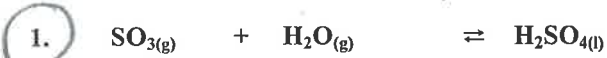


Worksheet A Equilibrium Calculations

63

Solve each problem and show all of your work.



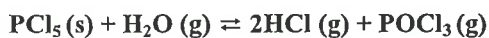
At equilibrium $[\text{SO}_3] = 0.400\text{M}$ $[\text{H}_2\text{O}] = 0.480\text{M}$ $[\text{H}_2\text{SO}_4] = 0.600\text{M}$

Calculate the value of the equilibrium constant.

2. At equilibrium at 100°C , a 2.0L flask contains:

$\frac{0.075 \text{ mol of } \text{PCl}_5}{2} = 0.0375$ $\frac{0.050 \text{ mol of } \text{H}_2\text{O}}{2} = 0.025$ $\frac{0.750 \text{ mol of } \text{HCl}}{2} = 0.375$ $\frac{0.500 \text{ mol of } \text{POCl}_3}{2} = 0.25$

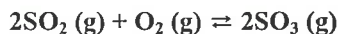
Calculate the K_{eq} for the reaction:



3. $K_{eq} = 798$ at 25°C for the reaction: $2\text{SO}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{SO}_3(g)$.

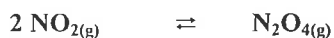
In a particular mixture at equilibrium, $[\text{SO}_2] = 4.20\text{M}$ and $[\text{SO}_3] = 11.0\text{M}$. Calculate the equilibrium $[\text{O}_2]$ in this mixture at 25°C .

4. Consider the following equilibrium:



0.600 moles of SO_2 and 0.600 moles of O_2 are present in a 4.00 L flask at equilibrium at 100°C . If the $K_{eq} = 680$, calculate the SO_3 concentration at 100°C .

5. Consider the following equilibrium:

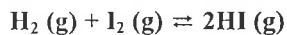


2.00 moles of NO_2 and 1.60 moles of N_2O_4 are present in a 4.00 L flask at equilibrium at 20°C . Calculate the K_{eq} at 20°C .

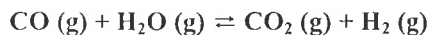


4.00 moles of SO_2 and 5.00 moles O_2 are present in a 2.00 L container at 100°C and are at equilibrium. Calculate the equilibrium concentration of SO_3 and the number of moles SO_3 present if the $K_{eq} = 1.47 \times 10^{-3}$.

7. If at equilibrium $[\text{H}_2] = 0.200\text{M}$ and $[\text{I}_2] = 0.200\text{M}$ and $K_{eq} = 55.6$ at 250°C , calculate the equilibrium concentration of HI.



8. 1.60 moles CO , 1.60 moles H_2O , 4.00 moles CO_2 , 4.00 moles H_2 are found in a 8.00L container at 690°C at equilibrium.



Calculate the value of the equilibrium constant.

Worksheet B Equilibrium Calculations

Solve each problem and show all of your work.

1. At equilibrium, a 5.0L flask contains: 0.75 mol of PCl_5 0.50 mol of H_2O 7.50 mol of HCl 5.00 mol of POCl_3

Calculate the K_{eq} for the reaction: $\text{PCl}_5(\text{s}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons 2\text{HCl}(\text{g}) + \text{POCl}_3(\text{g})$

2. $K_{eq} = 798$ for the reaction: $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$

In a particular mixture at equilibrium, $[\text{SO}_2] = 4.20 \text{ M}$ and $[\text{SO}_3] = 11.0 \text{ M}$. Calculate the equilibrium $[\text{O}_2]$ in this mixture.

3. Consider the following equilibrium: $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$

When a 0.600 moles of SO_2 and 0.600 moles of O_2 are placed into a 1.00 litre container and allowed to reach equilibrium, the equilibrium $[\text{SO}_3]$ is to be 0.250M. Calculate the K_{eq} value.

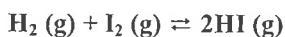
4. Consider the following equilibrium: $2 \text{NO}_2(\text{g}) \rightleftharpoons \text{N}_2\text{O}_4(\text{g})$

If 2.00 moles of NO_2 are placed in a 1.00 L flask and allowed to react. At equilibrium 1.80 moles NO_2 are present. Calculate the K_{eq} .

5. $2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{SO}_3(\text{g})$

4.00 moles of SO_2 and 5.00 moles O_2 are placed in a 2.00 L container at 200°C and allowed to reach equilibrium. If the equilibrium concentration of O_2 is 2.00 M, calculate the K_{eq}

6. If the initial $[\text{H}_2] = 0.200\text{M}$, $[\text{I}_2] = 0.200\text{M}$ and $K_{eq} = 55.6$ at 250°C calculate the equilibrium concentrations of all molecules.



7. 1.60 moles CO and 1.60 moles H_2O are placed in a 2.00L container at 690°C ($K_{eq} = 10.0$).

Calculate all equilibrium concentrations. $\text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}_2(\text{g}) + \text{H}_2(\text{g})$

8. $\text{SO}_3(\text{g}) + \text{NO}(\text{g}) \rightleftharpoons \text{NO}_2(\text{g}) + \text{SO}_2(\text{g})$

$K_{eq} = 0.800$ at 100°C . If 4.00 moles of each reactant are placed in a 2.00L container, calculate all equilibrium concentrations at 100°C .

9. Consider the following equilibrium system: $2\text{NO}_2(\text{g}) \rightleftharpoons \text{N}_2\text{O}_4$

Two sets of equilibrium data are listed for the same temperature.

| | | | |
|-------------|--------|--------------------------|-----------------------------------|
| Container 1 | 2.00 L | 0.12 moles NO_2 | 0.16 moles N_2O_4 |
| Container 2 | 5.00 L | 0.26 moles NO_2 | ? moles N_2O_4 |

Determine the number of moles N_2O_4 in the second container. Get a K_{eq} from the first container and use it for the second container.

Worksheet C Equilibrium Calculations

Solve each problem and show all of your work in your portfolio.

1. At equilibrium, a 2.0 L flask contains: 0.200 mol of PCl_5 0.30 mol of H_2O 0.60 mol of HCl 0.300 mol of POCl_3

Calculate the K_{eq} for the reaction: $\text{PCl}_5(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons 2\text{HCl}(\text{g}) + \text{POCl}_3(\text{g})$

2. $K_{\text{eq}} = 798$ for the reaction: $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$.

In a particular mixture at equilibrium, $[\text{SO}_2] = 4.20 \text{ M}$ and $[\text{SO}_3] = 11.0 \text{ M}$. Calculate the equilibrium $[\text{O}_2]$ in this mixture.

3. Consider the following equilibrium: $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$

When a 0.600 moles of SO_2 and 0.600 moles of O_2 are placed into a 2.00 litre container and allowed to reach equilibrium, the equilibrium $[\text{SO}_3]$ is to be 0.250M. Calculate the K_{eq} value.

4. $\text{H}_2(\text{g}) + \text{S}(\text{s}) \rightleftharpoons \text{H}_2\text{S}(\text{g})$ $K_{\text{eq}} = 14$

0.60 moles of H_2 and 1.4 moles of S are placed into a 2.0L flask and allowed to reach equilibrium. Calculate the $[\text{H}_2]$ at equilibrium.

5. $K_{\text{eq}} = 0.0183$ for the reaction: $2\text{HI}(\text{g}) \rightleftharpoons \text{H}_2(\text{g}) + \text{I}_2(\text{g})$

If 3.0 moles of HI are placed in a 5.00L vessel and allowed to reach equilibrium, what is the equilibrium concentration of H_2 ?

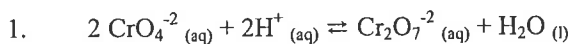
6. Consider the equilibrium: $\text{I}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons 2\text{ICl}(\text{g})$ $K_{\text{eq}} = 10.0$

The same number of moles of I_2 and Cl_2 are placed in a 1.0L flask and allowed to reach equilibrium. If the equilibrium concentration of ICl is 0.040 M, calculate the initial number of moles of I_2 and Cl_2 .

7. Consider the equilibrium: $2\text{ICl}(\text{g}) \rightleftharpoons \text{I}_2(\text{g}) + \text{Cl}_2(\text{g})$ $K_{\text{eq}} = 10.0$

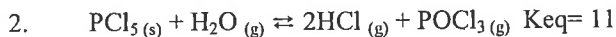
If x moles of ICl were placed in a 5.0 L container at 10°C and if an equilibrium concentration of I_2 was found to be 0.60 M, calculate the number of moles ICl initially present.

8. A student places 2.00 moles SO_3 in a 1.00 L flask. At equilibrium $[\text{O}_2] = 0.10 \text{ M}$ at 130°C . Calculate the K_{eq} .



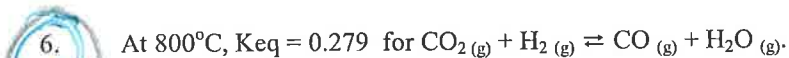
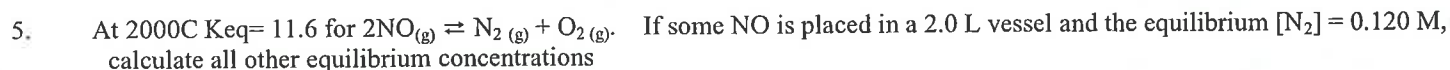
Calculate the Keq if the following amounts were found at equilibrium in a 2.0L volume.

$\text{CrO}_4^{2-} = .030 \text{ mol}, \text{H}^+ = .020 \text{ mol}, \text{Cr}_2\text{O}_7^{2-} = 0.32 \text{ mol}, \text{H}_2\text{O} = 110 \text{ mol}$



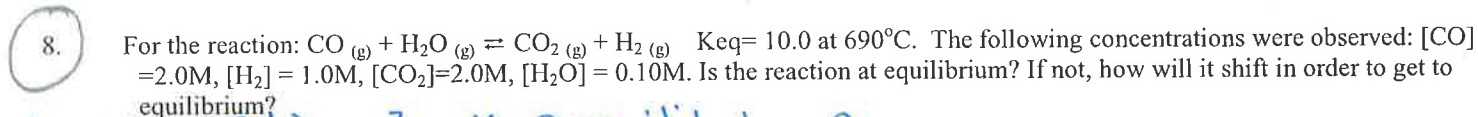
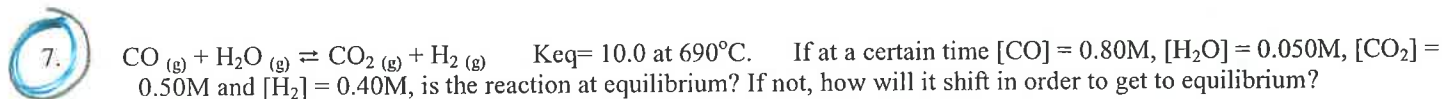
At equilibrium the 4.0L flask contains the indicated amounts of the three chemicals.

$\text{PCl}_5 \quad .012 \text{ mol} \quad \text{H}_2\text{O} \quad .016 \text{ mol} \quad \text{HCl} \quad .120 \text{ mol} \quad \text{Calculate } [\text{POCl}_3].$

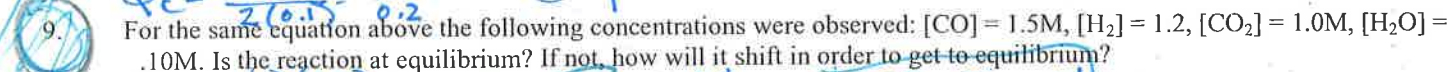


If 2.00 moles $\text{CO}(\text{g})$ and 2.00 moles $\text{H}_2\text{O}(\text{g})$ are placed in a 500 ml container, calculate all equilibrium concentrations.

Note that when two products are placed in a container it shifts to the left to get to equilibrium.



$Q_c = \frac{2(1)}{2(0.1)} = \frac{2}{0.2} = 10$ @ equilibrium



$Q_c = \frac{(1)(1.2)}{(1.5)(0.1)} = \frac{1.2}{.15} = 8 < K_c \therefore \text{shift Right}$



$K_c = \frac{[\text{O}_2]^3}{[\text{O}_3]^2}$

Predict the direction in which the equilibrium will proceed, if any, when the following amounts are introduced to a 10 L vessel.

$Q_c = \frac{(.3)^3}{(.06)^2} = 7.5 < K_c$

a) 0.60 mole of O_3 and 3.0 mol of O_2
 shift right

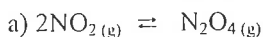
$Q_c = \frac{(.7)^3}{(.005)^2} = \frac{.343}{.005^2} = 13720$

b) 0.050 mole of O_3 and 7.0 mol of O_2
 shift left

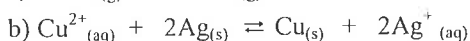
$Q_c \rightarrow \text{shift right}$

c) 1.5 mole of O_3 and no O_2

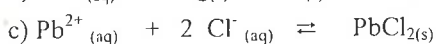
11. Consider the following equilibrium:



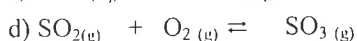
$\text{Keq} = 2.2$



$\text{Keq} = 1 \times 10^{-15}$



$\text{Keq} = 6.3 \times 10^4$



$\text{Keq} = 110$

Which equilibrium favors products to the greatest extent? **c)**

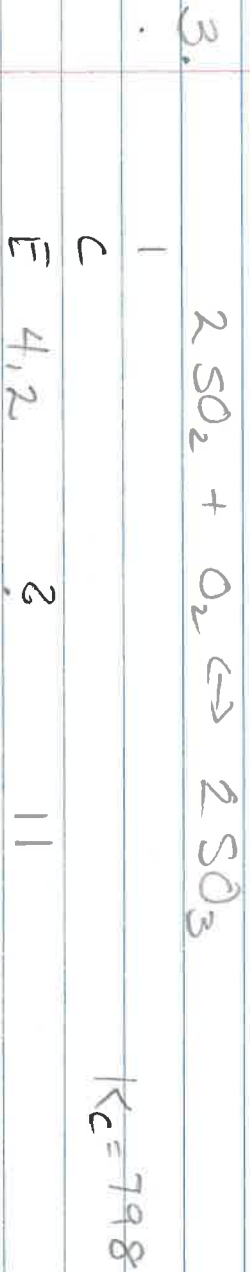
Which equilibrium favors reactants to the greatest extent? **b)**

(A)

$$1. K_c = \frac{1}{[SO_3][H_2O]}$$
$$= \frac{1}{(0.4)(0.48)}$$
$$= 5.21$$

3

$$2. K_c = \frac{[POCl_3][HCl]^2}{[PCl_5][H_2O]}$$
$$= \frac{(0.25)(0.375)^2}{(1)(0.025)}$$
$$= 1.41$$



$$K_c = \frac{[SO_3]^2}{[SO_2]^2 [O_2]}$$
$$798 = \frac{(11)^2}{(4.2)^2 (x)}$$
$$x = \frac{(11)^2}{(4.2)^2 (798)}$$

$$798 = \frac{121}{17.64 x}$$
$$x = \frac{121}{798(17.64)}$$

$$x = 8.596 \times 10^{-3}$$
$$= 0.0086 \text{ mol/L}$$

3

$$4. K_c = \frac{[SO_3]^2}{[SO_2]^2 [O_2]}$$

$$[SO_2]^2 [O_2]$$

$$680 = x^2$$

$$(0.15)^2 (0.15)$$

$$x^2 = 2.295$$

$$x = 1.515$$

$$\therefore [SO_3] = 1.515 \text{ mol/L}$$

$$5. K_c = \frac{[NO_2]^2}{[N_2O_4]}$$

$$= 1.6/4$$

$$= \frac{(2/4)^2}{1.25}$$

$$= 0.4$$

$$= 1.6$$

$$= 1.6$$

$$6. K_c = \frac{[SO_2]^2 [O_2]}{[SO_3]^2}$$

$$1.47 \times 10^{-3} = \frac{2^2 (2.5)}{x^2}$$

$$x^2 = 6.8021$$

$$x = 82.4786$$

$$\therefore [SO_3] = 82.4786 \text{ mol/L}$$

$$\therefore \text{in 2L ; } 164.9572 \text{ mol}$$

$$7. \quad K_c = \frac{[HI]^2}{[H_2][I_2]}$$

$$55.6 = \frac{x^2}{(0.2)(0.2)}$$

$$(0.2)(0.2)$$

$$x^2 = 2.224$$

$$x = 1.49$$

$$\therefore [HI] = 1.49 \text{ mol/L}$$

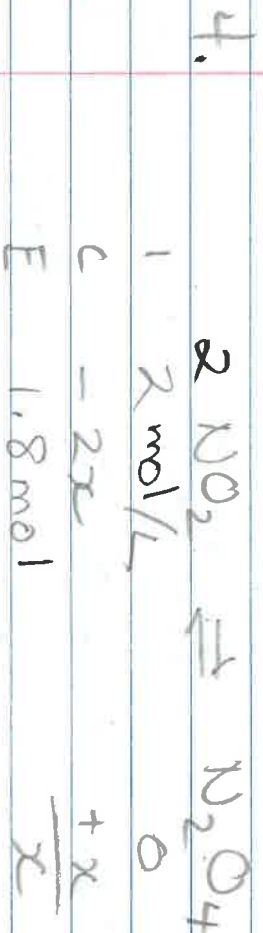
$$8. \quad K_c = \frac{[CO_2][H_2]}{[CO][H_2O]}$$

$$K_c = \frac{(4/8)(4/8)}{(1.6/8)(1.6/8)}$$

$$= \frac{(0.5)(0.5)}{(0.2)(0.2)} = \frac{0.25}{0.04}$$

$$= 6.25$$

(B)



$$K_c = \frac{[N_2O_4]}{[NO_2]^2} \quad 2-2x=1.8$$

$$= \frac{0.1}{(1.8)^2} \quad \frac{2-1.8=2x}{2} \quad 0.1=x$$

$$K_c = 0.031$$

5.



C -2x -x +2x
E 2-2x [2] 2x = [1]
= 2-1 2.5-x = 2
= [1] x = 0.5

K_c = $\frac{[SO_3]^2}{[SO_2]^2 [O_2]}$

= $\frac{1^2}{2}$
= $\frac{1}{2} = [0.5]$



1 0.2 0.2 0 K_c = 55.6
2 -x -x +2x
E 0.2-x 0.2-x 2x

K_c = $\frac{[HI]^2}{[H_2][I_2]} = 0.2-x$

55.6 = $\frac{[2x]^2}{(0.2-x)^2}$
[HI] = 2x = 0.3154 mol/l
= 2(0.1577)

7.45654 = 2x
0.2-x = [0.3154 mol/l]

1.49131 - 7.45654x = 2x

1.49131 = 2.45654x

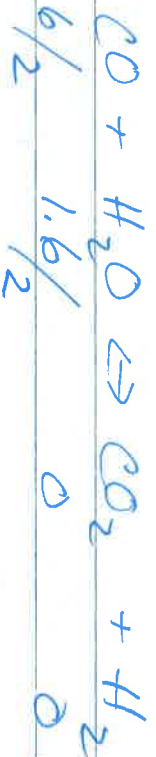
~~9.45654~~ 2.45654

~~0.1577~~ 0.1577

x = 0.1577

3.

7.



$$1.6/2 \quad 1.6/2$$

$$0$$

$$2x$$

$$C \quad -x$$

$$-x$$

$$+x$$

$$+x$$

$$E \quad 0.8-x$$

$$0.8-x$$

$$x$$

$$x$$

$$K_c = \frac{[\text{CO}_2][\text{H}_2]}{[\text{CO}][\text{H}_2\text{O}]}$$

$$[\text{CO}] = [\text{H}_2\text{O}]$$

$$= 0.8-x$$

$$= 0.8 - 0.6078$$

$$= 0.1922 \text{ mol/L}$$

$$\sqrt{10} = \sqrt{\frac{x^2}{(0.8-x)^2}}$$

$$[\text{CO}_2] = [\text{H}_2]$$

$$3.1623 = x$$

$$0.8-x$$

$$= x$$

$$2.5298 - 3.1623x = x$$

$$2.5298 = 4.1623x$$

$$x = 0.6078$$

9.

$$K_c = \frac{[\text{N}_2\text{O}_4]}{[\text{NO}_2]^2}$$

$$[\text{NO}_2]^2$$

$$= 8.08$$

$$= \frac{(0.06)^2}{22.2}$$

$$= 22.2$$

4

$$22.2 = \frac{[\text{N}_2\text{O}_4]}{(0.052)^2}$$

$$\frac{0.26}{5} = 0.052$$

$$[\text{N}_2\text{O}_4] = 0.06 \text{ mol/L}$$

10

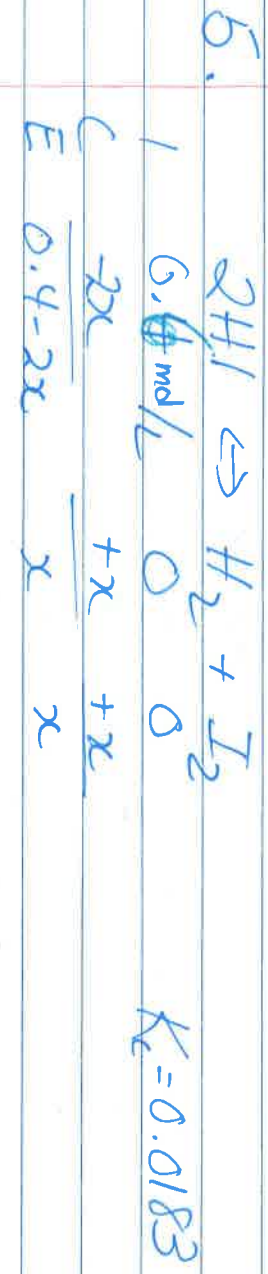
(c)



$$\begin{array}{l} I \\ C \\ E \end{array} \quad \begin{array}{l} \frac{0.6}{2} \\ -x \\ 0.3-x \end{array} \quad \begin{array}{l} \frac{1.4}{2} \\ -x \\ x \end{array} \quad \begin{array}{l} \checkmark \\ \checkmark \\ \checkmark \end{array} \quad \begin{array}{l} 0 \\ +x \\ x \end{array}$$

$$K_c = \frac{[H_2S]}{[H_2][S]} \quad [H_2] = 0.3 - 0.28 = 0.02 \text{ mol/L}$$
$$14 = \frac{15}{0.3-x} \quad \checkmark$$

$$4.2 - 14x = x$$
$$\frac{4.2}{15} = \frac{15x}{15} \quad \cdot 15$$
$$\boxed{x = 0.28} \quad \checkmark \quad 5 \sqrt{3.0}$$



$$K_c = \frac{[H_2][I_2]}{[H_2]^2} \quad [H_2] = x$$
$$\int \frac{0.0183}{(0.4-2x)^2} = x^2$$
$$0.1352775 = x$$

$$\frac{0.0811665}{0.054444} - 0.270555x = x$$
$$\frac{0.88499}{1.270555x} = x$$
$$\boxed{x = 0.0925885}$$
$$\boxed{x = 0.064}$$



| | | | | |
|---|------------------|------------------|--------------------|-----------|
| 1 | y | y | 0 | $K_c = 6$ |
| C | $\frac{-x}{y-x}$ | $\frac{-x}{y-x}$ | $\frac{+2x}{0.04}$ | |
| E | $y-x$ | $y-x$ | 0.04 | |
| | $y-0.02$ | $y-0.02$ | $2x=0.04$ | |
| | | | $x=0.02$ | |

$$K_c = \frac{[ICl]^2}{[I_2][Cl_2]}$$

$$10 = \frac{(0.04)^2}{(y-0.02)^2}$$

$$3.16227766 = 0.04$$

$$y = 0.02$$

$$3.16227766y - 0.063245553 = 0.04$$

$$3.16227766y = 0.103245553$$

$$y = 0.03265$$

∴ Initial concentration is 0.03265 mol/L



| | | | | |
|---|-----------------|------------------|------------------|------------|
| C | $\frac{-2y}{x}$ | $\frac{+y}{0.6}$ | $\frac{+y}{0.6}$ | $K_c = 10$ |
| E | $x-1.2$ | 0.6 | 0.6 | |

$$10 = \frac{(0.6)^2}{(x-1.2)^2}$$

$$3.16227766 = 0.6$$

$$x = 1.2$$

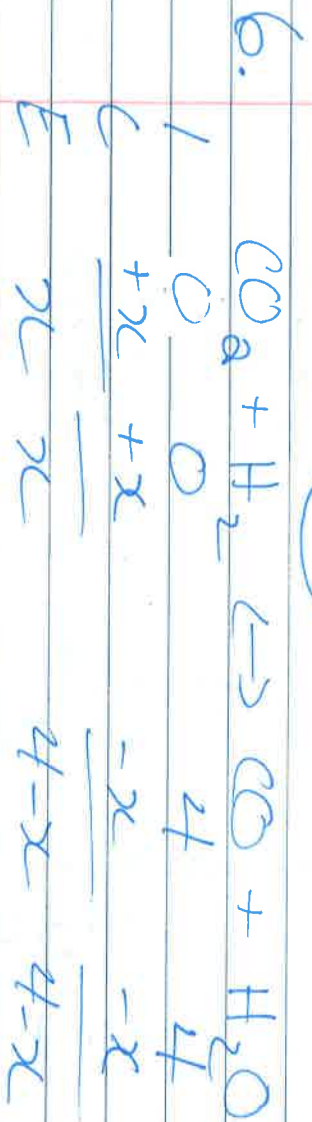
$$\therefore 1.38974 \times 5L = 6.9487 \text{ moles in } 5L$$

$$3.16227766x - 3.79473312 = 0.6$$

$$3.16227766x = 4.39473312$$

$$x = 1.38974 \text{ mol/L}$$

(D)



$$K_c = \frac{[\text{CO}][\text{H}_2\text{O}]}{[\text{CO}_2][\text{H}_2]}$$

$$\sqrt{0.279} = \frac{(4-x)^2}{x^2}$$

$$x(0.5282) = (4-x)x$$

$$1.5282x = 4 - x$$

$$x = 2.61746$$

$$[\text{CO}_2] = [\text{H}_2] = x = 2.61746 \text{ mol/L}$$

$$[\text{CO}] = [\text{H}_2\text{O}] = 4 - x = 1.38254 \text{ mol/L}$$

7. $Q_c = \frac{[\text{CO}_2][\text{H}_2]}{[\text{CO}][\text{H}_2\text{O}]}$

$$= \frac{(0.5)(0.4)}{(0.8)(0.05)}$$

$$= \frac{0.2}{0.04}$$

$$= 5$$

$$K_c = 10$$

$$Q_c < K_c$$

∴ shift to right

9