A Guide to Chemical Equilibrium

Teaching Approach

In this series we explain what we mean by chemical equilibrium and the factors that determine the position of the equilibrium. Note that the CAPS document separates Rate of Reaction and Chemical Equilibrium. This is because the underlying theory of each of these is very different. Chemical equilibrium is based on thermodynamics and answers the question, 'How far does the reaction go?' Or 'What is the Extent of the reaction? Rate of reaction deals with how *fast* a reaction happens. Learners are inclined to confuse the two concepts.

Up to this point learners have encountered reactions that go to completion, so the idea of reactions that stop before completion is new. Phase equilibria can be used to illustrate the concepts well, and it is recommended that learners get experience in observing the colour changes that occur when the equilibrium in certain reactions is disturbed.

The lessons focus on the calculation and use of equilibrium constants, and the effects on the equilibrium of temperature change, adding a common ion (change in concentration of a solution) and pressure changes in gases.

It is important to note that catalysts do not affect the position of equilibrium. Because temperature, pressure and concentration affect both the rate of a reaction and the position of the equilibrium, learners often confuse them. They need to carefully distinguish between questions about rates and equilibrium.

Video Summaries

Some videos have a 'PAUSE' moment, at which point the teacher or learner can choose to pause the video and try to answer the question posed or calculate the answer to the problem under discussion. Once the video starts again, the answer to the question or the right answer to the calculation is given

Mindset suggests a number of ways to use the video lessons. These include:

- Watch or show a lesson as an introduction to a lesson
- Watch or show a lesson after a lesson, as a summary or as a way of adding in some interesting real-life applications or practical aspects
- Design a worksheet or set of questions about one video lesson. Then ask learners to watch a video related to the lesson and to complete the worksheet or questions, either in groups or individually
- Worksheets and questions based on video lessons can be used as short assessments or exercises
- Ask learners to watch a particular video lesson for homework (in the school library or on the website, depending on how the material is available) as preparation for the next day's lesson; if desired, learners can be given specific questions to answer in preparation for the next day's lesson

1. An Introduction to Chemical Equilibrium

Basic features of chemical equilibrium are explained including reversible reactions, open and closed systems, and dynamic equilibrium. Examples of reactions are given to explain the concepts.

2. What is the Equilibrium Constant?

The equilibrium constant is explained and learners are given examples of how to calculate it for various different reactions.

3. Using the Equilibrium Constant

Learners are given more practice in the application of the equilibrium constant and how to calculate it.

4. Le Chatelier's Principle

The principle is stated and examples of reactions are given to illustrate the principle.

5. Chemical Equilibrium and Temperature

The effects of changes in temperature are investigated for both exothermic and endothermic reactions.

6. Chemical Equilibrium and Pressure

Gas phase equilibria are used to demonstrate the effect of changes in pressure on the equilibrium position.

Resource Material

Resource materials are a list of links available to teachers and learners to enhance their experience of the subject matter. They are not necessarily CAPS aligned and need to be used with discretion.

1. An Introduction to Chemical Equilibrium	http://chemwiki.ucdavis.edu/Under_Construction/chem1/Chemical_Equilibrium/Introduction_to_Chemical_Equilibrium	Basic concepts explained.
2. What is the Equilibrium Constant?	http://www.chemguide.co.uk/physical/equilibria/lechatelier.html	Excellent overview of topic.
3. Using the Equilibrium Constant	http://www.youtube.com/watch?v=L45HqoYsR6U	One of many short videos on various aspects of chemical equilibrium by thatchemguy.
4. Le Chatelier's Principle	https://www.boundless.com/chemistry/chemical-equilibrium/factors-that-affect-chemical-equilibrium/le-chatelier-s-principle/	Alternative statement of le Chatelier's principle and good explanations.
5. Chemical Equilibrium and Temperature	http://www.chm.davidson.edu/vce/equilibria/temperature.html	Simulation of changing temperature and effect on equilibrium
6. Chemical Equilibrium and Pressure	http://chemwiki.ucdavis.edu/Physical_Chemistry/Chemical_Equilibrium/Le_Chatelier's_Principle	Good explanations of effects of changing pressure, temperature and concentration.

Task

Question 1

1.1 What is a reversible reaction?
1.2 Explain dynamic equilibrium.
1.3 What are the factors that influence the position of chemical equilibrium for a particular reaction?

Question 2

Consider this equilibrium reaction:

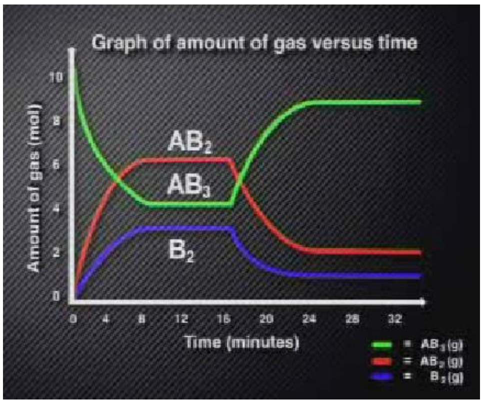
$N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g)$ $\Delta H < 0$

9 mol of N_2 and 15 mol of H_2 are pumped into a 500 cm^3 container at room temperature. The temperature of the gas mixture is now raised to 405°C resulting in 8 mol NH_3 being present at equilibrium.
Calculate the value of K_c at 405°C

Question 3

Consider the reaction $2AB_3(g) \rightleftarrows AB_2(g) + B_2(g)$

The system, as shown in the graph, reaches equilibrium after 8 minutes when placed in a 2 dm^3 container at 500°C.



3.1 Use the graph to calculate the equilibrium constant after 8 minutes.
The temperature is now increased to 600°C at 16 minutes.
3.2 Is the forward reaction exothermic or endothermic? Use le Chatelier's principle to explain your answer.
3.3 Would the change in temperature in the 16th minute cause the K_c to increase, decrease or remain the same?

Question 4

A mixture of 5 moles of $H_2(g)$ and 10 moles of $I_2(g)$ is placed in a 5 dm^3 container and is allowed to reach equilibrium at 448°C. The equation for the equilibrium reaction is:
$H_2(g) + I_2(g) \rightleftarrows 2HI(g)$

At equilibrium the concentration of HI(g) is equal to 1,88 $mol \cdot dm^{-3}$
4.1 Calculate the value of K_c at 448°C

4.2 While the system is in equilibrium, $H_2(g)$ is added to it. Explain by using Le Chatelier's principle how the addition of $H_2(g)$ influences the number of moles of HI(g) when a new equilibrium has been established. Assume that the temperature is kept constant.

Task Answers

Question 1

1.1 Reactions that take place in both the forward and reverse directions simultaneously are called reversible reactions.

1.2 When the rate of the forward reaction equals the rate of the reverse reaction, a state of dynamic equilibrium has been reached.

1.3 Temperature, concentration and pressure affect the position of equilibrium.

Question 2

	N_2	H_2	NH_3
Initial number of mole (mol)	9	15	0
Number of moles used/formed (mol)	-4	-12	8
Number of moles at equilibrium (mol)	5	3	8
Equilibrium concentration ($mol \cdot dm^{-3}$) c = n/V	10	6	16

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

$$= \frac{16^2}{(10)(6)^3}$$

$$=0,12$$

Question 3

3.1 $K_c = \frac{[AB_2]^2[B_2]}{[AB_3]^2} = \frac{6^2 \times 3}{4^2} = 6,75$

3.2 Since more reactant is made, the reverse reaction is favoured, so the reaction must be exothermic.

3.3 Decrease

Question 4

4.1

	H_2	I_2	HI
Initial number of mole (mol)	5	10	0
used/formed (mol	-4,7	-4,7	9,4
Number of moles at equilibrium (mol)	0,3	5,3	9,4
Equilibrium concentration ($mol \cdot dm^{-3}$) c = n/V	0,06	1,06	1,88

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

$$= \frac{(1,88)^2}{(0,06)(1,06)}$$

= 55,57

4.2 An increase in H_2 will according to Le Chatelier's Principle cause the equilibrium to shift so as to decrease the H_2 by forming more products. This favours the forward reaction.

In addition an increase in H_2 increases the pressure which will also favour the forward reaction to produce fewer moles of gas.

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