

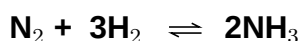


1 Chemical equilibrium

Chemical equilibrium is a dynamic equilibrium when the rate of the forward reaction equals the rate of the reverse reaction for a reversible reaction in a closed system.

isolated from the surroundings
no reagents can escape

reverse reaction can take place



N₂ and H₂ is sealed in a container:

Initially:	Over time:	Eventually:
High [N ₂] and [H ₂] → Forward reaction fast [NH ₃] = 0 → No reverse reaction	[N ₂] & [H ₂] decrease (used) → Forward reaction slower [NH ₃] increases (produced) → Reverse reaction faster	Chemical equilibrium reached Forward and reverse reaction at the same rate. [N ₂], [H ₂] & [NH ₃] constant.

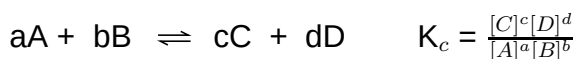
Draw reaction rate vs time graphs for both reactions:

Reaction rate

time(s)

Equilibrium constant (K_c)

The equilibrium constant is the ratio of concentration of the products to the concentration of the reactants in the equilibrium mixture and the value holds only for a **specific temperature**.



Square brackets [] represent concentrations and K_c has no unit.

Pure solids and liquids/solvents are left out.

K_c > 1: More products than reactants in the equilibrium mixture.

K_c < 1: More reactants than products in the equilibrium mixture.



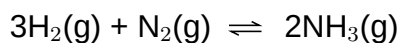
QUESTION 1

1.1 Write equations for the equilibrium constant for each of the following reactions:

$2\text{H}_2\text{O}_2(\text{aq}) \rightleftharpoons 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g})$	
$\text{AgCl}(\text{s}) \rightleftharpoons \text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq})$	
$6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{C}_6\text{H}_{12}\text{O}_6(\text{s}) + 6\text{O}_2(\text{g})$	

1.2

Ammonia is prepared according to the following reaction:



At a high temperature an equilibrium mixture for the above endothermic reaction has the following concentrations:

$$[\text{NH}_3] = 2 \text{ mol/dm}^3$$

$$[\text{H}_2] = 1,5 \text{ mol/dm}^3$$

$$[\text{N}_2] = 0,5 \text{ mol/dm}^3$$

Calculate the equilibrium constant (K_c) for the reaction at this temperature.



1.3 Hydrogen iodide can be produced by the following reversible reaction:



At a certain time during the reaction the concentrations in the container are:

$$[\text{H}_2] = 1,5 \text{ mol/dm}^3$$

$$[\text{I}_2] = 1,0 \text{ mol/dm}^3$$

$$[\text{HI}] = 2,5 \text{ mol/dm}^3$$

Do a calculation to determine if the reaction has reached chemical equilibrium.

1.4 Consider the following reaction: $2\text{A}(\text{g}) + \text{B}(\text{g}) \rightleftharpoons \text{C}(\text{g})$.

12 mol A and 10 mol B are sealed in a 2 dm^3 container. At equilibrium there are 4 mole of A in the container. Calculate the K_c value.

Reaction			
Mole initially			
Mole react			
Mole at equilibrium			
Concentration at equilibrium $c = \frac{n}{V}$			

**Le Chatelier's Principle:**

When the equilibrium in a closed system is disturbed, the system will re-instate a new equilibrium by favouring the reaction that will oppose the disturbance.

The following dynamic equilibrium is reached in a closed container:



$$K_c = \frac{[C]^2[D]}{[A]^2}$$

$$c = \frac{n}{V}$$

If A is added to the mixture in the container:

Disturbance: [A] increases.

According to Le Chatelier's principle the system reacts to decrease the [A] .

The forward reaction is favoured. (Use A)

More C and D is produced.

K_c remains the same.

If C is added to the mixture in the container:

Disturbance: [C] increases.

According to Le Chatelier's principle the system reacts to decrease the [C] .

The reverse reaction is favoured. (Use C)

D decreases.

K_c remains the same.

If A is removed from the mixture in the container:

Disturbance: [A] decreases.

According to Le Chatelier's principle the system reacts to increase [A] .

The reverse reaction is favoured (make A).

C and D decreases.

K_c remains the same.

B(s) is added:

Solid has no effect on equilibrium.

If the volume of the container is decreased:

Disturbance: pressure increases (Boyle's Law).

According to Le Chatelier's principle the system reacts to lower the pressure.

Reacts to produce less moles of gas.

Reverse reaction is favoured.

C and D decreases.

K_c remains the same.

If the temperature is increased:

Disturbance: Temperature increases.

According to Le Chatelier's principle the system reacts to decrease the temperature.

Endothermic reaction is favoured (uses energy).

(ΔH is negative $\therefore$ forward reaction exothermic.)

The reverse reaction is favoured.

C and D decreases.

K_c decreases.

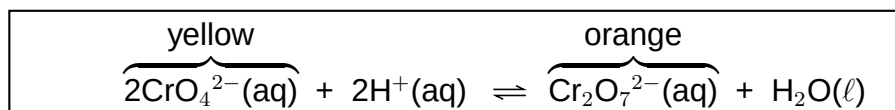
**Catalyst is added:**

No effect on equilibrium. The rate of both reactions increase **equally**.

Favoured does not indicate that the reaction happens faster than before, but that it happens faster than the reaction in the opposite direction.

Action	Disturbance	Explanation
Adding acid	$[H^+]$ increases	Acid donates H^+
Adding base	$[H^+]$ decreases	Base reacts with H^+
Adding $AgNO_3$	$[Cl^-]$ decreases	$Ag^+ + Cl^- \rightarrow AgCl(s)$ precipitate
Adding $BaCl_2$ or $Ba(NO_3)_2$	$[SO_4^{2-}]$ decreases	$Ba^{+2} + SO_4^{2-} \rightarrow BaSO_4(s)$ precipitate

The colours of compounds with transition elements are well-known. For example, consider the following equation of a reversible reaction:



1. Write down an expression for the equilibrium constant.

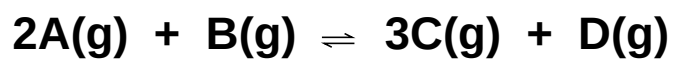
2. How will the equilibrium constant (K_c) be influenced in the following situations:

a) sodium chromate (Na_2CrO_4) is added. _____

b) Hydrochloric acid is added. _____

c) Sodium hydroxide is added _____

3. Explain in detail how the colour of the solution will be influenced when sodium hydroxide is added.



	A and B into container	A added	B removed	D added
Disturbance				
Le Chatelier: System reacts to ...				
The ... reaction is favoured				
[C] ...				
K_c				

Reaction rate

--	--	--	--	--	--	--	--

Concentrations

--	--	--	--	--	--	--	--



$$\Delta H < 0$$

Volume doubled	Temperatuur increased	Temperature decreased	Catalyst added

--	--	--	--	--	--	--	--

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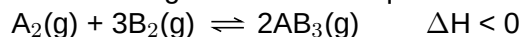


Le Chatelier, Temperature and Equilibrium constants

QUESTION 2

Choose the correct word in the brackets:

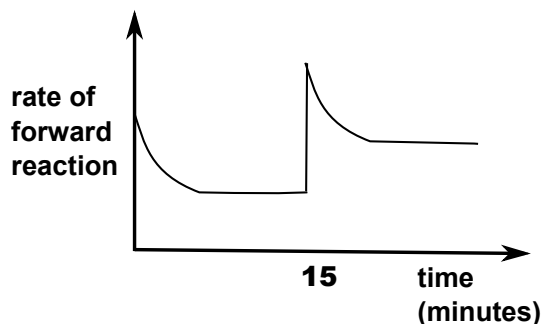
2.1 The following reaction is at equilibrium at 400K:



If the temperature is increased to 600 K
the K_c -value will (increase/decrease/stay the same).

2.2 A mixture of NO and Br_2 is placed in a container. The following reaction occurs: $2\text{NO}(\text{g}) + \text{Br}_2(\text{g}) \rightleftharpoons 2\text{NOBr}(\text{g})$

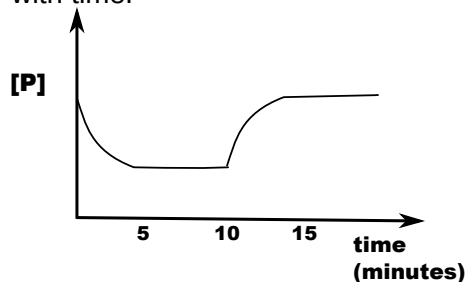
After 5 minutes chemical equilibrium is reached. The following graph shows how the rate of the forward reaction changes with time:



After 15 s the temperature was (increased/decreased) and
the K_c -value (increased/decreased/remained constant).

2.3 P and Q are sealed in a container and the following chemical equilibrium is reached after 5 minutes at 500 K: $\text{P}(\text{g}) + 2\text{Q}(\text{g}) \rightleftharpoons \text{R}(\text{g})$

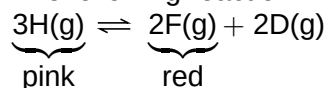
After 10 minutes the temperature is increased to 600 K and after 5 minutes a new chemical equilibrium is established. The following graph shows the change in concentration with time.



The K_c -value (increased/decreased/remained constant).
 ΔH for the reaction is (positive/negative).



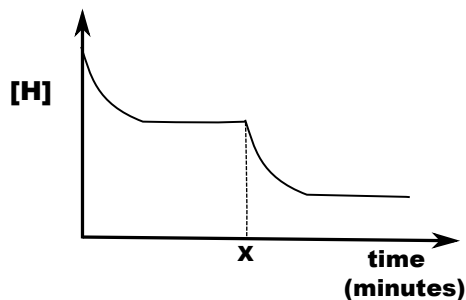
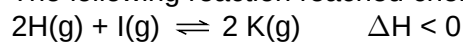
- 2.4 The following reaction mixture turns more red when the temperature is increased:



When the temperature is increased the equilibrium constant (increases/decreases).

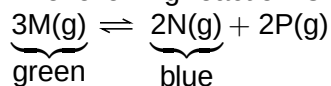
ΔH is (positive/negative).

- 2.5 The following reaction reached chemical equilibrium in a closed container:



At time X the temperature was (increased/decreased) and the K_c -value (increases/decreases/remains constant).

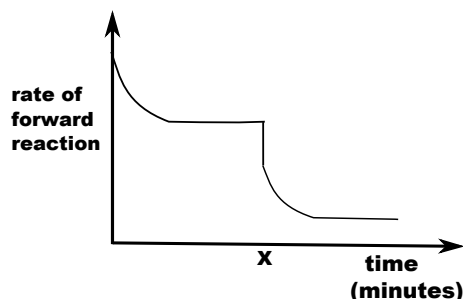
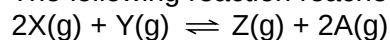
- 2.6 The following reaction is in chemical equilibrium:



When the temperature increases the mixture turns more blue.

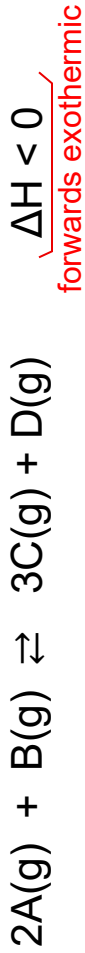
ΔH is (positive/negative).

- 2.7 The following reaction reached chemical equilibrium in a closed container:



After time X the K_c value is (larger/smaller) than before.

The heat of the reaction is (positive/negative).



	A and B in a container	A added	B removed	D added	Volume doubled	Temperature increased	Temperature decreased	Catalyst added
Disturbance		[A]↑	[B]↓	[D]↑	P↓	T↑	T↓	Both reactions equally faster
Le Chatelier's principle: the system reacts to ...		[A]↓	[B]↑	[D]↓	P↑	T↓	T↑	
The ... reaction is favoured		forward	reverse	reverse	more mol gas forward	endothermic reverse	exothermic forward	
[C] will ...		↑	↓	↓	↑	↓	↑	
Kc ...		constant	constant	constant	constant	↓	↑	constant

