18 How far? The extent of chemical change

Teaching plan

Sub-chapter	Approximate number of learning hours	Learning content	Resources
18.1 Reversible reactions and equilibrium	1–2	A state of dynamic equilibrium is reached in a closed system when the rates of forward and backward reactions are equal. The equilibrium law describes how the equilibrium constant, *K*, can be determined from the stoichiometry of a reaction.	**Coursebook** Section 18.1 Figs. **18.2–18.4** **Workbook** Exercise 18.1 **Teacher's resource** PowerPoint 18, slide 3 End of Chapter 18 test questions
18.2 The position of equilibrium	2–3	Le Chatelier's principle enables the prediction of the qualitative effects of changes in concentration, temperature and pressure to a system at equilibrium. Application of Le Chatelier's principle to predict and explain responses to changes of systems at equilibrium.	**Coursebook** Section 18.2 Test your understanding questions 1–6 **Workbook** Exercise 18.2 **Teacher's resource** PowerPoint 18, slide 4–6 End of Chapter 18 test

Sub-chapter	Approximate number of learning hours	Learning content	Resources
18.3 Equilibrium constants 18.4 Calculations involving equilibrium constants 18.5 Relationship between equilibrium constants and Gibbs energy	2–3	The reaction quotient, Q, is calculated using the equilibrium expression with non-equilibrium concentrations of reactants and products. The equilibrium law is the basis for quantifying the composition of an equilibrium mixture. The equilibrium constant and Gibbs energy change, ΔG, can both be used to measure the position of an equilibrium reaction.	**Coursebook** Sections 18.3–18.5 Exam-style questions **Workbook** Exercises 18.3–18.5 **Teacher's resource** PowerPoint 18, slide 7–8 End of Chapter 18 test

BACKGROUND KNOWLEDGE

- Students should have an understanding of the rates of reaction topic, including rate equations.
- Stoichiometry from Chapter 16.
- ΔG, as it is covered in the energetics topic (Chapter 15).
- Students should have seen the equation $\Delta G^{\ominus} = -RT\ln K$ before, as it is covered in Chapter 15.

Syllabus overview

- The students will be given the definitions of dynamic equilibrium and be able to explain how the rate of the forward reaction is equal to the rate of the reverse reaction.
- Students will then understand how to construct an equation to work out the equilibrium constant from the stoichiometry of the reaction.
- Students will be able to understand Le Chatelier's principle, and then they will be able to use this knowledge to work out how pressure, concentration and temperature affect the position of equilibrium of a reaction in a closed system.
- Students will also gain an understanding of the differences between the reaction quotient, Q, and the equilibrium constant, K.
- Students will then learn how equilibrium relates to Gibbs energy change.

18.1 Reversible reactions and equilibrium

LEARNING PLAN

Learning objectives	Success criteria
Understand what is meant by the term dynamic equilibrium	Students can explain what is meant by the term dynamic equilibrium.
Understand how to write an equilibrium law expression	Students can write an equilibrium law expression.
Understand the connection between the value of the equilibrium constant and the extent of reaction	Students can explain the connection between the value of the equilibrium constant and the extent of reaction.
Understand the connection between the value of the equilibrium constant and how the chemical equation is written	Students can explain the connection between how a reaction is written and the equilibrium constant expression.

Common misconceptions

Misconception	How to identify	How to overcome
Students calculate the equilibrium constant, *K*, incorrectly	Read Post-it notes from the plenary lesson to see whether the students understand how to do this calculation	Ensure that students know how to balance the equations correctly. Go through example calculations, highlighting how to use the coefficients of the reactants and products to calculate the equilibrium constant.

Starter ideas

1 Demonstration of equilibrium (20 minutes)

Resources: Chemicals and apparatus to perform the demonstration; information is available on the Royal Society of Chemistry website.

Description and purpose: The teacher demonstrates equilibrium using the chromate–dichromate equilibrium. This gives instructions on how to perform this reaction and shows the students that, by changing the conditions of the reaction, the colours will change (a risk assessment needs to be carried out before this is shown to the students).

What to do next: The teacher can write out an equilibrium chemical equation and explain the reversible reaction sign.

Main teaching ideas

1 Dynamic equilibrium (30 minutes)

Resources: Diagrams showing the rates of forward and reverse reactions for equilibrium reactions.

Description and purpose: The teacher explains what is meant by the term dynamic equilibrium and shows the students what happens to the rates of the forward and reverse reactions as they get to equilibrium. The teacher then explains the equilibrium law and equilibrium constant using the correct equations, linking these to the reaction that is taking place.

› **Language focus:** Students will be given the definitions needed to describe dynamic equilibrium and will need to understand the scientific vocabulary used in this section.

› **Differentiation ideas:**

Support: Students construct a mind map in groups to build up their knowledge of the topic. The teacher can spend more time with certain groups to help them better their understanding. The teacher can also assess the students learning as they go around the room.

Stretch and challenge: The students could do flipped learning and read ahead about Le Chatelier's principle and see how it fits in with the equilibrium topic.

› **Language focus:** Students can put keywords and definitions into their mind maps to help them use the correct terminology.

Plenary ideas

1 Post-it notes (15 minutes)

Resources: Post-it notes.

Description and purpose: Students write short summaries of what they have learned on Post-it notes. They then stick these on the board at the front of the class.

› **Language focus:** Writing short summaries using the correct terms in a clear way for others to understand.

› **Assessment ideas:** The students can then read each other's summaries and make any corrections. This will help the students gain a better understanding of the topic.

18.2 The position of equilibrium

LEARNING PLAN

Learning objectives	Success criteria
Use Le Chatelier's principle to explain how changes in conditions affect the position of equilibrium	Students can use Le Chatelier's principle to explain how changes in conditions affect the position of equilibrium.

Common misconceptions

Misconceptions	How to identify	How to overcome
Students get confused with the sign of enthalpy change and then how temperature affects the position of equilibrium	Give students incorrect calculations and ask them to correct them.	Go through this as a class, and highlight any mistakes and correct them for the whole class to see.

Misconceptions	How to identify	How to overcome
Students think that the catalyst will affect the position of equilibrium	Give students equilibrium reactions and ask them to predict what would happen if the temperature, pressure and concentration are changed or a catalyst is added	Have a discussion with the class to see what they think would happen to the equilibrium when these changes are made. Let the students vote to see who is correct and incorrect, and then explain the correct answers.

Starter ideas

1 Demonstration of cobalt chloride equilibrium (20 minutes)

Resources: Chemicals and equipment required for the practical.

Description and purpose: The teacher shows the cobalt chloride equilibrium practical to the class, to show a colour change when the conditions are changed, demonstrating Le Chatelier's principle.

Safety: A risk assessment should be written for this practical.

What to do next: The class has a discussion about what is causing the change in colour. This discussion can be guided by the teacher to elicit the correct information.

Main teaching ideas

1 Explanation of Le Chatelier's principle (40 minutes)

Resources: Examples of different reactions (including enthalpy changes and state symbols).

Description and purpose: The teacher explains Le Chatelier's principle and goes through the different changes that may affect a chemical reaction (temperature / pressure / catalyst).

› **Language focus:** The students can then work in groups and go through different chemical equations to say how temperature, pressure and catalysts will affect the position of equilibrium and the amount of product formed.

› **Differentiation ideas:**

Support: During the lesson, the teacher can go around the different groups and offer support to those that need it. The teacher can provide scaffolded worksheets. Questions can be separated into different sections (temperature and pressure). Worked examples can be given at the top to show students what they need to look for.

Stretch and challenge: Students are given IB questions on equilibrium, so they can get used to the exam wording.

› **Language focus:** Exam terminology.

2 Ammonia (40 minutes)

Resources: Ammonia equilibrium equation.

Description and purpose: Students are given the ammonia equilibrium equation and are asked to explain how increasing the temperature, concentration and adding a catalyst affects the rate of reaction and the position of equilibrium.

› **Differentiation ideas:**

Support: Students could be given a revision sheet of rates of reaction to help them understand what changes a rate of reaction.

Stretch and challenge: The students can be given the conditions that are used to make ammonia industrially and asked to explain these.

Plenary ideas

1 Discussion of the Haber process (15 minutes)

Resources: Diagram of the Haber process, including reaction conditions.

Description and purpose: The students look at an industrial process that uses equilibrium. Students have a discussion around why these are the conditions used. The teacher can ask the following questions: Why isn't a higher pressure used? Why isn't a lower temperature used?

2 Copper sulfate equilibrium (20 minutes)

Resources: Hydrated and anhydrous copper sulfate.

Description and purpose: The students are given the two copper sulfate compounds to look at, and then they have to create a reversible reaction for this equilibrium. They should then work out which conditions will move the equilibrium in which direction.

18.3 Equilibrium constants; 18.4 Calculations involving equilibrium constants and 18.5 Relationship between equilibrium and Gibbs energy

LEARNING PLAN

Learning objectives	Success criteria
Solve problems involving the equilibrium constant	Students can solve problems involving the equilibrium constant.
Calculate the value of the reaction quotient	Students can calculate the value of the reaction quotient.
Understand the connection between the change in Gibbs energy, the equilibrium constant and the reaction quotient	Students can explain the connection between the change in Gibbs energy, the equilibrium constant and the reaction quotient.
Solve problems involving the change in Gibbs energy, the equilibrium constant and the reaction quotient	Students can solve problems involving the change in Gibbs energy, the equilibrium constant and the reaction quotient.

Common misconceptions

Misconceptions	How to identify	How to overcome
Students calculate the reaction quotient incorrectly.	Go around the room and check students' working.	Set practice questions involving reaction quotients and show the students mark scheme answers.
Students do not understand the difference between reaction quotients and equilibrium constants.	Ask students to explain the difference between reaction quotients and equilibrium constants.	Students can correct other students' answers if needed; the teacher could give model answers to show the students the difference.

Misconceptions	How to identify	How to overcome
Students use the wrong equation to try and work out Gibbs free energy.	Through homework questions.	Mark students' questions and give corrections. Highlight the correct method to use during class.

Starter ideas

1 Review of Chapter 15 (25 minutes)

Resources: Coursebook.

Description and purpose: Students can recap from their own notes or use the textbook to go through Chapter 15. The reaction quotient and Gibbs free energy are discussed in Chapter 15. This is a good opportunity to scaffold the students' learning, as the teacher could help students who need it by giving sheets with hints or keywords to fill in. Revisiting this chapter will help to build their understanding of the content.

› **Language focus:** This is a good opportunity for students to recap key phrases and terminology from Chapter 15.

What to do next: Students can read through each other's recap and see if they have missed anything from the topic. They could test each other on their knowledge.

Main teaching ideas

1 Reaction quotients (25 minutes)

Resources: Equilibrium equations.

Description and purpose: Students write out expressions for the reaction quotient, Q, for different equilibrium equations. The students are then asked to explain how increasing the products would affect the reaction quotient.

› **Differentiation ideas:**

Support: The teacher could go through an example to show how to write a reaction quotient expression.

Stretch and challenge: Students could be asked to think about the link between reaction quotients and equilibrium constants.

2 Solving problems involving Gibbs free energy, reactant quotients and equilibrium constants (45 minutes)

Resources: Questions involving Gibbs free energy, reactant quotients and equilibrium constants.

Description and purpose: The teacher will explain the relationship between reactant quotients and equilibrium constants and the relationship between Gibbs free energy and reactant quotients. The teacher will go through some example calculations and give model answers to the students. The students can then practice solving problems involving Gibbs free energy, reactant quotients and equilibrium constants.

› **Differentiation ideas:**

Support: The questions can be staggered, so the students work through how to calculate reaction quotients and equilibrium constants first, and then they can build on this knowledge to calculate Gibbs free energy.

Stretch and challenge: Students can be asked to work backwards and be given the Gibbs free energy and asked to work out the reaction quotient and whether it is at equilibrium or not. They could also be given some incorrect answers and will need to correct these. Doing both of these things will enhance the students' understanding of the content.

3 Interpreting Gibbs free energy graphs (30 minutes)

Resources: Gibbs free energy graphs showing the composition of a mixture.

Description and purpose: Students are given Gibbs free energy graphs and are asked to interpret them, linking their answers to equilibrium.

› **Differentiation ideas:**

Support: The students can be given definitions and answers, which they can label on the graph, to help with their understanding

Stretch and challenge: Students could be asked to sketch Gibbs free energy graphs and use these graphs to explain the link between Gibbs free energy and equilibrium.

Plenary ideas

1 Pop quiz (20 minutes)

Resources: Laptops, computers, tablets.

Description and purpose: Students can use an online tool (kahoot, quizlet, etc.) to do a pop quiz on the topic.

› **Assessment ideas:** This will give the teacher a chance to assess the students' learning. The pop quiz can be tailored to the level of the students and either support or challenge them, depending on their understanding.

Assessment ideas

- Exam-style questions from the end of the chapter in the Coursebook.
- IB past paper questions on equilibrium.
- Students could give a presentation on one aspect of the topic to the class.

Homework ideas

› **Language focus:** Students could make revision resources for the whole class for one part of the topic (flash cards, quizzes, etc.).

- Students could be given scaffolded questions (with different difficulties) to test their understanding.
- Students could be given some videos on equilibrium to watch and make notes on. Richard Thornley's YouTube channel has lots of videos on IB chemistry and equilibrium.
- Students read through the chapter and come up with 10 questions about things they do not fully understand.
- Students should go through the syllabus content and mark with green, yellow or red their understanding of each syllabus point. They can then focus on those areas where their knowledge is the weakest.

Links to digital resources

- Practical experiment on the chromate–dichromate equilibrium
- Cobalt chloride equilibrium, which the teacher can use to show a colour change when the conditions are changed, demonstrating le Chatelier's principle
- Richard Thornley' has lots of videos on IB chemistry and equilibrium. Search the internet using his name.