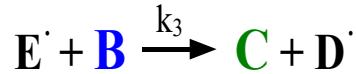
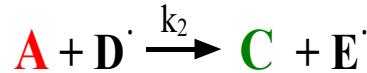
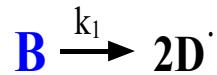


$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + \underbrace{v_{A5} \mathbf{r}_5}_0$$

$$\therefore \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

Velocidades absolutas:



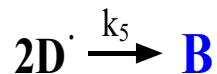
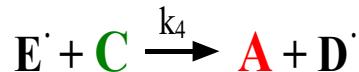
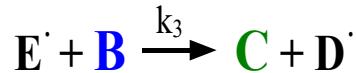
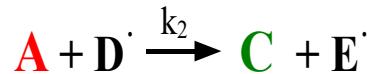
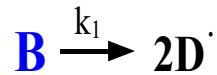
$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + \underbrace{v_{A5} \mathbf{r}_5}_0$$

$$\therefore \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 \mathbf{C}_B$$



$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

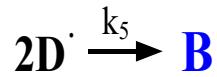
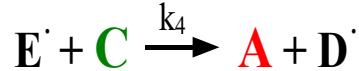
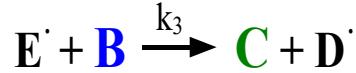
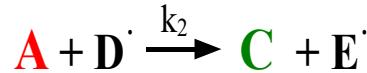
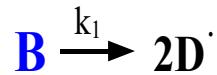
$$\therefore \quad \mathbf{r}_A = \underbrace{\upsilon_{A1} \mathbf{r}_1}_0 + \underbrace{\upsilon_{A2} \mathbf{r}_2}_{-1} + \underbrace{\upsilon_{A3} \mathbf{r}_3}_0 + \underbrace{\upsilon_{A4} \mathbf{r}_4}_{+1} + \underbrace{\upsilon_{A5} \mathbf{r}_5}_0$$

$$\therefore \quad \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 \mathbf{C}_B$$

$$\mathbf{r}_2 = k_2 \mathbf{C}_A \mathbf{C}_{D^\bullet}$$



$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + \underbrace{v_{A5} \mathbf{r}_5}_0$$

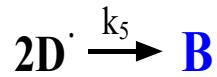
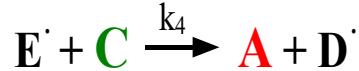
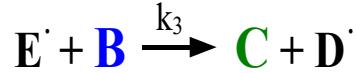
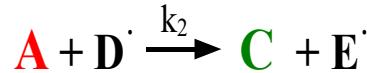
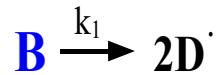
$$\therefore \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 \mathbf{C}_B$$

$$\mathbf{r}_2 = k_2 \mathbf{C}_A \mathbf{C}_{D^{\cdot}}$$

$$\mathbf{r}_3 = k_3 \mathbf{C}_{E^{\cdot}} \mathbf{C}_B$$



$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \quad \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + \underbrace{v_{A5} \mathbf{r}_5}_0$$

$$\therefore \quad \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

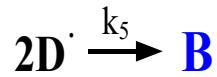
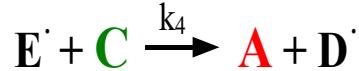
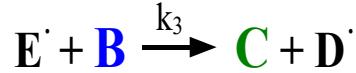
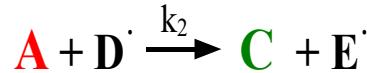
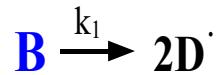
Velocidades absolutas:

$$\mathbf{r}_1 = k_1 \mathbf{C}_B$$

$$\mathbf{r}_2 = k_2 \mathbf{C}_A \mathbf{C}_{D^{\cdot}}$$

$$\mathbf{r}_3 = k_3 \mathbf{C}_{E^{\cdot}} \mathbf{C}_B$$

$$\mathbf{r}_4 = k_4 \mathbf{C}_{E^{\cdot}} \mathbf{C}_C$$



$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + \underbrace{v_{A5} \mathbf{r}_5}_0$$

$$\therefore \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

Velocidades absolutas:

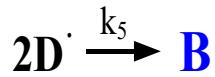
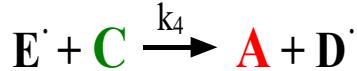
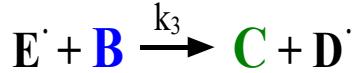
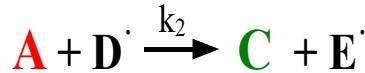
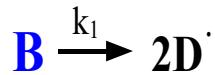
$$\mathbf{r}_1 = k_1 \mathbf{C}_B$$

$$\mathbf{r}_2 = k_2 \mathbf{C}_A \mathbf{C}_{D^{\cdot}}$$

$$\mathbf{r}_3 = k_3 \mathbf{C}_{E^{\cdot}} \mathbf{C}_B$$

$$\mathbf{r}_4 = k_4 \mathbf{C}_{E^{\cdot}} \mathbf{C}_C$$

$$\mathbf{r}_5 = k_5 \mathbf{C}_{D^{\cdot}}^2$$



$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \quad \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + \underbrace{v_{A5} \mathbf{r}_5}_0$$

$$\therefore \quad \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

$$\therefore \quad \mathbf{r}_A = -k_2 C_A C_{D^{\cdot}} + k_4 C_{E^{\cdot}} C_C$$

Velocidades absolutas:

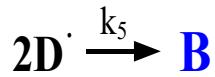
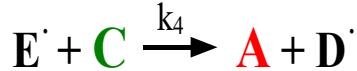
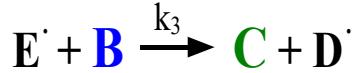
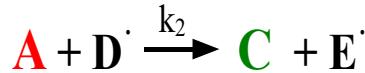
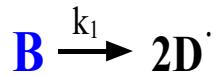
$$\mathbf{r}_1 = k_1 C_B$$

$$\mathbf{r}_2 = k_2 C_A C_{D^{\cdot}}$$

$$\mathbf{r}_3 = k_3 C_{E^{\cdot}} C_B$$

$$\mathbf{r}_4 = k_4 C_{E^{\cdot}} C_C$$

$$\mathbf{r}_5 = k_5 C_{D^{\cdot}}^2$$



$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \quad \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + \underbrace{v_{A5} \mathbf{r}_5}_0$$

$$\therefore \quad \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

$$\therefore \quad \mathbf{r}_A = -k_2 C_A C_{D^{\cdot}} + k_4 C_{E^{\cdot}} C_C$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 \mathbf{C}_B$$

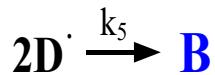
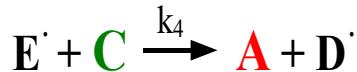
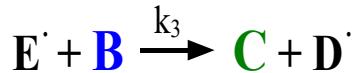
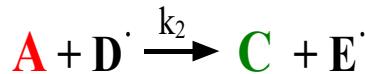
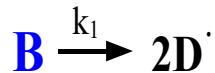
$$\mathbf{r}_2 = k_2 \mathbf{C}_A \mathbf{C}_{D^{\cdot}}$$

$$\mathbf{r}_3 = k_3 \mathbf{C}_{E^{\cdot}} \mathbf{C}_B$$

$$\mathbf{r}_4 = k_4 \mathbf{C}_{E^{\cdot}} \mathbf{C}_C$$

$$\mathbf{r}_5 = k_5 \mathbf{C}_{D^{\cdot}}^2$$

$$\mathbf{r}_D = \mathbf{r}_{D1} + \mathbf{r}_{D2} + \mathbf{r}_{D3} + \mathbf{r}_{D4} + \mathbf{r}_{D5}$$



$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \quad \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + \underbrace{v_{A5} \mathbf{r}_5}_0$$

$$\therefore \quad \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

$$\therefore \quad \mathbf{r}_A = -k_2 C_A C_{D^{\cdot}} + k_4 C_{E^{\cdot}} C_C$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 \mathbf{C}_B$$

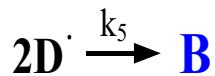
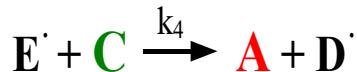
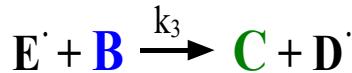
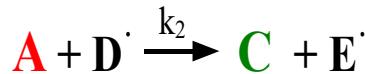
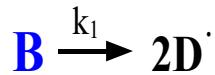
$$\mathbf{r}_2 = k_2 \mathbf{C}_A \mathbf{C}_{D^{\cdot}}$$

$$\mathbf{r}_3 = k_3 \mathbf{C}_{E^{\cdot}} \mathbf{C}_B$$

$$\mathbf{r}_4 = k_4 \mathbf{C}_{E^{\cdot}} \mathbf{C}_C$$

$$\mathbf{r}_5 = k_5 \mathbf{C}_{D^{\cdot}}^2$$

$$\therefore \quad \mathbf{r}_{D^{\cdot}} = v_{D^{\cdot}1} \mathbf{r}_1 + v_{D^{\cdot}2} \mathbf{r}_2 + v_{D^{\cdot}3} \mathbf{r}_3 + v_{D^{\cdot}4} \mathbf{r}_4 + v_{D^{\cdot}5} \mathbf{r}_5$$



$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \quad \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + \underbrace{v_{A5} \mathbf{r}_5}_0$$

$$\therefore \quad \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

$$\therefore \quad \mathbf{r}_A = -k_2 C_A C_{D^{\cdot}} + k_4 C_{E^{\cdot}} C_C$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 C_B$$

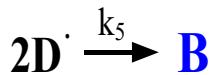
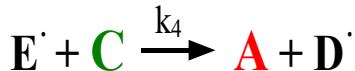
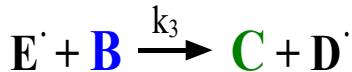
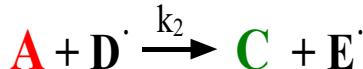
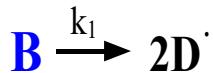
$$\mathbf{r}_2 = k_2 C_A C_{D^{\cdot}}$$

$$\mathbf{r}_3 = k_3 C_{E^{\cdot}} C_B$$

$$\mathbf{r}_4 = k_4 C_{E^{\cdot}} C_C$$

$$\mathbf{r}_5 = k_5 C_{D^{\cdot}}^2$$

$$\therefore \quad \mathbf{r}_{D^{\cdot}} = \underbrace{v_{D^{\cdot}1} \mathbf{r}_1}_{+2} + v_{D^{\cdot}2} \mathbf{r}_2 + v_{D^{\cdot}3} \mathbf{r}_3 + v_{D^{\cdot}4} \mathbf{r}_4 + v_{D^{\cdot}5} \mathbf{r}_5$$



$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \quad \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + \underbrace{v_{A5} \mathbf{r}_5}_0$$

$$\therefore \quad \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

$$\therefore \quad \mathbf{r}_A = -k_2 C_A C_{D^{\cdot}} + k_4 C_{E^{\cdot}} C_C$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 C_B$$

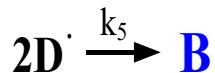
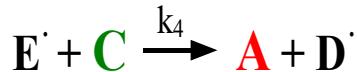
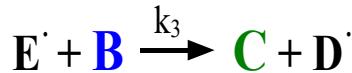
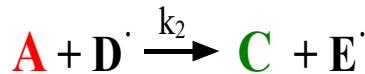
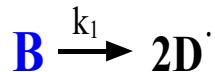
$$\mathbf{r}_2 = k_2 C_A C_{D^{\cdot}}$$

$$\mathbf{r}_3 = k_3 C_{E^{\cdot}} C_B$$

$$\mathbf{r}_4 = k_4 C_{E^{\cdot}} C_C$$

$$\mathbf{r}_5 = k_5 C_{D^{\cdot}}^2$$

$$\therefore \quad \mathbf{r}_{D^{\cdot}} = \underbrace{v_{D^{\cdot}1} \mathbf{r}_1}_{+2} + \underbrace{v_{D^{\cdot}2} \mathbf{r}_2}_{-1} + v_{D^{\cdot}3} \mathbf{r}_3 + v_{D^{\cdot}4} \mathbf{r}_4 + v_{D^{\cdot}5} \mathbf{r}_5$$



$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \quad \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + \underbrace{v_{A5} \mathbf{r}_5}_0$$

$$\therefore \quad \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

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Velocidades absolutas:

$$\mathbf{r}_1 = k_1 C_B$$

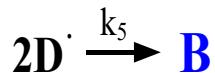
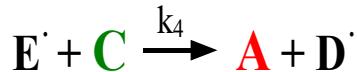
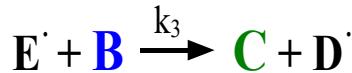
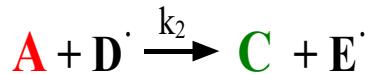
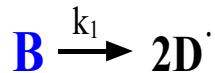
$$\mathbf{r}_2 = k_2 C_A C_{D^{\cdot}}$$

$$\mathbf{r}_3 = k_3 C_{E^{\cdot}} C_B$$

$$\mathbf{r}_4 = k_4 C_{E^{\cdot}} C_C$$

$$\mathbf{r}_5 = k_5 C_{D^{\cdot}}^2$$

$$\therefore \quad \mathbf{r}_{D^{\cdot}} = \underbrace{v_{D^{\cdot}1} \mathbf{r}_1}_{+2} + \underbrace{v_{D^{\cdot}2} \mathbf{r}_2}_{-1} + \underbrace{v_{D^{\cdot}3} \mathbf{r}_3}_{+1} + v_{D^{\cdot}4} \mathbf{r}_4 + v_{D^{\cdot}5} \mathbf{r}_5$$



$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \quad \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + \underbrace{v_{A5} \mathbf{r}_5}_0$$

$$\therefore \quad \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

$$\therefore \quad \mathbf{r}_A = -k_2 C_A C_{D^{\cdot}} + k_4 C_{E^{\cdot}} C_C$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 C_B$$

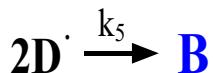
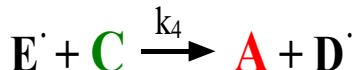
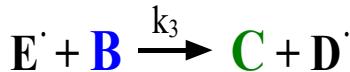
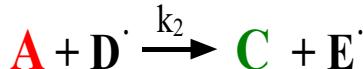
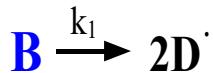
$$\mathbf{r}_2 = k_2 C_A C_{D^{\cdot}}$$

$$\mathbf{r}_3 = k_3 C_{E^{\cdot}} C_B$$

$$\mathbf{r}_4 = k_4 C_{E^{\cdot}} C_C$$

$$\mathbf{r}_5 = k_5 C_{D^{\cdot}}^2$$

$$\therefore \quad \mathbf{r}_{D^{\cdot}} = \underbrace{v_{D^{\cdot}1} \mathbf{r}_1}_{+2} + \underbrace{v_{D^{\cdot}2} \mathbf{r}_2}_{-1} + \underbrace{v_{D^{\cdot}3} \mathbf{r}_3}_{+1} + \underbrace{v_{D^{\cdot}4} \mathbf{r}_4}_{+1} + v_{D^{\cdot}5} \mathbf{r}_5$$



$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \quad \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + \underbrace{v_{A5} \mathbf{r}_5}_0$$

$$\therefore \quad \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

$$\therefore \quad \mathbf{r}_A = -k_2 C_A C_{D^{\bullet}} + k_4 C_{E^{\bullet}} C_C$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 C_B$$

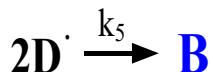
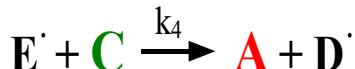
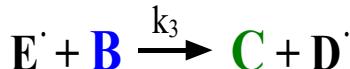
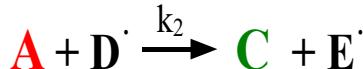
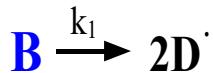
$$\mathbf{r}_2 = k_2 C_A C_{D^{\bullet}}$$

$$\mathbf{r}_3 = k_3 C_{E^{\bullet}} C_B$$

$$\mathbf{r}_4 = k_4 C_{E^{\bullet}} C_C$$

$$\mathbf{r}_5 = k_5 C_{D^{\bullet}}^2$$

$$\therefore \quad \mathbf{r}_{D^{\bullet}} = \underbrace{v_{D^{\bullet}1} \mathbf{r}_1}_{+2} + \underbrace{v_{D^{\bullet}2} \mathbf{r}_2}_{-1} + \underbrace{v_{D^{\bullet}3} \mathbf{r}_3}_{+1} + \underbrace{v_{D^{\bullet}4} \mathbf{r}_4}_{+1} + \underbrace{v_{D^{\bullet}5} \mathbf{r}_5}_{-2}$$



$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \quad \mathbf{r}_A = \underbrace{v_{A1}}_0 \mathbf{r}_1 + \underbrace{v_{A2}}_{-1} \mathbf{r}_2 + \underbrace{v_{A3}}_0 \mathbf{r}_3 + \underbrace{v_{A4}}_{+1} \mathbf{r}_4 + \underbrace{v_{A5}}_0 \mathbf{r}_5$$

$$\therefore \quad \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

$$\therefore \quad \mathbf{r}_A = -k_2 C_A C_{D^{\cdot}} + k_4 C_{E^{\cdot}} C_C$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 C_B$$

$$\mathbf{r}_2 = k_2 C_A C_{D^{\cdot}}$$

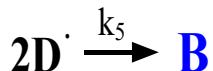
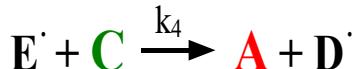
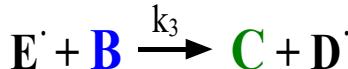
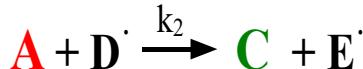
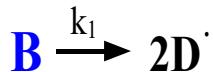
$$\mathbf{r}_3 = k_3 C_{E^{\cdot}} C_B$$

$$\mathbf{r}_4 = k_4 C_{E^{\cdot}} C_C$$

$$\mathbf{r}_5 = k_5 C_{D^{\cdot}}^2$$

$$\therefore \quad \mathbf{r}_{D^{\cdot}} = \underbrace{v_{D^{\cdot}1}}_{+2} \mathbf{r}_1 + \underbrace{v_{D^{\cdot}2}}_{-1} \mathbf{r}_2 + \underbrace{v_{D^{\cdot}3}}_{+1} \mathbf{r}_3 + \underbrace{v_{D^{\cdot}4}}_{+1} \mathbf{r}_4 + \underbrace{v_{D^{\cdot}5}}_{-2} \mathbf{r}_5$$

$$\therefore \quad \mathbf{r}_{D^{\cdot}} = 2\mathbf{r}_1 - \mathbf{r}_2 + \mathbf{r}_3 + \mathbf{r}_4 - 2\mathbf{r}_5$$



$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \quad \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + \underbrace{v_{A5} \mathbf{r}_5}_0$$

$$\therefore \quad \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

$$\therefore \quad \mathbf{r}_A = -k_2 C_A C_{D^{\cdot}} + k_4 C_{E^{\cdot}} C_C$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 C_B$$

$$\mathbf{r}_2 = k_2 C_A C_{D^{\cdot}}$$

$$\mathbf{r}_3 = k_3 C_{E^{\cdot}} C_B$$

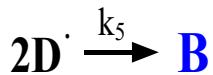
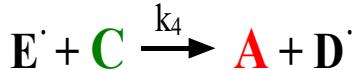
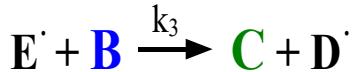
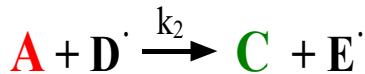
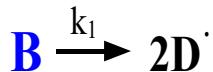
$$\mathbf{r}_4 = k_4 C_{E^{\cdot}} C_C$$

$$\mathbf{r}_5 = k_5 C_{D^{\cdot}}^2$$

$$\therefore \quad \mathbf{r}_{D^{\cdot}} = \underbrace{v_{D^{\cdot}1} \mathbf{r}_1}_{+2} + \underbrace{v_{D^{\cdot}2} \mathbf{r}_2}_{-1} + \underbrace{v_{D^{\cdot}3} \mathbf{r}_3}_{+1} + \underbrace{v_{D^{\cdot}4} \mathbf{r}_4}_{+1} + \underbrace{v_{D^{\cdot}5} \mathbf{r}_5}_{-2}$$

$$\therefore \quad \mathbf{r}_{D^{\cdot}} = 2\mathbf{r}_1 - \mathbf{r}_2 + \mathbf{r}_3 + \mathbf{r}_4 - 2\mathbf{r}_5$$

$$\begin{aligned} \mathbf{r}_{D^{\cdot}} &= 2k_1 C_B - k_2 C_A C_{D^{\cdot}} + k_3 C_{E^{\cdot}} C_B + k_4 C_{E^{\cdot}} C_C - \\ &\quad - 2k_5 C_{D^{\cdot}}^2 \end{aligned}$$



$$\mathbf{r}_A = \mathbf{r}_{A1} + \mathbf{r}_{A2} + \mathbf{r}_{A3} + \mathbf{r}_{A4} + \mathbf{r}_{A5}$$

$$\therefore \quad \mathbf{r}_A = \underbrace{v_{A1} \mathbf{r}_1}_0 + \underbrace{v_{A2} \mathbf{r}_2}_{-1} + \underbrace{v_{A3} \mathbf{r}_3}_0 + \underbrace{v_{A4} \mathbf{r}_4}_{+1} + \underbrace{v_{A5} \mathbf{r}_5}_0$$

$$\therefore \quad \mathbf{r}_A = -\mathbf{r}_2 + \mathbf{r}_4$$

$$\therefore \quad \mathbf{r}_A = -k_2 C_A C_{D^{\cdot}} + k_4 C_{E^{\cdot}} C_C$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 C_B$$

$$\mathbf{r}_2 = k_2 C_A C_{D^{\cdot}}$$

$$\mathbf{r}_3 = k_3 C_{E^{\cdot}} C_B$$

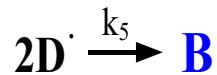
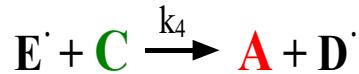
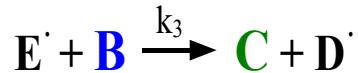
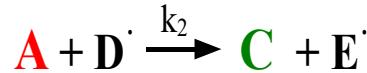
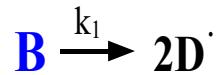
$$\mathbf{r}_4 = k_4 C_{E^{\cdot}} C_C$$

$$\mathbf{r}_5 = k_5 C_{D^{\cdot}}^2$$

$$\therefore \quad \mathbf{r}_{D^{\cdot}} = \underbrace{v_{D^{\cdot}1} \mathbf{r}_1}_{+2} + \underbrace{v_{D^{\cdot}2} \mathbf{r}_2}_{-1} + \underbrace{v_{D^{\cdot}3} \mathbf{r}_3}_{+1} + \underbrace{v_{D^{\cdot}4} \mathbf{r}_4}_{+1} + \underbrace{v_{D^{\cdot}5} \mathbf{r}_5}_{-2}$$

$$\therefore \quad \mathbf{r}_{D^{\cdot}} = 2\mathbf{r}_1 - \mathbf{r}_2 + \mathbf{r}_3 + \mathbf{r}_4 - 2\mathbf{r}_5$$

$$\begin{aligned} \mathbf{r}_{D^{\cdot}} &= 2k_1 C_B - k_2 C_A C_{D^{\cdot}} + k_3 C_{E^{\cdot}} C_B + k_4 C_{E^{\cdot}} C_C - \\ &\quad - 2k_5 C_{D^{\cdot}}^2 = 0 \end{aligned}$$



Velocidades absolutas:

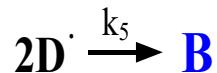
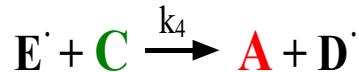
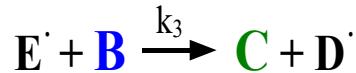
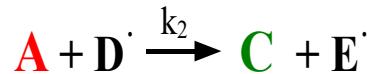
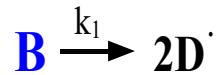
$$r_1 = k_1 C_B$$

$$r_2 = k_2 C_A C_{D^{\cdot}}$$

$$r_3 = k_3 C_{E^{\cdot}} C_B$$

$$r_4 = k_4 C_{E^{\cdot}} C_C$$

$$r_5 = k_5 C_{D^{\cdot}}^2$$



$$r_{E^{\bullet}} = r_{E^{\bullet}1} + r_{E^{\bullet}2} + r_{E^{\bullet}3} + r_{E^{\bullet}4} + r_{E^{\bullet}5}$$

Velocidades absolutas:

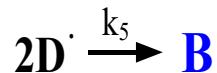
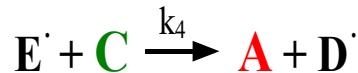
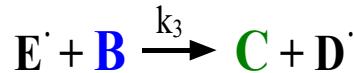
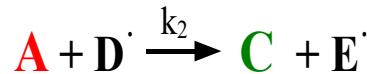
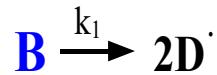
$$r_1 = k_1 C_B$$

$$r_2 = k_2 C_A C_{D^{\bullet}}$$

$$r_3 = k_3 C_{E^{\bullet}} C_B$$

$$r_4 = k_4 C_{E^{\bullet}} C_C$$

$$r_5 = k_5 C_{D^{\bullet}}^2$$



$$\mathbf{r}_{E^{\bullet}} = \mathbf{r}_{E^{\bullet}1} + \mathbf{r}_{E^{\bullet}2} + \mathbf{r}_{E^{\bullet}3} + \mathbf{r}_{E^{\bullet}4} + \mathbf{r}_{E^{\bullet}5}$$

$$\therefore \mathbf{r}_{E^{\bullet}} = v_{E^{\bullet}1} \mathbf{r}_1 + v_{E^{\bullet}2} \mathbf{r}_2 + v_{E^{\bullet}3} \mathbf{r}_3 + v_{E^{\bullet}4} \mathbf{r}_4 + v_{E^{\bullet}5} \mathbf{r}_5$$

Velocidades absolutas:

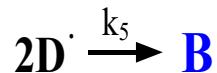
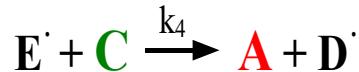
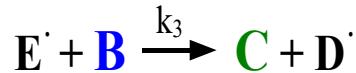
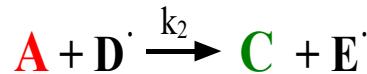
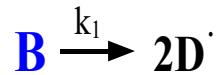
$$r_1 = k_1 C_B$$

$$r_2 = k_2 C_A C_{D^{\bullet}}$$

$$r_3 = k_3 C_{E^{\bullet}} C_B$$

$$r_4 = k_4 C_{E^{\bullet}} C_C$$

$$r_5 = k_5 C_{D^{\bullet}}^2$$



$$\mathbf{r}_{E^{\bullet}} = \mathbf{r}_{E^{\bullet}1} + \mathbf{r}_{E^{\bullet}2} + \mathbf{r}_{E^{\bullet}3} + \mathbf{r}_{E^{\bullet}4} + \mathbf{r}_{E^{\bullet}5}$$

$$\therefore \underbrace{\mathbf{r}_{E^{\bullet}} = v_{E^{\bullet}1} \mathbf{r}_1 + v_{E^{\bullet}2} \mathbf{r}_2 + v_{E^{\bullet}3} \mathbf{r}_3 + v_{E^{\bullet}4} \mathbf{r}_4 + v_{E^{\bullet}5} \mathbf{r}_5}_0$$

Velocidades absolutas:

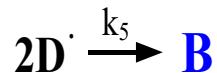
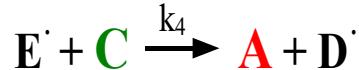
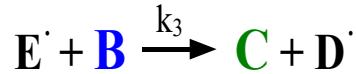
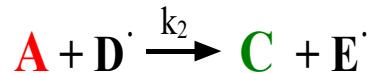
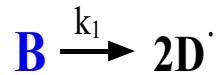
$$r_1 = k_1 C_B$$

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$$r_3 = k_3 C_{E^{\bullet}} C_B$$

$$r_4 = k_4 C_{E^{\bullet}} C_C$$

$$r_5 = k_5 C_{D^{\bullet}}^2$$



$$\mathbf{r}_{E^{\bullet}} = \mathbf{r}_{E^{\bullet}1} + \mathbf{r}_{E^{\bullet}2} + \mathbf{r}_{E^{\bullet}3} + \mathbf{r}_{E^{\bullet}4} + \mathbf{r}_{E^{\bullet}5}$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \underbrace{\nu_{E^{\bullet}1} \mathbf{r}_1}_0 + \underbrace{\nu_{E^{\bullet}2} \mathbf{r}_2}_{+1} + \nu_{E^{\bullet}3} \mathbf{r}_3 + \nu_{E^{\bullet}4} \mathbf{r}_4 + \nu_{E^{\bullet}5} \mathbf{r}_5$$

Velocidades absolutas:

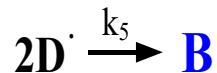
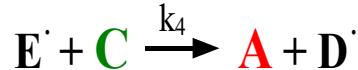
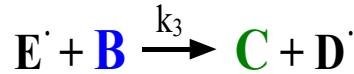
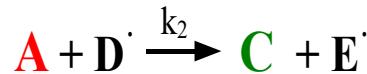
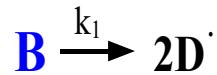
$$r_1 = k_1 C_B$$

$$r_2 = k_2 C_A C_{D^{\bullet}}$$

$$r_3 = k_3 C_{E^{\bullet}} C_B$$

$$r_4 = k_4 C_{E^{\bullet}} C_C$$

$$r_5 = k_5 C_{D^{\bullet}}^2$$



$$\mathbf{r}_{E^{\bullet}} = \mathbf{r}_{E^{\bullet}1} + \mathbf{r}_{E^{\bullet}2} + \mathbf{r}_{E^{\bullet}3} + \mathbf{r}_{E^{\bullet}4} + \mathbf{r}_{E^{\bullet}5}$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \underbrace{\nu_{E^{\bullet}1}}_0 \mathbf{r}_1 + \underbrace{\nu_{E^{\bullet}2}}_{+1} \mathbf{r}_2 + \underbrace{\nu_{E^{\bullet}3}}_{-1} \mathbf{r}_3 + \nu_{E^{\bullet}4} \mathbf{r}_4 + \nu_{E^{\bullet}5} \mathbf{r}_5$$

Velocidades absolutas:

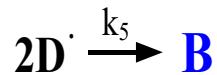
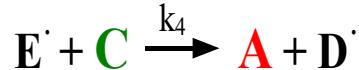
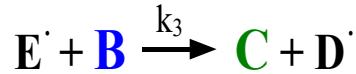
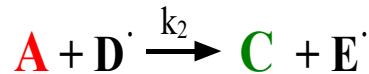
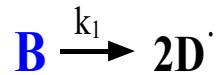
$$r_1 = k_1 C_B$$

$$r_2 = k_2 C_A C_{D^{\bullet}}$$

$$r_3 = k_3 C_{E^{\bullet}} C_B$$

$$r_4 = k_4 C_{E^{\bullet}} C_C$$

$$r_5 = k_5 C_{D^{\bullet}}^2$$



$$\mathbf{r}_{E^{\bullet}} = \mathbf{r}_{E^{\bullet}1} + \mathbf{r}_{E^{\bullet}2} + \mathbf{r}_{E^{\bullet}3} + \mathbf{r}_{E^{\bullet}4} + \mathbf{r}_{E^{\bullet}5}$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \underbrace{\nu_{E^{\bullet}1}}_0 \mathbf{r}_1 + \underbrace{\nu_{E^{\bullet}2}}_{+1} \mathbf{r}_2 + \underbrace{\nu_{E^{\bullet}3}}_{-1} \mathbf{r}_3 + \underbrace{\nu_{E^{\bullet}4}}_{-1} \mathbf{r}_4 + \underbrace{\nu_{E^{\bullet}5}}_{-1} \mathbf{r}_5$$

Velocidades absolutas:

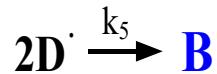
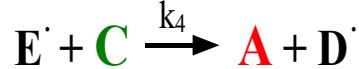
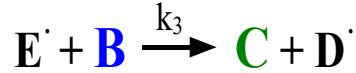
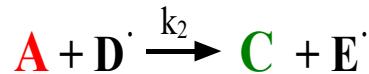
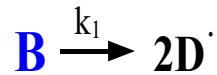
$$r_1 = k_1 C_B$$

$$r_2 = k_2 C_A C_{D^{\bullet}}$$

$$r_3 = k_3 C_{E^{\bullet}} C_B$$

$$r_4 = k_4 C_{E^{\bullet}} C_C$$

$$r_5 = k_5 C_{D^{\bullet}}^2$$



$$\mathbf{r}_{E^{\bullet}} = \mathbf{r}_{E^{\bullet}1} + \mathbf{r}_{E^{\bullet}2} + \mathbf{r}_{E^{\bullet}3} + \mathbf{r}_{E^{\bullet}4} + \mathbf{r}_{E^{\bullet}5}$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \underbrace{\nu_{E^{\bullet}1}}_0 \mathbf{r}_1 + \underbrace{\nu_{E^{\bullet}2}}_{+1} \mathbf{r}_2 + \underbrace{\nu_{E^{\bullet}3}}_{-1} \mathbf{r}_3 + \underbrace{\nu_{E^{\bullet}4}}_{-1} \mathbf{r}_4 + \underbrace{\nu_{E^{\bullet}5}}_0 \mathbf{r}_5$$

Velocidades absolutas:

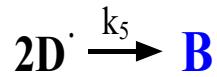
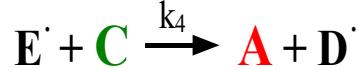
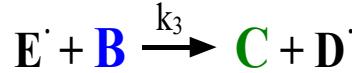
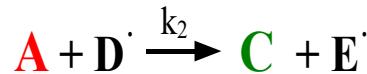
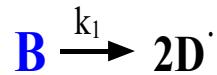
$$r_1 = k_1 C_B$$

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$$r_4 = k_4 C_{E^{\bullet}} C_C$$

$$r_5 = k_5 C_{D^{\bullet}}^2$$



$$\mathbf{r}_{E^{\bullet}} = \mathbf{r}_{E^{\bullet}1} + \mathbf{r}_{E^{\bullet}2} + \mathbf{r}_{E^{\bullet}3} + \mathbf{r}_{E^{\bullet}4} + \mathbf{r}_{E^{\bullet}5}$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \underbrace{\nu_{E^{\bullet}1} \mathbf{r}_1}_0 + \underbrace{\nu_{E^{\bullet}2} \mathbf{r}_2}_{+1} + \underbrace{\nu_{E^{\bullet}3} \mathbf{r}_3}_{-1} + \underbrace{\nu_{E^{\bullet}4} \mathbf{r}_4}_{-1} + \underbrace{\nu_{E^{\bullet}5} \mathbf{r}_5}_0$$
$$\therefore \mathbf{r}_{E^{\bullet}} = \mathbf{r}_2 - \mathbf{r}_3 - \mathbf{r}_4$$

Velocidades absolutas:

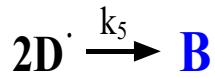
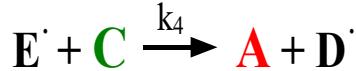
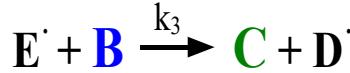
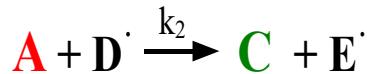
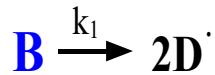
$$\mathbf{r}_1 = k_1 C_B$$

$$\mathbf{r}_2 = k_2 C_A C_{D^{\bullet}}$$

$$\mathbf{r}_3 = k_3 C_{E^{\bullet}} C_B$$

$$\mathbf{r}_4 = k_4 C_{E^{\bullet}} C_C$$

$$\mathbf{r}_5 = k_5 C_{D^{\bullet}}^2$$



$$\mathbf{r}_{E^{\bullet}} = \mathbf{r}_{E^{\bullet}1} + \mathbf{r}_{E^{\bullet}2} + \mathbf{r}_{E^{\bullet}3} + \mathbf{r}_{E^{\bullet}4} + \mathbf{r}_{E^{\bullet}5}$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \underbrace{\nu_{E^{\bullet}1} \mathbf{r}_1}_0 + \underbrace{\nu_{E^{\bullet}2} \mathbf{r}_2}_{+1} + \underbrace{\nu_{E^{\bullet}3} \mathbf{r}_3}_{-1} + \underbrace{\nu_{E^{\bullet}4} \mathbf{r}_4}_{-1} + \underbrace{\nu_{E^{\bullet}5} \mathbf{r}_5}_0$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \mathbf{r}_2 - \mathbf{r}_3 - \mathbf{r}_4$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 \mathbf{C}_B$$

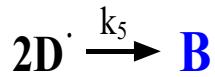
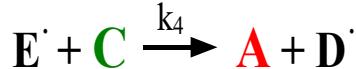
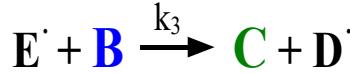
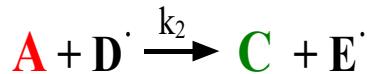
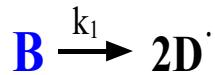
$$\mathbf{r}_2 = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}}$$

$$\mathbf{r}_3 = k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B$$

$$\mathbf{r}_4 = k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C$$

$$\mathbf{r}_5 = k_5 \mathbf{C}_{D^{\bullet}}^2$$

$$\therefore \mathbf{r}_{E^{\bullet}} = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}} - k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B - k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C$$



$$\mathbf{r}_{E^{\bullet}} = \mathbf{r}_{E^{\bullet}1} + \mathbf{r}_{E^{\bullet}2} + \mathbf{r}_{E^{\bullet}3} + \mathbf{r}_{E^{\bullet}4} + \mathbf{r}_{E^{\bullet}5}$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \underbrace{\nu_{E^{\bullet}1} \mathbf{r}_1}_0 + \underbrace{\nu_{E^{\bullet}2} \mathbf{r}_2}_{+1} + \underbrace{\nu_{E^{\bullet}3} \mathbf{r}_3}_{-1} + \underbrace{\nu_{E^{\bullet}4} \mathbf{r}_4}_{-1} + \underbrace{\nu_{E^{\bullet}5} \mathbf{r}_5}_0$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \mathbf{r}_2 - \mathbf{r}_3 - \mathbf{r}_4$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 \mathbf{C}_B$$

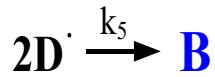
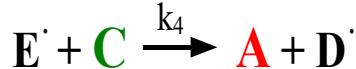
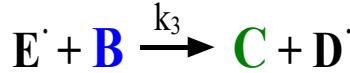
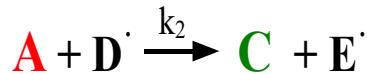
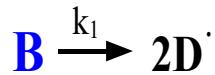
$$\mathbf{r}_2 = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}}$$

$$\mathbf{r}_3 = k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B$$

$$\mathbf{r}_4 = k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C$$

$$\mathbf{r}_5 = k_5 \mathbf{C}_{D^{\bullet}}^2$$

$$\therefore \mathbf{r}_{E^{\bullet}} = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}} - k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B - k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C = 0$$



$$\mathbf{r}_{E^{\bullet}} = \mathbf{r}_{E^{\bullet}1} + \mathbf{r}_{E^{\bullet}2} + \mathbf{r}_{E^{\bullet}3} + \mathbf{r}_{E^{\bullet}4} + \mathbf{r}_{E^{\bullet}5}$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \underbrace{\nu_{E^{\bullet}1} \mathbf{r}_1}_0 + \underbrace{\nu_{E^{\bullet}2} \mathbf{r}_2}_{+1} + \underbrace{\nu_{E^{\bullet}3} \mathbf{r}_3}_{-1} + \underbrace{\nu_{E^{\bullet}4} \mathbf{r}_4}_{-1} + \underbrace{\nu_{E^{\bullet}5} \mathbf{r}_5}_0$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \mathbf{r}_2 - \mathbf{r}_3 - \mathbf{r}_4$$

$$\therefore \mathbf{r}_{E^{\bullet}} = k_2 C_A C_{D^{\bullet}} - k_3 C_{E^{\bullet}} C_B - k_4 C_{E^{\bullet}} C_C = 0$$

$$\mathbf{r}_{D^{\bullet}} = 0$$

Velocidades absolutas:

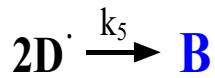
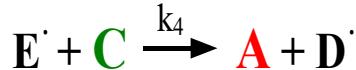
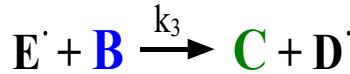
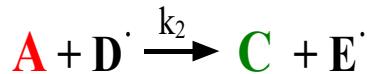
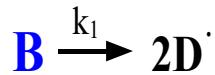
$$\mathbf{r}_1 = k_1 C_B$$

$$\mathbf{r}_2 = k_2 C_A C_{D^{\bullet}}$$

$$\mathbf{r}_3 = k_3 C_{E^{\bullet}} C_B$$

$$\mathbf{r}_4 = k_4 C_{E^{\bullet}} C_C$$

$$\mathbf{r}_5 = k_5 C_{D^{\bullet}}^2$$



Velocidades absolutas:

$$r_1 = k_1 C_B$$

$$r_2 = k_2 C_A C_{D^{\cdot}}$$

$$r_3 = k_3 C_{E^{\cdot}} C_B$$

$$r_4 = k_4 C_{E^{\cdot}} C_C$$

$$r_5 = k_5 C_{D^{\cdot}}^2$$

$$r_{E^{\bullet}} = r_{E^{\bullet}1} + r_{E^{\bullet}2} + r_{E^{\bullet}3} + r_{E^{\bullet}4} + r_{E^{\bullet}5}$$

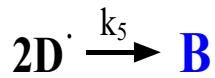
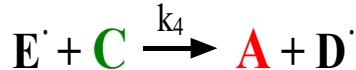
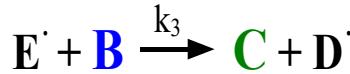
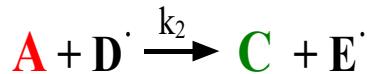
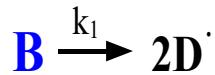
$$\therefore r_{E^{\bullet}} = \underbrace{v_{E^{\bullet}1}}_0 r_1 + \underbrace{v_{E^{\bullet}2}}_{+1} r_2 + \underbrace{v_{E^{\bullet}3}}_{-1} r_3 + \underbrace{v_{E^{\bullet}4}}_{-1} r_4 + \underbrace{v_{E^{\bullet}5}}_0 r_5$$

$$\therefore r_{E^{\bullet}} = r_2 - r_3 - r_4$$

$$\therefore r_{E^{\bullet}} = k_2 C_A C_{D^{\bullet}} - k_3 C_{E^{\bullet}} C_B - k_4 C_{E^{\bullet}} C_C = 0$$

$$r_{D^{\bullet}} = 0$$

$$r_{E^{\bullet}} = 0$$



Velocidades absolutas:

$$r_1 = k_1 C_B$$

$$r_2 = k_2 C_A C_{D^{\cdot}}$$

$$r_3 = k_3 C_{E^{\cdot}} C_B$$

$$r_4 = k_4 C_{E^{\cdot}} C_C$$

$$r_5 = k_5 C_{D^{\cdot}}^2$$

$$r_{E^{\bullet}} = r_{E^{\bullet}1} + r_{E^{\bullet}2} + r_{E^{\bullet}3} + r_{E^{\bullet}4} + r_{E^{\bullet}5}$$

$$\therefore r_{E^{\bullet}} = \underbrace{v_{E^{\bullet}1}}_0 r_1 + \underbrace{v_{E^{\bullet}2}}_{+1} r_2 + \underbrace{v_{E^{\bullet}3}}_{-1} r_3 + \underbrace{v_{E^{\bullet}4}}_{-1} r_4 + \underbrace{v_{E^{\bullet}5}}_0 r_5$$

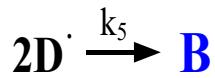
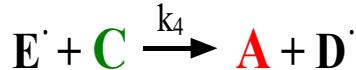
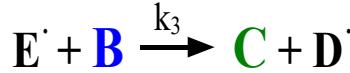
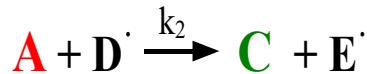
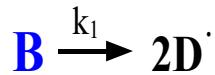
$$\therefore r_{E^{\bullet}} = r_2 - r_3 - r_4$$

$$\therefore r_{E^{\bullet}} = k_2 C_A C_{D^{\bullet}} - k_3 C_{E^{\bullet}} C_B - k_4 C_{E^{\bullet}} C_C = 0$$

$$r_{D^{\bullet}} = 0$$

$$r_{E^{\bullet}} = 0$$

$$\Rightarrow r_{D^{\bullet}} + r_{E^{\bullet}} = 0$$



$$\mathbf{r}_{E^{\bullet}} = \mathbf{r}_{E^{\bullet}1} + \mathbf{r}_{E^{\bullet}2} + \mathbf{r}_{E^{\bullet}3} + \mathbf{r}_{E^{\bullet}4} + \mathbf{r}_{E^{\bullet}5}$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \underbrace{\nu_{E^{\bullet}1} \mathbf{r}_1}_0 + \underbrace{\nu_{E^{\bullet}2} \mathbf{r}_2}_{+1} + \underbrace{\nu_{E^{\bullet}3} \mathbf{r}_3}_{-1} + \underbrace{\nu_{E^{\bullet}4} \mathbf{r}_4}_{-1} + \underbrace{\nu_{E^{\bullet}5} \mathbf{r}_5}_0$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \mathbf{r}_2 - \mathbf{r}_3 - \mathbf{r}_4$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 \mathbf{C}_B$$

$$\mathbf{r}_2 = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}}$$

$$\mathbf{r}_3 = k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B$$

$$\mathbf{r}_4 = k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C$$

$$\mathbf{r}_5 = k_5 \mathbf{C}_{D^{\bullet}}^2$$

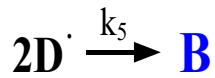
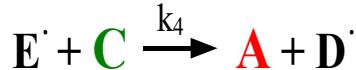
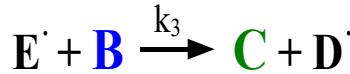
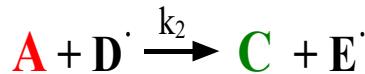
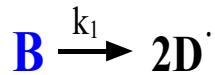
$$\therefore \mathbf{r}_{E^{\bullet}} = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}} - k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B - k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C = 0$$

$$\mathbf{r}_{D^{\bullet}} = 0$$

$$\Rightarrow \mathbf{r}_{D^{\bullet}} + \mathbf{r}_{E^{\bullet}} = 0$$

$$\mathbf{r}_{E^{\bullet}} = 0$$

$$2k_1 \mathbf{C}_B - k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}} + k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B + k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C - 2k_5 \mathbf{C}_{D^{\bullet}}^2$$



$$\mathbf{r}_{E^{\bullet}} = \mathbf{r}_{E^{\bullet}1} + \mathbf{r}_{E^{\bullet}2} + \mathbf{r}_{E^{\bullet}3} + \mathbf{r}_{E^{\bullet}4} + \mathbf{r}_{E^{\bullet}5}$$

$$\therefore \quad \mathbf{r}_{E^{\bullet}} = \underbrace{\nu_{E^{\bullet}1} \mathbf{r}_1}_0 + \underbrace{\nu_{E^{\bullet}2} \mathbf{r}_2}_{+1} + \underbrace{\nu_{E^{\bullet}3} \mathbf{r}_3}_{-1} + \underbrace{\nu_{E^{\bullet}4} \mathbf{r}_4}_{-1} + \underbrace{\nu_{E^{\bullet}5} \mathbf{r}_5}_0$$

$$\therefore \quad \mathbf{r}_{E^{\bullet}} = \mathbf{r}_2 - \mathbf{r}_3 - \mathbf{r}_4$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 \mathbf{C}_B$$

$$\mathbf{r}_2 = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}}$$

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$$\mathbf{r}_4 = k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C$$

$$\mathbf{r}_5 = k_5 \mathbf{C}_{D^{\bullet}}^2$$

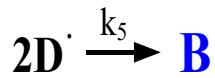
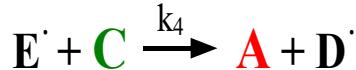
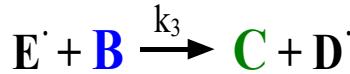
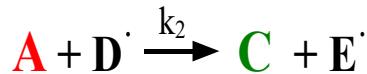
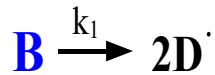
$$\therefore \quad \mathbf{r}_{E^{\bullet}} = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}} - k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B - k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C = 0$$

$$\mathbf{r}_{D^{\bullet}} = 0$$

$$\Rightarrow \quad \mathbf{r}_{D^{\bullet}} + \mathbf{r}_{E^{\bullet}} = 0$$

$$\mathbf{r}_{E^{\bullet}} = 0$$

$$2k_1 \mathbf{C}_B - k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}} + k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B + k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C - \\ - 2k_5 \mathbf{C}_{D^{\bullet}}^2 + k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}} - k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B - k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C$$



$$\mathbf{r}_{E^{\bullet}} = \mathbf{r}_{E^{\bullet}1} + \mathbf{r}_{E^{\bullet}2} + \mathbf{r}_{E^{\bullet}3} + \mathbf{r}_{E^{\bullet}4} + \mathbf{r}_{E^{\bullet}5}$$

$$\therefore \quad \mathbf{r}_{E^{\bullet}} = \underbrace{\nu_{E^{\bullet}1} \mathbf{r}_1}_0 + \underbrace{\nu_{E^{\bullet}2} \mathbf{r}_2}_{+1} + \underbrace{\nu_{E^{\bullet}3} \mathbf{r}_3}_{-1} + \underbrace{\nu_{E^{\bullet}4} \mathbf{r}_4}_{-1} + \underbrace{\nu_{E^{\bullet}5} \mathbf{r}_5}_0$$

$$\therefore \quad \mathbf{r}_{E^{\bullet}} = \mathbf{r}_2 - \mathbf{r}_3 - \mathbf{r}_4$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 \mathbf{C}_B$$

$$\mathbf{r}_2 = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}}$$

$$\mathbf{r}_3 = k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B$$

$$\mathbf{r}_4 = k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C$$

$$\mathbf{r}_5 = k_5 \mathbf{C}_{D^{\bullet}}^2$$

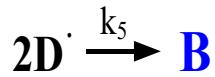
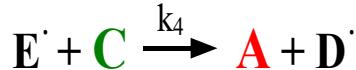
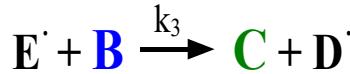
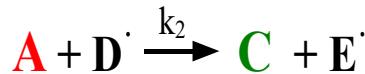
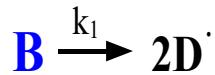
$$\therefore \quad \mathbf{r}_{E^{\bullet}} = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}} - k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B - k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C = 0$$

$$\mathbf{r}_{D^{\bullet}} = 0$$

$$\Rightarrow \quad \mathbf{r}_{D^{\bullet}} + \mathbf{r}_{E^{\bullet}} = 0$$

$$\mathbf{r}_{E^{\bullet}} = 0$$

$$2k_1 \mathbf{C}_B - k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}} + k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B + k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C - \\ - 2k_5 \mathbf{C}_{D^{\bullet}}^2 + k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}} - k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B - k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C = 0$$



$$\mathbf{r}_{E^{\bullet}} = \mathbf{r}_{E^{\bullet}1} + \mathbf{r}_{E^{\bullet}2} + \mathbf{r}_{E^{\bullet}3} + \mathbf{r}_{E^{\bullet}4} + \mathbf{r}_{E^{\bullet}5}$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \underbrace{\nu_{E^{\bullet}1} \mathbf{r}_1}_0 + \underbrace{\nu_{E^{\bullet}2} \mathbf{r}_2}_{+1} + \underbrace{\nu_{E^{\bullet}3} \mathbf{r}_3}_{-1} + \underbrace{\nu_{E^{\bullet}4} \mathbf{r}_4}_{-1} + \underbrace{\nu_{E^{\bullet}5} \mathbf{r}_5}_0$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \mathbf{r}_2 - \mathbf{r}_3 - \mathbf{r}_4$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 \mathbf{C}_B$$

$$\mathbf{r}_2 = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}}$$

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$$\mathbf{r}_4 = k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C$$

$$\mathbf{r}_5 = k_5 \mathbf{C}_{D^{\bullet}}^2$$

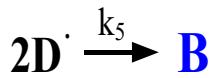
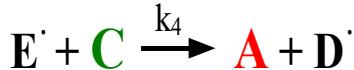
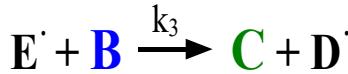
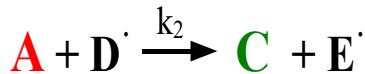
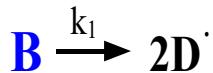
$$\therefore \mathbf{r}_{E^{\bullet}} = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}} - k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B - k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C = 0$$

$$\mathbf{r}_{D^{\bullet}} = 0$$

$$\Rightarrow \mathbf{r}_{D^{\bullet}} + \mathbf{r}_{E^{\bullet}} = 0$$

$$\mathbf{r}_{E^{\bullet}} = 0$$

$$2k_1 \mathbf{C}_B - \cancel{k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}}} + k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B + k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C - \\ - \cancel{2k_5 \mathbf{C}_{D^{\bullet}}^2} + \cancel{k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}}} - k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B - k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C = 0$$



$$\mathbf{r}_{E^{\bullet}} = \mathbf{r}_{E^{\bullet}1} + \mathbf{r}_{E^{\bullet}2} + \mathbf{r}_{E^{\bullet}3} + \mathbf{r}_{E^{\bullet}4} + \mathbf{r}_{E^{\bullet}5}$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \underbrace{\nu_{E^{\bullet}1} \mathbf{r}_1}_0 + \underbrace{\nu_{E^{\bullet}2} \mathbf{r}_2}_{+1} + \underbrace{\nu_{E^{\bullet}3} \mathbf{r}_3}_{-1} + \underbrace{\nu_{E^{\bullet}4} \mathbf{r}_4}_{-1} + \underbrace{\nu_{E^{\bullet}5} \mathbf{r}_5}_0$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \mathbf{r}_2 - \mathbf{r}_3 - \mathbf{r}_4$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 \mathbf{C}_B$$

$$\mathbf{r}_2 = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}}$$

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$$\mathbf{r}_5 = k_5 \mathbf{C}_{D^{\bullet}}^2$$

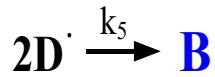
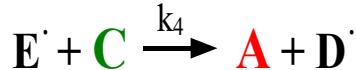
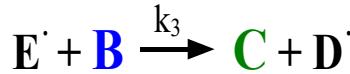
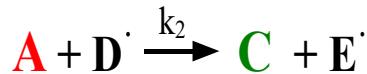
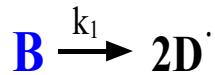
$$\therefore \mathbf{r}_{E^{\bullet}} = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}} - k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B - k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C = 0$$

$$\mathbf{r}_{D^{\bullet}} = 0$$

$$\Rightarrow \mathbf{r}_{D^{\bullet}} + \mathbf{r}_{E^{\bullet}} = 0$$

$$\mathbf{r}_{E^{\bullet}} = 0$$

$$2k_1 \mathbf{C}_B - \cancel{k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}}} + \cancel{k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B} + \cancel{k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C} - \\ - 2k_5 \mathbf{C}_{D^{\bullet}}^2 + \cancel{k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}}} - \cancel{k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B} - \cancel{k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C} = 0$$



Velocidades absolutas:

$$r_1 = k_1 C_B$$

$$r_2 = k_2 C_A C_{D^{\cdot}}$$

$$r_3 = k_3 C_{E^{\cdot}} C_B$$

$$r_4 = k_4 C_{E^{\cdot}} C_C$$

$$r_5 = k_5 C_{D^{\cdot}}^2$$

$$r_{E^{\cdot}} = r_{E^{\cdot}1} + r_{E^{\cdot}2} + r_{E^{\cdot}3} + r_{E^{\cdot}4} + r_{E^{\cdot}5}$$

$$\therefore r_{E^{\cdot}} = \underbrace{v_{E^{\cdot}1}}_0 r_1 + \underbrace{v_{E^{\cdot}2}}_{+1} r_2 + \underbrace{v_{E^{\cdot}3}}_{-1} r_3 + \underbrace{v_{E^{\cdot}4}}_{-1} r_4 + \underbrace{v_{E^{\cdot}5}}_0 r_5$$

$$\therefore r_{E^{\cdot}} = r_2 - r_3 - r_4$$

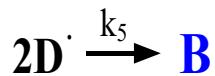
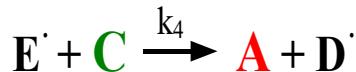
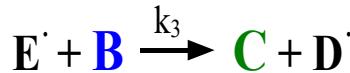
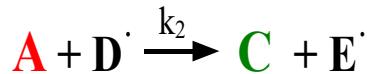
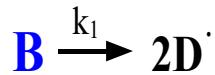
$$\therefore r_{E^{\cdot}} = k_2 C_A C_{D^{\cdot}} - k_3 C_{E^{\cdot}} C_B - k_4 C_{E^{\cdot}} C_C = 0$$

$$r_{D^{\cdot}} = 0$$

$$\Rightarrow r_{D^{\cdot}} + r_{E^{\cdot}} = 0$$

$$r_{E^{\cdot}} = 0$$

$$2k_1 C_B - \cancel{k_2 C_A C_{D^{\cdot}}} + \cancel{k_3 C_{E^{\cdot}} C_B} + \cancel{k_4 C_{E^{\cdot}} C_C} - \\ - 2k_5 C_{D^{\cdot}}^2 + \cancel{k_2 C_A C_{D^{\cdot}}} - \cancel{k_3 C_{E^{\cdot}} C_B} - \cancel{k_4 C_{E^{\cdot}} C_C} = 0$$



$$\mathbf{r}_{E^{\bullet}} = \mathbf{r}_{E^{\bullet}1} + \mathbf{r}_{E^{\bullet}2} + \mathbf{r}_{E^{\bullet}3} + \mathbf{r}_{E^{\bullet}4} + \mathbf{r}_{E^{\bullet}5}$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \underbrace{\nu_{E^{\bullet}1} \mathbf{r}_1}_0 + \underbrace{\nu_{E^{\bullet}2} \mathbf{r}_2}_{+1} + \underbrace{\nu_{E^{\bullet}3} \mathbf{r}_3}_{-1} + \underbrace{\nu_{E^{\bullet}4} \mathbf{r}_4}_{-1} + \underbrace{\nu_{E^{\bullet}5} \mathbf{r}_5}_0$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \mathbf{r}_2 - \mathbf{r}_3 - \mathbf{r}_4$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 \mathbf{C}_B$$

$$\mathbf{r}_2 = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}}$$

$$\mathbf{r}_3 = k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B$$

$$\mathbf{r}_4 = k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C$$

$$\mathbf{r}_5 = k_5 \mathbf{C}_{D^{\bullet}}^2$$

$$\therefore \mathbf{r}_{E^{\bullet}} = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}} - k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B - k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C = 0$$

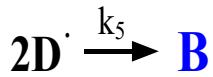
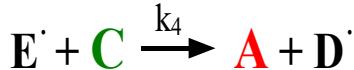
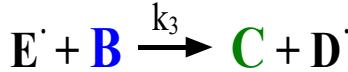
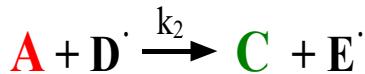
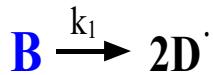
$$\mathbf{r}_{D^{\bullet}} = 0$$

$$\Rightarrow \mathbf{r}_{D^{\bullet}} + \mathbf{r}_{E^{\bullet}} = 0$$

$$\mathbf{r}_{E^{\bullet}} = 0$$

$$2k_1 \mathbf{C}_B - \cancel{k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}}} + \cancel{k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B} + \cancel{k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C} - \\ - 2k_5 \mathbf{C}_{D^{\bullet}}^2 + \cancel{k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}}} - \cancel{k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B} - \cancel{k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C} = 0$$

$$\therefore 2k_1 \mathbf{C}_B - 2k_5 \mathbf{C}_{D^{\bullet}}^2 = 0$$



$$\mathbf{r}_{E^{\bullet}} = \mathbf{r}_{E^{\bullet}1} + \mathbf{r}_{E^{\bullet}2} + \mathbf{r}_{E^{\bullet}3} + \mathbf{r}_{E^{\bullet}4} + \mathbf{r}_{E^{\bullet}5}$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \underbrace{\nu_{E^{\bullet}1} \mathbf{r}_1}_0 + \underbrace{\nu_{E^{\bullet}2} \mathbf{r}_2}_{+1} + \underbrace{\nu_{E^{\bullet}3} \mathbf{r}_3}_{-1} + \underbrace{\nu_{E^{\bullet}4} \mathbf{r}_4}_{-1} + \underbrace{\nu_{E^{\bullet}5} \mathbf{r}_5}_0$$

$$\therefore \mathbf{r}_{E^{\bullet}} = \mathbf{r}_2 - \mathbf{r}_3 - \mathbf{r}_4$$

Velocidades absolutas:

$$\mathbf{r}_1 = k_1 \mathbf{C}_B$$

$$\mathbf{r}_2 = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}}$$

$$\mathbf{r}_3 = k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B$$

$$\mathbf{r}_4 = k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C$$

$$\mathbf{r}_5 = k_5 \mathbf{C}_{D^{\bullet}}^2$$

$$\therefore \mathbf{r}_{E^{\bullet}} = k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}} - k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B - k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C = 0$$

$$\mathbf{r}_{D^{\bullet}} = 0$$

$$\Rightarrow \mathbf{r}_{D^{\bullet}} + \mathbf{r}_{E^{\bullet}} = 0$$

$$\mathbf{r}_{E^{\bullet}} = 0$$

$$2k_1 \mathbf{C}_B - \cancel{k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}}} + \cancel{k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B} + \cancel{k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C} - \\ - 2k_5 \mathbf{C}_{D^{\bullet}}^2 + \cancel{k_2 \mathbf{C}_A \mathbf{C}_{D^{\bullet}}} - \cancel{k_3 \mathbf{C}_{E^{\bullet}} \mathbf{C}_B} - \cancel{k_4 \mathbf{C}_{E^{\bullet}} \mathbf{C}_C} = 0$$

$$\therefore 2k_1 \mathbf{C}_B - 2k_5 \mathbf{C}_{D^{\bullet}}^2 = 0$$

$$\therefore \mathbf{C}_{D^{\bullet}} = \left(\frac{k_1}{k_5} \mathbf{C}_B \right)^{1/2}$$

$$\therefore r_{E^\bullet} = k_2 C_A C_{D^\bullet} - k_3 C_{E^\bullet} C_B - k_4 C_{E^\bullet} C_C = 0$$

$$\therefore \quad r_{E^\bullet} = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - k_3 C_{E^\bullet} C_B - k_4 C_{E^\bullet} C_C \, = \, 0$$

$$\therefore r_E = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - k_3 C_E C_B - k_4 C_E C_C = 0$$

$$\therefore r_E = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - (k_3 C_B + k_4 C_C) C_E = 0$$

$$\therefore \quad r_{E^\bullet} = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - k_3 C_{E^\bullet} C_B - k_4 C_{E^\bullet} C_C = 0$$

$$\therefore \quad r_{E^\bullet} = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - (k_3 C_B + k_4 C_C) C_{E^\bullet} = 0$$

$$\therefore \quad C_{E^\bullet} = \frac{k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2}}{k_3 C_B + k_4 C_C}$$

$$\therefore r_E = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - k_3 C_E C_B - k_4 C_E C_C = 0$$

$$\therefore r_E = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - (k_3 C_B + k_4 C_C) C_E = 0$$

$$\therefore C_E = \frac{k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2}}{k_3 C_B + k_4 C_C} = \frac{k_2 \left(\frac{k_1}{k_5} \right)^{1/2} C_A C_B^{1/2}}{k_3 C_B + k_4 C_C}$$

$$\therefore r_E = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - k_3 C_E C_B - k_4 C_E C_C = 0$$

$$\therefore r_E = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - (k_3 C_B + k_4 C_C) C_E = 0$$

$$\therefore C_E = \frac{k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2}}{k_3 C_B + k_4 C_C} = \frac{k_2 \left(\frac{k_1}{k_5} \right)^{1/2} C_A C_B^{1/2}}{k_3 C_B + k_4 C_C}$$

$$r_A = \left| -k_2 C_A C_D + k_4 C_E C_C \right|$$

$$\therefore r_E = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - k_3 C_E C_B - k_4 C_E C_C = 0$$

$$\therefore r_E = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - (k_3 C_B + k_4 C_C) C_E = 0$$

$$\therefore C_E = \frac{k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2}}{k_3 C_B + k_4 C_C} = \frac{k_2 \left(\frac{k_1}{k_5} \right)^{1/2} C_A C_B^{1/2}}{k_3 C_B + k_4 C_C}$$

$$r_A = -k_2 C_A C_D + k_4 C_E C_C$$

$$0 = k_2 C_A C_D - k_4 C_E C_C - k_3 C_E C_B = r_E$$

$$\therefore r_E = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - k_3 C_E C_B - k_4 C_E C_C = 0$$

$$\therefore r_E = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - (k_3 C_B + k_4 C_C) C_E = 0$$

$$\therefore C_E = \frac{k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2}}{k_3 C_B + k_4 C_C} = \frac{k_2 \left(\frac{k_1}{k_5} \right)^{1/2} C_A C_B^{1/2}}{k_3 C_B + k_4 C_C}$$

$$r_A = -k_2 C_A C_D + k_4 C_E C_C$$

$$0 = k_2 C_A C_D - k_4 C_E C_C - k_3 C_E C_B = r_E$$

$$\therefore r_E = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - k_3 C_E C_B - k_4 C_E C_C = 0$$

$$\therefore r_E = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - (k_3 C_B + k_4 C_C) C_E = 0$$

$$\therefore C_E = \frac{k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2}}{k_3 C_B + k_4 C_C} = \frac{k_2 \left(\frac{k_1}{k_5} \right)^{1/2} C_A C_B^{1/2}}{k_3 C_B + k_4 C_C}$$

$$r_A = \cancel{-k_2 C_A C_D} + k_4 C_E C_C$$

$$0 = \cancel{k_2 C_A C_D} - k_4 C_E C_C - k_3 C_E C_B = r_E$$

$$\therefore r_E = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - k_3 C_E \cdot C_B - k_4 C_E \cdot C_C = 0$$

$$\therefore r_E = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - (k_3 C_B + k_4 C_C) C_E = 0$$

$$\therefore C_E = \frac{k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2}}{k_3 C_B + k_4 C_C} = \frac{k_2 \left(\frac{k_1}{k_5} \right)^{1/2} C_A C_B^{1/2}}{k_3 C_B + k_4 C_C}$$

$$r_A = \cancel{-k_2 C_A C_D} + \cancel{k_4 C_E \cdot C_C}$$

$$0 = \cancel{k_2 C_A C_D} - \cancel{k_4 C_E \cdot C_C} - k_3 C_E \cdot C_B = r_E$$

$$\therefore r_E = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - k_3 C_E \cdot C_B - k_4 C_E \cdot C_C = 0$$

$$\therefore r_E = k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2} - (k_3 C_B + k_4 C_C) C_E = 0$$

$$\therefore C_E = \frac{k_2 C_A \left(\frac{k_1}{k_5} C_B \right)^{1/2}}{k_3 C_B + k_4 C_C} = \frac{k_2 \left(\frac{k_1}{k_5} \right)^{1/2} C_A C_B^{1/2}}{k_3 C_B + k_4 C_C}$$

$$\begin{aligned}
r_A &= \cancel{-k_2 C_A C_D} + \cancel{k_4 C_E \cdot C_C} \\
0 &= \cancel{k_2 C_A C_D} - \cancel{k_4 C_E \cdot C_C} - k_3 C_E \cdot C_B = r_E
\end{aligned}$$

$$r_A = -k_3 C_E \cdot C_B$$

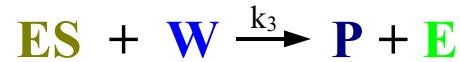
$$\therefore \quad r_A = - k_3 C_{E^\bullet} C_B$$

$$\therefore \quad r_A = -k_3 \quad \frac{k_2 \left(\frac{k_1}{k_5} \right)^{1/2} C_A C_B^{1/2}}{k_3 C_B + k_4 C_C} \quad C_B$$

$$\therefore \quad r_A = -k_3 \quad \frac{k_2 \left(\frac{k_1}{k_5} \right)^{1/2} C_A C_B^{1/2}}{\underbrace{k_3 C_B + k_4 C_C}_{C_E \bullet}} \quad C_B$$

Exemplo 2:

Reacção enzimática



E – enzima; **S** – substrato; **W** – água; **P** – produto; **ES** – complexo enzima-substrato.

Exemplo 2:

Reacção enzimática



E – enzima; **S** – substrato; **W** – água; **P** – produto; **ES** – complexo enzima-substrato.

$$r_S = r_{S1} + r_{S2} + r_{S3}$$

Exemplo 2:



Reacção enzimática



E – enzima; **S** – substrato; **W** – água; **P** – produto; **ES** – complexo enzima-substrato.

$$r_S = r_{S1} + r_{S2} + r_{S3}$$

$$\therefore r_S = v_{S1} r_1 + v_{S2} r_2 + v_{S3} r_3$$

Exemplo 2:



Reacção enzimática



E – enzima; **S** – substrato; **W** – água; **P** – produto; **ES** – complexo enzima-substrato.

$$r_S = r_{S1} + r_{S2} + r_{S3}$$

$$\therefore r_S = \underbrace{v_{S1}}_{-1} r_1 + v_{S2} r_2 + v_{S3} r_3$$

Exemplo 2:



Reacção enzimática



E – enzima; **S** – substrato; **W** – água; **P** – produto; **ES** – complexo enzima-substrato.

$$r_S = r_{S1} + r_{S2} + r_{S3}$$

$$\therefore r_S = \underbrace{v_{S1}}_{-1} r_1 + \underbrace{v_{S2}}_{+1} r_2 + v_{S3} r_3$$

Exemplo 2:



Reacção enzimática



E – enzima; **S** – substrato; **W** – água; **P** – produto; **ES** – complexo enzima-substrato.

$$r_S = r_{S1} + r_{S2} + r_{S3}$$

$$\therefore r_S = \underbrace{v_{S1}}_{-1} r_1 + \underbrace{v_{S2}}_{+1} r_2 + \underbrace{v_{S3}}_0 r_3$$

Exemplo 2:



Reacção enzimática



E – enzima; **S** – substrato; **W** – água; **P** – produto; **ES** – complexo enzima-substrato.

$$r_S = r_{S1} + r_{S2} + r_{S3}$$

$$\therefore r_S = \underbrace{v_{S1}}_{-1} r_1 + \underbrace{v_{S2}}_{+1} r_2 + \underbrace{v_{S3}}_0 r_3 = -r_1 + r_2$$

Exemplo 2:



Reacção enzimática



E – enzima; **S** – substrato; **W** – água; **P** – produto; **ES** – complexo enzima-substrato.

$$r_S = r_{S1} + r_{S2} + r_{S3}$$

$$\therefore r_S = \underbrace{v_{S1}}_{-1} r_1 + \underbrace{v_{S2}}_{+1} r_2 + \underbrace{v_{S3}}_0 r_3 = -r_1 + r_2$$

Exemplo 2:



Reacção enzimática



E – enzima; **S** – substrato; **W** – água; **P** – produto; **ES** – complexo enzima-substrato.

**Velocidades absolutas
dos passos elementares:**

$$r_S = r_{S1} + r_{S2} + r_{S3}$$

$$\therefore r_S = \underbrace{v_{S1}}_{-1} r_1 + \underbrace{v_{S2}}_{+1} r_2 + \underbrace{v_{S3}}_0 r_3 = -r_1 + r_2$$

Exemplo 2:



Reacção enzimática



E – enzima; **S** – substrato; **W** – água; **P** – produto; **ES** – complexo enzima-substrato.

**Velocidades absolutas
dos passos elementares:**

$$r_S = r_{S1} + r_{S2} + r_{S3}$$

$$r_1 = k_1 C_E C_S$$

$$\therefore r_S = \underbrace{v_{S1}}_{-1} r_1 + \underbrace{v_{S2}}_{+1} r_2 + \underbrace{v_{S3}}_0 r_3 = -r_1 + r_2$$

Exemplo 2:



Reacção enzimática



E – enzima; **S** – substrato; **W** – água; **P** – produto; **ES** – complexo enzima-substrato.

**Velocidades absolutas
dos passos elementares:**

$$r_S = r_{S1} + r_{S2} + r_{S3}$$

$$r_1 = k_1 C_E C_S$$

$$\therefore r_S = \underbrace{v_{S1}}_{-1} r_1 + \underbrace{v_{S2}}_{+1} r_2 + \underbrace{v_{S3}}_0 r_3 = -r_1 + r_2$$

$$r_2 = k_2 C_{ES}$$

Exemplo 2:

Reacção enzimática



E – enzima; **S** – substrato; **W** – água; **P** – produto; **ES** – complexo enzima-substrato.

**Velocidades absolutas
dos passos elementares:**

$$r_S = r_{S1} + r_{S2} + r_{S3}$$

$$r_1 = k_1 C_E C_S$$

$$\therefore r_S = \underbrace{v_{S1}}_{-1} r_1 + \underbrace{v_{S2}}_{+1} r_2 + \underbrace{v_{S3}}_0 r_3 = -r_1 + r_2$$

$$r_2 = k_2 C_{ES}$$

$$r_3 = k_3 C_{ES} C_W$$

Exemplo 2:

Reacção enzimática



E – enzima; **S** – substrato; **W** – água; **P** – produto; **ES** – complexo enzima-substrato.

**Velocidades absolutas
dos passos elementares:**

$$r_S = r_{S1} + r_{S2} + r_{S3}$$

$$r_1 = k_1 C_E C_S$$

$$\therefore r_S = \underbrace{v_{S1}}_{-1} r_1 + \underbrace{v_{S2}}_{+1} r_2 + \underbrace{v_{S3}}_0 r_3 = -r_1 + r_2$$

$$r_2 = k_2 C_{ES}$$

$$\therefore r_S = -k_1 C_E C_S + k_2 C_{ES}$$

$$r_3 = k_3 C_{ES} C_W$$

Velocidades absolutas dos passos elementares:

$$r_1 = k_1 C_E C_S$$

$$r_2 = k_2 C_{ES}$$

$$r_3 = k_3 C_{ES} C_W$$



**Velocidades absolutas
dos passos elementares:**

$$r_1 = k_1 C_E C_S$$

$$r_2 = k_2 C_{ES}$$

$$r_3 = k_3 C_{ES} C_W$$

$$r_{ES} = r_{ES1} + r_{ES2} + r_{ES3}$$



**Velocidades absolutas
dos passos elementares:**

$$r_1 = k_1 C_E C_S$$

$$r_2 = k_2 C_{ES}$$

$$r_3 = k_3 C_{ES} C_W$$

$$r_{ES} = r_{ES1} + r_{ES2} + r_{ES3}$$

$$\therefore r_{ES} = \underbrace{v_{ES1}}_{+1} r_1 + \underbrace{v_{ES2}}_{-1} r_2 + \underbrace{v_{ES3}}_{-1} r_3 = r_1 - r_2 - r_3$$



**Velocidades absolutas
dos passos elementares:**

$$r_1 = k_1 C_E C_S$$

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$$\therefore r_{ES} = \underbrace{v_{ES1}}_{+1} r_1 + \underbrace{v_{ES2}}_{-1} r_2 + \underbrace{v_{ES3}}_{-1} r_3 = r_1 - r_2 - r_3$$

$$\therefore r_{ES} = k_1 C_E C_S - k_2 C_{ES} - k_3 C_{ES} C_W$$



Velocidades absolutas dos passos elementares:

$$r_1 = k_1 C_E C_S$$

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$$\therefore r_{ES} = k_1 C_E C_S - k_2 C_{ES} - k_3 C_{ES} C_W$$

$$\therefore r_{ES} = k_1 C_E C_S - k_2 C_{ES} - k_3 C_{ES} C_W = 0$$



Velocidades absolutas dos passos elementares:

$$r_1 = k_1 C_E C_S$$

$$r_2 = k_2 C_{ES}$$

$$r_3 = k_3 C_{ES} C_W$$

$$C_{Et} = C_E + C_{ES}$$

$$r_{ES} = r_{ES1} + r_{ES2} + r_{ES3}$$

$$\therefore r_{ES} = \underbrace{v_{ES1}}_{+1} r_1 + \underbrace{v_{ES2}}_{-1} r_2 + \underbrace{v_{ES3}}_{-1} r_3 = r_1 - r_2 - r_3$$

$$\therefore r_{ES} = k_1 C_E C_S - k_2 C_{ES} - k_3 C_{ES} C_W$$

$$\therefore r_{ES} = k_1 C_E C_S - k_2 C_{ES} - k_3 C_{ES} C_W = 0$$



**Velocidades absolutas
dos passos elementares:**

$$r_1 = k_1 C_E C_S$$

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$$C_{Et} = C_E + C_{ES}$$

$$r_{ES} = r_{ES1} + r_{ES2} + r_{ES3}$$

$$\therefore r_{ES} = \underbrace{v_{ES1}}_{+1} r_1 + \underbrace{v_{ES2}}_{-1} r_2 + \underbrace{v_{ES3}}_{-1} r_3 = r_1 - r_2 - r_3$$

$$\therefore r_{ES} = k_1 C_E C_S - k_2 C_{ES} - k_3 C_{ES} C_W$$

$$\therefore r_{ES} = k_1 C_E C_S - k_2 C_{ES} - k_3 C_{ES} C_W = 0$$

$$\therefore C_E = C_{Et} - C_{ES}$$



Velocidades absolutas dos passos elementares:

$$r_1 = k_1 C_E C_S$$

$$r_2 = k_2 C_{ES}$$

$$r_3 = k_3 C_{ES} C_W$$

$$C_{Et} = C_E + C_{ES}$$

$$\therefore C_E = C_{Et} - C_{ES}$$

$$r_{ES} = r_{ES1} + r_{ES2} + r_{ES3}$$

$$\therefore r_{ES} = \underbrace{v_{ES1}}_{+1} r_1 + \underbrace{v_{ES2}}_{-1} r_2 + \underbrace{v_{ES3}}_{-1} r_3 = r_1 - r_2 - r_3$$

$$\therefore r_{ES} = k_1 C_E C_S - k_2 C_{ES} - k_3 C_{ES} C_W$$

$$\therefore r_{ES} = k_1 C_E C_S - k_2 C_{ES} - k_3 C_{ES} C_W = 0$$

$$\Rightarrow r_{ES} = k_1 (C_{Et} - C_{ES}) C_S - k_2 C_{ES} - k_3 C_{ES} C_W = 0$$



Velocidades absolutas dos passos elementares:

$$r_1 = k_1 C_E C_S$$

$$r_2 = k_2 C_{ES}$$

$$r_3 = k_3 C_{ES} C_W$$

$$C_{Et} = C_E + C_{ES}$$

$$\therefore C_E = C_{Et} - C_{ES}$$

$$r_{ES} = r_{ES1} + r_{ES2} + r_{ES3}$$

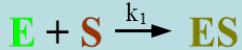
$$\therefore r_{ES} = \underbrace{v_{ES1}}_{+1} r_1 + \underbrace{v_{ES2}}_{-1} r_2 + \underbrace{v_{ES3}}_{-1} r_3 = r_1 - r_2 - r_3$$

$$\therefore r_{ES} = k_1 C_E C_S - k_2 C_{ES} - k_3 C_{ES} C_W$$

$$\therefore r_{ES} = k_1 C_E C_S - k_2 C_{ES} - k_3 C_{ES} C_W = 0$$

$$\Rightarrow r_{ES} = k_1 (C_{Et} - C_{ES}) C_S - k_2 C_{ES} - k_3 C_{ES} C_W = 0$$

$$\therefore r_{ES} = k_1 C_S C_{Et} - k_1 C_S C_{ES} - k_2 C_{ES} - k_3 C_{ES} C_W = 0$$



Velocidades absolutas dos passos elementares:

$$r_1 = k_1 C_E C_S$$

$$r_2 = k_2 C_{ES}$$

$$r_3 = k_3 C_{ES} C_W$$

$$C_{Et} = C_E + C_{ES}$$

$$\therefore C_E = C_{Et} - C_{ES}$$

$$r_{ES} = r_{ES1} + r_{ES2} + r_{ES3}$$

$$\therefore r_{ES} = \underbrace{v_{ES1}}_{+1} r_1 + \underbrace{v_{ES2}}_{-1} r_2 + \underbrace{v_{ES3}}_{-1} r_3 = r_1 - r_2 - r_3$$

$$\therefore r_{ES} = k_1 C_E C_S - k_2 C_{ES} - k_3 C_{ES} C_W$$

$$\therefore r_{ES} = k_1 C_E C_S - k_2 C_{ES} - k_3 C_{ES} C_W = 0$$

$$\Rightarrow r_{ES} = k_1 (C_{Et} - C_{ES}) C_S - k_2 C_{ES} - k_3 C_{ES} C_W = 0$$

$$\therefore r_{ES} = k_1 C_S C_{Et} - k_1 C_S C_{ES} - k_2 C_{ES} - k_3 C_{ES} C_W = 0$$

$$\therefore r_{ES} = k_1 C_S C_{Et} - (k_1 C_S + k_2 + k_3 C_W) C_{ES} = 0$$



Velocidades absolutas dos passos elementares:

$$r_1 = k_1 C_E C_S$$

$$r_2 = k_2 C_{ES}$$

$$r_3 = k_3 C_{ES} C_W$$

$$C_{Et} = C_E + C_{ES}$$

$$\therefore C_E = C_{Et} - C_{ES}$$

$$r_{ES} = r_{ES1} + r_{ES2} + r_{ES3}$$

$$\therefore r_{ES} = \underbrace{v_{ES1}}_{+1} r_1 + \underbrace{v_{ES2}}_{-1} r_2 + \underbrace{v_{ES3}}_{-1} r_3 = r_1 - r_2 - r_3$$

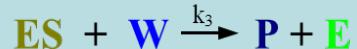
$$\therefore r_{ES} = k_1 C_E C_S - k_2 C_{ES} - k_3 C_{ES} C_W$$

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$$\Rightarrow r_{ES} = k_1 (C_{Et} - C_{ES}) C_S - k_2 C_{ES} - k_3 C_{ES} C_W = 0$$

$$\therefore r_{ES} = k_1 C_S C_{Et} - k_1 C_S C_{ES} - k_2 C_{ES} - k_3 C_{ES} C_W = 0$$

$$\therefore r_{ES} = k_1 C_S C_{Et} - (k_1 C_S + k_2 + k_3 C_W) C_{ES} = 0$$



$$\therefore C_{ES} = \frac{k_1 C_S C_{Et}}{k_1 C_S + k_2 + k_3 C_W}$$

$$\therefore r_S = -k_1 C_E C_S + k_2 C_{ES} = -k_1 (C_{Et} - C_{ES}) C_S + k_2 C_{ES}$$

$$\therefore r_S = -k_1 C_E C_S + k_2 C_{ES} = -k_1 (C_{Et} - C_{ES}) C_S + k_2 C_{ES}$$

$$r_S + \underbrace{r_{ES}}_{=0} = r_S$$

$$\therefore r_S = -k_1 C_E C_S + k_2 C_{ES} = -k_1 (C_{Et} - C_{ES}) C_S + k_2 C_{ES}$$

$$r_S + \underbrace{r_{ES}}_{=0} = r_S$$

$$\begin{aligned}\therefore r_S &= \underbrace{-k_1 C_S C_{Et} + k_1 C_S C_{ES}}_{r_S} + k_2 C_{ES} + \\ &+ \underbrace{k_1 C_S C_{Et} - k_1 C_S C_{ES} - k_2 C_{ES} - k_3 C_{ES} C_W}_{r_{ES}}\end{aligned}$$

$$\therefore r_S = -k_1 C_E C_S + k_2 C_{ES} = -k_1 (C_{Et} - C_{ES}) C_S + k_2 C_{ES}$$

$$r_S + \underbrace{r_{ES}}_{=0} = r_S$$

$$\begin{aligned}\therefore r_S &= \underbrace{-k_1 C_S C_{Et} + k_1 C_S C_{ES}}_{r_S} + k_2 C_{ES} + \\ &+ \underbrace{k_1 C_S C_{Et} - k_1 C_S C_{ES} - k_2 C_{ES} - k_3 C_{ES} C_W}_{r_{ES}}\end{aligned}$$

$$\therefore r_S = -k_3 C_{ES} C_W = -k_3 \frac{k_1 C_S C_{Et}}{k_1 C_S + k_2 + k_3 C_W} C_W$$

$$\therefore r_S = -k_1 C_E C_S + k_2 C_{ES} = -k_1 (C_{Et} - C_{ES}) C_S + k_2 C_{ES}$$

$$r_S + \underbrace{r_{ES}}_{=0} = r_S$$

$$\begin{aligned}\therefore r_S &= \underbrace{-k_1 C_S C_{Et} + k_1 C_S C_{ES}}_{r_S} + k_2 C_{ES} + \\ &+ \underbrace{k_1 C_S C_{Et} - k_1 C_S C_{ES} - k_2 C_{ES} - k_3 C_{ES} C_W}_{r_{ES}}\end{aligned}$$

$$\therefore r_S = -k_3 C_{ES} C_W = -k_3 \frac{k_1 C_S C_{Et}}{k_1 C_S + k_2 + k_3 C_W} C_W$$

$$C_W \gg C_{ES}, C_E \text{ e } C_S$$

$$\therefore r_S = -k_1 C_E C_S + k_2 C_{ES} = -k_1 (C_{Et} - C_{ES}) C_S + k_2 C_{ES}$$

$$r_S + \underbrace{r_{ES}}_{=0} = r_S$$

$$\begin{aligned}\therefore r_S &= \underbrace{-k_1 C_S C_{Et} + k_1 C_S C_{ES}}_{r_S} + k_2 C_{ES} + \\ &+ \underbrace{k_1 C_S C_{Et} - k_1 C_S C_{ES} - k_2 C_{ES} - k_3 C_{ES} C_W}_{r_{ES}}\end{aligned}$$

$$\therefore r_S = -k_3 C_{ES} C_W = -k_3 \frac{k_1 C_S C_{Et}}{k_1 C_S + k_2 + k_3 C_W} C_W$$

$$C_W \gg C_{ES}, C_E \text{ e } C_S \quad C_W \approx C^{te}$$

$$\therefore r_S = -k_1 C_E C_S + k_2 C_{ES} = -k_1 (C_{Et} - C_{ES}) C_S + k_2 C_{ES}$$

$$r_S + \underbrace{r_{ES}}_{=0} = r_S$$

$$\begin{aligned}\therefore r_S &= \underbrace{-k_1 C_S C_{Et} + k_1 C_S C_{ES} + k_2 C_{ES}}_{r_S} + \\ &+ \underbrace{k_1 C_S C_{Et} - k_1 C_S C_{ES} - k_2 C_{ES} - k_3 C_{ES} C_W}_{r_{ES}}\end{aligned}$$

$$\therefore r_S = -k_3 C_{ES} C_W = -k_3 \frac{k_1 C_S C_{Et}}{k_1 C_S + k_2 + k_3 C_W} C_W$$

$$C_W \gg C_{ES}, C_E \text{ e } C_S \quad C_W \approx C^{te} \quad \therefore k_3 C_W = k'$$

$$\therefore r_S = -k_1 C_E C_S + k_2 C_{ES} = -k_1 (C_{Et} - C_{ES}) C_S + k_2 C_{ES}$$

$$r_S + \underbrace{r_{ES}}_{=0} = r_S$$

$$\begin{aligned}\therefore r_S &= \underbrace{-k_1 C_S C_{Et} + k_1 C_S C_{ES} + k_2 C_{ES}}_{r_S} + \\ &+ \underbrace{k_1 C_S C_{Et} - k_1 C_S C_{ES} - k_2 C_{ES} - k_3 C_{ES} C_W}_{r_{ES}}\end{aligned}$$

$$\therefore r_S = -k_3 C_{ES} C_W = -k_3 \frac{k_1 C_S C_{Et}}{k_1 C_S + k_2 + k_3 C_W} C_W$$

$$C_W \gg C_{ES}, C_E \text{ e } C_S \quad C_W \approx C^{te} \quad \therefore k_3 C_W = k'$$

$$\therefore r_S = -\frac{k' k_1 C_S C_{Et}}{k_1 C_S + k_2 + k'} = -\frac{k' C_{Et} C_S}{C_S + \frac{k_2 + k'}{k_1}}$$

$$\therefore r_S = -k_1 C_E C_S + k_2 C_{ES} = -k_1 (C_{Et} - C_{ES}) C_S + k_2 C_{ES}$$

$$r_S + \underbrace{r_{ES}}_{=0} = r_S$$

$$\begin{aligned}\therefore r_S &= \underbrace{-k_1 C_S C_{Et} + k_1 C_S C_{ES} + k_2 C_{ES}}_{r_S} + \\ &+ \underbrace{k_1 C_S C_{Et} - k_1 C_S C_{ES} - k_2 C_{ES} - k_3 C_{ES} C_W}_{r_{ES}}\end{aligned}$$

$$\therefore r_S = -k_3 C_{ES} C_W = -k_3 \frac{k_1 C_S C_{Et}}{k_1 C_S + k_2 + k_3 C_W} C_W$$

$$C_W \gg C_{ES}, C_E \text{ e } C_S \quad C_W \approx C^{te} \quad \therefore k_3 C_W = k'$$

$$K_M = \frac{k_2 + k'}{k_1}$$

$$\therefore r_S = -\frac{k' k_1 C_S C_{Et}}{k_1 C_S + k_2 + k'} = -\frac{k' C_{Et} C_S}{C_S + \frac{k_2 + k'}{k_1}}$$

$$\therefore r_S = -k_1 C_E C_S + k_2 C_{ES} = -k_1 (C_{Et} - C_{ES}) C_S + k_2 C_{ES}$$

$$r_S + \underbrace{r_{ES}}_{=0} = r_S$$

$$\begin{aligned}\therefore r_S &= \underbrace{-k_1 C_S C_{Et} + k_1 C_S C_{ES} + k_2 C_{ES}}_{r_S} + \\ &+ \underbrace{k_1 C_S C_{Et} - k_1 C_S C_{ES} - k_2 C_{ES} - k_3 C_{ES} C_W}_{r_{ES}}\end{aligned}$$

$$\therefore r_S = -k_3 C_{ES} C_W = -k_3 \frac{k_1 C_S C_{Et}}{k_1 C_S + k_2 + k_3 C_W} C_W$$

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$$K_M = \frac{k_2 + k'}{k_1}$$

$$\therefore r_S = -\frac{k' k_1 C_S C_{Et}}{k_1 C_S + k_2 + k'} = -\frac{k' C_{Et} C_S}{C_S + \frac{k_2 + k'}{k_1}}$$

Constante de Michaelis-Menten

Equação de Michaelis-Menten

$$r_S = -\frac{k' C_{Et} C_S}{C_S + K_M}$$

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Situações limite:

Equação de Michaelis-Menten

$$r_S = -\frac{k' C_{Et} C_S}{C_S + K_M}$$

Situações limite:

Caso 1:

Equação de Michaelis-Menten

$$r_S = -\frac{k' C_{Et} C_S}{C_S + K_M}$$

Situações limite:

Caso 1: $C_S \ll K_M \Rightarrow C_S + K_M \approx K_M$

Equação de Michaelis-Menten

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Situações limite:

Caso 1: $C_S \ll K_M \Rightarrow C_S + K_M \approx K_M$

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Equação de Michaelis-Menten

$$r_S = -\frac{k' C_{Et} C_S}{C_S + K_M}$$

Situações limite:

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(1^a ordem)

Equação de Michaelis-Menten

$$r_S = -\frac{k' C_{Et} C_S}{C_S + K_M}$$

Situações limite:

Caso 1: $C_S \ll K_M \Rightarrow C_S + K_M \approx K_M \quad \therefore r_S = -\frac{k' C_{Et} C_S}{K_M} = k'' C_S$
(1^a ordem)

Caso 2:

Equação de Michaelis-Menten

$$r_S = -\frac{k' C_{Et} C_S}{C_S + K_M}$$

Situações limite:

Caso 1: $C_S \ll K_M \Rightarrow C_S + K_M \approx K_M \quad \therefore r_S = -\frac{k' C_{Et} C_S}{K_M} = k'' C_S$
(1^a ordem)

Caso 2: $C_S \gg K_M \Rightarrow C_S + K_M \approx C_S$

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Caso 2: $C_S \gg K_M \Rightarrow C_S + K_M \approx C_S \quad \therefore r_S = -\frac{k' C_{Et} C_S}{C_S} = -k' C_{Et} = -v_{máx}$

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$$r_S = -\frac{k' C_{Et} C_S}{C_S + K_M}$$

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Caso 2: $C_S \gg K_M \Rightarrow C_S + K_M \approx C_S \quad \therefore r_S = -\frac{k' C_{Et} C_S}{C_S} = -k' C_{Et} = -v_{máx}$
(ordem zero)

Equação de Michaelis-Menten

$$r_S = -\frac{k' C_{Et} C_S}{C_S + K_M}$$

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