МОН, LVIII НАЦИОНАЛНА ОЛИМПИАДА ПО ХИМИЯ И ОПАЗВАНЕ НА ОКОЛНАТА СРЕДА

Подборно контролно (08 - 09 май 2026 г.)

ПРИМЕРНИ РЕШЕНИЯ НА ТЕОРЕТИЧНИТЕ ЗАДАЧИ

Задача 1

1. $K_{S1} = \frac{[E][S1]}{[ES1]}$ $K_{S2} = \frac{[E][S2]}{[ES2]}$

$K'_{S1} = \frac{[ES2][S1]}{[ES1S2]}$ $K'_{S2} = \frac{[ES1][S2]}{[ES1S2]}$

2. $c = \frac{n}{V}$; за обем 1 L и $n = \frac{m}{M} = \frac{V\rho}{M}$

$c = \frac{1\times1000}{18}$ = **55, 6 mol/dm^3**

3. Когато [S2] → ∞, $K_{S2}/[S2] \to 0$ и $K'_{S1}K'_{S2}/([S1][S2]) \to 0$.

Тогава ур. (*) има следния вид: $\boldsymbol{v = \frac{V_{max}}{1 + K_{S1}/[S1]}}$

4. Когато [S1]→0, $K_{S1}/[S1] \to \infty$ и $K_{S1}/[S1] >> 1$, тогава $v = \frac{V_{max}}{K_{S1}/[S1]}$

Ур. (*) има следния вид: $\boldsymbol{v = \frac{V_{max}[S1]}{K_{S1}}}$

Порядъкът на реакцията по отношение на S1 е **първи.**

5. Когато [S1]→∞, $K_{S1}/[S1] \to 0$ и $K_{S1}/[S1] << 1$,

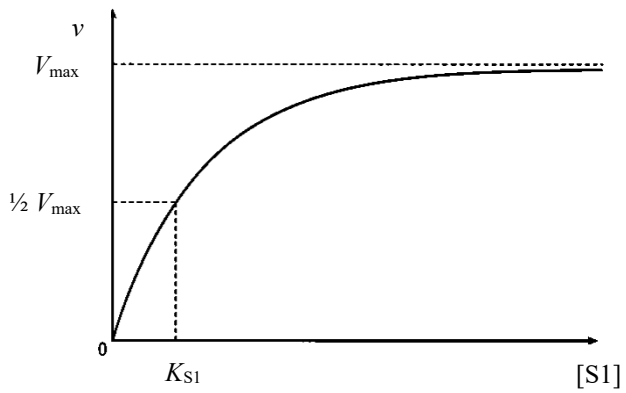
Тогава ур. (*) има следния вид: $\boldsymbol{v = V_{max}}$

Порядъкът на реакцията по отношение на S1 е **нулев.**

6. Висок афинитет съответства на ниска стойност на K_{S1}.

Когато [S1] = K_{S1}, $\boldsymbol{v = \frac{V_{max}}{1 + K_{S1}/[S1]} = \frac{1}{2}V_{max}}$

7.



8. Квазистационарно приближение:

$$\frac{d[\mathrm{ES}]}{dt} = k_1[\mathrm{E}][\mathrm{S}] - k_{-1}[\mathrm{ES}] - k_2[\mathrm{ES}] = 0$$

$$[\mathrm{ES}] = \frac{k_1[\mathrm{E}][\mathrm{S}]}{k_{-1}+k_2} \qquad \text{ур. (**)}$$

$$[\mathrm{E}]_0 = [\mathrm{E}] + [\mathrm{ES}] \qquad [\mathrm{E}] = [\mathrm{E}]_0 - [\mathrm{ES}] \qquad \text{ур. (***)}$$

От ур. (**) и ур. (***) следва:

$$[\mathrm{ES}](k_{-1} + k_2) = k_1[\mathrm{E}]_0[\mathrm{S}] - k_1[\mathrm{ES}][\mathrm{S}]$$

$$[\mathrm{ES}] = \frac{k_1[\mathrm{E}]_0[\mathrm{S}]}{k_1[\mathrm{S}]+k_{-1}+k_2} = \frac{[\mathrm{E}]_0[\mathrm{S}]}{[\mathrm{S}]+\frac{k_{-1}+k_2}{k_1}} \qquad [\mathrm{ES}] = \frac{[\mathrm{E}]_0[\mathrm{S}]}{[\mathrm{S}]+K_\mathrm{M}}$$

$$v = \frac{d[\mathrm{P}]}{dt} = k_2[\mathrm{ES}]$$

Понеже принципно $[\mathrm{E}]_0 \ll [\mathrm{S}]_0$, то $[\mathrm{S}] \approx [\mathrm{S}]_0$,

$$\boldsymbol{v = \frac{d[\mathrm{P}]}{dt} = \frac{k_2[\mathrm{E}]_0[\mathrm{S}]_0}{[\mathrm{S}]_0+K_\mathrm{M}}} \qquad \text{ур. (****)}$$

9. За висока концентрация на субстрата $[\mathrm{S}] \gg K_\mathrm{M}$

$$v = \frac{d[\mathrm{P}]}{dt} = \boldsymbol{k_2[\mathrm{E}]_0 = V_{max}}$$

$$k_2 = \frac{V_\mathrm{max}}{[\mathrm{E}]_0} = \frac{3{,}0\times10^{-6}}{1{,}5\times10^{-9}} = \mathbf{2{,}0\times10^{3}\ s^{-1}}$$

10. От ур. (****) следва:

$$v = \frac{k_2[\mathrm{E}]_0[\mathrm{S}]_0}{[\mathrm{S}]_0+K_\mathrm{M}} = \frac{2{,}0\times10^{3}\times1{,}5\times10^{-9}\times1{,}0\times10^{-4}}{1{,}0\times10^{-4}+5{,}0\times10^{-5}} = \mathbf{2{,}0\times10^{-6}\ mol/(dm^3\ s)}$$

11. $K_\mathrm{M} = \frac{k_{-1}+k_2}{k_1}$

Равновесието в първия етап се установява бързо, т.е. $k_{-1} \gg k_2$ и k_2 може да се пренебрегне.

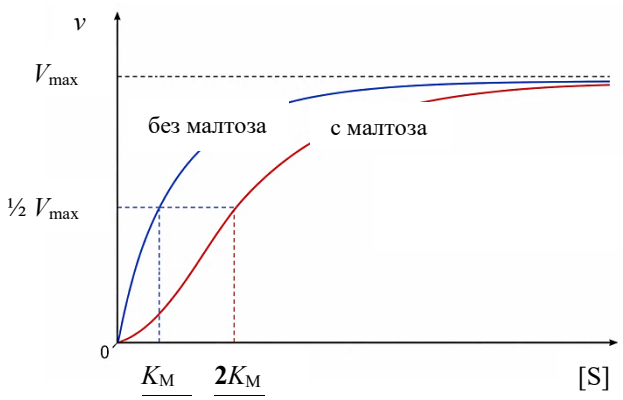
$K_\mathrm{M} = \frac{k_{-1}}{k_1} = 5{,}0\times10^{-5}$ mol/dm^3

Равновесната константа на образуване на ензим-субстратния комплекс е:

$$K = \frac{k_1}{k_{-1}} = \frac{1}{5{,}0\times10^{-5}} = \mathbf{2{,}0\times10^{4}}$$

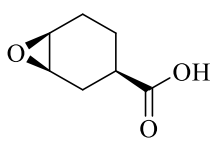
12. **б)** Малтозата действа като **конкурентен инхибитор**.

13.

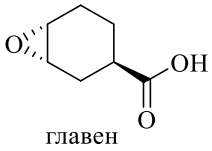


Задача 2

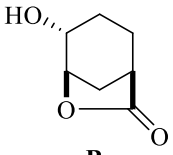
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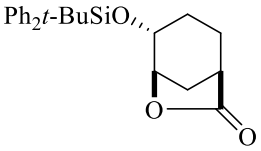
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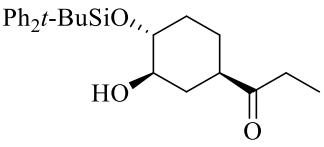
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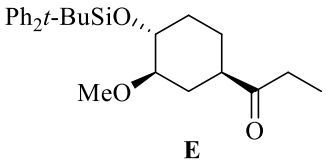
B_1



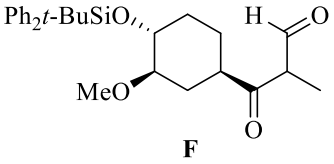
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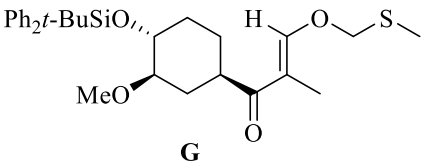
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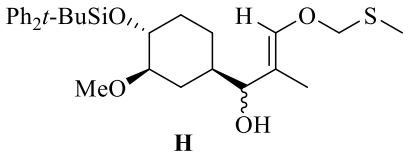
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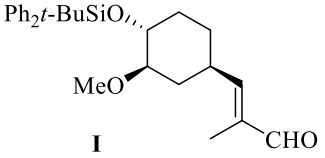
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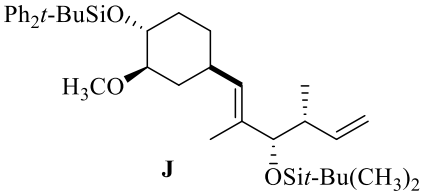
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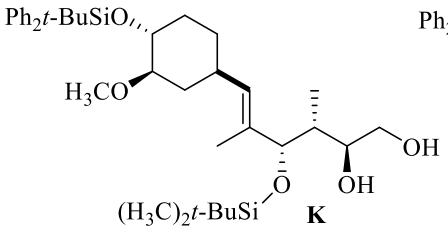
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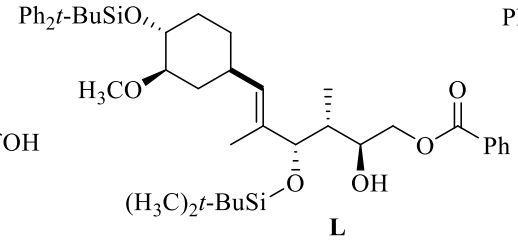
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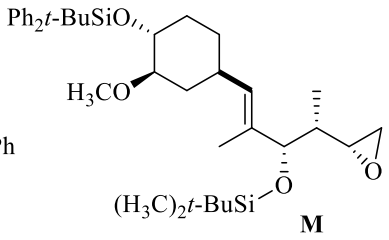
J



K

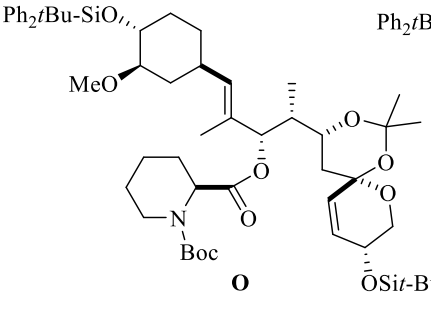


L

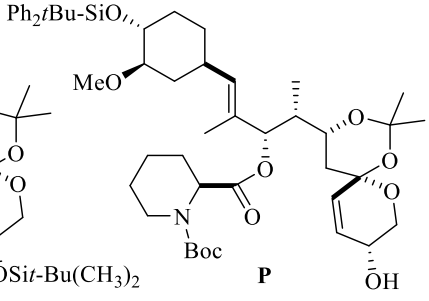


M

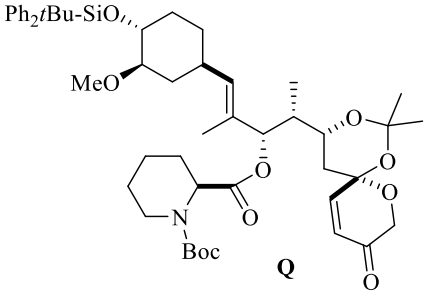
Схема 2:



O

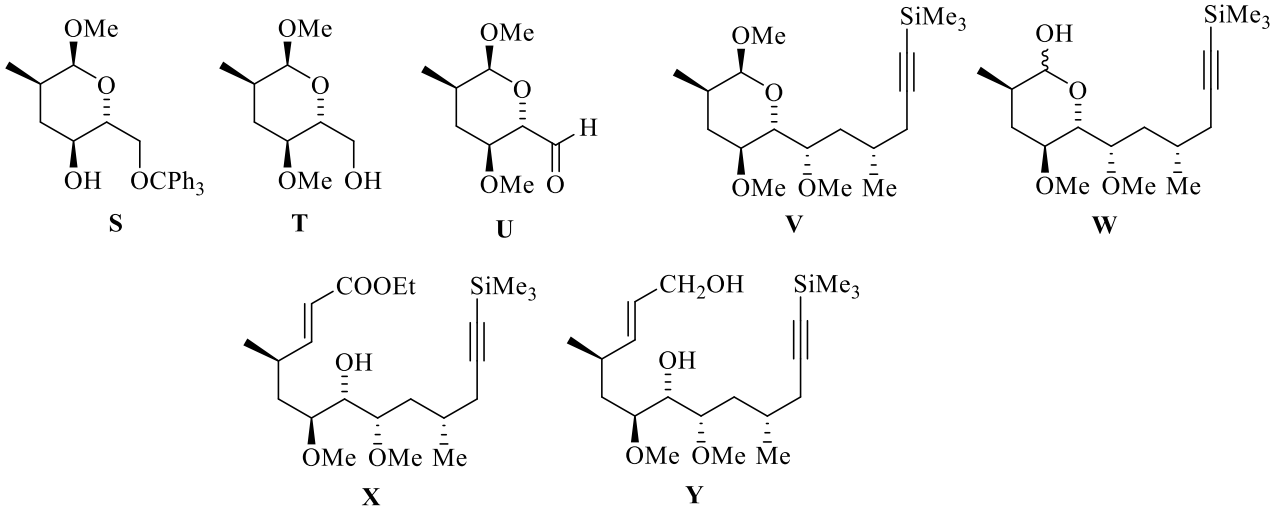


P

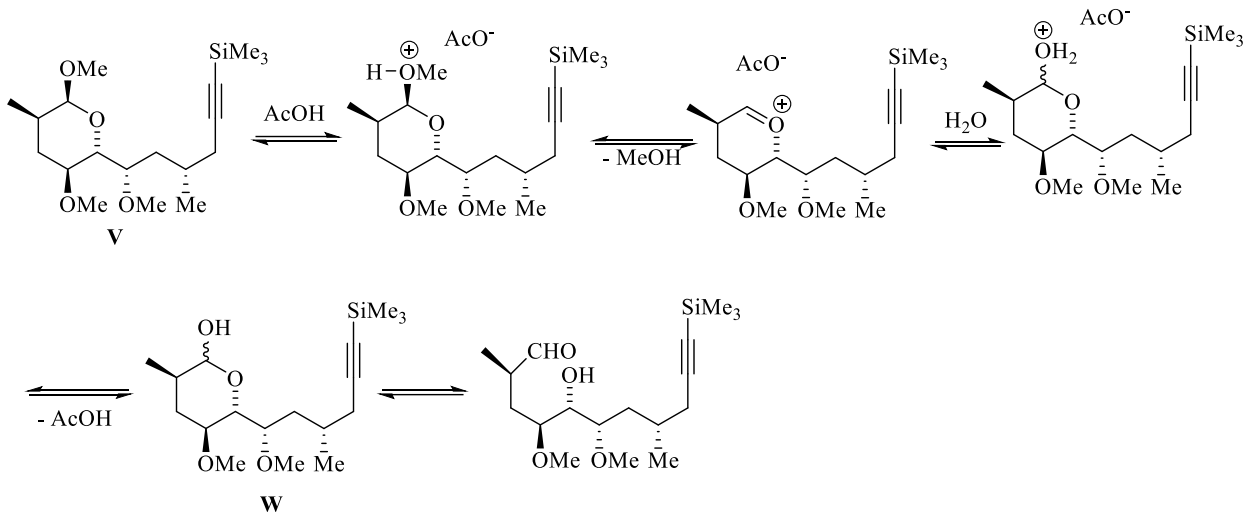


Q

Схема 3:



2. Механизъм на прехода **V → W:**



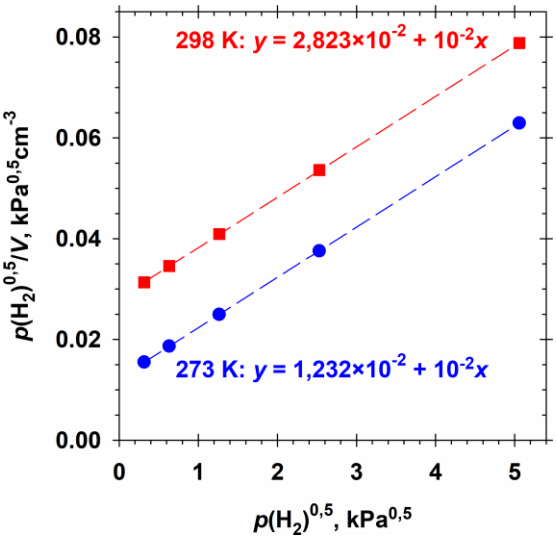
Задача 3

1. $$\frac{\theta^2}{(1-\theta)^2} = K_{\text{ads}}p(\text{H}_2) \Rightarrow \frac{\theta}{(1-\theta)} = \sqrt{K_{\text{ads}}p(\text{H}_2)} \Rightarrow \theta = \frac{V}{V_\infty} = \frac{\sqrt{K_{\text{ads}}p(\text{H}_2)}}{1+\sqrt{K_{\text{ads}}p(\text{H}_2)}}$$

2. $$\frac{V_\infty}{V} = \frac{1+\sqrt{K_{\text{ads}}p(\text{H}_2)}}{\sqrt{K_{\text{ads}}p(\text{H}_2)}} = \frac{1}{\sqrt{K_{\text{ads}}p(\text{H}_2)}} + 1 \Rightarrow \frac{\sqrt{p(\text{H}_2)}}{V} = \frac{1}{\sqrt{K_{\text{ads}}}V_\infty} + \frac{1}{V_\infty}\sqrt{p(\text{H}_2)}$$

3. Данни за адсорбцията на H_2 върху Cu при 273 K и 298 K са представени по-долу таблично и графично във вида $\sqrt{p(\text{H}_2)}/V$ като функция на $\sqrt{p(\text{H}_2)}$.

$\sqrt{p(\text{H}_2)}$, **kPa^{0,5}**	$\sqrt{p(\text{H}_2)}/V$, **kPa^{0,5}cm^{-3}**	
	при 273 K	**при 298 K**
0,32	0,0155	0,0313
0,63	0,0187	0,0346
1,26	0,0249	0,0409
2,53	0,0376	0,0536
5,06	0,0629	0,0788



$K_{\text{ads}}(273\text{ K}) = [10^{-2}/(1{,}232\times10^{-2})]^2 = 0{,}659\text{ kPa}^{-1}$

$K_{\text{ads}}(298\text{ K}) = [10^{-2}/(2{,}823\times10^{-2})]^2 = 0{,}125\text{ kPa}^{-1}$

$$\Delta_\text{r}H^\circ = -\frac{R\ln\left[K_{\text{ads}}(T_2)/K_{\text{ads}}(T_1)\right]}{1/T_2 - 1/T_1} = -45{,}0\text{ kJ/mol}$$

4. $V_\infty(273\text{ K}) = V_\infty(298\text{ K}) = 1/10^{-2} = 100\text{ cm}^3$

$$n(\text{H}) = 2n(\text{H}_2) = 2\frac{pV_\infty}{RT} = 8{,}81\times10^{-3}\text{ mol}$$

$$S_{\text{cat}} = n(\text{H})N_\text{A}\pi r_\text{H}^2 = 2{,}40\times10^{20}\text{ nm}^2 = 240\text{ m}^2$$

5. За реакция P1:

$$\Delta_\text{r}H^\circ = \Delta_\text{f}H^\circ(\text{CO}_{(\text{g})}) + 3\Delta_\text{f}H^\circ(\text{H}_{2(\text{g})}) - \Delta_\text{f}H^\circ(\text{CH}_{4(\text{g})}) - \Delta_\text{f}H^\circ(\text{H}_2\text{O}_{(\text{g})}) = 205{,}9\text{ kJ/mol}$$

$$\Delta_\text{r}S^\circ = S^\circ(\text{CO}_{(\text{g})}) + 3S^\circ(\text{H}_{2(\text{g})}) - S^\circ(\text{CH}_{4(\text{g})}) - S^\circ(\text{H}_2\text{O}_{(\text{g})}) = 214{,}7\text{ J/(mol}\cdot\text{K)}$$

$\Delta_\text{r}G^\circ = \Delta_\text{r}H^\circ - T\Delta_\text{r}S^\circ = 141{,}9\text{ kJ/mol} > 0 \Rightarrow$ реакцията не е спонтанна.

За реакция P2:

$$\Delta_r H^\circ = \Delta_f H^\circ\left(\mathrm{CO}_{2(g)}\right) + \Delta_f H^\circ\left(\mathrm{H}_{2(g)}\right) - \Delta_f H^\circ\left(\mathrm{CO}_{(g)}\right) - \Delta_f H^\circ\left(\mathrm{H_2O}_{(g)}\right) = -41,2 \text{ kJ/mol}$$

$$\Delta_r S^\circ = S^\circ\left(\mathrm{CO}_{2(g)}\right) + S^\circ\left(\mathrm{H}_{2(g)}\right) - S^\circ\left(\mathrm{CO}_{(g)}\right) - S^\circ\left(\mathrm{H_2O}_{(g)}\right) = -42,0 \text{ J/(mol}\cdot\text{K)}$$

$\Delta_r G^\circ = \Delta_r H^\circ - T\Delta_r S^\circ = -28,7 \text{ kJ/mol} < 0 \Rightarrow$ реакцията е спонтанна.

6. За реакция P1: $K_p = K_x p^2 \Rightarrow K_x = K_p / p^2 \Rightarrow$ добивът на водород намалява с увеличаване на налягането.

За реакция P2: $K_p = K_x \Rightarrow$ добивът на водород не зависи от налягането.

7. $\Delta_r c_p = c_p\left(\mathrm{CO}_{2(g)}\right) + c_p\left(\mathrm{H}_{2(g)}\right) - c_p\left(\mathrm{CO}_{(g)}\right) - c_p\left(\mathrm{H_2O}_{(g)}\right) = 3,2 \text{ J/(mol}\cdot\text{K)}$

$\Delta_r H(T) = \Delta_r H^\circ + \Delta_r c_p (T - 298) \Rightarrow$
$\Delta_r H(523 \text{ K}) = -40,5 \text{ kJ/mol}$ и $\Delta_r H(723 \text{ K}) = -39,8 \text{ kJ/mol}$

$$\Delta_r S(T) = \Delta_r S^\circ + \Delta_r c_p \ln\frac{T}{298} \Rightarrow$$
$\Delta_r S(523 \text{ K}) = -40,2 \text{ J/(mol}\cdot\text{K)}$ и $\Delta_r S(723 \text{ K}) = -39,2 \text{ J/(mol}\cdot\text{K)}$

$\Delta_r G = \Delta_r H - T\Delta_r S \Rightarrow \Delta_r G(523 \text{ K}) = -19,5 \text{ kJ/mol}$ и $\Delta_r G(723 \text{ K}) = -11,5 \text{ kJ/mol}$

8. $\Delta_r G = -RT \ln K_p \Rightarrow K_p(523 \text{ K}) = 89$ и $K_p(723 \text{ K}) = 6,8$

(а) CO:H₂O = 1:1 $\Rightarrow p(\mathrm{CO}) = p(\mathrm{H_2O}) = 0,5 - x$ и $p(\mathrm{CO_2}) = p(\mathrm{H_2}) = x$

$$K_p = \frac{p(\mathrm{CO_2})\,p(\mathrm{H_2})}{p(\mathrm{CO})\,p(\mathrm{H_2O})} = \frac{x^2}{(0,5-x)^2} \Rightarrow x = \frac{0,5\sqrt{K_p}}{1+\sqrt{K_p}}$$

При 523 K, $p(\mathrm{CO}) = p(\mathrm{H_2O}) = 0,048$ bar и $p(\mathrm{CO_2}) = p(\mathrm{H_2}) = 0,452$ bar

При 723 K, $p(\mathrm{CO}) = p(\mathrm{H_2O}) = 0,139$ bar и $p(\mathrm{CO_2}) = p(\mathrm{H_2}) = 0,361$ bar

(б) CO:H₂O = 9:1 $\Rightarrow p(\mathrm{CO}) = 0,9 - x$, $p(\mathrm{H_2O}) = 0,1 - x$ и $p(\mathrm{CO_2}) = p(\mathrm{H_2}) = x$

$$K_p = \frac{p(\mathrm{CO_2})\,p(\mathrm{H_2})}{p(\mathrm{CO})\,p(\mathrm{H_2O})} = \frac{x^2}{(0,9-x)(0,1-x)} \Rightarrow x = \frac{1-\sqrt{0,64+0,36/K_p}}{2\left(1-1/K_p\right)}$$

При 523 K, $p(\mathrm{CO}) = 0,800$ bar, $p(\mathrm{H_2O}) = 1,4\times10^{-4}$ bar и $p(\mathrm{CO_2}) = p(\mathrm{H_2}) = 0,100$ bar

При 723 K, $p(\mathrm{CO}) = 0,802$ bar, $p(\mathrm{H_2O}) = 1,8\times10^{-3}$ bar и $p(\mathrm{CO_2}) = p(\mathrm{H_2}) = 0,098$ bar