

1 Explain what you understand by the term *dynamic equilibrium*.

All concentrations remain constant/macrosopic properties constant

Rate of forward reaction = rate of reverse reaction

2 Explain what is meant by a *closed system*.

No exchange of matter with surroundings

3 Describe, on a molecular level, how equilibrium is established when a liquid is placed in a closed container.

Rate of evaporation = rate of condensation

4 Write expressions for the equilibrium constant, K_c , for

$K_c = \frac{[\text{CO}_2(\text{g})][\text{H}_2(\text{g})]^4}{[\text{CH}_4(\text{g})][\text{H}_2\text{O}(\text{g})]^2}$
$K_c = \frac{[\text{NH}_3(\text{g})]^2}{[\text{N}_2(\text{g})][\text{H}_2(\text{g})]^3}$
$K_c = \frac{[\text{SO}_3(\text{g})]^2}{[\text{SO}_2(\text{g})]^2[\text{O}_2(\text{g})]}$

$\text{CH}_4(\text{g}) + 2\text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}_2(\text{g}) + 4\text{H}_2(\text{g})$
$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$
$2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$

5 Write expressions for the equilibrium constant, K_{c1} , for the reactions shown and state the relationship between the values of K_{c1} and K_c in 4

$K_c = \frac{[\text{CO}_2(\text{g})][\text{H}_2(\text{g})]^4}{[\text{CH}_4(\text{g})][\text{H}_2\text{O}(\text{g})]^2}$	$K_{c1} = \frac{[\text{CH}_4(\text{g})][\text{H}_2\text{O}(\text{g})]^2}{[\text{CO}_2(\text{g})][\text{H}_2(\text{g})]^4}$	$K_{c1} = 1/K_c$
$K_c = \frac{[\text{NH}_3(\text{g})]^2}{[\text{N}_2(\text{g})][\text{H}_2(\text{g})]^3}$	$K_{c1} = \frac{[\text{NH}_3(\text{g})]}{[\text{N}_2(\text{g})]^{1/2}[\text{H}_2(\text{g})]^{3/2}}$	$K_{c1} = \sqrt{K_c}$
$K_c = \frac{[\text{SO}_3(\text{g})]^2}{[\text{SO}_2(\text{g})]^2[\text{O}_2(\text{g})]}$	$K_{c1} = \frac{[\text{SO}_2(\text{g})][\text{O}_2(\text{g})]^{1/2}}{[\text{SO}_3(\text{g})]}$	$K_{c1} = 1/\sqrt{K_c}$

$\text{CO}_2(\text{g}) + 4\text{H}_2(\text{g}) \rightleftharpoons \text{CH}_4(\text{g}) + 2\text{H}_2\text{O}(\text{g})$
$1/2\text{N}_2(\text{g}) + 3/2\text{H}_2(\text{g}) \rightleftharpoons \text{NH}_3(\text{g})$
$\text{SO}_3(\text{g}) \rightleftharpoons \text{SO}_2(\text{g}) + 1/2\text{O}_2(\text{g})$

6 Explain the connection between the value of the equilibrium constant and the position of equilibrium.

Bigger value of K_c – more the position of equilibrium lies towards the right

$K_c \gg 1$ position of equilibrium long way to right

$K_c \ll 1$ position of equilibrium long way to left

7 Predict, for each of the reactions shown, the effect of the changes below on the position of equilibrium and the value of the equilibrium constant

$\text{CH}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + 3\text{H}_2(\text{g})$	$\Delta H = +206 \text{ kJ mol}^{-1}$
$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$	$\Delta H = -92 \text{ kJ mol}^{-1}$
$\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$	$\Delta H = +52 \text{ kJ mol}^{-1}$

increasing the pressure decreasing the temperature adding hydrogen adding a catalyst

$\text{CH}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + 3\text{H}_2(\text{g})$	Increase P	Decrease T	Add H ₂	Catalyst
Effect on position of equilibrium	To left	To left	To left	No change
Effect on K_c	No change	decreases	No change	No change
$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$	Increase P	Decrease T	Add H ₂	Catalyst
Effect on position of equilibrium	To right	To right	To right	No change
Effect on K_c	No change	increases	No change	No change
$\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$	Increase P	Decrease T	Add H ₂	Catalyst
Effect on position of equilibrium	No change	To left	To right	No change
Effect on K_c	No change	decreases	No change	No change

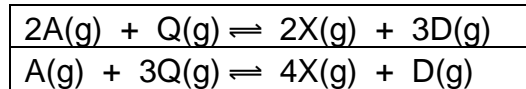
- 8 Explain whether the reaction $A \rightleftharpoons B$ is endothermic or exothermic from the values of the equilibrium constant.

$$K_c = 1.2 \times 10^4 \text{ at } 500 \text{ K and } K_c = 5.6 \times 10^5 \text{ at } 1000 \text{ K}$$

Endothermic

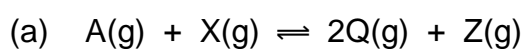
- 9 Write expressions for the reaction quotient, Q , for the following reactions

$Q = \frac{[X]^2[D]^3}{[A]^2[Q]}$
$Q = \frac{[X]^4[D]}{[A][Q]^3}$



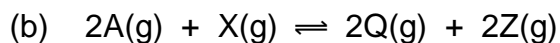
- 10 Given the value of K_c and the value of Q deduce whether

- A the system is at equilibrium
 B proceeds to the right towards equilibrium
 C proceeds to the left towards equilibrium



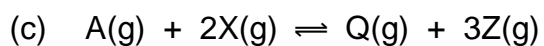
Value of $K_c = 0.0300$	Value of $Q = 0.100$
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$Q > K_c$ therefore to the left



Value of $K_c = 0.0200$	Value of $Q = 0.0100$
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$Q < K_c$ therefore to the right



Value of $K_c = 0.160$	Value of $Q = 0.160$
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$Q = K_c$ therefore at equilibrium