Quiz 1. Given Reaction :

$$CO(g) + 2H_2(g) \xrightleftharpoons{Cu} CH_3OH(g)$$

$P_T = 200$ bars

$T = 275\,^\circ C$

$\Rightarrow T = (275 + 273)\,K = 548\,K$

Now,	T_c (K)	P_c (bar)	$T_{red.}$	$P_{red.}$	ϕ
H_2	33	35	16.61	5.71	1.05
CO	134	13	4.09	15.38	1.05
CH_3OH	513	82	1.07	2.44	0.45

+10

Note: $P_{red.} = P/P_c$ and $T_{red} = T/T_c$

$$K_f = K_a = \frac{\left(\left(\frac{\hat{f}_{CH_3OH}}{1}\right)\right)}{\left(\frac{\hat{f}_{CO}}{1}\right)\left(\frac{\hat{f}_{H_2}}{1}\right)^2} = \frac{\hat{\phi}_{CH_3OH} \cdot Y_{CH_3OH} \cdot \cancel{P_T}}{\hat{\phi}_{CO}\,\hat{\phi}_{H_2}^2\,\cancel{P_T} \cdot P_T^2 \cdot Y_{CO} \cdot Y_{H_2}^2}$$

+10 * For Ideal solution : fugacity coeff. in mixture of i^{th} component is same as that for pure component.

Thus, +10

$$K_f = \frac{\phi_{CH_3OH} \cdot Y_{CH_3OH}}{\phi_{CO} \cdot \phi_{H_2}^2\, Y_{CO} \cdot Y_{H_2}^2 \cdot P_T^2} = \frac{(0.45)\quad Y_{CH_3OH}}{(1.05)(1.05)^2\; Y_{CO} \cdot Y_{H_2}^2 \cdot P_T^2}$$

$$\Rightarrow \boxed{K_f = \frac{0.389\, Y_{CH_3OH}}{Y_{CO} \cdot Y_{H_2}^2 \cdot P_T^2}} \quad - (1)$$

also,

$$\log_{10} K_f = \frac{3835}{T} - 9.150 \log_{10} T + (3.08 \times 10^{-3} T) + 13.20$$

+20

$$= \frac{3835}{548} - 9.150 \log_{10} (548) + \left(\frac{3.08}{1000} \times 548\right) + 13.20$$

$$\Rightarrow \log_{10} K_f = -3.174$$

or, $\boxed{K_f = 6.7 \times 10^{-4}}$ — (ii)

From the reaction : $CO(g) + 2H_2(g) \underset{}{\overset{Cu}{\rightleftharpoons}} CH_3OH(g)$

	CO	H_2	CH_3OH
initially	1	2	0
finally	$(1-\varepsilon)$	$(2-2\varepsilon)$	ε

+10

$$y_{CO} = \frac{(1-\varepsilon)}{(3-2\varepsilon)} \; ; \quad y_{H_2} = \frac{(2-2\varepsilon)}{(3-2\varepsilon)} \quad \text{and} \quad y_{CH_3OH} = \frac{\varepsilon}{(3-2\varepsilon)}$$

from (i)

$$K_f = \frac{0.389\, \varepsilon\, \cancel{(3-2\varepsilon)}\, (3-2\varepsilon)^2}{\cancel{(3-2\varepsilon)}\, (1-\varepsilon)\, (2-2\varepsilon)^2 \cdot P_T^2}$$

$$\Rightarrow K_f = \frac{0.389\, \varepsilon\, (3-2\varepsilon)^2}{(1-\varepsilon)\, (2-2\varepsilon)^2 \cdot P_T^2}$$

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From (ii) :

$$\frac{6.7}{10000} = \frac{0.389\,\varepsilon\,(3-2\varepsilon)^2}{4\,(1-\varepsilon)^3 \cdot P_T^2}$$

$$\Rightarrow \quad 275.578 = \frac{\varepsilon\,(9+4\varepsilon^2-12\varepsilon)}{(1-3\varepsilon+3\varepsilon^2-\varepsilon^3)}$$

or,

$$279.578\,\varepsilon^3 - 838.734\,\varepsilon^2 + 835.734\,\varepsilon - 275.578 = 0$$

Thus

$$\varepsilon = 0.824 \quad \text{or} \quad \varepsilon = 1.088$$

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Then,

$$\boxed{\varepsilon = 0.824}$$

Ans.

Thus Effluent composition :

$$CH_3OH = \frac{0.824}{3-2(0.824)} = 0.61 = 61\,\%$$

$$H_2 = \frac{2-2(0.824)}{3-2(0.824)} = 0.26 = 26\,\%$$

$$CO = \frac{(1-0.824)}{3-2(0.824)} = 0.13 = 13\,\%$$

+10

Ans.

*. MARKING SCHEME :→

↦ T_{red}, P_{red} and ϕ from Graph → +10

↦ Ideal sol.ⁿ assumption → +10

↦ K_f (mole fr.) → +10

↦ K_f (ε extent of reac^n) → +10

↦ K_f from given relation → +20

↦ Mole fr. as function of ε → +10

↦ ε value → +20

↦ outlet composition → +10