Ball Games

Contents: Information and problem-solving practical exercises on the science and technology of ball games.

Time: 2 to 4 periods or more, depending on the number of parts and activities attempted.

Intended use: GCSE Physics and Science courses.

Aims:

- To practise measurement skills
- To practise skills in data collection and analysis
- To complement prior work on friction and to introduce ideas on air resistance, turbulence and drag
- To heighten awareness of some of the scientific principles underlying ball games
- To provide an opportunity to practise problem-solving skills
- To link with work in physical education.

Requirements: Students' worksheets No.809. Access to a range of balls, e.g. soccer, netball, hockey, golf, tennis, table tennis, squash. Basic laboratory apparatus, e.g. metre rule, clamp and stand, beaker, balance, tape measure. (See below for further details.)

Author: Bill Harrison

This unit is in two parts:

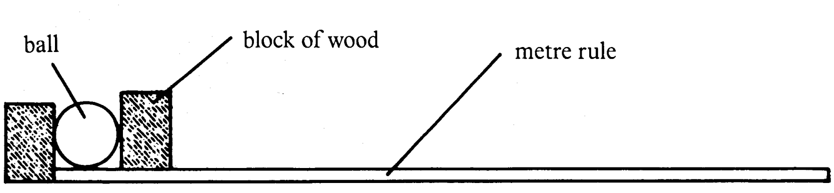
Part 1 Ball types
Part 2 Balls on the move.

Notes on the activities

Activity 1 Looking at different balls

Some students will be able to calculate the volumes of the balls. Others may prefer to measure the volumes by displacement. In addition to the apparatus listed under *Requirements* they may need access to equipment such as calipers, displacement cans, measuring cylinders, lengths of wood.

The diagram shows one method which can be used to determine the diameter of a ball.



Activity 2 Comparing how well different balls can bounce.

This is presented as a problem-solving exercise.

A simple solution is to clamp a metre rule vertically and then to allow balls to bounce from a fixed height of 1m.

Activity 3 What factors affect the flight of a ball?

This is also presented as a problem-solving exercise and is best carried out on the playing field. In order to ensure a fair test, each of the balls should be thrown as far as possible, by the same student, using the same action and the same force. This is probably best done in groups of 3; one throwing, one noting where the ball hits the ground and the third student measuring the distance.

A hockey ball can easily be thrown 50 m but it is difficult to throw a table tennis ball 20 m.

The retardation in flight is proportional to: $\frac{(\text{diameter})^2}{\text{mass}}$

The greater the ratio of (diameter)^2 to mass, the greater will be the retardation force of the air and the more the ball will slow down in flight. In other words, the greater the ratio of mass to (diameter)^2, the less the retardation and the more easily it will 'fly'.

Here are some typical values:

Ball type	*Diameter (cm)*	*Mass (g)*	$\frac{\textit{Mass}}{(\textit{diameter})^2}$
hockey	6.4	160	$\frac{160}{6.4^2} = 3.9\ \text{gcm}^{-2}$
table tennis	3.8	2.4	$\frac{2.4}{3.8^2} = 0.2\ \text{gcm}^{-2}$

Further activities

A Designing a new game. This could be an associated activity with the PE department. It could be run as a competition, perhaps judged by the head of PE. Possible instructions:

- Working in a small group make up a new ball game.
- What size and type of ball will you use - material, surface?
- Will it require a hitting instrument - make a sketch stating what materials it is made from - what the hitting surface is like, particularly if it gives spin to the ball.
- Do the players need to wear any special equipment? How many players? Is it a team game?
- What will you call this game? Can you try it out? Perhaps your PE teacher will give you some help?
- Think about the science involved in your game.

B Comparing the friction of different ball surfaces. Place a ball on a level plank and raise the plank until the ball just rolls. Measure the angle of the plank in each case.

C Investigating the effect of top spin and back spin on a table tennis ball; sketching flight path and direction and extent of bounce. Considering the surfaces of each side of the table-tennis bat.

D Investigating the spin pass and throw of a rugby ball.

E Finding the best spot on a cricket bat to strike the ball, i.e. the centre of percussion.

F Measuring impact times and force of impact between bat and ball.

G Designing a simple machine to project a ball with a constant force in Activity 3 or for dropping a ball and measuring bounce in Activity 2.

H Investigating how angle of club face affects the trajectory of a golf ball. Investigating why golf club faces are ridged.

I Considering which law of physics is obeyed when a ball hits the cushion of a snooker table.

J Investigating the structure of a selection of balls.

K Finding out how balls and tennis rackets are manufactured - use of 'modern' materials, e.g. glass fibre, carbon-graphite.

L Investigating playing surfaces and design of footwear (particularly soles of shoes).

Further resources

Hawkey, R., *Sport Science.* Hodder & Stoughton, 1981.

Page, R.L., *The Physics of Human Movement.* Arnold-Wheaton, Leeds, 1977.

Acknowledgements: Figure 3 supplied by Fort Photography; Figure 6 supplied by Sport & General.

BALL GAMES

Introduction

Some of the ball games we play today were first played hundreds of years ago. A game similar to soccer called 'Tsu Chu' was played in China in 206BC. The goals were about 9 metres high but only 1 metre wide. The leather ball was stuffed with horse hair. For the losers there were no suspensions, fines or yellow cards, simply floggings or even executions depending on the emperor's mood!

An early form of rugby called 'harpastum' was played throughout the world. Ball games can be a source of great enjoyment all through our lives.

Answer questions 1 to 3.

Questions

1 *List as many different ball games as you can think of. Can you think of 50?*

2 *Try sorting the games you have listed. Put them into groups such as: stick and ball games, court games, team games, target ball games.*

3 *Draw a scale diagram to compare the size of the goal used in Tsu Chu with the size of a modern soccer goal.*

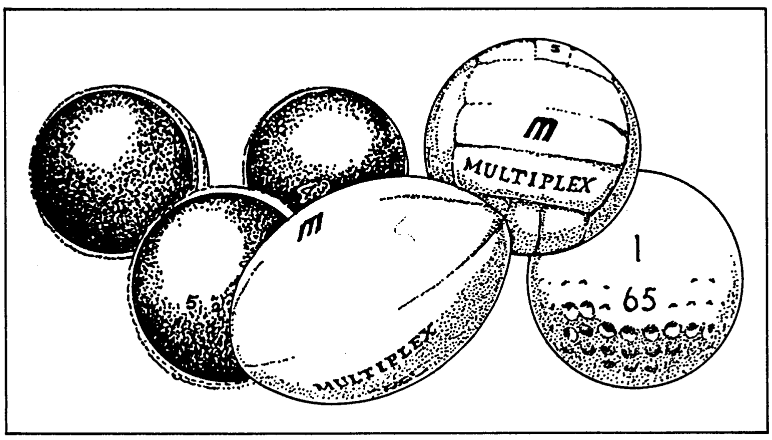


Figure 1

Good health

Games can help to keep us fit and to make friends. There are ball games for all seasons and for all ages, for indoors and outdoors.

You need regular exercise throughout your life if you are to keep healthy. Exercise improves your coordination, and your lung capacity. It can also help with weight control. Taking regular exercise makes it less likely that you will have a heart attack.

Answer questions 4 and 5.

Questions

4 *(a) Which ball games do you play at school?*
(b) Which ball games do you play out of school?
(c) Which of these games do you hope to go on playing after you leave school?

5 *(a) How will you take exercise and keep fit when you have left school?*
(b) Which games are you likely to want to go on playing all your life?

Science and ball games

There is a good deal of science involved in modern ball games. Examples include the striking of a ball, the flight of a ball through the air or its path along the ground. The amount of bounce a ball has is also an important property in games such as table tennis, squash, tennis or basket ball.

Science and technology also play an important part in the choice of materials used for making bats and balls. Science is also involved in preparing the surfaces that the games are played on.

Part 1 Ball types

Activity 1 Looking at different balls

You will need

- A number of different balls
- Apparatus for making measurements of length and mass

What to do

- Measure the diameter of each ball
- Find the volume of each ball by experiment, or by calculation
- Find the mass of each ball
- Examine the material each ball is made from; describe its surface
- Record your results in a table like the one below.

Ball type	*Diameter (cm)*	*Volume (cm^3)*	*Mass (g)*	*Material and surface type*
soccer	22	5576	420	leather - segments
hockey				
table tennis				

Answer questions 6 to 8.

Questions

6 *In what ways are the balls similar? How do they differ?*

7 *Why do the various ball games need different types of ball?*

8 *How many of the balls are made of natural materials? How many are made of synthetic materials like plastic?*

Part 2 Balls on the move

Bounce

Each ball game requires a ball with a certain amount of bounce. A ball is flattened when it hits the ground or when a bat strikes it.

Balls are **elastic**. They can store **energy** for a short time and then release it as they spring back to their usual shape — so they can bounce.

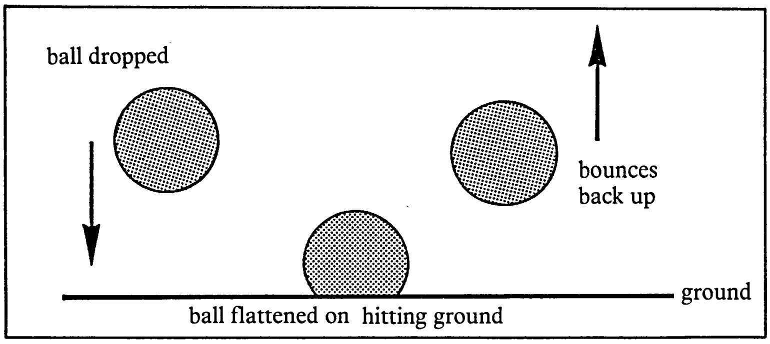


Figure 2

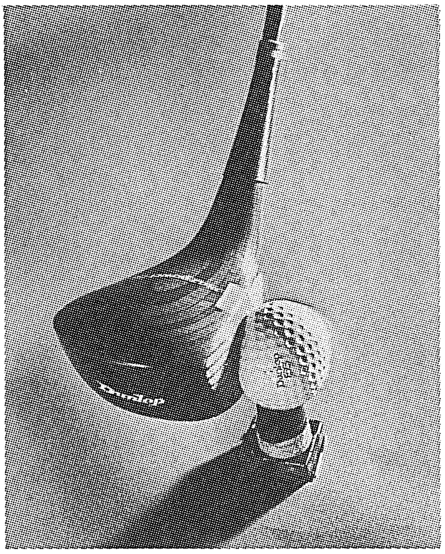


Figure 3 A golf ball at the moment when it is hit by a club

Activity 2 Comparing how well different balls can bounce

What to do

- Design an experiment to measure the amount of bounce of each of the balls you looked at in Activity 1. (How will you make sure that you are carrying out a fair test?)
- Record your results in a table like the one below.

Ball type	*Material*	*Height of bounce (cm)*
squash		
table tennis		

Now answer questions 9 to 11.

Questions

9 Are the results as you expected?

10 Which ball is the most elastic?

11 Can you see any connection between the way a game is played and the bounciness of the ball used?

Moving over a surface — friction

Friction is a force we notice when one surface moves over another. Friction slows down things on the move. When a ball moves over a surface it is slowed down by friction.

Snooker players try to spin the ball when striking it with a cue. Spin reduces skidding. This reduces friction and allows the ball to run freely. The player makes the ball spin by hitting it about 3.5 cm above the table (Figure 4a).

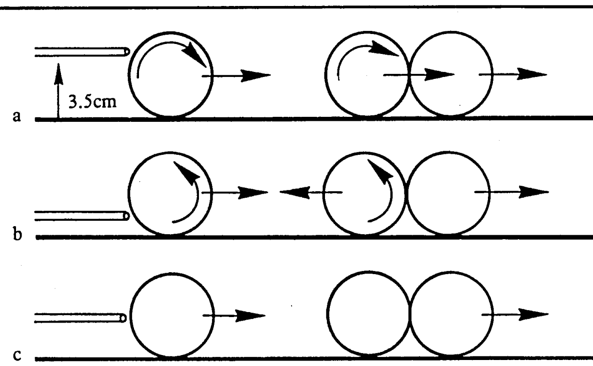


Figure 4

Players also use spin to position the cue ball ready for the next shot. If the cue ball is hit near bottom (see Figure 4b) it gains bottom spin so that it rolls back towards the cue when it hits another ball.

Hitting the cue ball near the top (Figure 4a) gives it top spin. It moves forard after hitting another ball. A cue ball hit in the centre with a 'stunned' action (Figure 4c) skids along and stops on impact.

Friction is *least* when a ball is **rolling** or **spinning.**

Friction is *greatest* when a ball is **gliding** or **skidding.**

Bowls and ten-pin bowling players also try to stop their bowls sliding or skidding by giving them top spin. Try it for yourself and you will see the bowl runs along with a smooth, rolling action.

Moving through the air — Air resistance

Air resistance slows down a moving ball so that it does not go as far as it would in a vacuum.

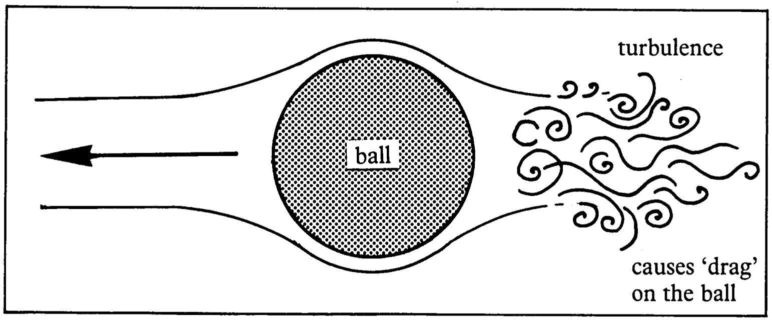


Figure 5

Air has to flow past the ball. The air flow is usually *turbulent* not smooth (Figure 5). The uneven air flow causes *drag*. Drag is a force which slows down the ball. This is similar to the wake behind a ship moving through water.

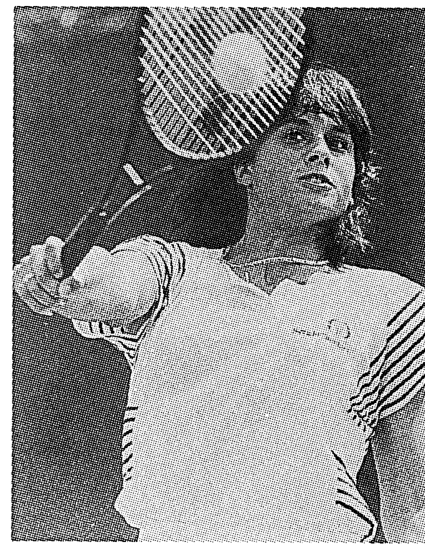


Figure 6 Gabriella Sabatini keeping her eye on the ball at Wimbledon.

Activity 3 What factors affect the flight of a ball?

You will need:

- A range of balls from earlier activity (mass and diameter known)
- Apparatus to measure distance
- A suitable space in which to throw the balls

What to do

- Design an experiment to find out if the flight of a ball is affected by its diameter and mass
- Make sure it is a fair test
- Record your results in a table like the one below.

Ball type	*Diameter (cm)*	*Mass (g)*	*Length of throw*
hockey			
table tennis			

Now answer questions 12 to 14.

Questions

12 *Which go further: heavy balls or light balls?*

13 *Which go further: large balls or small balls?*

14 *It has been suggested that the value of this formula gives a good idea of how far you can throw a ball:*

$$\frac{mass}{diameter^2}$$

Do your results agree with this?

High Pressure Chemistry

Contents: Reading and questions about the work of Carl Bosch and the commercial development of the Haber process.

Time: 1 period or homework.

Intended use: GCSE Chemistry and Integrated Science

Aims:

- To complement prior work on the Haber process and on the uses of metals
- To illustrate some of the problems faced by chemical engineers when they scale up a process for use in industry
- To provide opportunitites to practise skills in reading and comprehension

Requirements: Students' worksheets No.810

Author: Tony Travis

This unit could be used in conjunction with unit 207, *The Story of Fritz Haber.*

The passage of reading and the associated questions can be used in class or for homework. It is assumed that the students have already studied the Haber process. They may need to refer to their notes, or textbook, for help with some of the answers to the questions. It may be best to delay issuing page 3 until students have attempted their own design of reactor vessel in question 7.

Once Bosch had demonstrated the success of his first design he tried some other variations. In one of his later reactors he did away with the holes in the outer wall. Instead he passed the compresssed mixture of nitrogen through the gap between the two walls before it entered the bed of catalyst. This meant that the pressure on both sides of the inner wall was the same. The flow of compressed gas kept the outer wall cool and prevented any reaction between hydrogen and carbon in the steel.

Finding a cheaper catalyst to replace platinum was a major research undertaking. Over 20 000 experiments were carried out in twenty-four small test reactors over a ten-year period. Bosch and his team finally developed an iron catalyst with added promoters. This type of catalyst is still in use.

Other development work required the design and manufacture of high pressure compressors, new valves, pipe fittings and pipe joints.

Bosch also had to develop new methods of getting cheap nitrogen and hydrogen. Synthesis gas was made from coal, steam and air. Nowadays natural gas or fractions from oil distillation are used instead of coal but the essential chemistry is very similar in principle.

A 35-ton ICI gas compressor used for the Haber process at Billingham from 1923, and a 1917 BASF ammonia convertor can be seen at the Science Museum at the Wroughton airfield outstation near Swindon.

Other resources

Further information about this topic can be found in *The High Pressure Chemists* written by Dr Tony Travis for the Brent Schools and Industry Project. This is available from the ASE Bookselling Department.

Acknowledgement Figures 1, 3 and 4 reproduced by permission of BASF UK Ltd.

HIGH PRESSURE CHEMISTRY

This unit describes part of the work of Carl Bosch (Figure 1). Bosch worked for the large German manufacturing firm called Badische Anilin and Soda-Fabrik (BASF).

BASF bought the rights to the Haber process in 1909. You may remember that Haber invented this process as a means of solving the 'nitrogen problem' At that time many scientists were trying to discover new methods for 'fixing nitrogen'.

Answer questions 1 to 3.

Bosch and his team of engineers were the first to manufacture chemicals at very high presssures. You can appreciate one of their problems if you look at Figure 2.

The steam inside a pressure cooker is at twice atmospheric pressure while food is cooking. The metal wall of the cooker has to be much thicker than in a normal saucepan. The designers of a pressure cooker have to be sure that it can hold the steam safely.

Bosch faced a much bigger problem. He had to design a reactor vessel which would contain gases at 200 times atmospheric pressure.

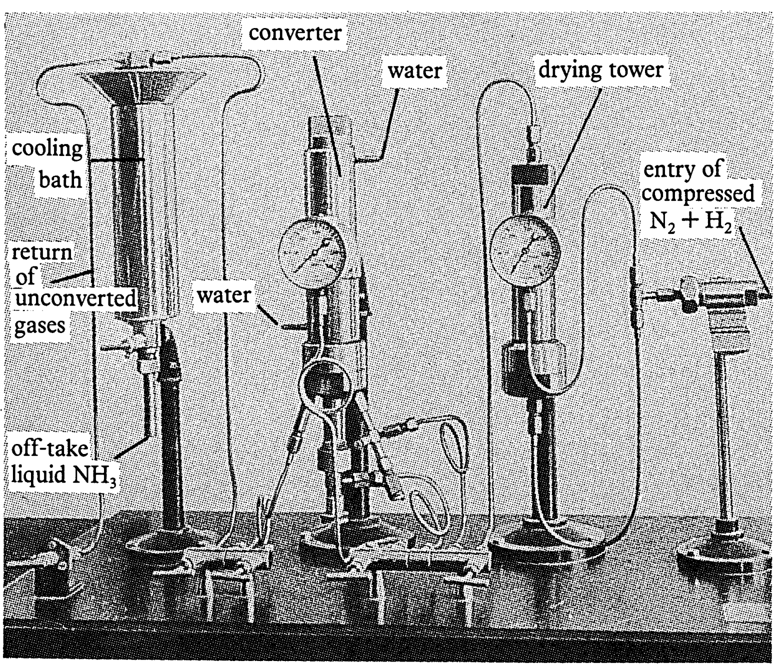


Figure 3 Haber's experimental apparatus for making ammonia

Figure 3 shows the size of apparatus used by Haber in his laboratory trials.

Figure 1 Carl Bosch (1874-1940)

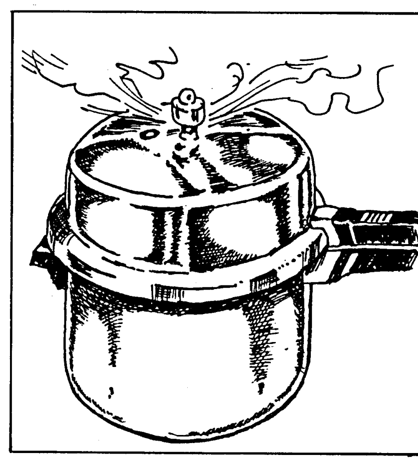


Figure 2 A pressure cooker

Questions

(You will find it helpful to refer to other sources when answering these questions including your notes and your textbook).

1 *Which chemical is manufactured by the Haber process and why is it needed on a large scale?*

2 *Why were large chemical companies such as BASF interested in investing in the development of the Haber process in 1909?*

3 *What is meant by the term 'nitrogen fixation'?*

Bosch's engineers had to 'scale up' Haber's small-scale process. They had to solve three main problems:

- They had to design a large reactor vessel to work at pressures up to 200 times atmospheric pressure at temperatures around 500°C.
- They had to find a cheap catalyst in place of the platinum catalyst used by Haber.
- They had to find large-scale methods of making the nitrogen and hydrogen needed by the plant.

Figure 4 shows what Bosch and his team achieved in the space of five years.

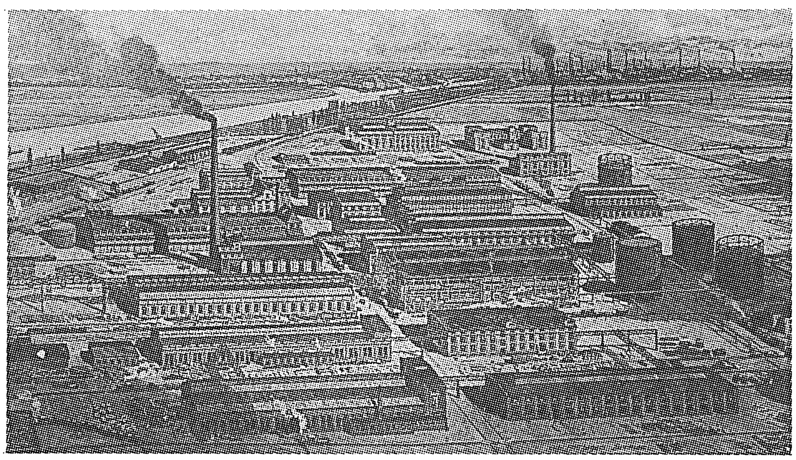


Figure 4 A painting of the first synthetic ammonia plant at Oppau in 1914

Designing the reactor vessel

Designing the reactor vessel involved many problems for Bosch and his team. The first small-scale test plants exploded under pressure. They discovered that this happened because some of the hydrogen used in the process was reacting with carbon in the steel walls of the vessel. This made the metal brittle. The brittle metal could not withstand the pressure.

Bosch's solution to the problem is shown on the next page. But before you look at that page try to answer questions 4 to 7.

Questions

4 *Why do you think that Bosch had to find another catalyst to replace the platinum used by Haber?*

5 *Bosch's father owned a plumber's business. Bosch himself worked as a fitter for some time before going to university to read chemistry. How might this background have helped Bosch in his work?*

6 *Why did the first reactors made by Bosch explode?*

7 *Try to think of a way of solving the problem that made the reactor vessel explode.*

Bosch realised that the problem could be solved by using steel with a very low carbon content. But the trouble is that low-carbon steel is relatively soft. It could not stand up to the pressure in the reactor vessel.

Bosch found a solution to the problem in 1911. His design is shown in Figure 5.

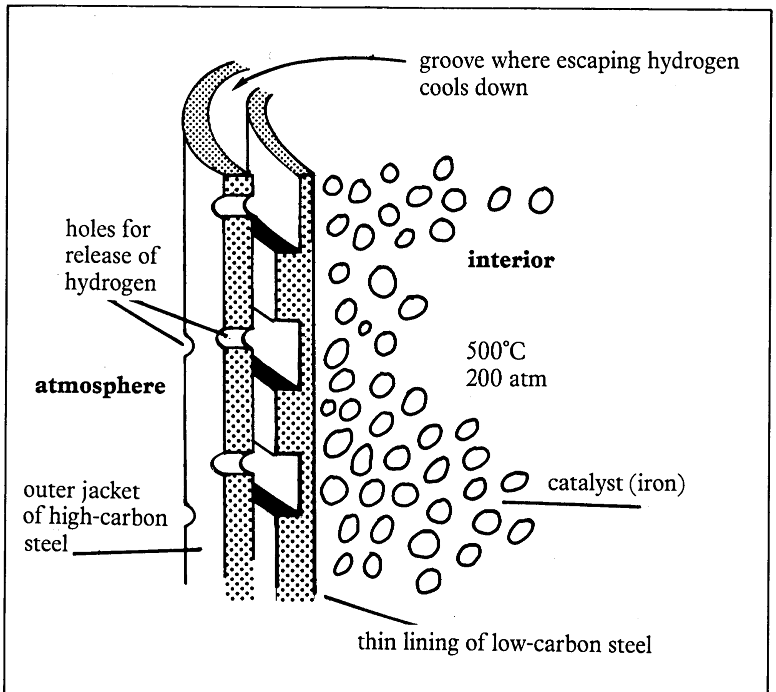


Figure 5 A section of Bosch's double-walled reactor for the Haber process

Bosch's idea was to make a reactor vessel from a double-walled tube. The inner wall was made of soft steel with a very low carbon content. This steel could be exposed safely to the mixture of nitrogen and hydrogen at high temperatures.

The inner wall was not strong enough to contain the gases at high pressure. So it was supported by a strong outer wall made of a higher carbon steel. The outer wall was designed to stand the stresses of the high pressure in the reactor.

A little hydrogen diffused through the inner wall at high pressures. The escaping hydrogen cooled in the grooves cut in the steel wall. Tiny holes drilled in the outer wall allowed the hydrogen to escape. In this way Bosch made sure that there was no danger of the carbon in the steel of the outer wall reacting with hydrogen under pressure.

The basic methods developed by Haber and Bosch are still used today. They are essential for making the huge amounts of ammonia needed in the modern world.

Answer questions 8 to 12.

Questions

8 *Why did Bosch use a low-carbon steel for the inner wall of his new reactor vessel?*

9 *Why could Bosch not make the whole reactor from the low-carbon steel used for the inner wall?*

10 *Hydrogen is more likely than nitrogen to diffuse through the metal wall of a reactor. Suggest a reason why.*

11 *What was the purpose of the outer wall and why was it made of high-carbon steel?*

12 *How did Bosch's design (Figure 5) prevent the strong outer wall from being weakened by the reaction between carbon in the steel and hydrogen from the reaction mixture?*

Contributors to the units in SATIS 8

Many people have contributed to the units in this book as writers, reviewers and editors. Some of the contributors are:

Dr Michael Appleby, Chesham
Sara Berry, Tameside and Glossop MIND
Angelika Biela, South West Hertfordshire Health Authority
Peter Borrows, London Borough of Waltham Forest
Martin Brown, North East Education and Library Board, Northern Ireland
Julian Cohen, Tameside
Anabel Curry, The Misbourne School, Buckinghamshire
Dr R Fawcett, ICI Engineering Department
Gerry Gibbons, Central Electricity Generating Board
Bill Harrison, Sheffield City Polytechnic
John Holman, Watford Grammar School
Andrew Hunt, Durrants School, Croxley Green
Tom Kempton, Didcot Girls' School, Oxfordshire
Dr Robin Millar, University of York
M J Nicolson, Thames Water
Dr Colin Richards, Pfizer Central Research
Ann Stillings, Tameside and Glossop MIND
Kris Stutchbury, Poynton County High School, Stockport
Dr Richard Taylor, Central Electricity Generating Board
Tony Travis, Preston Manor High School, Wembley
Sylvia Ware, The American Chemical Society
Tony Wrixon, National Radiological Protection Board

Some of the schools involved in trialling the units in this book

Backwell School, Avon
Blackheath High School, London
Brimsham Green School, Avon
Broxbourne School, Hertfordshire
Cowes High School, Isle of Wight
Cheadle Hulme School, Cheshire
Cranford Community School, Hounslow
Crookhorn Comprehensive School, Portsmouth
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Rickstones School, Essex
Royal Grammar School, Colchester
St Albans Girls' School, Hertfordshire
St Clement Danes School, Hertfordshire
Sandown High School, Isle of Wight
Stanborough School, Welwyn Garden City
Whitecross Comprehensive School, Gloucestershire

SATIS central team

The SATIS central team determines overall policy for the project, and individual members contribute to the project in many ways, including writing, reviewing and revising units.

Frank Bollen, formerly Education Department, Newcastle upon Tyne
Martin Brown, North East Education and Library Board, Northern Ireland
Julian Cohen, Tameside
Anabel Curry, The Misbourne School, Buckinghamshire
Ann Fullick, St Michael's School, Watford
Patrick Fullick, St Michael's School, Watford
Mike Griffiths, Babington Community College, Leicester
Bill Harrison, Sheffield City Polytechnic
Graham Hill, Dr Challoner's Grammar School, Amersham
Susan Hinckley, NFER, Slough
Chris Hurst, Eton College
Roland Jackson, Backwell School, Avon
Tom Kempton, Didcot Girls' School, Oxfordshire
Jean Mackie, Sheredes School, Hertfordshire
Christine Morris, Egerton Park High School, Tameside
Ballinda Myers, Education Department, Hertfordshire
Malcolm Oakes, The Bordesley Centre, Birmingham
Elizabeth Passmore, Cheadle Hulme School, Cheshire
John Raffan, University of Cambridge
Kris Stutchbury, Poynton County High School, Stockport
Jim Teasdale, Wirral Schools Technology Centre
Tony Travis, Preston Manor High School, Wembley
David Ward, Salford Education Centre
Mary Whitehouse, formerly North Worcestershire College
Dave Wright, Pelsall Community School, Walsall

Evaluation Officer: David Walker, The Simon Balle School, Hertford

Editor: Andrew Hunt, Durrants School, Croxley Green

Project Organizer: John Holman, Watford Grammar School

Design and Publishing: Jane Hanrott
Barry Johnson
Sheila Payne
Evelyn Van Dyk

SATIS 8

List of units in this book

The Association for Science Education
College Lane
Hatfield
Herts AL10 9AA

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