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CHEMISTRY
PHYSICAL CHEMISTRY

Level & Board	AQA (A-LEVEL)
TOPIC:	CHEMICAL EQUILIBRIA
PAPER TYPE:	QUESTION PAPER - 3
TOTAL QUESTIONS	10
TOTAL MARKS	37

Chemical Equilibria - 3

1.

(a)

Kc expression:

$$Kc = \frac{[HI]^2}{[H2]\,[I2]}$$

Kc (forward)×Kc (reverse)=Kc (net)
Kc (reverse)= 1/ Kc (forward)
Given that Kc (forward)=20:
Kc (reverse)=1/20=0.05

(2)

(b)

Effect on Rates of Forward and Reverse Reactions:

- **Forward Reaction Rate:** Increasing the pressure leads to an increase in the rate of the forward reaction.
- **Reverse Reaction Rate:** Simultaneously, the rate of the reverse reaction also increases due to the pressure change.

Position of Equilibrium:

- **No Change in Equilibrium Position:** Despite the change in pressure, the position of the equilibrium remains unaffected. The increase in pressure doesn't alter the equilibrium state.

Effect on Equilibrium Constant:

- **No Change in Equilibrium Constant (Kc):** The numerical value of the equilibrium constant (Kc) remains constant at a given temperature, unaffected by the pressure change.

(4)

2. (A)

(Total 1 mark)

3. (C)

(Total 1 mark)

4. (D)

(Total 1 mark)

5. The manufacture of methanol can be achieved in two stages.
In the first stage, methane and steam react according to the following equation. $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ $\Delta H^o = +210$ kJ mol^{-1}
Discuss, with reasons, the effects of increasing separately the temperature and the pressure on the yield of the products and on the rate of this reaction.

Effect of Increasing Temperature:
$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ $\Delta H^o = +210$ kJ mol^{-1}
Yield of Products:
According to Le Chatelier's Principle, increasing the temperature in an endothermic reaction ($\Delta H^o = +210$ kJ mol^{-1}) will shift the equilibrium in the direction that consumes heat. In this case, the forward reaction is endothermic, so raising the temperature will favor the formation of products (CO and H_2) to counteract the increase in temperature. Therefore, increasing the temperature will likely increase the yield of carbon monoxide and hydrogen.
Rate of Reaction:
Higher temperatures generally lead to an increase in the rate of reaction. Elevated temperatures provide more kinetic energy to the molecules, resulting in more frequent and energetic collisions between methane, steam, and the catalyst (if present), thus increasing the rate of the reaction.
Effect of Increasing Pressure:
$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ $\Delta H^o = +210$ kJ mol^{-1}
Yield of Products:
Increasing the pressure, according to Le Chatelier's Principle, will favor the side of the reaction with fewer gas molecules to counteract the change.
In this case, there are fewer gas molecules on the product side (1 mole of CO and 3 moles of H_2) compared to the reactant side (1 mole each of CH_4 and H_2O). Therefore, increasing the pressure will favor the formation of more gas molecules, which would be the reactants. Thus, increasing the pressure may decrease the yield of carbon monoxide and hydrogen.
Rate of Reaction:
In general, increasing the pressure tends to increase the rate of a reaction involving gases. Higher pressure means a greater concentration of gas particles in a given volume, leading to more frequent collisions between the reactant molecules, thus increasing the rate of the reaction.

(6)

6. (C)

(Total 1 mark)

7.

(a)

Equation for reaction is:

$N_2 + O_2 \rightleftharpoons 2NO$

Expression for the equilibrium is:

$$Kc=\frac{[NO]^2}{[N2][O2]}$$

(2)

(b)

Graph shows that temperature increases so Kc increases and yield increases. Hence reaction will be endothermic
For an endothermic reaction, an increase in temperature will favor the forward reaction, leading to an increase in the equilibrium constant (Kc) and higher yield of products.

(2)

(c)

The equilibrium constant $Kc=1\times10^{-5}$ at 1500 K implies a very low yield of nitrogen monoxide.
Attempting to increase yield by raising temperature might not be cost-effective, as the small increase in product yield may not justify the high production costs associated with maintaining elevated temperatures.

(2)

(d)

Equation for reaction is:

$2NO + O_2 \rightleftharpoons 2NO_2$

Increase in pressure would shift the equilibrium to the right, favoring more NO_2 formation, as it reduces the total gas moles. However, the equilibrium constant (Kc) remains unchanged by the pressure alteration.

(3)

8. (B)

(Total 1 mark)

9.

Reducing the size of the lumps of marble increases the rate of reaction when it's reacted with dilute hydrochloric acid due to increased surface area.
Because:
Surface Area Increase:
Breaking down the marble into smaller pieces significantly increases the total surface area exposed to the hydrochloric acid. Smaller marble particles provide more surface area for the acid to come into contact with compared to larger lumps. This increased surface area exposes more marble to the acid, allowing more collisions between the acid particles and the marble surface.
More Collisions:
The increased surface area means more marble particles are available for collision with the hydrochloric acid molecules in the solution. This increases the frequency of collisions between the reacting particles per unit time.

(2)

10.

(a)

Homogeneous: It is a state where all reactants and products are in the same phase, such as all gases in this case.
Dynamic Equilibrium: Occurs when the rates of the forward and reverse reactions are equal, leading to a stable concentration of reactants and products over time.
Equilibrium: A state in a reversible reaction where the rates of the forward and reverse reactions are equal, resulting in a constant concentration of all species involved.
The equation for ammonia decomposition:
$2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$
Expression for equilibrium constant (Kc):

$$Kc = \frac{[N2][H2]^3}{[NH3]^2}$$

(5)

(b)

High Temperature Favors Decomposition:

Given that the decomposition of ammonia ($2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$) is endothermic (absorbs heat), according to Le Chatelier's Principle, increasing the temperature will favor the forward direction. This condition encourages the decomposition of ammonia into nitrogen and hydrogen to absorb the added heat.

Le Chatelier's Principle Applied:

When the system is at equilibrium, decreasing the pressure will shift the equilibrium to the side with more moles of gas to counteract the change. In this reaction, the production of nitrogen and hydrogen involves fewer gas moles (4 moles: 1 mole of N_2 and 3 moles of H_2) compared to the 2 moles of gas in ammonia. Therefore, a decrease in pressure will favor the formation of more gas molecules, promoting the decomposition of ammonia.

(4)

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