CHEMISTRY ONLINE
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CHEMISTRY

PHYSICAL CHEMISTRY

Level & Board	AQA (A-LEVEL)
TOPIC:	CHEMICAL EQUILIBRIA
PAPER TYPE:	SOLUTION -1
TOTAL QUESTIONS	10
TOTAL MARKS	60

Chemical Equilibria - I

1. (A)

(Total 1 mark)

2. (D)

(Total 1 mark)

3.

(a)

High pressure favors the side with fewer gas molecules, which in this case is the formation of methanol (CH_3OH).
Low temperature benefits the exothermic forward reaction. Both conditions enhance the yield of methanol by pushing the equilibrium towards its production.

(2)

(b)

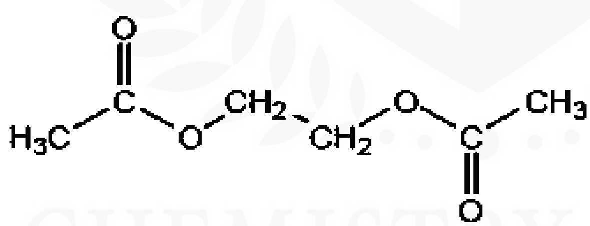
The actual conditions used in the chemical industry might be different from those mentioned above as it can be too expensive to use a high pressure or could be too slow to use a low temperature.

(2)

4.

(a)

Structural formula for the diester $C_6H_{10}O_4$



(1)

(b)

Amount in the mixture / mol				
	CH_3COOH	$HOCH_2CH_2OH$	$C_6H_{10}O_4$	H_2O
At the start	0.470	0.205	0	0
At equilibrium	0.180	0.06	0.145	0.29

(3)

(c)

$2CH_3COOH(l) + HOCH_2CH_2OH(l) \rightleftharpoons C_6H_{10}O_4(l) + 2H_2O(l)$

So,

$$Kc = \frac{[C6H10O4][H2O]^2}{[CH3COOH]^2[HOCH2CH2OH]}$$

(2)

(d)

Kc=6.45

Initial amounts:

$HOCH_2CH_2OH$=0.264 mol

$C_6H_{10}O_4$=0.802 mol

H_2O=1.15 mol

$$Kc = \frac{[C6H10O4][H2O]^2}{[CH3COOH]^2[HOCH2CH2OH]}$$

$$[\text{mol CH3COOH/V}]^2 = \frac{[\text{mol C6H10O4/V}][\text{mol H2O/V}]^2}{\text{Kc [mol HOCH2CH2OH/V]}}$$

$$\left[\text{mol}\frac{\text{CH3COOH}}{\text{V}}\right]^2 = \frac{\left[\frac{8.02 \times 10^{-1}}{V}\right]\left[\frac{1.15}{V}\right]^2}{6.45\left[\frac{2.64 \times 10^{-1}}{V}\right]}$$

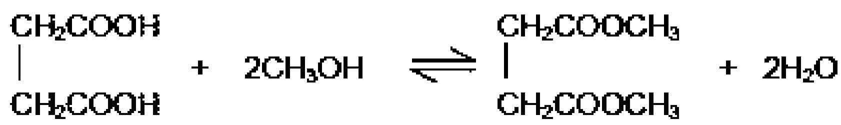
$$\text{mol} = \sqrt{\frac{8.02 \times 10^{-1}[1.15]^2}{6.45 \times 2.64 \times 10^{-1}}}$$

Mol CH_3COOH = 0.789

(3)

5.

(a)



X Y

$$Kc = \frac{[Y][H2O]^2}{[X][CH3OH]^2}$$

(1)

(b)

The reaction between an acid (X) and methanol (CH_3OH) to form an ester (Y) and water (H_2O) is typically represented as:

$X + CH_3OH \rightleftharpoons Y + H_2O$

So, at equilibrium:

Amount of acid X = 0.32 mol (initial) - 0.26 mol (consumed) = 0.06 mol

Amount of methanol (CH_3OH) at equilibrium: 0.32 mol
Amount of water (H_2O) at equilibrium: 0.84-0.32=0.52 mol

(3)

(c)

$$Kc = \frac{0.26 \times 0.52^2}{0.06 \times 0.32^2}$$

No units as moles of reactants are equal to products.

(3)

(d)
If the reaction is carried out at a lower temperature Kc will increase

(1)

6.

(a)

$C_2H_5OH(g) + H_2O(g) \rightleftharpoons 2CO(g) + 4H_2(g)$

The expression for Kc for this reaction is:

$$Kc=\frac{[CO]^2\,[H2]^4}{[H2O][C2H5OH]}$$

Units: $mol^4\ dm^{-1}$

(2)

(b)

Given:

- Volume of the container = 750 cm^3 = 0.75 L (since 1 L = 1000 cm^3)
- $C_2H_5OH(g)$: 0.0750 mol / 0.75 L = 0.100 M
- $H_2O(g)$: 0.156 mol / 0.75 L = 0.208 M
- $CO(g)$: 0.110 mol / 0.75 L = 0.147 M
- $H_2(g)$: 0.220 mol / 0.75 L = 0.293 M

$$Kc=\frac{[CO]^2\,[H2]^4}{[H2O][C2H5OH]}$$

$$Kc=\frac{[0.147\,]^2\,[0.293]^4}{[0.208][0.100]}$$

$Kc= 7.66 \times 10^{-3}$

(3)

(c)

Equilibrium Yield of Hydrogen :

- **Yield would decrease.**
- **Explanation:**

  Effect on Equilibrium Position:

  Equilibrium position shifts to the left/in the direction of the reverse reaction. As movement occurs to oppose/in response to the increase in pressure/reduce pressure.

  Regarding Moles/Molecules of Gases :

Fewer moles/molecules of gas on the left-hand side compared to the right-hand side. Specifically, 2 moles/molecules of gas on the left-hand side and 6 moles/molecules of gas on the right-hand side.

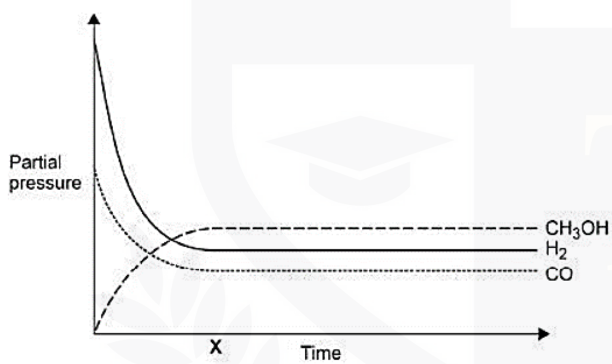
Effect on Kc :

- ***No effect on Kc***
- ***Explanation:*** *Kc remains constant as it's determined solely by the concentrations of products and reactants at equilibrium, unaffected by changes in pressure.*

(4)

7.

(a)



(1)

(b)

Total moles at equilibrium = Moles of H_2 + Moles of CO
Total moles at equilibrium = 0.24 + 0.23
Total moles at equilibrium = 0.47

At equilibrium, the moles of hydrogen (H_2) are 0.24, and the moles of carbon monoxide (CO) are 0.23, resulting in a total of 0.47 moles in the system.

Equilibrium moles of hydrogen :

- *$n(H_2)$ at equilibrium = 0.24 mol*

Total number of moles at equilibrium :

- *Total moles = 0.47 mol*

Mole fraction of hydrogen :

- *Mole fraction of H_2*

= $n(H_2)$/Total number of moles

- Mole fraction of H_2= 0.24 mol/0.47 mol
- Mole fraction of H_2 = 0.5106

Partial pressure of hydrogen :

Partial pressure of H_2 = Mole fraction of H_2 × Total pressure
= 0.5106 × 1.04 × 10^4 kPa
=5310 kPa

(4)

(c)

Given the balanced equation:

$CO(g)+2H_2(g) \rightleftharpoons CH_3OH$

$$Kp=\frac{\text{(partial pressure of CH3OH)}}{\text{(partial pressure of CO)}\times\text{(partial pressure of H2)}^2}$$

Units: Pa^{-2} or kPa^{-2}

(2)

(d)

Adding more carbon monoxide (CO) will cause the partial pressure of methanol (CH_3OH) to increase as the equilibrium shifts to produce more methanol. However, the value of the equilibrium constant (Kp) remains unchanged at the specified temperature.

(2)

(e)

The addition of a catalyst does not alter the value of the equilibrium constant (Kp) as it affects the rates of the forward and reverse reactions equally without changing the position of the equilibrium.

(2)

8.

(a)

Initially:
NO=1.50mol
Cl_2=1.00mol
NOCl formed at equilibrium =0.350 mol
The change in moles of NO (x) is equal to the moles of NOCl formed, which is 0.350 mol

So,
x=0.350mol (moles of NO consumed/converted to NOCl).

This means that at equilibrium:
Moles of NO
=1.50mol−x=1.50mol−0.350mol=1.15mol
Moles of Cl_2
=1.00mol−2x
=1.00mol−(0.350mol/2)
=0.825mol

(2)

(b)

$$Kc=\frac{[NOCl]^2}{[Cl][NO]^2}$$

(1)

(c)

Given:
$Kc=1.32\times10^{-2}mol^{-1}dm^3$
Moles of NO = 0.850 mol
Moles of Cl_2 = 0.458 mol
Volume of flask = 800 cm^3

$$Kc=\frac{[NOCl]^2}{[Cl][NO]^2}$$

$$1.32\times10^{-2}=\frac{[NOCl]^2}{[0.85/800][0.458/800]^2}$$

$[NOCl]^2 = 8.53 \times 10^{-3}\ mol^2dm^{-6}$
$[NOCl]=\sqrt{8.53\times10^{-3}}$
$[NOCl]=0.0924mol\ dm^{-3}$
Volume = 800 cm^3 = 0.800 dm^3
n(NOCl) = 0.0924 x 0.800 = 0.0739 mol

(4)

I am Sorry !!!!!

9. (A)

(Total 1 mark)

10.

(a)

At equilibrium:
Moles of X(aq) remaining
= Initial moles of X(aq) - Moles of X(aq) reacted Moles of X(aq)remaining
= 0.50 mol - 0.20 mol = 0.30 mol
Moles of Y(aq) remaining
= Initial moles of Y(aq) - Moles of Y(aq) reacted Moles of Y(aq) remaining
= 0.50 mol - (2 × 0.20) = 0.10 mol

(2)

(b)

$$Kc = \frac{[Z]}{[X][Y]^2}$$

$$[Y]^2 = \frac{[Z]}{Kc[X]}$$

$$\sqrt{[Y]^2} = \sqrt{\frac{[Z]}{Kc[X]}}$$

$$\sqrt{\frac{0.35}{2.9 \times 0.4}} = 0.5498$$

$0.55 mol\ dm^{-3}$

(3)

(c)

The addition of Y(aq) would cause the equilibrium to shift to the right, leading to a darker or more orange color in the mixture. This shift occurs to counteract the increase in Y(aq) concentration by favoring the formation of more Z(aq).

(3)

(d)
If the student warmed the equilibrium mixture the orange colour would fade.

(1)