

# Unit Preparation Booklet

## C5.2 Controlling Reactions

Teacher name:

Science
**Mastery**

Ark **Curriculum+**

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# Steps to Success

| | | What? | Why? | Who? | Page # |
|---|---|---|---|---|---|
| **Preparing to teach** | **1** | ☐ Print this booklet or save a copy in a personal folder | To allow for engagement during planning and co-planning | *All teachers* | |
| | **2** | ☐ Engage with the unit preparation checklist | To prepare for delivering the sequence of lessons | *All teachers* | 4 |
| | **3** | ☐ Read the scope and sequence for the unit | To review the scope and sequence of the unit | *All teachers* | 5 |
| | **4** | ☐ Complete the pre-unit quiz reflections task after administering to class | To plan how to remedy prior knowledge gaps | *New to teaching the unit only* | 10 |
| | **6** | ☐ Complete the Mastery Quiz and exam-style questions activity | To learn/revisit the key assessment objectives of the unit | *New to teaching the unit only* | 11-22 |
| | **7** | ☐ Complete the misconception activities | To develop a strong understanding of the most common misconceptions for the unit and how to address them | *New to teaching the unit only* | 23-25 |
| **Delivering the unit** | **8** | ☐ Use the lesson-by-lesson objectives to monitor progression through the unit | To maintain a record of completion and to recognise what needs to be reviewed after each lesson | *Novice teachers only* | 26-41 |
| **Utilise other features of the booklet** | **9** | ☐ Complete the A-level/ GCSE activity | To develop an understanding of where the unit can lead | *Non A-level/GCSE specialists* | 42 |
| | **10** | ☐ Engage in the keywords for the unit | To identify the correct definitions for keywords throughout the unit | *Novice teachers only* | 43-44 |

# Unit preparation checklist

**Resources can and should be tailored to meet your pupils' needs**. We have aimed to do as much resourcing as possible so that teachers' time can be spent on co-planning and preparation; however, they are only ready for your pupils once you have decided how to make use of them.

**Here is a suggested checklist:**

**Locate:**

- ☐ **Find** the unit resources using MyMastery or SharePoint

**Engage:**

- ☐ Work through the preparation booklet. Complete the pre-unit quiz, mastery quiz and exam-style questions yourself and reflect (all enclosed)
- ☐ Set your class the **pre-unit quiz** (in advance of the unit).
- ☐ Note which topics are **areas of weakness** for the class (space available in this booklet or on the planning pro-forma)
- ☐ **Decide** which topics you will re-visit 'in advance' and which to tackle during the unit (space available in this booklet or on the planning pro-forma)
- ☐ Identify where in the sequence of learning there are opportunities for embedding **guided reading**
- ☐ Use the **lesson planning guidance** to develop a grasp of the purpose of each lesson element

**Adapt:**

- ☐ Consider key timings for each lesson. Identify which lessons may need to be adapted to account for the length of your lessons or ability level of your class
- ☐ Identify what could be used as **homework** activities to support in-class learning in line with school policy
- ☐ Review the resources ahead of each lesson and ensure you are clear on the objectives of each lesson
- ☐ **Select** appropriate activities for each lesson from the selection within each lesson folder/on the slide deck
- ☐ **Administer** exit tickets and use outcomes of this to plan 'fix-it' tasks to tackle misunderstanding or misconception.
- ☐ Set the **mastery quiz** for your class. Use the information to plan a suitable re-teach lesson and further response, using the resources available.

# Scope and Sequence

## Scope

This unit covers the topic of rates of reaction, including the required practical. It also covers reversible reactions and equilibrium, including Le Chatelier's principle for higher tier students and the Haber process and fertilisers for chemistry only students.

## Sequence

The unit begins with a review of exothermic and endothermic reactions and reaction profiles, leading into the introduction of collision theory. Students have already met the term activation energy and can now put that into the context of a collision being successful. Students then cover the different factors that affect the rate of reaction, each explained in the context of collision theory. Students will meet temperature, concentration, surface area and pressure before meeting catalysts separately. This is to avoid confusion about the effect of catalysts on chemical reactions and ensure that there is an opportunity to revisit the effect of a catalyst on a reaction profile.

From here students look at rate of reaction graphs, using their knowledge of collision theory and the factors that affect rate of reaction to draw conclusions from graphs. Higher tier students will also learn how to draw and calculate the gradient of a tangent to a curve to determine the instantaneous rate of reaction. After rate of reaction graphs, students will go on to understand how they can actually measure rate of reaction themselves, from quantities of reactants used or products made in a given time, preparing them for the two methods used in the required practical. The required practical focuses on concentration and how the rate of reaction can be determined, allowing students an opportunity to revisit uncertainty and explain why there may be uncertainty from measurements in each method.

The unit then moves on to reversible reactions and dynamic equilibrium, linking back to knowledge of yield from C4.3. Higher tier students will then look at dynamic equilibrium and Le Chatelier's principle and the effects of changing conditions. Separate science students will then use their knowledge of reaction conditions and the effect of changing these on yield to look at the example of the Haber process. Finally they will look at how the Haber process is linked to fertilisers, making links to biology and the role of fertilisers on plant growth.
A full set of knowledge objectives for this unit can be found as **Appendix 3.**

| **1** | **2** | **3** | **4** |
|---|---|---|---|
| Prior Knowledge Review | Collision Theory | Temperature and Concentration | Surface Area and Pressure |
| **5** | **6** | **7** | **8** |
| Catalysts | Rate of Reaction Graphs | Maths in Science: (HT) Tangents | Measuring Rate of Reaction |
| **9** | **10** | **11** | **12** |
| RPA Investigating the Effect of Concentration | RPA Investigating the Effect of Concentration Analysis | Reversible Reactions and Equilibrium | (HT) Le Chatelier's Principle: Concentration |

| 13 | 14 | 15 | 16 |
|---|---|---|---|
| (HT) Le Chatelier's Principle: Temperature and Pressure | Taking it Further: The Haber Process | Taking it Further: Fertilisers | Feedback Lesson |

**TASKS:**

| |
|---|
| *New teachers:* Organise the lesson titles into those you feel most to least confident about<br><br>*Experienced teachers:* Reflect on prior experience of teaching this unit. Which lessons have gone well? Which would you like to target for improvement this year? |
| |

# Pre-unit quiz

1. A chemical reaction …[1]
   Tick (✓) **one** box.
   A. produces a new substance whereas a physical change does not. ☐
   B. is reversible whereas a physical change is not. ☐
   C. has the same reactants and products, whereas they are different for a physical change. ☐

2. Choose the relative formula mass of $(NH_4)_3PO_4$.

   (Ar: N = 14; H = 1; P = 31; O = 16) [1]
   Tick (✓) **one** box.
   A. $M_r = 123$ ☐
   B. $M_r = 121$ ☐
   C. $M_r = 149$ ☐
   D. $M_r = 144$ ☐

3. Choose which of the symbol equations below is balanced. [1]
   Tick (✓) **one** box.
   A. $N_2 + H_2 \rightarrow NH_3$ ☐
   B. $3\ N_2 + 3\ H_2 \rightarrow NH_3$ ☐
   C. $N_2 + 3\ H_2 \rightarrow 2\ NH_3$ ☐

4. Select the correct definition of an exothermic reaction.
   Tick (✓) **one** box. [1]
   A. A reaction that takes in more energy to break the bonds of the reactants than it gives out when the new bonds are made in the products ☐
   B. A reaction that takes in less energy to break the bonds of the reactants than it gives out when the new bonds are made in the products ☐
   C. A reaction that takes in more energy to form the new bonds in the products than it gives out when breaking the bonds of the reactants than it gives out ☐
   D. A reaction that takes in less energy to form the new bonds in the products than it gives out when breaking the bonds of the reactants than it gives out ☐

5. Select the chemical reaction that is an endothermic reaction.
Tick (✓) **one** box. [1]

A. Aerobic respiration ☐

B. Anaerobic respiration ☐

C. Photosynthesis ☐

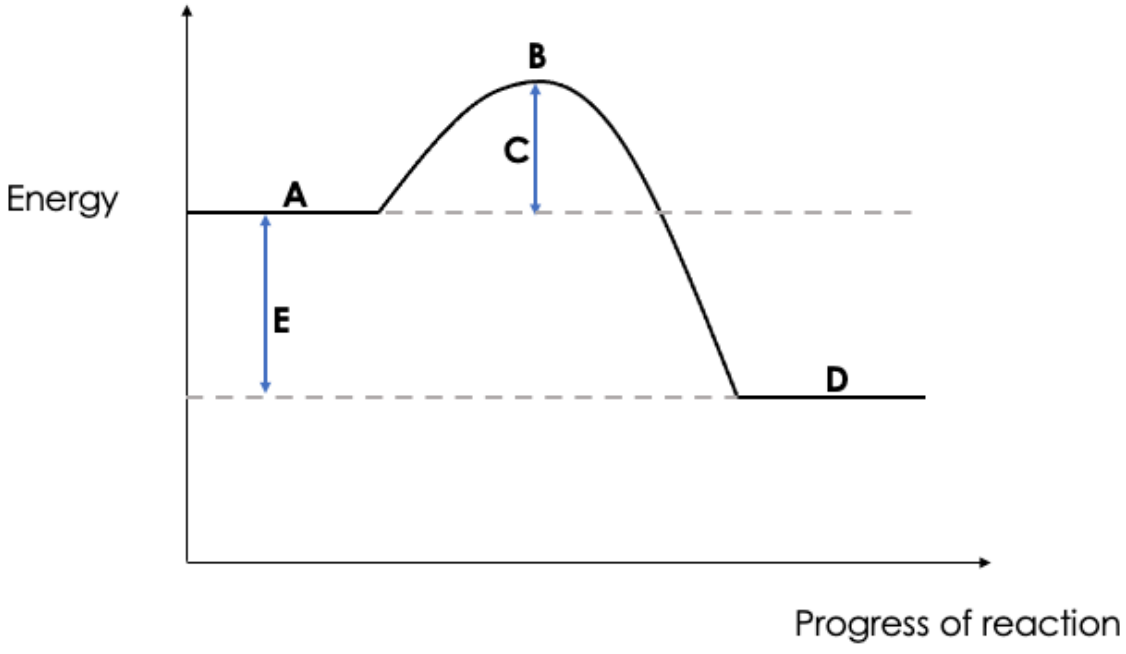
6. Select the application that uses an endothermic reaction.
Tick (✓) **one** box. [1]

A. Sport injury pack ☐

B. Hand warmer ☐

C. Self-heating can ☐

**Use the reaction profile to answer questions 7-10.**




7. Which letter represents the overall change in energy?
Tick (✓) **one** box[1]

A. E ☐

B. D ☐

C. C ☐

8. Which letter represents the activation energy for the reaction?
Tick (✓) **one** box. [1]

A. A ☐

B. B ☐

C. C ☐

9. What type of reaction does this reaction profile show?
Tick (✓) **one** box. [1]

A. Exothermic ☐

B. Endothermic ☐

C. Either exothermic or endothermic ☐

10. Choose the correct description of what would happen to the reaction profile if a catalyst was added. [1]

Tick (✓) **one** box.

A. C would increase ☐

B. C would decrease ☐

C. E would increase ☐

D. E would decrease ☐

## Pre-unit quiz reflections

*To be completed once you have reviewed your pupils' response to the pre-unit quiz.*

| What topics are your pupils confident with? |
| --- |
| |
| What topics need to be reviewed? |
| |
| What are the **highest leverage** piece(s) of knowledge (2-3) to explicitly re-teach? |
| |
| What could be interleaved throughout the unit? |
| |

**Other notes**

# Mastery Quiz

**TASK:** Below is the mastery quiz available for your pupils to sit at the end of the unit. Complete yourself and consider the key misconceptions this quiz aims to address. See **Appendix 2** for the mark scheme.

## Section A

1. Select the correct definition of activation energy.
   Tick (✓) **one** box.[1]
   - A. The amount of energy that particles get when they react ☐
   - B. The minimum amount of energy particles must have to react ☐
   - C. The difference in energy between reactants and products ☐

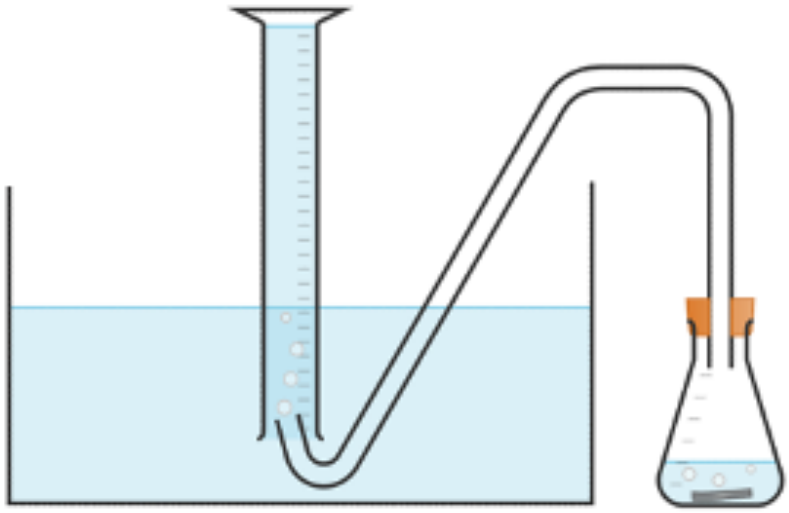
2. Select the correct definition of a catalyst.
   Tick (✓) **one** box. [1]
   - A. A substance that increases the rate of reaction ☐
   - B. A substance that breaks down a large molecule ☐
   - C. A substance that increases the energy of particles ☐

3. Select the factor that would <u>increase</u> the rate of a chemical reaction.
   Tick (✓) **one** box. [1]
   - A. Increasing surface area ☐
   - B. Decreasing concentration ☐
   - C. Decreasing pressure ☐

4. Select the meaning of a reversible reaction.
   Tick (✓) **one** box.[1]
   - A. A reaction in which the reactants and products are the same ☐
   - B. A reaction in which the rate of reaction can be controlled ☐
   - C. A reaction in which the products of the reaction can react to produce the original reactants ☐

**Use the information below to answer questions 5-9.**

A student is investigating the reaction between magnesium and hydrochloric acid. They added 5 g of magnesium ribbon to 10 $cm^3$ of hydrochloric acid using the apparatus below.



5. Which describes how the student can measure the rate of reaction?
   Tick (✓) **one** box. [1]

   A. Measuring the total volume of gas produced ☐

   B. Measuring the volume of gas produced in a given time period ☐

   C. Measuring the time taken for the solution to become cloudy ☐

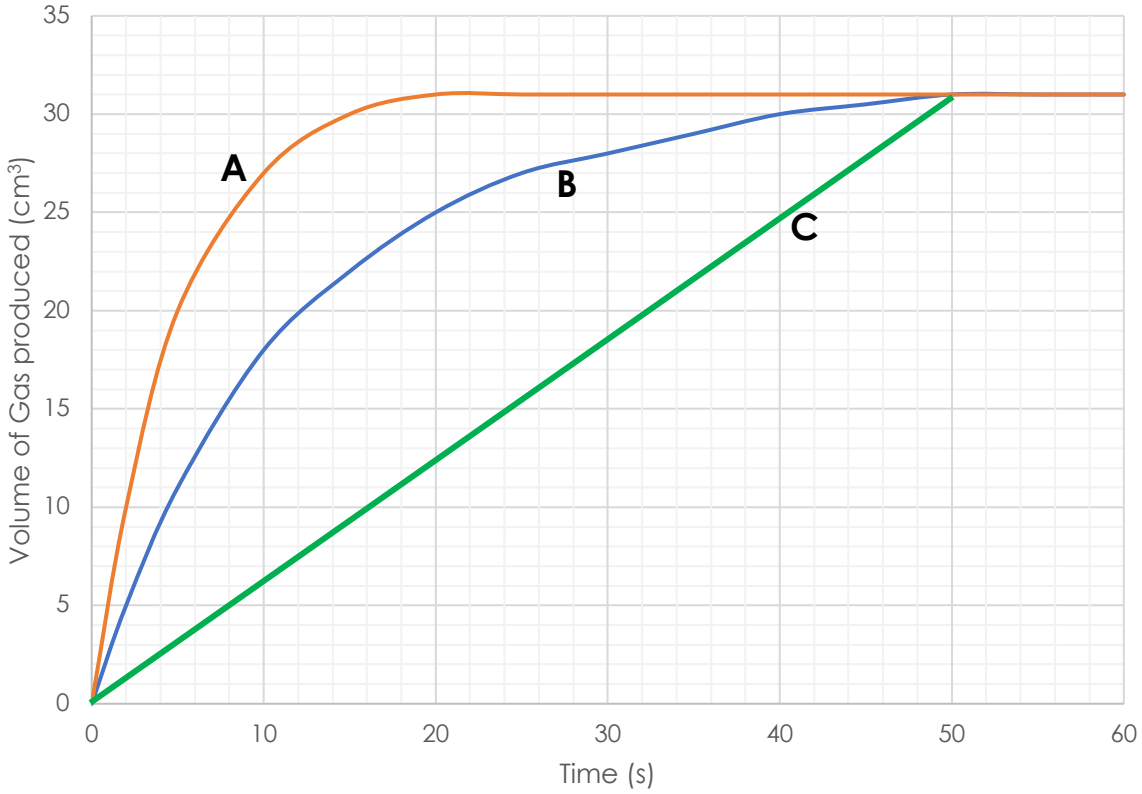
6. The student repeats the experiment with 5 g of magnesium powder instead of magnesium ribbon. What is their independent variable?
   Tick (✓) **one** box. [1]

   A. Concentration ☐

   B. Mass ☐

   C. Surface area ☐

The student presented their results in the following graph:




7. Which line on the graph shows the student's results when they used the magnesium powder?

Tick (✓) **one** box. [1]

A. A ☐

B. B ☐

C. C ☐

8. What is the rate of reaction for the first 10 seconds of line B?

Tick (✓) **one** box. [1]

A. 10 ☐

B. 18 ☐

C. 1.8 ☐

D. 0.56 ☐

9. What are the units for rate of reaction from this graph?
Tick (✓) **one** box. [1]

A. $cm^3/s$ ☐

B. $s/cm^3$ ☐

C. cm/s ☐

D. s/cm ☐

10. What would the student expect when they repeated the investigation at 40 °C instead of room temperature?
Tick (✓) **one** box. [1]

A. The reaction would stop ☐

B. The rate of reaction would increase ☐

C. The rate of reaction would decrease ☐

**Use the following information to answer questions 11-13.**

A student is investigating the effect of concentration on the rate of reaction. They added 10 ml of 10 $g/dm^3$ sodium thiosulfate solution to 10 ml of hydrochloric acid in a conical flask.

They recorded the time taken for the cross below the conical flask to no longer be visible.



The student presented their results in the table below:

| **Concentration ($g/dm^3$)** | **Time taken for cross to disappear** | | |
|---|---|---|---|
| | **Trial 1** | **Trial 2** | **Trial 3** |
| **10** | 85 | 82 | 88 |
| **20** | 50 | 52 | 54 |
| **30** | 29 | 31 | 30 |

11. Which shows how the student should present the mean and uncertainty for a concentration of 10 g/dm$^3$?

Tick (✓) **one** box. [1]

A. 85 ± 6 ☐

B. 85 ± 3 ☐

C. 85 ± 29.5 ☐

12. When any measurements are taken, there is likely to be some uncertainty about the measurements. What is the most likely source of uncertainty in this investigation? [1]

Tick (✓) **one** box.

A. Determining when the reaction has finished ☐

B. Measuring the time using a stopclock ☐

C. Measuring how much product has been made ☐

13. Choose a suitable conclusion that the student can draw from their results. [1]

Tick (✓) **one** box.

A. The higher the concentration, the lower the rate of reaction ☐

B. The higher the concentration, the higher the rate of reaction ☐

C. The higher the concentration, the greater the mass of product made ☐

**HIGHER TIER ONLY**

Ammonia can be produced from nitrogen and hydrogen in a closed system according to the reaction:

$$N_2\ (g) + 3\ H_2\ (g) \rightleftharpoons 2\ NH_3\ (g)$$

14. What is the effect of increasing the pressure inside the reaction vessel?

Tick (✓) **one** box. [1]

A. The yield of ammonia stays the same ☐

B. The yield of ammonia increases ☐

C. The yield of ammonia decreases ☐

15. The forward reaction to produce ammonia is exothermic.
What is the effect of increasing the temperature inside the reaction vessel?
Tick (✓) **one** box. [1]

A. The yield of ammonia stays the same ☐

B. The yield of ammonia increases ☐

C. The yield of ammonia decreases ☐

**SEPARATE SCIENCE ONLY**

16. Select the conditions required for the Haber process.

Tick (✓) **one** box. [1]

A. Room temperature and pressure ☐

B. 450 °C and 200 atm of pressure ☐

C. 200 °C and 450 atm of pressure ☐

17. Ammonium phosphate ($(NH_4)_3PO_4$) is a fertiliser. Select the elements from ammonium phosphate that promote plant growth.
Tick (✓) **one** box. [1]

A. Ammonia and phosphorus ☐

B. Nitrogen and phosphorus ☐

C. Nitrogen and potassium ☐

D. Ammonia and potassium ☐

18. Calculate the relative formula mass of ammonium phosphate ($(NH_4)_3PO_4$).
$A_r$: N =14, H = 1, P = 31, O = 16
Tick (✓) **one** box. [1]

A. 121 ☐

B. 149 ☐

C. 242 ☐

## Section B

1. Some chemical reactions are reversible.
   a. Draw the symbol that shows a reaction is reversible. [1]

   b. When a reversible reaction takes place and the reactants and products cannot escape, equilibrium is reached.

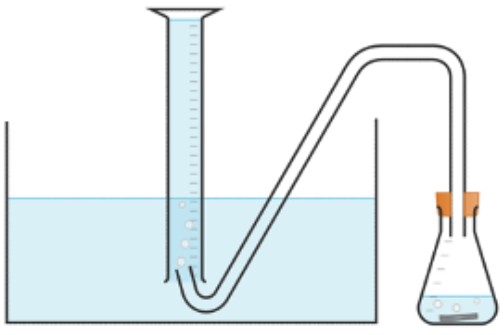
      Explain what is meant by equilibrium. [2]

2. Temperature affects the rate of a chemical reaction.
   Explain how temperature affects the rate of a chemical reaction. [4]

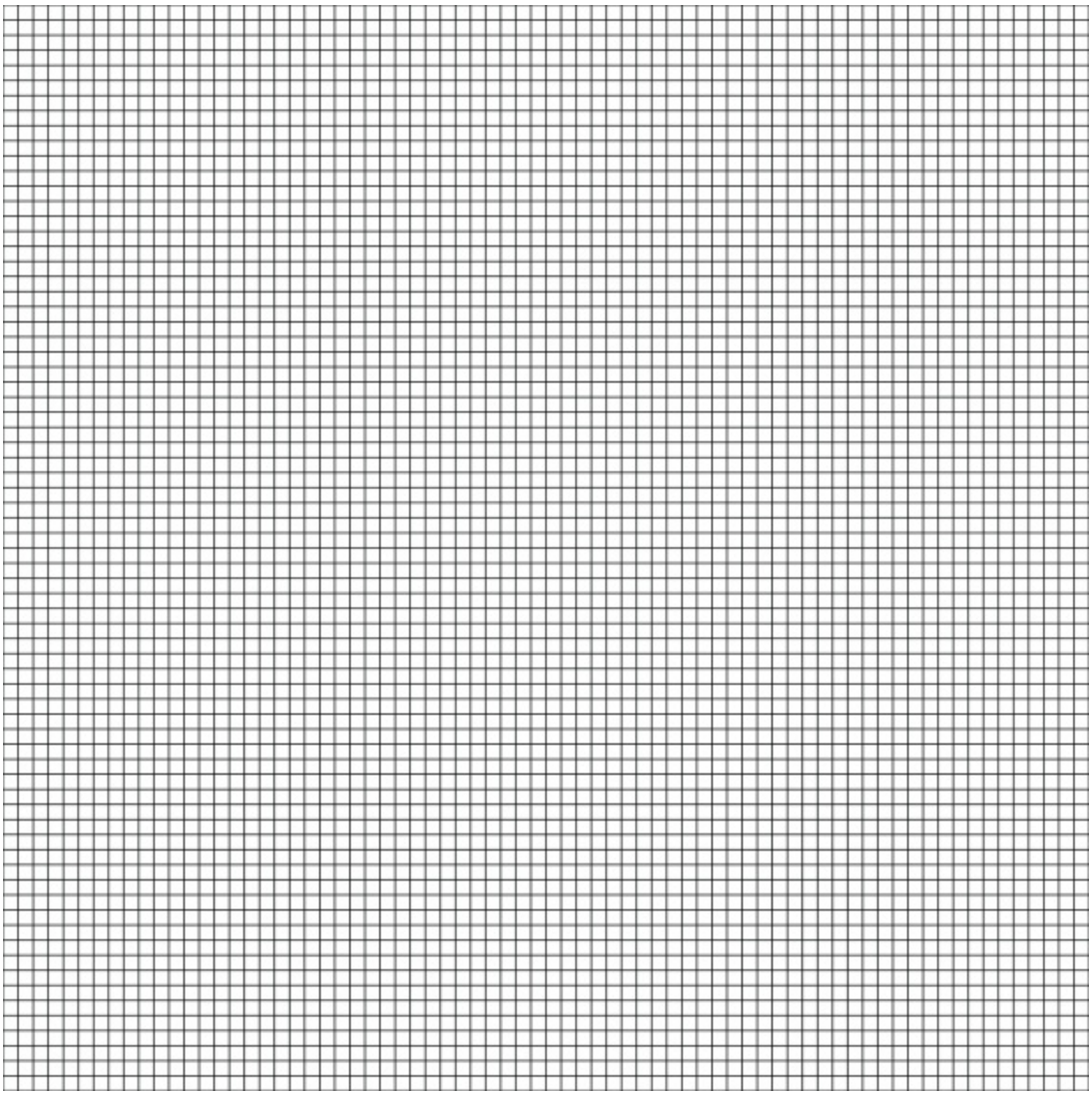
3. A student measures the rate of reaction between magnesium and sulfuric acid.

   They used the apparatus shown and their results are shown in the table below.

| Time (s) | Volume of gas ($cm^3$) |
|---|---|
| 0 | 0 |
| 10 | 26 |
| 20 | 39 |
| 30 | 45 |
| 40 | 47 |
| 50 | 49 |
| 60 | 49 |



a. Plot the student's results below. You should include a suitable line of best fit. [5]



11. Using the graph and your own knowledge, explain when the rate of reaction is highest. [3]

**SEPARATE SCIENCE ONLY**

4. The Haber process is used to make ammonia according to the following equation:

$$N_2\ (g) + 3\ H_2\ (g) \rightleftharpoons 2\ NH_3\ (g)$$

a. Calculate the volume of ammonia that could be produced from 150 $dm^3$ of hydrogen gas if the reaction was carried out at standard temperature and pressure. [2]

b. Describe where the nitrogen and hydrogen reactants involved in the Haber process are obtained from. [2]

## Mastery quiz reflections

| Which aspects of this unit are likely to be the most challenging to teach? | |
|---|---|
| | |
| What are your pupils likely to find most challenging and why? | |
| Challenging..... | Because.... |
| *E.g. The number of new keywords* | *They are abstract words that aren't used in other areas of science* |
| | |
| | |
| How can you pre-empt some of the key misconceptions the mastery quiz aims to identify? | |
| **Misconception** | **How to avoid** |
| | |
| | |
| | |
| | |

# Exam-style questions

**TASK:** Using Exampro (or the software used by your exam board), look through the typical exam-style questions for this topic. These sorts of questions are posed throughout the unit and pupils should be prepared to answer similar questions in the end-of-year assessments.

Suggested questions to guide this process:

| How is knowledge from this unit typically assessed? What are the most common questions? |
| --- |
| |
| Which question types are the most challenging? |
| |
| What general trends can you spot in the typical errors pupils make (from examiner reports/notes)? |
| |
| How could you help prepare your students for answering these types of questions? |
| |

# Common mistakes, errors and misconceptions

How would you tackle the following common mistakes, errors and misconceptions by pupils?

**TASK:** Consider why each of the following typically seen statements is a mistake/misconception. What possible approaches can you plan to pre-empt and respond to this? Which lessons do these correlate to?

CHALLENGE: Cover the middle column and explain yourself why each is a mistake.

| **Mistake** | **Reason why it's a mistake** | **Possible approaches to pre-empt and respond?** |
|---|---|---|
| Endothermic reactions take in energy so they should get hotter. | More energy is taken in to break the bonds of the reactants than is released when the new bonds are made. | |
| A reaction profile shows that energy can be lost or made. | The reaction profile shows the energy of the reactants and products, not the total energy of the system, which remains constant. | |
| Particles are stationary. | Unless a substance is at absolute zero, the particles within it have some intrinsic motion. | |
| If particles collide with each other, they will react. | A reaction will only occur if particles have sufficient energy (the activation energy). | |
| Changing concentration (or surface area) affects the energy of particles. | Only increasing the temperature affects the energy of particles. Other factors increase the frequency of collisions proportionally because the frequency of collisions has increased. | |
| Adding a catalyst gives particles more energy. | A catalyst provides an alternate reaction pathway, with a lower activation energy. The particles themselves do not gain energy, but more may now have energy greater than the activation energy. | |
| Speed and rate can be used interchangeably. | A rate is the change in a quantity per unit time. Speed is specifically the change in distance over time, so cannot be used to refer to the rate of a reaction. | |
| In a reversible reaction, the forwards reaction happens then the backwards reaction happens (oscillation). | Both reactions are taking place at the same time. | |

## Planning for the misconceptions

| **Misconception: All the factors that affect rate of reaction do so by changing the energy of particles** |
|---|
| Rate of reaction questions need to be answered in the same way each time, which can lead to students memorising the same stock answer, regardless of the factor that is being changed.<br>Only temperature affects the energy of particles. The other factors affect the spacing/availability of particles to react. |
| **Supporting pupil understanding** |
| This can be introduced with a review of the effect of temperature on the energy/motion of particles.<br>*What happens to the particles in a substance when it is heated?*<br>***They start to move more quickly.***<br>*Why?*<br>***They gain energy.***<br>Increasing the temperature of a reaction means that the reactant particles gain energy. This means that:<br>• Particles collide more frequently and with more force<br>• A greater proportion of the particles now have energy greater than the activation energy<br>• So the frequency of successful collisions increases because the frequency of all collisions increases and a higher proportion of collisions are successful (because they exceed the activation energy).<br><br>For other factors (e.g. concentration, pressure and surface area):<br>• Increasing the factor affects the spacing/availability of particles to react<br>• This means there are more frequent collisions<br>• As there are more frequent collisions, there will also be more frequent successful collisions<br>• The proportion of collisions that are successful does not change because the energy has not been affected but because the overall frequency of collisions has increased, the frequency of collisions that are successful will also increase<br><br>Making explicit reference to whether or not energy of particles has been affected during first teaching, and then coming back to this question frequently, can help to address the misconception. |

| **Misconception: A catalyst increases the energy of particles** |
| --- |
| **Supporting pupil understanding** |
| In a similar way to the other factors that affect the rate of reaction, many students conflate the effect of a catalyst with increasing the temperature.<br><br>Again, it is important to explicitly show students that the catalyst does not change the energy of the particles themselves. This would only be changed by heating. So if a catalyst does not change the energy of particles, how does it increase the rate of reaction?<br><br>The catalyst provides an alternative reaction pathway, which has a lower activation energy.<br><br>Although not necessary, it can actually be useful to show students the Maxwell-Boltzmann distribution so they can visualise what this means for particles.<br><br>The particles themselves do not have more energy. The new activation energy is lower, which means now that more particles have energy greater than the activation energy. Students can find this useful to imagine a high jump or bar that needs to be cleared. The particles/jumper has not been given a boost, but the bar has been lowered so more particles/people can get over it.<br><br>As the activation energy is lower and more particles have energy greater than the activation energy, the proportion of collisions that are successful increases. The overall frequency of collisions has not changed because the spacing and motion of particles has not been affected, but because the proportion of collisions being successful has increased, the frequency of succcessful collisions increases. |

# Unit objectives: knowledge, skills and concepts

As you teach the lessons, track here the objectives you meet.

TKT = to know that  TBAT = to be able to

**Critical:** it is critical that all pupils become proficient; future learning will be very challenging for them if they do not and it is likely they will not come across this content again. These are priority objectives for reteaching, revision, and intervention. Before moving on, discuss a strategy with your HOD if some pupils are not making progress with these objectives.
**Core:** it is important for all pupils to learn this, and it will be essential for success at GCSE. However, it will not impede them in other units if they are not (yet) proficient in it as they are likely to revisit it again in subsequent units.
**Stretch:** pupils should have the opportunity to be work on this aspect of science. This content is crucial for pupils to achieve the highest GCSE grades and to succeed at A-level.
**Key skill:** pupils should have the opportunity to develop this key skill as part of this unit.

Separate Science only objectives will be underlined.
*Higher tier only objectives will be in italics.*

## Lesson 1: Prior Knowledge Review

| Intended outcome | Example questions |
|---|---|
| **These are the main objectives for the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document.* | |
| TBAT define exothermic and endothermic reactions | Define an exothermic reaction<br>Define an endothermic reaction<br>Explain the difference between exothermic and endothermic reactions<br>(HT) Define an exothermic reaction in terms of bond making and bond breaking |
| TBAT identify exothermic and endothermic reactions | Give an example of an exothermic reaction<br>Give an example of an endothermic reaction<br>The temperature of a reaction decreases. Is this an exothermic or endothermic reaction? |
| TBAT interpret reaction profile diagrams | Explain whether a given diagram shows an exothermic or endothermic reaction<br>Sketch a reaction profile for an exothermic or endothermic reaction<br>Label activation energy<br>Label overall energy change |
| What did the Exit Ticket data tell me? | |
| What do I need to review in future lessons? | |

## Lesson 2: Collision Theory

| Intended outcome | Example questions |
|---|---|
| **These are the main objectives for the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document.* | |
| TBAT define activation energy | Define activation energy<br>Label activation energy on a reaction profile<br>Describe what is needed for a chemical reaction to occur<br>Explain what is meant by a successful collision |
| TBAT describe the factors that affect rate of reaction | State the factors that affect rate of reaction<br>Describe how each factor affects the rate of reaction |
| TBAT describe how the rate of a chemical reaction can be determined | Explain what is meant by the rate of a chemical reaction<br>Describe how the rate of a reaction can be measured/determined<br>Describe the relationship between rate of reaction and frequency of successful collisions |
| What did the Exit Ticket data tell me? | |
| What do I need to review in future lessons? | |

## Lesson 3: Temperature and Concentration

| Intended outcome | Example questions |
|---|---|
| **These are the main objectives for the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document.* | |
| TBAT state the factors that affect rate of reaction | State the factors that affect rate of reaction |
| TBAT describe and explain the effect of increasing temperature on the rate of reaction | Describe the effect of increasing temperature on the rate of reaction<br>Explain why increasing the temperature increases the rate of reaction<br>Use collision theory to explain the relationship between temperature and rate of reaction |
| TBAT describe and explain the effect of increasing concentration on the rate of reaction | Describe the effect of increasing concentration on the rate of reaction<br>Explain why increasing the concentration increases the rate of reaction<br>Use collision theory to explain the relationship between concentration and rate of reaction |
| What did the Exit Ticket data tell me? | |
| What do I need to review in future lessons? | |

## Lesson 4: Surface Area and Pressure

| Intended outcome | Example questions |
|---|---|
| **These are the main objectives for the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document.* | |
| TBAT describe and explain the effect of increasing surface area on the rate of reaction | Describe the effect of increasing surface area on the rate of reaction<br>Explain why increasing the surface area increases the rate of reaction<br>Use collision theory to explain the relationship between surface area and rate of reaction |
| TBAT describe how the surface area of a solid can be increased | Explain what is meant by surface area<br>Calculate surface area<br>Identify whether a solid piece of material or powder has a greater surface area<br>Describe how the surface area of a solid could be increased |
| TBAT describe and explain the effect of increasing pressure on the rate of reaction | Describe the effect of increasing pressure on the rate of reaction<br>Explain why increasing the pressure increases the rate of reaction<br>Use collision theory to explain the relationship between pressure and rate of reaction |
| What did the Exit Ticket data tell me? | |
| What do I need to review in future lessons? | |

## Lesson 5: Catalysts

| Intended outcome | Example questions |
|---|---|
| **These are the main objectives for the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document.* | |
| TBAT define a catalyst | Define a catalyst<br>Describe the function of a catalyst<br>Explain why catalysts are used<br>Give an example of a catalyst<br>Define an enzyme |
| TBAT describe the effect of a catalyst on rate of reaction | Describe the effect of adding a catalyst on the rate of reaction<br>Add a line to a reaction profile to show the effect of adding a catalyst on the energy of a reaction |
| TBAT explain the effect of a catalyst on rate of reaction | Explain why adding a catalyst increases the rate of reaction |
| What did the Exit Ticket data tell me? | |
| What do I need to review in future lessons? | |

## Lesson 6: Rate of Reaction Graphs

| Intended outcome | Example questions |
|---|---|
| **These are the main objectives for the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document.* | |
| TBAT describe how to measure rate of reaction. | Describe how to measure the rate of a reaction<br>State the two ways of measuring rate of reaction |
| TBAT determine the rate of reaction from a graph | Describe how to calculate rate of reaction from a graph<br>Calculate the gradient of a graph<br>Calculate when rate of reaction is highest |
| TBAT use collision theory to explain the shape of a rate of reaction graph | Explain why the gradient is steepest at the start of a reaction<br>Add lines to rate of reaction graphs to show the effect of changing temperature, concentration, pressure, surface area or catalysts<br>Explain the effect of each factor on the shape of the graph |
| What did the Exit Ticket data tell me? | |
| What do I need to review in future lessons? | |

# Lesson 7: Maths in Science (HT) Tangents

| Intended outcome | Example questions |
|---|---|
| *These are the main objectives for the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document. | |
| TBAT draw a tangent to a curve | Draw a tangent to the curve at 10 seconds |
| TBAT calculate the gradient of a tangent | Describe how to calculate a gradient<br>Calculate the gradient of a tangent |
| TBAT determine the rate of a reaction using a tangent | Describe a method for calculating the rate of reaction from a curve<br>Calculate the rate of reaction at 10 seconds |
| What did the Exit Ticket data tell me? | |
| What do I need to review in future lessons? | |

# Lesson 8: Measuring Rate of Reaction

| Intended outcome | Example questions |
|---|---|
| **These are the main objectives for the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document.* | |
| TBAT describe how to measure rate of reaction | Describe how to measure the rate of a reaction<br>State the two ways of measuring rate of reaction |
| TBAT take accurate measurements | Identify errors with measurements |
| TBAT plot a graph of rate of reaction | Plot a graph including a line of best fit |
| What did the Exit Ticket data tell me? | |
| What do I need to review in future lessons? | |

## Lesson 9 and 10: RPA The Effect of Concentration

| Intended outcome | Example questions |
|---|---|
| *These are the main objectives for the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document. | |
| TBAT identify variables when investigating the effect of concentration on rate of reaction | Define an independent variable<br>Define a dependent variable<br>Define a control variable<br>Identify the IV, DV and CVs when investigating the effect of concentration on rate of reaction |
| TBAT describe and explain the effect of concentration on rate of reaction | Describe the effect of increasing concentration on the rate of reaction<br>Explain why increasing the concentration increases the rate of reaction<br>Use collision theory to explain the relationship between concentration and rate of reaction |
| TBAT determine the uncertainty of a measurement | Calculate the uncertainty from a range of measurements<br>Explain what uncertainty means in terms of measurements<br>Explain why there may be uncertainties in this investigation |
| What did the Exit Ticket data tell me? | |
| What do I need to review in future lessons? | |

## Lesson 11: Reversible Reactions and Equilibrium

| Intended outcome | Example questions |
|---|---|
| *These are the main objectives for the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document. | |
| TBAT define a reversible reaction | Define a reversible reaction<br>Draw the symbol for a reversible reaction |
| TBAT define equilibrium | Define equilibrium<br>Explain what it means for a system to be in equilibrium<br>Describe how equilibrium is reached<br>Explain why equilibrium is reached in a closed system |
| TBAT interpret information from reversible reactions | If a reaction is exothermic in the forward direction, what can be said about the reverse reaction?<br>(from a written equation) This shows the reaction between X and Y, which is reversible. Write the chemical equation for the backwards reaction. |
| What did the Exit Ticket data tell me? | |
| What do I need to review in future lessons? | |

# Lesson 12: (HT) Le Chatelier's Principle: Concentration

| Intended outcome | Example questions |
|---|---|
| **These are the main objectives for the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document.* | |
| *TBAT describe Le Chatelier's principle* | Describe Le Chatelier's principle<br>Define equilibrium<br>Describe what happens to a system if the conditions change |
| *TBAT predict the effect of changing the concentration of reactants on a reaction* | (from given equations)<br>Predict the effect of increasing the concentration of reactant X on the position of equilibrium<br>Predict the effect of decreasing the concentration of reactant X on the position of equilibrium |
| *TBAT explain the effect of changing the concentration of reactants on a reaction* | (from given equations)<br>Explain why increasing the concentration of reactant X shifts the position of equilibrium to the right<br>Explain why decreasing the concentration of reactant X shifts the position of equilibrium to the left |
| What did the Exit Ticket data tell me? | |
| What do I need to review in future lessons? | |

# Lesson 13: (HT) Le Chatelier's Principle: Temperature and Pressure

| Intended outcome | Example questions |
|---|---|
| **These are the main objectives for the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document.* | |
| *TBAT predict and explain the effect of changing the temperature on the position of equilibrium* | (from given equations)<br>The forward reaction is exothermic.<br>Predict the effect of increasing the temperature on the position of equilibrium<br>Explain why increasing the temperature shifts the position of equilibrium to the left<br>Predict the effect of decreasing the temperature on the position of equilibrium<br>Explain why decreasing the temperature shifts the position of equilibrium to the right |
| *TBAT predict and explain the effect of changing the pressure of gaseous reactants on the position of equilibrium* | (from given equations)<br>The forward reaction produces fewer molecules of gas.<br>Predict the effect of increasing the pressure on the position of equilibrium<br>Explain why increasing the pressure shifts the position of equilibrium to the right<br>Predict the effect of decreasing the pressure on the position of equilibrium<br>Explain why decreasing the pressure shifts the position of equilibrium to the left |
| What did the Exit Ticket data tell me? | |
| What do I need to review in future lessons? | |

# Lesson 14: Taking it Further: The Haber Process

| Intended outcome | Example questions |
|---|---|
| **These are the main objectives for the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document.* | |
| TBAT describe the conditions required for the Haber process | Describe the conditions used in the Haber process<br>State the word equation for the Haber process<br>Balance the symbol equation for the Haber process |
| TBAT explain why the conditions for the Haber process are a compromise between yield and rate of reaction | Explain the effect of decreasing the temperature on the yield of ammonia<br>Explain why a low temperature is not used for the Haber process<br>Explain the effect of increasing the pressure on the yield of ammonia<br>Explain why a high pressure is not used for the Haber process |
| TBAT interpret graphs of conditions and yield | (from given graph)<br>At what temperature is the yield of ammonia highest?<br>At what pressure is the yield of ammonia highest? |
| What did the Exit Ticket data tell me? | |
| What do I need to review in future lessons? | |

# Lesson 15: Taking it Further: Fertilisers

| Intended outcome | Example questions |
|---|---|
| **These are the main objectives for the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document.* | |
| TBAT identify compounds from fertilisers | Identify NPK fertilisers<br>Which compound in a formulation acts as a fertiliser? |
| TBAT explain why fertilisers are useful | Define a fertiliser<br>Define a formulation<br>Explain why fertilisers are used<br>Describe the effects of fertilisers on the growth of plants and crops |
| TBAT evaluate methods for producing compounds for fertilisers | Describe the advantages and disadvantages of industrial methods of producing compounds such as ammonium sulfate<br>Describe the advantages and disadvantages of laboratory methods of producing compounds such as ammonium sulfate<br>Evaluate the usefulness of both types of production method |
| What did the Exit Ticket data tell me? | |
| What do I need to review in future lessons? | |

## Mastery Quiz Re-teach Planning

*To be completed once you have reviewed your pupils' response to the mastery quiz.*

| What topics are your pupils confident with? |
| --- |
| |
| What topics need to be reviewed? |
| |
| What are the **highest leverage** piece(s) of knowledge (2-3) to explicitly re-teach? |
| |
| What could be interleaved throughout another unit? When will that be taught? |
| |

**Other notes**

## Lesson 16: Feedback Lesson

| Intended outcome | Example questions |
|---|---|
| *Teacher to look at mastery quiz/exit tickets and choose intended outcomes.* | |
| | |
| | |
| What did the Exit Ticket data tell me? | |
| What do I need to review in future lessons? | |

## Advanced Subject Knowledge

**Where does this learning lead?**

At A-Level, this unit feeds into several different places. One of the main areas is kinetics, where students will look at collision theory and Maxwell-Boltzmann distribution, as well as building on knowledge from GCSE about the effects of different factors on rates of reaction. At A-Level, students will also learn more about chemical equilibria and the use of Le Chatelier's principle, including calculation of the equilibrium constant.

*Have a look at the questions below and think about what this means for this unit.*

| How does learning from this unit develop at KS5? |
| --- |
| |
| What content from this unit is fundamental to student understanding at KS5? |
| |
| How could you check that students have grasped these fundamentals? |
| |

# Vocabulary and literacy

Tier 3 vocabulary that will need to be explicitly taught in context:

| | |
|---|---|
| **Activation energy** | The minimum energy needed for particles to react.<br>*Particles will not react unless they have the **activation energy**.* |
| **Catalyst** | A substance that speeds up a chemical reaction without being used up.<br>*A **catalyst** is useful in a chemical reaction as it lowers activation energy.* |
| **Collision** | When two objects (or particles) hit or bump into each other.<br>*The rate of reaction depends on the frequency of successful **collisions**.* |
| **Concentration** | The mass of solute dissolved in a given volume of solvent<br>*The **concentration** of the copper sulphate solution was 0.1 g/cm$^3$* |
| **Endothermic** | A reaction that takes in energy from the surroundings.<br>*An **endothermic** reaction happens when sports injury packs get cooler.* |
| **Enzyme** | A biological catalyst.<br>*Amylase is an **enzyme** that speeds up the breakdown of starch.* |
| **Equilibrium** | When the forward reaction and reverse reaction take place at the same rate.<br>*When a reversible reaction takes place and reactants and products cannot escape, **equilibrium** is reached.* |
| **Exothermic** | A reaction that transfers energy to the surroundings.<br>*An **exothermic** reaction happens when hand warmers get warmer.* |
| **Fertiliser** | A substance added to soil or plants to promote growth.<br>*The Haber process is used to make ammonia for **fertilisers**.* |
| **Formulation** | A mixture containing specific substances in specific proportions.<br>*Many fertilisers are **formulations** so they provide particular nutrients.* |
| **Frequency** | The rate at which something occurs.<br>*The **frequency** of successful collisions is how many successful collisions there are per unit time.* |
| **Gradient** | The slope of a graph.<br>*The steeper the **gradient** on a rate of reaction graph, the higher the rate of reaction.* |

| | |
|---|---|
| **Le Chatelier's principle** | The theory that predicts how the position of equilibrium will shift to counteract a change in the reaction conditions.<br>***Le Chatelier's principle*** *can be used to predict the effect of changing the temperature or pressure of a reaction vessel.* |
| **Molecule** | A group of non-metal atoms chemically bonded together.<br>*Oxygen gas is made up of many oxygen* ***molecules****, each with the chemical formula* $O_2$*.* |
| **Neutralisation** | A chemical reaction in which an acid and a base react with each other.<br>***Neutralisation*** *reactions produce a salt and water.* |
| **Pressure** | The force per unit area.<br>*Increasing* ***pressure*** *means that particles become more crowded in a container.* |
| **Product** | The substance(s) that are made in a chemical reaction.<br>*In the equation* $2Mg + O_2 \rightarrow 2MgO$*, magnesium oxide is the* ***product****.* |
| **Reactant** | The substance(s) that react in a chemical reaction to form a new substance.<br>*In the equation* $2Mg + O_2 \rightarrow 2MgO$*, magnesium and oxygen are the* ***reactants****.* |
| **Reaction profile** | A diagram that shows the relative energy of reactants and products in a chemical reaction.<br>*A* ***reaction profile*** *for an exothermic reaction shows that the reactants have more energy than the products.* |
| **Reversible reaction** | A reaction in which the products can react again to form the reactants.<br>***Reversible reactions*** *take place in a closed system so products cannot escape and can react to form reactants again****.*** |
| **Surface area** | How much space there is on the outside of an object.<br>*Breaking a piece of metal into small pieces increases the* ***surface area.*** |
| **Tangent** | A straight line that touches a curve at a point.<br>*When a rate of reaction graph is a curve, a* ***tangent*** *can be drawn to determine rate of reaction at that point in time.* |
| **Turbidity** | A measure of how cloudy a liquid is.<br>*When sodium thiosulfate reacts with hydrochloric acid, the time taken for the solution to reach a certain level of* ***turbidity*** *is a measure of the rate of reaction.* |

# Appendices

## Appendix 1: Mark scheme for pre-unit quiz

## B5.2 Pre-Unit Quiz: Controlling Reproduction Mark Scheme

| Qu | Answer | Marks | Supporting information for fix-it tasks |
|---|---|---|---|
| 1 | A | 1 | Answering B suggests a gap in knowledge that physical changes are reversible and chemical changes are not. *To fix it, reteach, using examples (e.g. burning magnesium in oxygen vs. ice melting), that chemical changes are not reversible but physical changes are. Then ask students to compare physical and chemical changes.*<br>Answering C suggests a gap in knowledge that physical changes have the same reactants and products but chemical changes do not. *To fix it, reteach, using examples (e.g. burning magnesium in oxygen vs. ice melting), that chemical changes produce new products but physical changes are the same substance. Then ask students to compare physical and chemical changes.* |
| 2 | C | 1 | Answering A suggests the misconception that the subscript number refers to the elements after it rather than before it. *To fix it, reteach what the subscript numbers and the coefficients mean and then give students more practice questions to determine the numbers of atoms.*<br><br>Answering B suggests the misconception that $SO_4$ is an atom. *To fix it, you may want to review that sulfate is a polyatomic ion found on the formula sheet, but that the question is specifically asking about the number of atoms.* |
| 3 | C | 1 | Answering A suggests a gap in knowledge about balanced equations because there is no attempt to balance A. *To fix it, ask students to write out how many atoms of each element are in the reactants and the products and then explain why it is not balanced.*<br><br>Answering B suggests a misconception that the subscript 3 in $NH_3$ applies to the N as well as the H. *to fix it, reteach what the coefficient and the subscript numbers mean and then give practice examples of compound formulae to deduce the number of types of atoms.* |
| 4 | B | 1 | Answering A shows that students have identified the correct bond making and bond breaking energy directions but not the correct magnitude of each.<br><br>Answering C or D shows that students are not clear on whether bond making or breaking are exothermic or endothermic processes.<br><br>*To fix-it, review the definitions of exothermic and endothermic reactions and ask students to explain why each of the other options to this question are incorrect.* |
| 5 | C | 1 | Answering A or B means students are not clear on why photosynthesis is an endothermic reaction or why respiration is an exothermic reaction. |

| | | | |
|---|---|---|---|
| | | | *To fix it, model the word equations for each and use a different colour to show where energy is taken in or released for each process to show why they are endothermic or exothermic.* |
| 6 | A | 1 | Answering B or C shows that students cannot recall an application of an endothermic reaction in real life.<br><br>*To fix-it, review with students the temperature change of an exothermic reaction and an endothermic reaction, then explain why in some cases it is useful to increase the temperature and in some cases it is useful to decrease the temperature.* |
| 7 | A (E) | 1 | Answering B suggests the misconception that the products' energy is the difference in energy. *To fix it, review the features of a reaction profile and get students to annotate an example of an endothermic and an exothermic reaction profile.*<br><br>Answering C shows that students have confused the enthalpy change with the activation energy. *To fix it, review the features of a reaction profile and get students to annotate an example of an endothermic and an exothermic reaction profile.* |
| 8 | C (C) | 1 | Answering A suggests the misconception that because the reactants are the substance(s) reacting, their energy is the activation energy.<br><br>Answering B suggests the misconception that the point on the graph is the activation energy rather than the difference between the reactants' energy and the peak.<br><br>*To fix it, review the features of a reaction profile and get students to annotate an example of an endothermic and an exothermic reaction profile* |
| 9 | A | 1 | Answering B shows that students are not clear on the reaction profiles for endothermic and exothermic reactions.<br><br>Answering C shows that students do not understand that a reaction profile must be one or the other.<br><br>*To fix it, review the features of a reaction profile and get students to annotate an example of an endothermic and an exothermic reaction profile, explaining the difference in shape.* |
| 10 | B | 1 | Answering A shows that students have recognised that a catalyst affects the activation energy but have incorrectly suggested that this would increase the activation energy.<br><br>Answering C or D shows that students have confused the energy change with the activation energy.<br><br>*To fix it, review activation energy on the reaction profile and use an example of a reaction to show students that even if a catalyst is added, it does not affect the energy of reactants or products, so cannot affect the overall energy change.* |

Appendix 2: Mark Scheme for Mastery Quiz

# B5.2 Mastery Quiz: Controlling Reproduction Mark Scheme

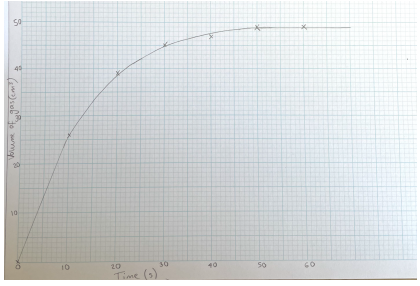
## Section A

| Qu | Answer | Marks | Supporting information for fix-it tasks |
|---|---|---|---|
| 1 | B | 1 | Answering A shows that the student has a misconception that the particles gain energy when they react, rather than requiring enough energy to react.<br><br>Answering C suggests that students may have confused the features of a reaction profile.<br><br>*To fix it, review the definition of activation energy.* |
| 2 | A | 1 | Answering B shows that students have confused the definition of a catalyst with the function of biological catalysts in digestion.<br><br>Answering C shows that students have confused the effects of catalysts and temperature, which is a common misconception.<br><br>*To fix it, review the definition of a catalyst and show students the difference between the effects of temperature and a catalyst.* |
| 3 | A | 1 | Answering B or C means students are not clear on how different factors affect the rate of reaction.<br><br>*To fix it, review the factors that affect rate of reaction and how each factor affects the rate.* |
| 4 | C | 1 | Answering A shows a confusion about the meaning of a reversible reaction. This is an answer that is commonly seen in student exam answers.<br><br>Answering B shows that students have confused the idea of rate of reaction with reversible reactions.<br><br>*To fix-it, review the meaning of a reversible reaction with examples.* |
| 5 | B | 1 | Answering A shows a lack of understanding about the term rate. *To fix it, review the two calculations that can be used to find/measure the rate of reaction.*<br><br>Answering C shows that students have confused the setup of measuring a gas with measuring the precipitate formed experiment. *To fix it, model with students the different ways that the rate of a reaction can be measured and explain how this set up shows the collection of a gas.* |
| 6 | C | 1 | Answering A shows that students have taken the independent variable from the required practical and not been able to apply to a different scenario.<br><br>Answering B shows that students have confused independent and |

| | | | |
|---|---|---|---|
| | | | control variables.<br><br>*To fix it, review the difference between independent, dependent and control variables and give students practice identifying them from different investigations.* |
| 7 | A | 1 | Answering B shows that students have not recognised the relationship between surface area and rate of reaction.<br><br>Answering C shows that students have not recognised the shape of a typical rate of reaction graph.<br><br>*To fix it, review rate of reaction graphs and how the changing of each factor affects them.* |
| 8 | C | 1 | Answering A shows that students have just read the value for time.<br><br>Answering B shows that students have read the value of gas produced after 10 seconds.<br><br>Answering D shows that students have used change in x/change in y.<br><br>*To fix it, review how to calculate rate of reaction.* |
| 9 | A | 1 | Answering B shows that students have read the correct values but confused how to determine the units.<br><br>Answering C shows that students have the right method but have not read the units from the y axis correctly.<br><br>Answering D shows that students have neither chosen the right method or read the axis correctly.<br><br>*To fix it, give students practice determining different units for rate of reaction from graphs.* |
| 10 | B | 1 | Answering A shows that students may have confused the idea of temperature on the rate of reaction with denaturation of enzymes.<br><br>Answering C shows that students are not clear on the effect of temperature on the rate of reaction.<br><br>*To fix it, review the effect of temperature on the rate of reaction.* |
| 11 | B | 1 | Answering A shows that students have not recognised the uncertainty is half the range rather than the whole range.<br><br>Answering C shows that students have taken the range of all the data, rather than the range of the data for the given trial, although they have correctly halved this value.<br><br>*To fix it, review the meaning of uncertainty and how to calculate it.* |
| 12 | A | 1 | Answering B or C show that students have identified possible sources of error but not applied the understanding of this particular required practical. |

| | | | |
|---|---|---|---|
| | | | *To fix it, review the analysis for the required practical and show students why the opacity is a source of uncertainty.* |
| 13 | B | 1 | Answering A shows that students have made the common mistake of confusing time and rate.<br><br>Answering C shows students have confused what is being measured in this investigation.<br><br>*To fix it, review the effect of concentration on rate of reaction.* |
| 14 | B | 1 | Answering A shows that students are not clear on Le Chatelier's principle.<br><br>Answering C shows that students have misinterpreted the effect of changing pressure. A common reason for this misconception is students confusing number of molecules with individual number of reactants, i.e. they have chosen the $N_2$.<br><br>*To fix it, review Le Chatelier's principle and give students practise predicting the effects of changing conditions.* |
| 15 | C | 1 | Answering A shows that students are not clear on Le Chatelier's principle.<br><br>Answering B shows that students have misinterpreted the effect of changing temperature, confusing the meaning of equilibrium shifting to the left or right.<br><br>*To fix it, review Le Chatelier's principle and give students practise predicting the effects of changing conditions.* |
| 16 | B | 1 | Answering A shows that students have confused the conditions for the Haber process with standard room temperature and pressure.<br><br>Answering C shows that students have confused the conditions of temperature and pressure.<br><br>*To fix it, review the conditions of the Haber process and why this compromise is reached to maximise the yield of ammonia using the fastest rate of reaction.* |
| 17 | B | 1 | Answering A or D shows that students are not clear that ammonia is not an element.<br><br>Answering C shows students have confused the symbol for potassium and phosphorus. This is a simple mistake but is very common and easy for students to lose the mark.<br><br>*To fix it, review the meaning of NPK fertilisers and where they can be obtained from.* |
| 18 | B | | Answering A shows that students have not applied the subscript outside the brackets to the nitrogen.<br><br>Answering C shows that students have applied the oxygen subscript to the potassium as well.<br>*To fix it, give students plenty of practice calculating $M_r$.* |

## Section B

| Qu | Answer | Marks | Supporting information *Suggestions for fix-it tasks* |
|---|---|---|---|
| 1a | ⇌ | 1 | |
| 1b | The rate of reaction<br><br>Of the forwards reaction is equal to the rate of the backwards reaction | 1<br><br>1 | |
| 2 | Increasing temperature increases kinetic energy of particles<br><br>This means that more particles have energy greater than the activation energy<br><br>This means that the frequency of successful collisions increases<br><br>So the rate of reaction increases | 1<br><br>1<br><br>1<br><br>1<br><br>Allow converse answers | |
| 3a | Axes correct way round and labelled<br><br>Suitable scale used for each axis<br><br>Points plotted accurately<br><br>Line of best fit<br><br>Model answer (see feedback lesson for copy):<br> | 1<br><br>1<br><br>2 (allow 1 mark for 1 or 2 incorrect points)<br><br>1 | *For some students, you may want to give different levels of scaffolding (e.g. including the scales already) or ask students to spot the errors in different examples.* |
| 3b | At the start/between 0 and 10 seconds<br><br>There are more/the most reactant particles present | 1<br><br>1 | |

| | | | |
|---|---|---|---|
| | This is when the frequency of successful collisions is highest | 1 | |
| 4a | Molar ratio = 3:2<br><br>Volume of ammonia = 100 $dm^3$<br><br>Allow both marks an answer of 100 $dm^3$ without working<br><br>*Alternative method:*<br>*Number of moles hydrogen = 150/24*<br>*Number of moles hydrogen = 6.25*<br><br>*Molar ratio = 3:2*<br><br>*Number of moles ammonia = 4.167*<br>*Volume of ammonia = 4.167 x 24*<br>*Volume of ammonia = 100 $dm^3$* | 1<br><br>1 | |
| 4b | Nitrogen is obtained from air<br><br>Hydrogen is obtained from natural gas/methane | 1<br><br>1 | |

## Appendix 3: Core Knowledge Statements

**Collision Theory**

1. Chemical reactions can occur only when reacting particles **collide** with each other and with sufficient energy.
2. The **minimum amount** of energy that particles must have to react is called the **activation energy**.
3. The rate of a chemical reaction can be measured using the quantity of product produced in a given time or the quantity of reactant used up in a given time.
4. The rate of a chemical reaction is affected by:
    - concentration
    - pressure
    - surface area
    - temperature
    - the presence of a catalyst

**Rate of Reaction**

5. Increasing the **concentration** of reactants in solution increases the **frequency of collisions** and so increases the rate of reaction.
6. Increasing the temperature increases the frequency of collisions and makes the collisions more energetic, and so increases the rate of reaction.
7. Increasing the **surface area** of solid reactants increases the surface area to volume ratio of the reactant, meaning that more reactant particles are exposed at the surface.
8. This increases the frequency of collisions and so increases the rate of reaction.
9. Increasing the **pressure** of reacting gases increases the frequency of collisions and so increases the rate of reaction.
10. A **catalyst** is a substance that:
    - increases the rate of a reaction
    - does not alter the products of the reaction
    - is not chemically changed or used up at the end of the reaction
11. Only a very small mass of catalyst is needed to increase the rate of a reaction.
12. Not all reactions have suitable catalysts.
13. Biological catalysts are called **enzymes**.
14. Using a catalyst provides an **alternative reaction pathway**, with a lower activation energy.
15. The frequency of collisions is not affected but the frequency of successful collisions is increased because more particles have energy greater than the activation energy, so using a catalyst increases the rate of reaction.
16. The effect of a catalyst on the activation energy is shown on a reaction profile.
17. The rate of a chemical reaction can be determined using:
    - the quantity of product formed in a given time
    - the quantity of a reactant used up in a given time
18. $Mean\ rate\ of\ reaction\ = \frac{quantity\ of\ reactant\ used}{time\ taken}$
19. $Mean\ rate\ of\ reaction\ = \frac{quantity\ of\ product\ made}{time\ taken}$
20. The quantity of reactant or product can be measured by the mass in grams or by a volume in $cm^3$.
21. The units of rate of reaction may be g/s or cm3/s.

22. Rate of reaction can be determined from a graph.
23. The steeper the **gradient**, the greater the rate of reaction.
24. *Quantity of reactant or product can also be determined in moles and rate of reaction in mol/s.*
25. *The rate of reaction at a point in time can be determined by calculating the gradient of a **tangent**.*
26. The **volume** of a **gas** produced in a given time can be used to determine rate of reaction.
27. The **time taken** for a change in **colour** or **turbidity** to occur can be used to determine rate of reaction.

**Reversible Reactions and Equilibrium**

28. In some chemical reactions, the products of the reaction can react to produce the original reactants.
29. Such reactions are called **reversible** reactions and are represented:
    $A + B \rightleftharpoons C + D$
30. The direction of reversible reactions can be changed by changing the conditions.
31. Even though no atoms are gained or lost in a chemical reaction, it is not always possible to obtain the calculated amount of a product because:
    - the reaction may not go to completion because it is reversible
    - some of the product may be lost when it is separated from the reaction mixture
    - some of the reactants may react in ways different to the expected reaction.
32. If a reversible reaction is **exothermic** in one direction, it is **endothermic** in the opposite direction.
33. The same amount of energy is transferred in each case.
34. When a reversible reaction occurs in apparatus which prevents the escape of reactants and products, **equilibrium** is reached when the **forward** and **reverse reactions** occur at exactly the same **rate**.
35. *The relative amounts of all the reactants and products at equilibrium depend on the conditions of the reaction.*
36. *If a system is at equilibrium and a change is made to any of the conditions, then the system responds to **counteract the change**.*
37. *The effects of changing conditions on a system at equilibrium can be predicted using **Le Chatelier's Principle.***
38. *If the **concentration** of one of the reactants or products is changed, the system is no longer at equilibrium and the concentrations of all the substances will change until equilibrium is reached again.*
39. *If the concentration of a reactant is increased, more products will be formed until equilibrium is reached again.*
40. *If the concentration of a product is decreased, more reactants will react until equilibrium is reached again.*
41. *If the **temperature** of a system at equilibrium is **increased**:*
    - *the relative amount of products at equilibrium increases for an **endothermic** reaction*
    - *the relative amount of products at equilibrium decreases for an **exothermic** reaction.*
42. *If the **temperature** of a system at equilibrium is **decreased**:*
    - *the relative amount of products at equilibrium decreases for an **endothermic** reaction*

- *the relative amount of products at equilibrium increases for an **exothermic** reaction.*

43. *For gaseous reactions at equilibrium:*
    - *an **increase** in **pressure** causes the equilibrium position to shift towards the side with the **smaller number of molecules** as shown by the symbol equation for that reaction*
    - *a **decrease** in **pressure** causes the equilibrium position to shift towards the side with the **larger number** of **molecules** as shown by the symbol equation for that reaction.*

**Chemistry Only**

**The Haber Process and Fertilisers**

44. The Haber process is used to manufacture **ammonia**, which can be used to produce nitrogen-based **fertilisers**.
45. The raw materials for the Haber process are **nitrogen** and **hydrogen**.
46. Nitrogen can be obtained from **air** and hydrogen can be obtained from **natural gas.**
47. The purified gases are passed over a **catalyst** of **iron** at a **high temperature** (about 450°C) and a **high pressure** (about 200 atmospheres).
48. Some of the hydrogen and nitrogen reacts to form ammonia.
49. The reaction is reversible so some of the ammonia produced breaks down into nitrogen and hydrogen:
    nitrogen + hydrogen ⇌ ammonia
50. On cooling, the **ammonia liquefies** and is removed.
51. The remaining **hydrogen** and **nitrogen** are **recycled**.
52. Compounds of **nitrogen**, **phosphorus** and **potassium** are used as fertilisers to improve agricultural productivity.
53. **NPK** fertilisers contain compounds of all three elements.
54. Industrial production of NPK fertilisers can be achieved using a variety of raw materials in several integrated processes.
55. NPK fertilisers are **formulations** of various salts containing appropriate percentages of the elements.
56. Ammonia can be used to manufacture ammonium salts and nitric acid.
57. Potassium chloride, potassium sulfate and phosphate rock are obtained by mining, but phosphate rock cannot be used directly as a fertiliser.
58. Phosphate rock is treated with nitric acid or sulfuric acid to produce soluble salts that can be used as fertilisers.

**Disciplinary Knowledge**

18. A. Understand the importance of control experiments.
B. Design an investigation which includes the use of a control experiment.
61. Describe mathematical relationships in terms of proportionality
70. Draw and use the slope of a tangent to a curve as a measure of rate of change
73. Apply the idea that whenever a measurement is made, there is always some uncertainty about the result obtained.
74. Use the range of a set of measurements about the mean as a measure of uncertainty.
76a. Comment on the extent to which data is consistent with a given hypothesis.
b. Identify which of two or more hypotheses provides a better explanation of observations.
c. correlation vs causation
77. Apply the following ideas to evaluate data to suggest improvements to procedures and

techniques.
a. An accurate measurement is one that is close to the true value.
b. Measurements are precise if they cluster closely.
c. Measurements are repeatable when repetition, under the same conditions by the same investigator, gives similar results.
d. Measurements are reproducible if similar results are obtained by different investigators with different equipment.
84. a. Use percentages
b. calculate percentage increase and decrease.
98. Relate derived quantities with the formulae to calculate those quantities

**Practical Skills**

26. Measure time accurately
27. Measure temperature accurately
28. Measure pH
32. Measurement of rates of reaction by a variety of methods including production of gas, uptake of water and colour change of indicator.