15 Entropy and spontaneity

Teaching plan

Sub-chapter	Approximate number of learning hours	Learning content	Resources
15.1 Entropy	1–2	Entropy, S, is a measure of the dispersal or distribution of matter and / or energy in a system. The more ways the energy can be distributed, the higher the entropy. Under the same conditions, entropy of gas > liquid > solid. Prediction of whether a physical or chemical change will result in an increase or decrease in entropy of a system. Calculation of standard entropy changes, $\Delta S^{\ominus}$ from standard entropy values, $S^{\ominus}$.	**Coursebook** Section 15.1 Test your understanding Questions 1–2 **Workbook** Exercise 15.1 **Teacher's resource** PowerPoint 15, slides 3–4
15.2 Spontaneous reactions 15.3 Gibbs energy and equilibrium	1–2	Change in Gibbs energy, ΔG, relates the energy that can be obtained from a chemical reaction to the change in enthalpy, ΔH; change in entropy, ΔS; and absolute temperature, T. Application of the equation $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$ to calculate unknown values of these terms. At constant pressure, a change is spontaneous if the change in Gibbs energy, ΔG, is negative. Interpretation of the sign of ΔG calculated from thermodynamic data. Determination of the temperature at which a reaction becomes spontaneous. As a reaction approaches equilibrium, ΔG becomes less negative and finally reaches zero. Calculations using the equation $\Delta G = \Delta G^{\ominus} + RT\ln Q$, and its application to a system at equilibrium, $\Delta G^{\ominus} = -RT\ln K$.	**Coursebook** Sections 15.2–15.3 Test your understanding questions 3–12 **Workbook** Exercises 15.2–15.3 **Teacher's resource** PowerPoint 15, slides 5–7 End of Chapter 15 test

BACKGROUND KNOWLEDGE

- Students should have an understanding of energy cycles from the previous topic.
- Students should be able to calculate enthalpies of reaction.

Syllabus overview

- Students will gain an understanding of what spontaneous reactions are and why they occur. They will also gain an understanding of entropy, and from this, they should be able to calculate entropy changes of a reaction.
- Students will then be taught about Gibbs free energy and be able to use the equations to work out ΔG and, therefore, work out if reactions are spontaneous or not. They will also be able to understand the link between ΔG and equilibrium.

15.1 Entropy

LEARNING PLAN

Learning objectives	Success criteria
Understand the term entropy Predict whether a chemical / physical reaction involves an increase or decrease in entropy Calculate standard entropy changes	Students can explain the term entropy. Students can predict whether a chemical / physical reaction involves an increase or decrease in entropy. Students can calculate standard entropy changes.

Common misconceptions

Misconception	How to identify	How to overcome
Students don't calculate standard entropy changes correctly – they don't multiply by the coefficients.	When going through calculations, the teacher can see which students have made mistakes.	Highlight how to do this when going through the example calculations. The teacher checks upon going around the class to make sure the students are doing it correctly.

Starter ideas

1 Entropy introduction (20 minutes)

Description and purpose: The teacher explains the term entropy and then gives the students some different equations on the board to see what the change in entropy is. For example, ice going to water or an increase or decrease in the number of moles of gas. An increase in the number of moles of gas indicates an entropy increase, and a decrease in the number of moles of gas indicates a decrease in entropy.

› **Language focus:** Definition of entropy is given from the syllabus, so students know the language to use.

What to do next: Students could watch a video or read about the laws of thermodynamics to understand how they are linked to entropy and give themselves a greater understanding of the topic.

Main teaching ideas

1 Increase or decrease in entropy? (30 minutes)

Resources: Fifteen chemical equations that show a change in entropy.

Description and purpose: The students are given 15 equations and are asked to work out if there is an increase or a decrease for each one. This could be done as a game in class, such as higher or lower.

› **Differentiation ideas:**

Support: The teacher can start with an example to work through with the class, to show how the entropy can be worked out. They can then work with individual students or groups, to help the students gain a better understanding of this topic.

Stretch and challenge: Students could be given equations that have the same number of gas particles on both sides, or equations with reactants or products in different states, and be asked to work out what would happen to the entropy in each case.

2 Entropy calculations (30 minutes)

Resources: Equation on the board.

Description and purpose: The teacher explains the equation to work out change in entropy and goes through an example calculation with the class, to show the students how to do the calculations. The students are then given some questions, with the data required, and should work through these to show their understanding of the topic.

› **Differentiation ideas:**

Support: The questions can be scaffolded, breaking down the calculation into small steps, so it is easier to follow and will allow the students to have a better understanding of the content.

Stretch and challenge: Students can be given some harder examples and questions that do not have a scaffolded approach.

Plenary ideas

1 Spot the mistake (10 minutes)

Resources: Questions with answers that have deliberate mistakes.

Description and purpose: Students go through the answers and correct the mistakes in them. This will give them a deeper understanding of the topic and help them identify some common misconceptions.

› **Language focus:** Go through the correct model answers, so students can correct their own language and use the correct terminology

15.2 Spontaneous reactions and 15.3 Gibbs energy and equilibrium

LEARNING PLAN

Learning objectives	Success criteria
Understand the term change in Gibbs energy	Students can explain the term change in Gibbs energy.
Calculate the change in Gibbs energy	Students can calculate the change in Gibbs energy.
Relate the change in Gibbs energy to the spontaneity of a reaction	Students can relate the change in Gibbs energy to the spontaneity of a reaction.
Explain the changes in Gibbs energy as a system reaches equilibrium	Student can explain the changes in Gibbs energy as a system reaches equilibrium.
Calculate Gibbs energy changes for systems approaching equilibrium and at equilibrium	Students are able to calculate Gibbs energy changes for systems approaching equilibrium and at equilibrium.

Common misconceptions

Misconceptions	How to identify	How to overcome
Students don't convert entropy into kJ.	Through example calculations, classwork and homework.	Highlight this common misconception and check work thoroughly every time to make sure students remember.
Students use degrees Celsius rather than kelvin for the temperature.	Through calculations in class and homework; by going around the room when doing the questions.	Highlight this error. When going through an example calculation, make sure to make a point of this.
Students get confused as to why Gibbs free energy goes down for both the forward and reverse reaction.	When explaining the content and during the plenary lesson, questions can be asked to elicit students' understanding.	Give a thorough explanation that covers this, to help the students understand the reasons for this occurring.

Starter ideas

1 Recap entropy (20 minutes)

Resources: Reactions on the board.

Description and purpose: Put some reactions on the board and ask the students to decide whether there is an increase or decrease in entropy.

What to do next: The teacher can explain the spontaneity of a reaction using the first law of thermodynamics and the second law of thermodynamics, relating it to entropy.

2 Recap Gibbs free energy calculations (15 minutes)

Resources: Exam-style questions on Gibbs free energy.

Description and purpose: Students will recap what they have learned from the previous lesson, to help assess their understanding of the content.

What to do next: Students can think about the links between Gibbs free energy and equilibrium.

Main teaching ideas

1 Calculate the change in Gibbs Energy (40 minutes)

Resources: Questions on Gibbs free energy.

Description and purpose: The teacher displays the Gibbs free energy equation on the board and explains the links to enthalpy and entropy. Then the teacher goes through an example calculation, highlighting that the units of both enthalpy and entropy will need to be in kJ and the temperature needs to be in kelvin.

› Differentiation ideas:

Support: The students can be given the enthalpy and entropy values (both in kJ), so they don't have to work those out, and be given the temperature in kelvin. Group work can be set, and the teacher can spend more time with those students that require more help.

Stretch and challenge: Students can be given some calculations that ask at which temperature does the reaction become spontaneous to test their understanding of the content.

2 Spontaneity of a reaction (30 minutes)

Resources: Different reactions with data to work out if the reaction is spontaneous.

Description and purpose: The teacher explains what spontaneity of a reaction means. Students are then given different reactions and asked to work out if the reaction will be spontaneous or not.

› Differentiation ideas:

Support: The students can be given a step-by-step method to work out the spontaneity of a reaction and a worked example of a calculation.

Stretch and challenge: Students could research the importance of spontaneity of a reaction in industrial processes.

3 Gibbs free energy and equilibrium (35 minutes)

Description and purpose: The teacher will explain the links between Gibbs free energy and equilibrium (They can use Fig. **15.4** from the Coursebook to help) and then go through the calculation of Gibbs free energy at equilibrium. An explanation of reaction quotients will be needed, unless already covered in the equilibrium chapter.

› Differentiation ideas:

Support: Fill in sheets with diagrams can be given to help support weaker students.

Stretch and challenge: Students try to figure this out for themselves before the teacher goes through it. This will get them thinking about the subject in more depth.

4 Gibbs free energy and equilibrium graphs (35 minutes)

Resources: Graph showing Gibbs free energy for equilibrium reactions.

Description and purpose: Students are given a graph and asked to interpret it, to explain the curves. This will help them to understand the link between Gibbs free energy and equilibrium.

› Differentiation ideas:

Support: Students could be given key phrases, which they could place on the correct part of the graph, to explain what is happening.

Stretch and challenge: Students could try and sketch their own Gibbs free energy graph for a different equilibrium reaction, perhaps a reaction that is endothermic in the forwards direction.

Plenary ideas

1 Spontaneity of a reaction quick check (20 minutes)

Description and purpose: The teacher gets the students to think about, and discuss, the spontaneity of a reaction when ΔH and ΔS are assigned either negative or positive values. They should also consider what would happen when temperature changes–does the spontaneity of the reaction become less spontaneous, more spontaneous or stay the same. This will help check on the students' understanding of Gibbs energy.

2 Correct the mistakes (20 minutes)

Resources: Mini-whiteboards, questions with incorrect answers and working.

Description and purpose: Students will go through the questions and correct the mistakes, showing these on the mini-whiteboards. This will help with the students' understanding of the topic and allow the teacher to assess this understanding.

Assessment ideas

- Exam-style questions from the Coursebook.
- Students could write a synopsis of the topic, showing their understanding of the topic.
- Past paper questions.

Homework ideas

- Test your understanding questions from the Coursebook.
- Flipped learning – students are asked to read the chapter before going to the lesson to see how much they understand about the topic.
- Make a video explaining the concepts taught in this topic.
- Go through the syllabus points and make a note of which ones the students understand completely, partially understand or don't understand.

Links to digital resources

- Video on the laws of thermodynamics, entropy and Gibbs free energy
- Explanation of entropy and the second law of thermodynamics