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# CHEMICAL INDUSTRIES

resource pack
*teacher's guide*


*Petrochemicals*

*Chlor-alkali*


*Batteries*

*Fertilisers*

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

PetroSA

c*change
DST-NRF Centre of Excellence in Catalysis

# CONTENTS

# INTRODUCTION

Dear Science-teaching colleague

This resource pack was prepared by the Schools Project Team of the Department of Chemical Engineering at the University of Cape Town. The Schools Project was initiated after the introduction of the FET school syllabus in 2006. The first resource pack on Mining and Mineral Processing was completed in 2009. This resource pack is the second in the series. We have been fortunate to have had the financial support of the Centre for Excellence in Catalysis (*c**change), Sasol Ltd and PetroSA for this resource pack.

Although we have tried to make this resource pack such that a variety of schools from different contexts would find it useful, we realise that no one resource will be a one-size-fits-all. This is therefore not the ultimate resource, but hopefully a pack that will support teachers in the teaching of Chemical Systems in a meaningful way.

This resource pack consists of a teacher's guide, learner information sheets, a set of posters, a periodic table, animations and movies of practical work. In the teacher's guide you will find three main sections: animations, research assignment and practical investigations. On the first few pages of the teacher's guide you will find some suggestions on how to use this pack in integrating its content into teaching Chemical Change and Chemical Systems.

This teacher's guide is written under a copyright restriction that allows you to make changes to the content and print copies of it for non-commercial use in your school. Please refer to the copyright information on page 63 of this guide. Please note that the information included in the learner information sheets as well as the movies and animations on the accompanying DVD can be reproduced, but may not be changed in any way.

We would appreciate your feedback concerning this resource pack. Please send us an email (rene.toerien@uct.ac.za) or fax your comments to 021 650 5501.

UCT Chemical Engineering Schools Project Team

10 September 2010

# INSTRUCTIONS FOR DVD

Included in this resource pack you will find a DVD. Insert the DVD into the D-drive of your computer and open it using the 'My Computer' icon. To start the DVD, click on the 'start-here' icon. Click 'Yes' if an Active content warning appears. This programme will not harm your computer. If you do not have a movie player or PDF reader installed on your computer, please open the 'Installers' folder and install Adobe Acrobat PDF reader, Quicktime Player (for the movies) or Adobe Flash Player (for the animations).

# OVERVIEW

## Purpose

This resource pack provides you with teaching and learning material to supplement your teaching of Grade 12 Chemical Systems. Simultaneously, it will support you in your teaching of some of the sections of Chemical Change, as follows:

| Topic (Chemical Systems) | Associated section(s) in Chemical Change |
|---|---|
| **Fertilisers** | Equilibrium |
| **Batteries** | Electrochemistry: voltaic and electrolytic cells |
| **Chlor-alkali** | Electrochemistry: electrolytic cells |
| **Petro-chemicals** | Organic chemistry |

## Resource summary

The following table summarises the resources provided and a general sequence to follow in using them in content teaching and learning. Refer to the glossary of terms (pp. 60-62), and make use of the posters and periodic table included in the pack. Also note the research assignment: pp. 33-38.

| Topic | Resources | Action | Reference | |
|---|---|---|---|---|
| | | | TG page | Other |
| **Fertilisers** | Learner sheets | Teach, aided by relevant learner sheets. See teaching schedule. | 5 | Learner sheets |
| | Animations<br>Worksheet<br>Memo | Watch animations. | | Disc |
| | | Complete worksheet. | 7 | |
| | | Discuss. Correct with memo. | 21 | |
| | Quizzes | Answer electronic quizzes. | | Disc |
| **Batteries** | Learner sheets | Teach, aided by relevant learner sheets. See teaching schedule. | 5 | Learner sheets |
| | Animations<br>Worksheet<br>Memo | Watch animations. | | Disc |
| | | Complete worksheet. | 12 | |
| | | Discuss. Correct with memo. | 25 | |
| | Practical movies<br>Worksheet<br>Memo | Watch practical movies. | | Disc |
| | | Complete worksheet. | 39 | |
| | | Discuss. Correct with memo. | 51 | |
| | Quizzes | Answer electronic quizzes. | | Disc |
| **Chlor-alkali** | Learner sheets | Teach, aided by relevant learner sheets. See teaching schedule. | 6 | Learner sheets |
| | Animations<br>Worksheet<br>Memo | Watch animations. | | Disc |
| | | Complete worksheet. | 16 | |
| | | Discuss. Correct with memo. | 28 | |
| | Practical movie<br>Worksheet<br>Memo | Watch practical movie. | | Disc |
| | | Perform practical. Complete worksheet. | 43 | |
| | | Discuss. Correct with memo. | 54 | |
| | Quizzes | Answer electronic quizzes. | | Disc |
| **Petrochemicals** | Learner sheets | Teach, aided by relevant learner sheets. See teaching schedule. | 6 | Learner sheets |
| | Animations<br>Worksheet<br>Memo | Watch animations. | | Disc |
| | | Complete worksheet. | 19 | |
| | | Discuss. Correct with memo. | 31 | |
| | Practical movie<br>Worksheet<br>Memo | Watch practical movie. | | Disc |
| | | Complete worksheet. | 47 | |
| | | Discuss. Correct with memo. | 57 | |
| | Quizzes | Answer electronic quizzes. | | Disc |

## Rationale

The following table summarises the intended purpose of each of the types of resources. Note that the worksheets and quizzes are not meant to simulate exam-style questions. They are a helpful starting point to help learners grasp the basic content.

| Resource | Purpose | Style | Motivation for style |
|---|---|---|---|
| **Animations** | To aid teaching and learning of content. | Visual and audio features are provided. | Learners' attention is directed to relevant aspects in a clear and incremental way. |
| **Animation worksheets** | To focus learners' attention while they watch the animations. To serve as notes for later reference. | Short answers, columns, True/False, gap-fill texts. | Quick to complete after watching the animations. Quick to mark while re-watching the animations. Engage learners with the animation content. Serve as notes for later reference. |
| **Electronic quizzes** | To aid learning of content. | Short answers, columns, True/False, gap-fill texts. | Quick to complete. Interactive. Give immediate feedback. |
| **Practical movies: Cell charge & discharge, Properties of floor wax** | To guide learners through the basic components of an experimental investigation. | Investigations are demonstrated by the teacher. Learners are not necessarily expected to perform these investigations. | General components of an experimental investigation are focussed on without the cognitive load of actual experimentation. This prepares learners for the electrolysis practical. |
| **Practical movie: Electrolysis** | To guide learners to plan, perform, analyse and report on an experimental investigation, which the learners perform practically themselves. | Each step in the process is discussed, followed by an expectation for learners to respond before proceeding. Learners should preferably perform this investigation practically. | Learners need to apply their knowledge of experimental investigations to undergo the entire investigation process. This involves planning, performing, analysing and reporting on findings for an investigation. |
| **Practical worksheets** | To support the practical movies in achieving their purposes. | Short to medium length answers, table and graph completion. | Easy to complete at relevant pauses while watching the movie or performing the investigation. |
| **Posters** | To support teaching. | Clear. Attractive. | Suitable as teaching aids. |
| **Periodic table** | A reference source. | Includes more information than most periodic tables. | Provides additional data for the teacher to use in teaching, and for learners to refer to. |
| **Learner sheets** | To support teaching. Resources for a research project. | Graphic and attractive, with a large amount of information. | Suitable as a teaching aid. Used in research project, learners will have to extract relevant information. |
| **Research assignment** | To guide the process of extracting, analysing and synthesising information. | Overarching controversial questions. Guiding content questions. Rubric and notes on doing a research assignment. | Having to answer a controversial question discourages copying-and-pasting, and encourages critical thinking. Guidance enables learners to manage the task. |

## Sequence

The various industries can be taught in any sequence. However, we recommend that batteries be taught before either chlor-alkali or petrochemicals since the battery practical (p. 39) has been designed to ease learners into the scientific method. The petrochemical practical (p. 47) repeats this process, in a more difficult context, and the chlor-alkali practical (p. 43) requires learners to apply their learning to their own planning and performance of an experiment. It makes sense to teach batteries and chlor-alkali consecutively, as they both involve electrochemistry, therefore we suggest the sequence: fertilisers, batteries, chlor-alkali, petrochemicals.

# WORK SCHEDULE

## General approach

This table summarises the two approaches you could take in organising the teaching of Chemical Change and Chemical Systems:

| Approach | Explanation | Advantage |
|---|---|---|
| **Integrated** | Teach both sections simultaneously, using the Chemical Systems applications to illustrate what you teach in Chemical Change. | More time efficient. |
| **Sequential** | Teach Chemical Change first, followed by Chemical Systems. | Revisiting Chemical Change topics after a delay can be effective revision. |

For simplicity, the work schedule given below refers only to the teaching of Chemical Systems. If you follow an integrated approach, you will need to insert the relevant sections from Chemical Change, and increase the time allocated to each topic.

## Notation

F1.2 is an example of the notation used to refer to the learner sheets. This refers to Fertiliser learner sheet number 1, page 2. Each industry is abbreviated using its first letter.

## Schedule

| Topic | Suggested time | Notes | Link to resources | |
|---|---|---|---|---|
| | | | **Relevant learner sheet numbers** | **Other** |
| **Fertilisers (5 lessons)** | | | | |
| **Introduction** | 1 lesson | Definition and use<br>NPK ratios | NPK ratio: F1.2<br>Organic & inorganic: F9.1 | |
| **Haber, Ostwald, Contact Processes** | 2 lessons | Application of:<br>dynamic equilibrium<br>Le Chatelier's principle | Properties $H_2$ & $N_2$: F4.1<br>Haber, $NH_3$ properties: F4.2<br>Ostwald Process: F5.1<br>Contact Process: F5.2<br>Flow chart: elements to fertiliser: F7.2<br>Ammonia, limestone, nitric acid flow charts: F11.2 | Animations and animation worksheet<br><br>Electronic quizzes |
| **Formation of fertiliser salts** | 1 lesson | Acid-base reactions<br>Writing formulae<br>Balancing equations | Lime: F3.2 (bottom left)<br>Phosphate: F6.2, F11.1 | |
| **Environmental impact** | 1 lesson | Eutrophication | Sustainable development: F9.2<br>Eutrophication: F12.1 | |
| **Batteries (6 lessons)** | | | | |
| **Voltaic cell** | 2 lessons | Use of redox potential table<br>Redox reactions | Basics, redox, conduction, electrolyte, cell structure: B1 | Cell charge and discharge movie and worksheet<br>Electronic quizzes |
| **Types of batteries** | 1 lesson | Primary and secondary: link to voltaic and electrolytic cells<br>Learners find half reactions for each, write balanced reaction and calculate cell potentials | First cells. Leclanché cell: B2<br>Primary, secondary: B3.1<br>Zinc-carbon, alkaline cells: B6<br>Mercury cells: B5.1<br>Nickel cells: B7.1<br>Lithium-ion cells: B8.1 | Battery dismantling movie |

| | | | | |
|---|---|---|---|---|
| **Lead acid battery** | 2 lessons | Charging:<br>electrolytic cell<br>Discharging: voltaic cell | Lead acid batteries: B4.1 | Animations and animation worksheet<br>Electronic quizzes |
| **Environmental issues** | ½ lesson | Recycling<br>Fuel cells | Recycling: B9; Flow chart: B9.1<br>Fuel Cell: B11<br>Lifespan details: B12 | |
| **Calculations** | ½ lesson | Cell capacity<br>Energy stored | Amp-hour: B3.2 | |
| **Chlor-alkali (4 lessons)** | | | | |
| **Electrolysis** | 2 lessons | Redox reactions<br>Electrolytic cells | Electrolytic cells: C1<br>Applications: B1 | Electrolysis movie and worksheet<br>Electronic quizzes |
| **Types of cells in chlor-alkali industry** | 1 lesson | Membrane, diaphragm, mercury cells | Diaphragm cell: C8<br>Membrane cell: C9<br>Mercury cell: C10 | Animations and animation worksheet<br>Electronic quizzes |
| **Applications of the chlor-alkali industry** | ⅓ lesson | Salt:<br>Revise bonding | Salt definition: C2<br>Crystal lattice: C2 | |
| | ⅓ lesson | NaOH and soap:<br>Ester reaction<br>Polarity and its relevance to solubility | Sodium hydroxide: C6 .1<br>Soap formation: C6.2<br>Like dissolves like: C7.1<br>Soap film: C7.2 | |
| | ⅓ lesson | Chlorine:<br>Use and ion formation<br>Applications | Uses: C3.1<br>Reactions: C3.2<br>Electrolysis in pools: C3.2<br>$HOCl^-$, HCl: C4.1<br>PVC, polymers: C4.2 | |
| **Petrochemicals (3 lessons)** | | | | |
| **Introduction** | 1 lesson | Alkanes, alkenes, polymers: structures and uses | Molecular representations: P1.2<br>Alkanes: properties: P1.1<br>Organic solvents: P12.1 | Properties of floor polish movie and worksheet |
| **Fischer-Tropsch reaction** | 1 lesson | Energy changes in reactions<br>Roles of catalysts | Fischer-Tropsch technology: P8, P9 | Animations and animation worksheet<br><br>Electronic quizzes |
| **Fractional distillation** | ⅓ lesson | Separating crude oil / Fischer-Tropsch products into its components | Fractional distillation of oil: P3.1, P1.1 | |
| **Cracking** | ⅓ lesson | Organic chemistry of cracking | Cracking: P3.2 | |
| **Environmental issues** | ⅓ lesson | Combustion of organic compounds | Combustion of organics: P6.1<br>Natural gas pros & cons: P7.2 | |

# FERTILISERS

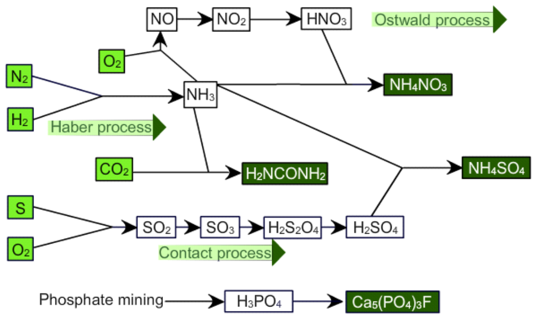
## Overview

1 Why is nitrogen important to plants?

2 In what forms can plants absorb nitrogen?

3 Complete to summarise the industrial processes:

**Industrial production of fertilisers**




| Process | Reactants | Products of step 1 | Products of step 2 | Final products |
|---|---|---|---|---|
| Haber | | not applicable | | |
| Ostwald | | | | |
| Contact | | | | |

## Haber Process

4 What is the purpose of the Haber Process?

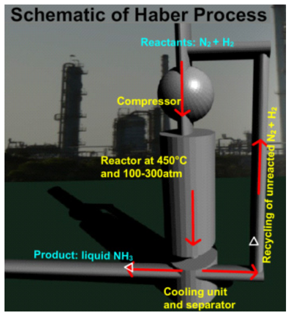
To produce ________________

from ________________ and ________________.

5 Write a balanced equation for the Haber Process's reversible reaction:

________ + ________ $\rightleftharpoons$ ________

Schematic of Haber Process




6 Name some uses of ammonia.

7 Name two conditions which must be met for a reaction to reach equilibrium.

8 Name two characteristics of equilibrium.

9 In the Haber Process an iron oxide catalyst is usually used. Ruthenium can also be used. What does a catalyst do in a reaction, and how does it do this?

10 Circle the correct option (True / False) for each of the following:

i A catalyst speeds up the Haber Process's forward reaction more than the reverse. [True / False]

ii A catalyst will cause more product to be formed. [True / False]

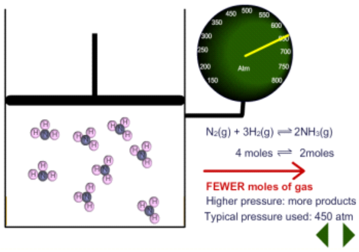
iii A catalyst will decrease the time it takes to reach equilibrium because it speeds up both forward and reverse reactions. [True / False]

iv A catalyst speeds both forward and reverse reactions equally. [True / False]

11 Link each element from Column A with its corresponding element in Column B.
Write the letter from A next to each item in B in the last column.

| Column A | Column B | A |
|---|---|---|
| a dynamic equilibrium | absorbs heat | ______ |
| b endothermic | a measure of the average kinetic energy of particles | ______ |
| c exothermic | disturbs equilibrium, favours increased crowding: more molecules | ______ |
| d Le Chatelier's principle | 273 K and 101,3 kPa | ______ |
| e decrease in pressure | disturbs equilibrium, favours exothermic reaction | ______ |
| f increase in pressure | releases heat | ______ |
| g removing heat | a state in which forward and reverse reactions occur at equal rates | ______ |
| h adding heat | force per area, in gases related to rate of particle collisions | ______ |
| i temperature | disturbs equilibrium, favours decreased crowding, fewer molecules | ______ |
| j pressure | disturbs equilibrium, favours endothermic reaction | ______ |
| k STP | when a system which is in equilibrium is disturbed, it will respond in such a way as to counteract the disturbance | ______ |

Le Chatelier: influence of pressure



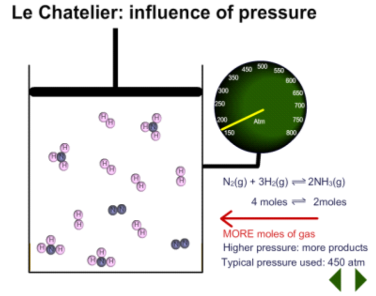

## Le Chatelier: Effect of pressure

12 Complete the explanation by filling the gaps or choosing from the options. Do this before, or after, but not during, watching the animations. Mark during re-watching.

### *Increased pressure*

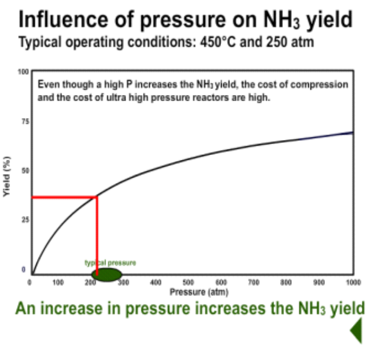
According to ____________________ principle, when a system which is in equilibrium is disturbed, it will respond in such a way as to ________________ the disturbance. An increase in pressure [de/in]creases the crowding of gaseous molecules. The system will respond by [de/in]creasing their crowding. Crowding is decreased in gases when [fewer/more] molecules are formed. In the Haber Process the [forward/reverse] reaction makes fewer molecules than the [forward/reverse] reaction. In the forward reaction _______ molecules of ammonia are made from every _______ molecules of reactants (__________ $N_2$ and ___________ $H_2$ molecules). Consequently, an increase in pressure ____________________ equilibrium for a while by making the [forward/reverse] reaction occur at a higher rate than the [forward/reverse] reaction. This causes [more/less] ammonia to be formed and [more/less] nitrogen and hydrogen. After a while a new dynamic equilibrium is reached. The rates of forward and reverse reactions are again __________ to one another, and the amounts of reactants and products will [change/remain constant]. However, compared to before the pressure was applied, there will now be [more/less] ammonia present at equilibrium. The equilibrium constant value, Kc, however, will be [higher than/lower than/the same as] it was in the original equilibrium.




### *Decreased pressure*

Decreasing pressure [de/in]creases the crowding of gaseous molecules. The system will respond by [de/in]creasing their crowding. Crowding can be increased by forming [fewer/more] molecules. In the Haber Process, that means that for a while the [forward/reverse] reaction will occur at a higher rate than the [forward/reverse] reaction. The reverse reaction changes every ________ molecules of ammonia into ________ molecules ( ________ nitrogen and ________ hydrogen molecules). This causes the amount of ammonia present to [de/in]crease and the amount of nitrogen and hydrogen to [de/in]crease. While this is happening the system [is/is not] in equilibrium. After a while a new dynamic equilibrium will be reached, in which the rates of both forward and reverse reactions will ____________ one another, and the amounts of reactants and products will remain ________. However, compared to before the pressure was decreased, there will now be [more/less] ammonia present at equilibrium. The equilibrium constant value, Kc, however, will be [higher than/lower than/the same as] it was in the original equilibrium.

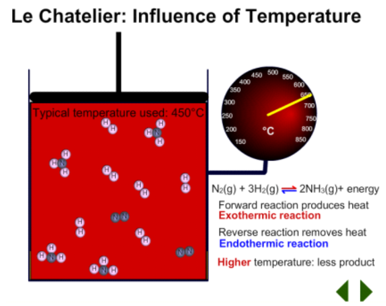



### *Optimum pressure*

In the Haber Process, we want to make as much ________ as possible. We want the dynamic equilibrium to be such that a lot of [reactant/product] is formed. A(n) [de/in]crease in pressure will cause more products to form. We need as [low/high] a pressure as it is safe and economical to use. We say we need to use an ____________ pressure: the pressure for which we get a good yield for a reasonable price while still being safe. Pressures between 200 and 300 atmospheres are typically used in the Haber Process.

## Le Chatelier: Effect of temperature

13 Complete the explanation by filling the gaps or choosing from the options. Do this before, or after, but not during, watching the animations. Mark during re-watching.




### *Heating*

Heating a reaction up increases the ________ energy of the particles, and so causes them to react more [slowly/rapidly] with one another. Additionally, heat can have an effect on disturbing the ________________ of a reaction. In the Haber Process the forward reaction is [exo/endo]thermic and the reverse is [exo/endo]thermic. This means that as nitrogen and hydrogen react with one another to form ammonia, heat is [absorbed/released], but as ammonia breaks up into hydrogen and nitrogen, heat is [absorbed/released]. According to Le Chatelier's principle, when a system which is in equilibrium is disturbed, it will respond in such a way as to counteract the disturbance. So if heat is added to a system in the Haber Process, the [exo/endo]thermic [forward/reverse] reaction is favoured to [absorb/release] some of that heat and so [cool the system back down/heat the system back up]. Both the forward and reverse reactions occur at [lower/higher] rates than before the heat was added, due to the additional kinetic energy of all the particles, but the [forward/reverse] reaction will have been speeded up to a greater extent than the [forward/reverse] reaction. So for a while, the system will not be in ________________ as the [forward/reverse] reaction occurs more rapidly than the [forward/reverse] reaction. This will [in/de]crease the amount of ammonia present, and [in/de]crease the amount of hydrogen and nitrogen. After a while a new dynamic equilibrium is reached. The rates of forward and reverse reactions are again ____________ to one another, and the amounts of reactants and products will remain ________________. However, compared to before the heat was added, there will now be [less/more] ammonia present at equilibrium. A new equilibrium constant, Kc, [higher than/lower than/the same as] that of the original equilibrium, is reached.

## Cooling

Cooling a system that is in equilibrium has two effects. Firstly, by [de/in]creasing the kinetic energy of all the molecules, it [reduces/increases] the rates of both the forward and reverse reactions. Secondly, it has the effect of disturbing the ____________________ by favouring the [exo/endo]thermic reaction until a new equilibrium is reached with [the same/a different] equilibrium constant.

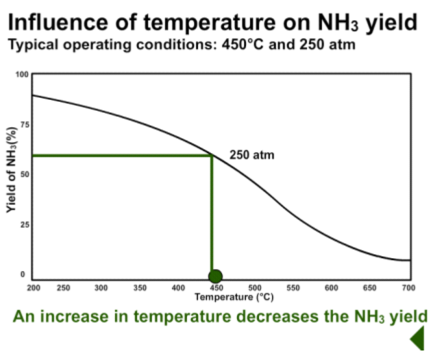
If heat is removed from a system in the Haber Process, the [exo/endo]thermic [forward/reverse] reaction is favoured to [cool the system back down/heat the system back up]. For a while, the system will not be in __________________ as the [forward/reverse] reaction occurs more rapidly than the [forward/reverse] reaction. This will [in/de]crease the amount of ammonia present, and [in/de]crease the amount of hydrogen and nitrogen. After a while a new dynamic equilibrium is reached. The rates of forward and reverse reactions are again ____________________ to one another, and the amounts of reactants and products will remain ____________________. However, compared to before the system was cooled, there will now be [less/more] ammonia present at equilibrium. A new equilibrium constant, Kc, [higher than/lower than/the same as] that of the original equilibrium, is reached.

## Optimum temperature

In the Haber Process, we want to get a high ammonia yield. We want a dynamic equilibrium which makes as much ammonia product as possible. Consequently, we need to use a fairly [high/low] temperature. However, this causes a problem, namely ________________________________________________

________________________________________________________.

Therefore, a compromise is made, and a temperature of approximately 450°C is often used.




## Units of pressure and temperature

14 Complete for units of pressure.

| Unit | | Pressure at sea level at 0°C |
|---|---|---|
| Name | Symbol | |
| | | |
| | | |
| | | |
| | | |

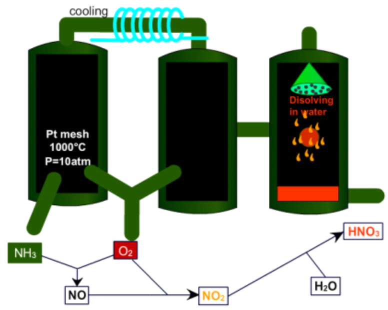
 

15 Kelvin is the SI (Standard International) unit for temperature. Complete for conversions.

| Temperature in degrees Celsius (°C) | Temperature in Kelvin (K) |
|---|---|
| 0 | |
| | 0 |
| 100 | |
| | 200 |
| 25 | |

## Ostwald Process

Oswald Process to produce $HNO_3$




16 What is the purpose of the Ostwald Process?

To produce ________________ from ____________________.

17 How is the product of the Ostwald Process useful for the fertiliser industry?

_______________________________________________

_______________________________________________

18 Why doesn't it matter that the platinum catalyst used is very expensive?

_______________________________________________

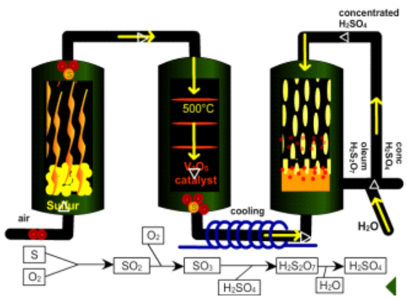
_______________________________________________

19 Complete.

| Step 1 | Step 2 | Step 3 |
|---|---|---|
| ______ + ______ ↓ ______ catalyst ______ → | ______ + ______ ↓ ______ → | ______ + ______ ↓ ______ |

## Contact Process

Contact Process to produce $H_2SO_4$




20 What is the purpose of the Contact Process?

To produce ________________ from ____________________.

21 Name some uses of sulfuric acid.

_______________________________________________

_______________________________________________

22 Complete.

| Step 1 | Step 2 | Step 3 | Step 4 |
|---|---|---|---|
| ______ + ______ ↓ ______ → | ______ + ______ ↓ ______ catalyst ______ → | ______ + ______ ↓ ______ → | ______ + ______ ↓ ______ |

# BATTERIES

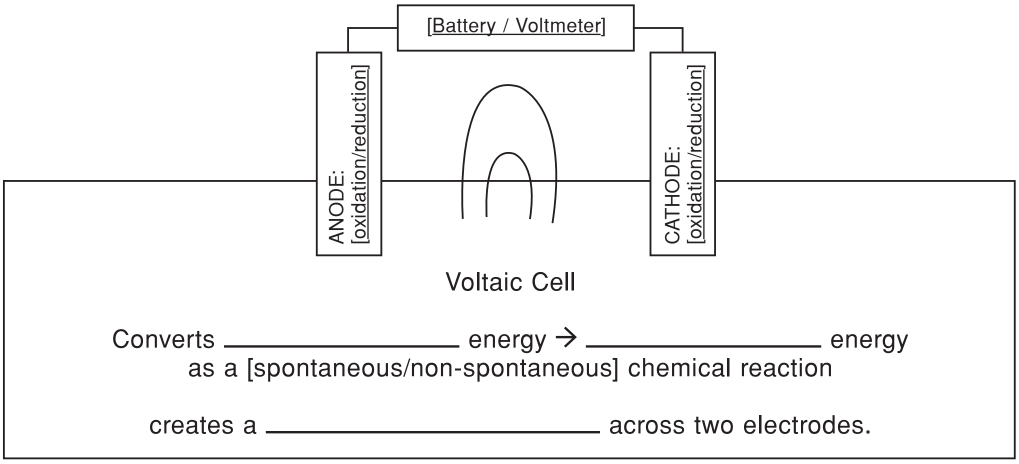
## Types of cells

1 Complete / choose from the options to summarise the types of cells.

| | Primary | Secondary |
|---|---|---|
| Rechargeable? | [rechargeable / non-rechargeable] | [rechargeable / non-rechargeable] |
| Voltaic / Electrolytic? | [only voltaic / voltaic and electrolytic] | [only voltaic / voltaic and electrolytic] |
| Name some examples | | |

## Voltaic cells

2 On the following diagram:
   a Add these labels: electrolyte, salt bridge, + electrode, - electrode
   b Complete / choose from the options to summarise the composition of a voltaic cell.




3 Answer concerning the salt bridge:
   a What is its purpose?

______________________________________________

______________________________________________

   b What kind of substance must it be made of?

______________________________________________

   c Why must it be made of this type of substance?

______________________________________________

______________________________________________

4 Choose from the options for a **voltaic cell**.

| VOLTAIC CELL | |
|---|---|
| **Anode** | **Cathode** |
| [oxidation / reduction] | [oxidation / reduction] |
| [positive / negative] | [positive / negative] |

5 Circle the correct option (True / False) for each of the following referring to a **voltaic cell**.

## VOLTAIC CELL:

a A battery makes one electrode positive and the other negative, and this causes a chemical reaction to occur. [True / False]

b A chemical reaction occurs, and this causes one electrode to be made positive and the other negative. [True / False]

c As oxidation happens, chemicals lose electrons, which then go onto the anode, making it negative. [True / False]

d The anode is made to be negative, and this makes chemicals lose electrons there, causing oxidation to happen. [True / False]

e As reduction happens, chemicals accept electrons, taking them from the cathode, causing it to become positive. [True / False]

f The cathode is made to be positive, and this makes chemicals gain electrons there, causing oxidation to happen. [True / False]

## Lead acid battery (Car battery)

### *Overview*

6 A lead acid battery consists of [primary / secondary] cells.

7 Complete / choose from the options.

| | **Discharging** | **Charging** |
|---|---|---|
| | [electrolytic / voltaic] cells | [electrolytic / voltaic] cells |
| | [produces / requires] electrical energy | [produces / requires] electrical energy |
| **Chemical reaction** | [spontaneous / non-spontaneous] | [spontaneous / non-spontaneous] |
| | [exothermic / endothermic] | [exothermic / endothermic] |
| **Energy conversion** | ____________ energy → ____________ energy | ____________ energy → ____________ energy |
| **Anode** | [Pb / $PbO_2$] | [Pb / $PbO_2$] |
| **Oxidation ½ reaction** | | |
| **Cathode** | [Pb / $PbO_2$] | [Pb / $PbO_2$] |
| **Reduction ½ reaction** | | |
| **Net redox reaction** | | |

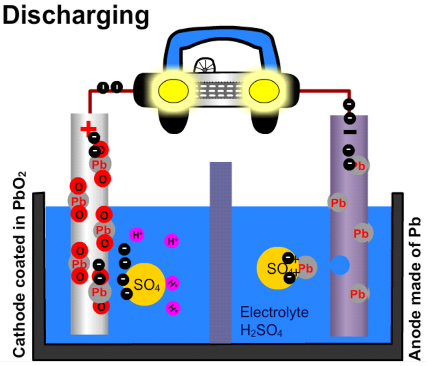
### *Discharging*

8 Complete the explanation by filling the gaps or choosing from the options. Do this before, or after, but not during, watching the animations. Mark during re-watching.

### *Overview*

When the lead acid battery is discharging it behaves as a set of [electrolytic/voltaic] cells. Each lead acid battery consists of six cells. Only one of these is shown here. Each cell converts ____________ energy into ____________ energy, as a [spontaneous/non-spontaneous] chemical reaction [requires/creates] a potential difference across two electrodes. A lead acid battery has one electrode made of lead dioxide and another of lead. These are inside a ____________ acid electrolyte.

**Discharging**



### *Anode*

Lead atoms in the lead electrode are [oxidised/reduced]: they [gain/lose] two electrons each. This changes them into [positively/negatively/neutrally] charged lead [atoms/ions] of formula ________. Since [oxidation/reduction] occurs at this electrode, we call it the anode. The $Pb^{2+}$ ions move away from the electrode, leaving the electrons they had just lost behind on the electrode. This makes this electrode, the anode, [positively/negatively/neutrally] charged, creating a ____________________ between it and the other electrode, which is positive relative to it. This causes electricity to flow between the two electrodes.

### *Cathode*

Electrons move from the [lead/lead dioxide] anode to the [lead/lead dioxide] cathode. There the electrons are [accepted/released] by positively charged ____________________ ions in the lead dioxide electrode. The lead ions here have a [4+/2+] charge. Each lead [4+/2+] ion accepts two ____________________ and is reduced to a lead [4+/2+] ion. [Oxidation/Reduction] occurs at this electrode. It is therefore called the [cathode/anode]. Because electrons are removed from the electrode in this way, it is charged [negatively/positively]. These lead ions combine with ____________________ ions from the sulfuric acid electrolyte to form ____________________. Hydrogen ions from the sulfuric acid electrolyte combine with ____________________ ions from the lead dioxide electrode to form ____________________.

### *Overall reaction*

The overall reaction of the discharging lead acid battery is the reaction of ______________ and ________________ electrodes with ________________ acid to form ____________________ and ________________. This is a spontaneous, redox reaction which converts chemical into electric energy.

- It is spontaneous because ____________________________________________.
- It is a redox reaction: it involves the transfer of __________________________ from one chemical to another.
- It converts ________________ into ______________ energy as ____________________

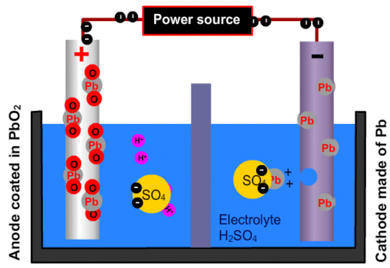
  ______________________________________________________________________.

## Charging

9 Complete the explanation by filling the gaps or choosing from the options. Do this before, or after, but not during, watching the animations. Mark during re-watching.

**Charging**




### Overview

When the lead acid battery is charging it behaves as a set of [electrolytic/voltaic] cells. It converts ________________ energy into ________________ energy as a [spontaneous/non-spontaneous] chemical reaction is forced to occur due to an external potential difference being placed across two electrodes.

To charge a lead acid battery, the lead dioxide electrode must be connected to the [positive/negative] terminal of an external power source, e.g. another battery. The lead electrode must be connected to the [positive/negative] terminal of this other battery. This pulls electrons from the [lead/lead dioxide] electrode and forces electrons into the [lead/lead dioxide] electrode. This causes the reactions which had occurred in the discharging reaction to take place [in the same direction/in reverse].

### Anode

The battery pulls electrons out of the electrode connected to its [positive/negative] terminal. Because of this, electrons are pulled out of the $Pb^{2+}$ ions in the ________________ around this electrode. This produces [$Pb^{2+}$/$Pb^{4+}$] ions. Because the [$Pb^{2+}$/$Pb^{4+}$] ions [gain/lose] electrons as they become $Pb^{4+}$ ions, [oxidation/reduction] is taking place. This electrode is therefore called the [anode/cathode]. Notice that in an electrolytic cell, such as this one, the anode is [positively/negatively] charged. This is opposite to the case of a voltaic cell. In an electrolytic cell the external ________________ charges the anode positively, which forces oxidation to occur there.

### Cathode

The external battery [pushes electrons into/pulls electrons out of] the electrode connected to its negative terminal, charging that electrode [positively/negatively]. This forces lead ions, of formula ________________, to accept two electrons each, changing them into lead atoms, of formula ________________. This is called [oxidation/reduction], since it involves ________________. Grey lead metal is formed through this reduction reaction. The electrode at which reduction happens is called the cathode. Therefore in an electrolytic cell, such as this one, the [positively/negatively] charged electrode is the cathode.

### Overall reaction

The overall reaction of the charging lead acid battery is the reaction of ________________ ions in lead sulfate to form ________________ at the cathode and ________________ at the anode. This is a non-spontaneous, redox reaction which converts electrical into chemical energy.

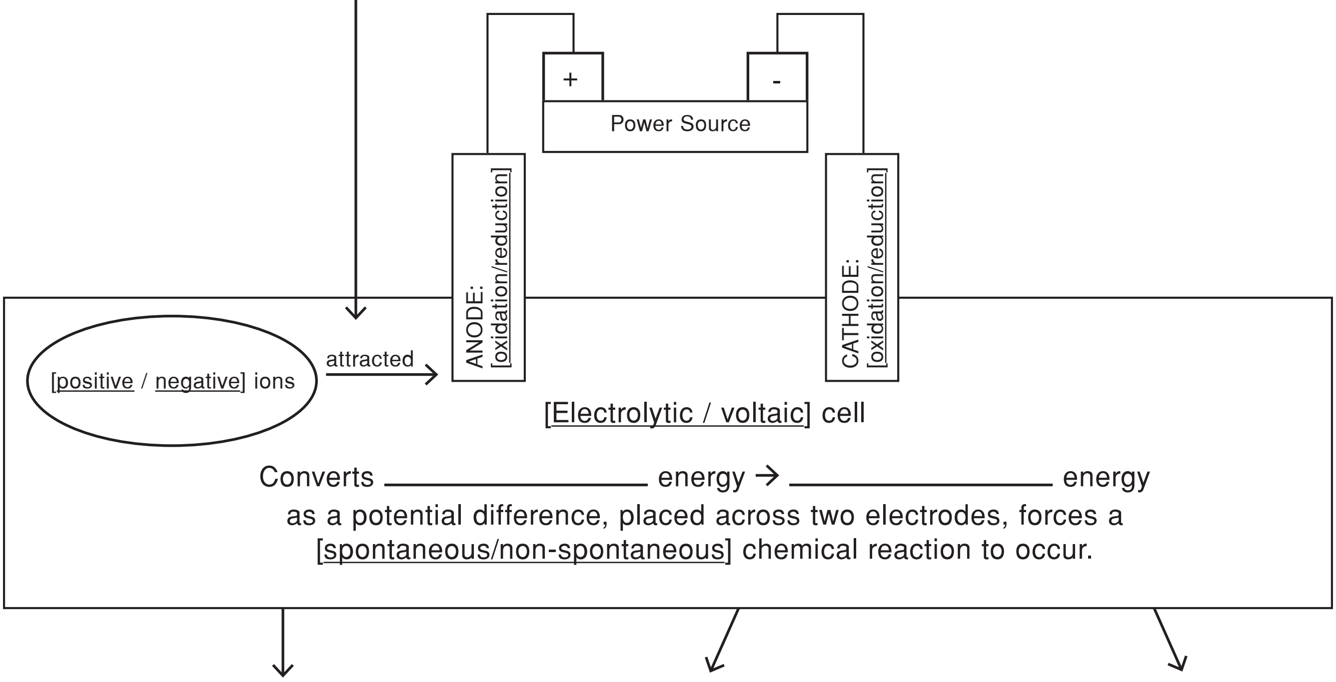
- It is non-spontaneous because ________________ .
- It is a redox reaction: it involves the transfer of ________________ from one chemical to another.
- It converts ________________ into ________________ energy as ________________.

# CHLOR-ALKALI

## Overview

1 Complete / choose from the options to summarise the purpose and process of the chlor-alkali industry.

Input: ______________________________ (brine)




Outputs: __________ : ____ (g) ______________ : ____ (aq) Hydrogen: $H_2$ (g)

Uses: ______________ ______________ ______________

______________ ______________ ______________

______________ ______________ ______________

2 Complete / choose from the options to summarise the types of chlor-alkali cells.

| | Membrane | Diaphragm | Mercury |
|---|---|---|---|
| **Cathode material** | carbon | carbon | |
| **Input** | | | |
| **Oxidation ½ reaction at anode** | | | |
| **Reduction ½ reaction at cathode** | ________ reduced to ______ + ______. Since there are $Na^+$ ions present too, ______ can be produced. | | ______ reduced to ______, which then reacts with ______ to form ______ + ______ |
| **What divides the electrolyte into two half cells?** | | | |
| **Disadvantages** | | | |

3 Choose from the options for an **electrolytic cell**.

| ELECTROLYTIC CELL | |
|---|---|
| **Anode** | **Cathode** |
| [oxidation / reduction] | [oxidation / reduction] |
| [positive / negative] | [positive / negative] |

4 Circle the correct option (True / False) for each of the following, referring to an **electrolytic cell**.

## ELECTROLYTIC CELL:

a A battery makes one electrode positive and the other negative, and this causes a chemical reaction to occur. [True / False]

b A chemical reaction occurs, and this causes one electrode to be made positive and the other negative. [True / False]

c As oxidation happens, chemicals lose electrons, which then go onto the anode, making it positive. [True / False]

d The battery makes the anode positive, and this makes chemicals lose electrons there as the battery sucks electrons away from them, causing oxidation to happen. [True / False]

e As reduction happens, chemicals accept electrons, taking them from the cathode, causing it to become negative. [True / False]

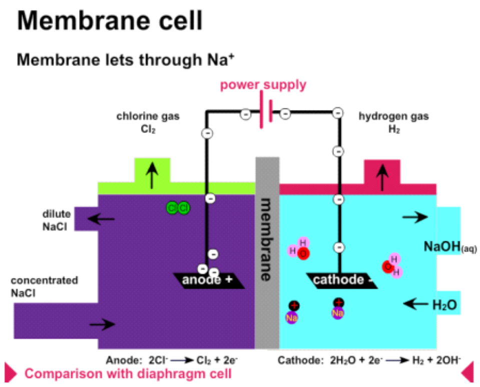
f The battery makes the cathode negative, and this makes chemicals gain electrons there, causing reduction to happen. [True / False]

5 Link each element from Column A with its corresponding element in Column B. Write the letter from A next to each item in B in the last column.

| | Column A | Column B | A |
|---|---|---|---|
| a | anode | colour-remover | ________ |
| b | cathode | a site at which the redox reactions of an electrochemical cell occur; often a rod | ________ |
| c | electrode | a half reaction in which one chemical loses electrons, donating them to another chemical | ________ |
| d | electrolyte | a half reaction in which one chemical gains electrons from another chemical | ________ |
| e | oxidation | an electrode at which oxidation occurs | ________ |
| f | reduction | a kind of reaction in which electrons are transferred from a reducing agent to an oxidising agent | ________ |
| g | redox | attracted to water | ________ |
| h | soap | an ionic solution, therefore able to conduct electricity | ________ |
| i | hydrophilic | repelled by water | ________ |
| j | hydrophobic | an electrode at which reduction occurs | ________ |
| k | bleach | an organic chemical which is able to make fat dissolve | ________ |
| l | chlorine ($Cl_2$) | a strong alkali; can be used to make soap; caustic soda | ________ |
| m | sodium hydroxide | a substance which kills germs | ________ |
| n | disinfectant | a dense green gas useful as bleach and disinfectant | ________ |

## Membrane Cell

6 Complete the explanation by filling the gaps or choosing from the options. Do this before, or after, but not during, watching the animations. Mark during re-watching.




### *Cell composition*

The membrane cell is a(n) [electrolytic/voltaic] cell. It consists of an external power supply (a battery), two ________________, and ________________. The cell is divided into two halves. The two halves are separated by a semi-permeable membrane. Semi-permeable means ________________________________________________.

### *Electrolyte*

________________ serves as the electrolyte for the anode's half reaction. An electrolyte is ________________________________________________.

Brine consists of ________________________ dissolved in water. When sodium chloride dissolves in water, its positively charged [sodium/chloride] ions are separated from its negatively charged [sodium/chloride] ions, and each ion is surrounded by ________________.

### *Anode*

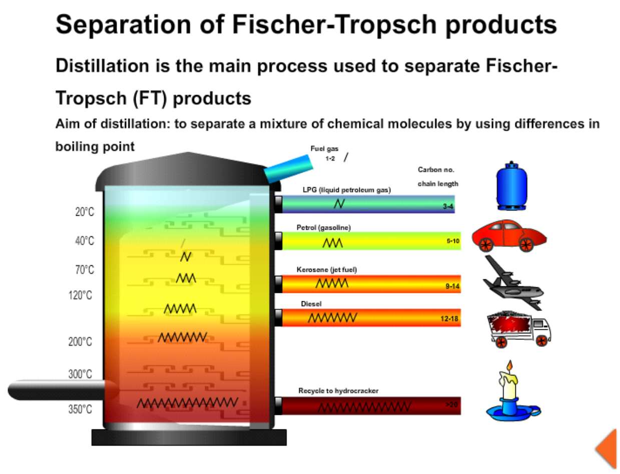
The battery creates a ________________________________ across the electrodes. The positive terminal of the battery [pulls electrons away from/pushes electrons into] the electrode connected to it, charging the electrode [positively/negatively]. This attracts the [positively/negatively/neutrally] charged [sodium/chloride] ions in the brine. When these reach the electrode, the battery [pulls an electron away from/pushes electrons into] each of them. This converts them from [positively/negatively/neutrally] charged chloride ions into [positive/negative/neutral] chlorine atoms. These are unstable, so they bond covalently with one another in pairs, forming diatomic molecules of ________________. This is what we often mean when we refer to chlorine. Chlorine is a dense green gas which bubbles away from this electrode and is collected. Chlorine was formed as chloride ions were stripped of electrons, so we call this half reaction [oxidation/reduction], which is the [gain/loss] of electrons. Each [chlorine atom/chloride ion] loses one electron to change it into a [chlorine atom/chloride ion]. The electrode at which oxidation occurs is called the [cathode/anode]. In an electrolytic cell, such as this, the battery charges the anode [positively/negatively].

### *Cathode*

The semi-permeable membrane allows [positively/negatively] charged sodium [ions/atoms] through into the other electrolytic half-cell. The electrode in this half-cell is connected to the negative terminal of the battery. The battery [pulls electrons away from/pushes electrons into] it, charging the electrode [positively/negatively/neutrally]. This causes water molecules to react at this electrode. The water molecules [lose/accept] the electrons. We say the water is [oxidised/reduced]. These electrons cause water to change into ________________ gas ($H_2$) and [positively/negatively/neutrally] charged hydroxyl ions ($OH^-$). These hydroxyl ions are dissolved in water, as are the sodium ions which moved through the membrane. Sodium ions and hydroxyl ions are therefore present in the solution. We call this a sodium hydroxide solution. The electrode at which reduction occurs is called the [cathode/anode]. In an electrolytic cell, such as this, the battery charges the cathode [positively/negatively].

# PETROCHEMICALS

## Distillation




1 Why is distillation important in the petrochemical industry following the Fischer-Tropsch reaction?

________________________________________

________________________________________

________________________________________

2 Complete the explanation by filling the gaps or choosing from the options. Do this before, or after, but not during, watching the animations. Mark during re-watching.

Distillation is the separation of a mixture into its components by using their differences in ____________________ points. Boiling point is the _________________________ at which a substance boils. This is also the temperature at which it [freezes/melts/condenses/sublimes]. During condensation, a substance changes from ___________ to __________________. Long-chained hydrocarbons condense at [higher/lower] temperatures than short-chained hydrocarbons.

A distillation column has different temperatures throughout its height. At the bottom it is very [cold/hot]. It gets cooler and cooler [higher up/lower down]. The hydrocarbon mixture formed by the Fischer-Tropsch process is heated to over 350°C, making all its components vaporise, that is, turn to ____________________. This hot mixture is fed into the bottom of the ____________________ column. Even though the temperature at the bottom of the column is hot, it is not hot enough to keep the [shortest/longest]-chained hydrocarbons in the gaseous phase. They____________________and sink to the bottom. These hydrocarbons have more than 20 carbon atoms per molecule. They are then led off. They may be used, for example in ____________________, or they may be sent back to the __________________ to be split into shorter chains.

The [shorter/longer] hydrocarbons, still in the ____________________ phase, rise. As they do so they come to cooler parts of the distillation column. At about 200°C, __________________ condenses, and is led off. __________________ is made of a mixture of hydrocarbons having from 12 to 18 carbon atoms per molecule. It is used in some vehicles. At about 120°C, kerosene condenses. Kerosene is used as ___________________ fuel. Kerosene is a mixture of hydrocarbons having 9 to 14 carbon atoms per molecule. At 40°C, __________________________, also called gasoline, condenses. It is made of a mixture of hydrocarbons having from 5 to 10 carbon atoms per molecule. This is used to power many vehicles. At 20°C____________________________________________________ (LPG) condenses. LPG is often sold in gas bottles and might be used in gas heaters or stoves. It contains very [short/long] hydrocarbon chains which have only 3 or 4 carbon atoms per molecule. Even smaller molecules, consisting of only 1 or 2 carbon atoms per molecule, form ____________________________. This exits at the top of the distillation column, still in the ________________ phase.

So by cooling the heated hydrocarbon mixture to different ____________________, it is separated into its components as each component ___________________ at a different temperature, and therefore a different ____________________, in the distillation column. A similar process is used in the separation of crude oil into its components. The temperatures used and products formed would, however, differ slightly from those given here.

## Hydrocracker

3 What is the purpose of the hydrocracker? ______________________________________________

______________________________________________________________________

4 Which chemical, in the presence of a catalyst, cracks the chains? ____________________

## Methane, Ethane, Ethene, Wax

5 Give the formulae of:
a. Methane ______________ b. Ethane ______________ c. Ethene ______________

6 Tick the relevant blocks in this table to show the classification of these chemicals.

| Chemical | Hydrocarbon? | Alkane? | Alkene? | Polymer? |
|---|---|---|---|---|
| Methane | | | | |
| Ethane | | | | |
| Ethene | | | | |
| Wax | | ✓ | ✓ | |

## General

7 Link each element from Column A with its corresponding element in Column B.
Write the letter from A next to each item in B in the last column.

| Column A | Column B | A |
|---|---|---|
| a hydrocarbons | bonds break | ________ |
| b alkanes | a single unit | ________ |
| c alkenes | energy needed to start a reaction | ________ |
| d adsorbed | consists of a long chain of repeated units | ________ |
| e dissociate | consist of only hydrogen and carbon atoms bonded together | ________ |
| f intramolecular | the process by which monomers bond with one another | ________ |
| g polymer | attaches to | ________ |
| h monomer | hydrocarbons with only single bonds | ________ |
| i polymerisation | between two atoms within a molecule | ________ |
| j catalyst | hydrocarbons with a double bond in them | ________ |
| k activation energy | a chemical which speeds up a reaction without itself being permanently changed by the reaction | ________ |

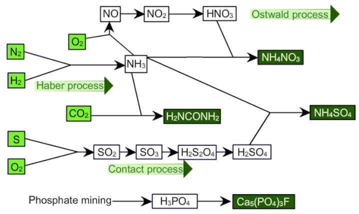
## Catalysts

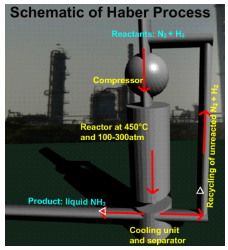
8 Complete the explanation by filling the gaps or choosing from the options. Do this before, or after, but not during, watching the animations. Mark during re-watching.

A catalyst speeds up a reaction without itself being permanently ______________ by the reaction. It serves as a ______________ site for a reaction to take place. Reactants are ______________ onto a catalyst surface. They then ______________, breaking into their component atoms as their [inter/intra]molecular bonds break. The loosened [molecules/atoms] can then bond with other atoms to form a [reactant/product]. The catalyst allows this reaction to occur more easily than if it wasn't there. Reactants can only bond with one another if they can hit against one another with enough ______________ and the right ______________ to stay together. We say they need ______________ energy in order to start them reacting. But if a catalyst holds the reactants in place to make reacting easier, the reactants need [more/less] energy to get to react. In other words, a catalyst [reduces/increases] the______________ energy needed to cause a reaction. Because of this, the reaction will occur more [slowly/quickly] with a catalyst than without one.

# FERTILISERS MEMO

Industrial production of fertilisers




## Overview

1 Why is nitrogen important to plants? **Nitrogen is found in all proteins, and so it is an essential nutrient.**

2. In what forms can plants absorb nitrogen? **Dissolved urea, nitrate, nitrite and ammonium ions.**

3 Complete to summarise the industrial processes.

| Process | Reactants | Products of step 1 | Products of step 2 | Final products |
|---|---|---|---|---|
| Haber | $N_2 + H_2$ | not applicable | | $NH_3$ |
| Ostwald | $NH_3 + O_2$ | NO | $NO_2$ | $HNO_3$ |
| Contact | $S + O_2$ | $SO_2$ | $SO_3$ | $H_2SO_4$ |

## Haber Process

4 What is the purpose of the Haber Process? To produce **ammonia ($NH_3$)** from **nitrogen ($N_2$)** and **hydrogen ($H_2$).**

5 Write a balanced equation for the Haber Process's reversible reaction. $\mathbf{N_2 + 3H_2 \rightleftharpoons 2NH_3}$

6 Name some uses of ammonia. **As a cleaning agent. As a coolant in some air conditioners. To manufacture nitrogen fertilisers.**

7 Name two conditions which must be met for a reaction to reach equilibrium.
- **reversible reaction**
- **closed system**

8 Name two characteristics of equilibrium.
- **rates of forward and reverse reactions are equal to one another**
- **the concentrations of reactants and products remain constant**

9 In the Haber Process an iron oxide catalyst is usually used. Ruthenium can also be used. What does a catalyst do to a reaction, and how does it do this? **It speeds up a reaction by lowering its activation energy. It does this by serving as a binding site on which the reaction can occur.**

10 Circle the correct option (True / False) for each of the following.

i A catalyst speeds up the Haber Process's forward reaction more than the reverse. [True / **False**]

ii A catalyst will cause more product to be formed. [True / **False**]

iii A catalyst will decrease the time it takes to reach equilibrium because it speeds up both forward and reverse reactions. [**True** / False]

iv A catalyst speeds both forward and reverse reactions equally [**True** / False]

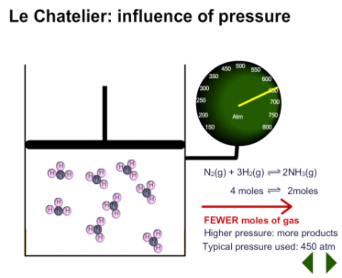
11 Link each element from Column A with its corresponding element in Column B. Write the letter from A next to each item in B in the last column.

| Column A | Column B | A |
|---|---|---|
| a dynamic equilibrium | absorbs heat | **b** |
| b endothermic | a measure of the average kinetic energy of particles | **i** |
| c exothermic | disturbs equilibrium, favours increased crowding, more molecules | **e** |
| d Le Chatelier's principle | 273 K and 101,3 kPa | **k** |
| e decrease in pressure | disturbs equilibrium, favours exothermic reaction | **g** |
| f increase in pressure | releases heat | **c** |
| g removing heat | a state in which forward and reverse reactions occur at equal rates | **a** |
| h adding heat | force per area, in gases related to rate of particle collisions | **j** |
| i temperature | disturbs equilibrium, favours decreased crowding, fewer molecules | **f** |
| j pressure | disturbs equilibrium, favours endothermic reaction | **h** |
| k STP | when a system which is in equilibrium is disturbed, it will respond in such a way as to counteract the disturbance | **d** |

# Le Chatelier: Effect of pressure

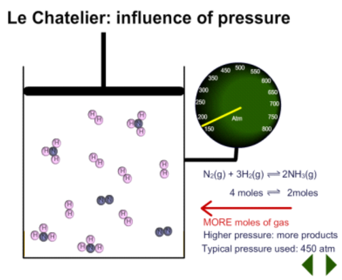
12 Complete the explanation by filling the gaps or choosing from the options. Do this before, or after, but not during, watching the animations. Mark during re-watching.

## *Increased pressure*



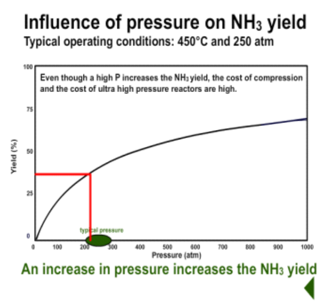

According to **Le Chatelier's** principle, when a system which is in equilibrium is disturbed, it will respond in such a way as to **counteract** the disturbance. An increase in pressure [de/**in**]creases the crowding of gaseous molecules. The system will respond by [**de**/in]creasing their crowding. Crowding is decreased in gases when [**fewer**/more] molecules are formed. In the Haber Process the [**forward**/reverse] reaction makes fewer molecules than the [forward/**reverse**] reaction. In the forward reaction **2** molecules of ammonia are made from every **4** molecules of reactants (**1** $N_2$ and **3** $H_2$ molecules). Consequently, an increase in pressure **disturbs** equilibrium for a while by making the [**forward**/reverse] reaction occur at a higher rate than the [forward/**reverse**] reaction. This causes [**more**/less] ammonia to be formed and [more/**less**] nitrogen and hydrogen. After a while a new dynamic equilibrium is reached. The rates of forward and reverse reactions are again **equal** to one another, and the amounts of reactants and products will [change/**remain constant**]. However, compared to before the pressure was applied, there will now be [**more**/less] ammonia present at equilibrium. The equilibrium constant value, Kc, however, will be [higher than/lower than/**the same as**] it was in the original equilibrium.

## *Decreased pressure*




Decreasing pressure [**de**/in]creases the crowding of gaseous molecules. The system will respond by [de/**in**]creasing their crowding. Crowding can be increased by forming [fewer/**more**] molecules. In the Haber Process, that means that for a while the [forward/**reverse**] reaction will occur at a higher rate than the [**forward**/reverse] reaction. The reverse reaction changes every 2 molecules of ammonia into **4** molecules (**1** nitrogen and **3** hydrogen molecules). This causes the amount of ammonia present to [**de**/in]crease and the amount of nitrogen and hydrogen to [de/**in**]crease. While this is happening the system [is/**is not**] in equilibrium. After a while a new dynamic equilibrium will be reached, in which the rates of both forward and reverse reactions will **equal** one another, and the amounts of reactants and products will remain **constant**. However, compared to before the pressure was decreased, there will now be [more/**less**] ammonia present at equilibrium. The equilibrium constant value, Kc, however, will be [higher than/lower than/**the same as**] it was in the original equilibrium.

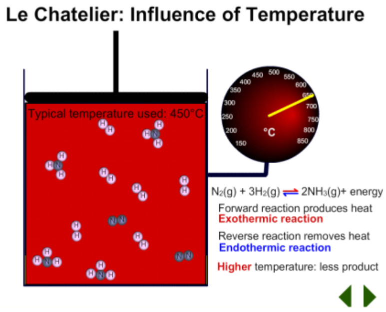
## *Optimum pressure*




In the Haber Process, we want to make as much **ammonia** as possible. We want the dynamic equilibrium to be such that a lot of [reactant/**product**] is formed. A(n) [de/**in**]crease in pressure will cause more products to form. We need as [low/**high**] a pressure as it is safe and economical to use. We say we need to use an **optimal** pressure: the pressure for which we get a good yield for a reasonable price while still being safe. Pressures between 200 and 300 atmospheres are typically used in the Haber Process.

## Le Chatelier: Effect of temperature

13 Complete the explanation by filling the gaps or choosing from the options. Do this before, or after, but not during, watching the animations. Mark during re-watching.




### *Heating*

Heating a reaction up increases the **kinetic** energy of the particles, and so causes them to react more [slowly/**rapidly**] with one another. Additionally, heat can have an effect on disturbing the **equilibrium** of a reaction.

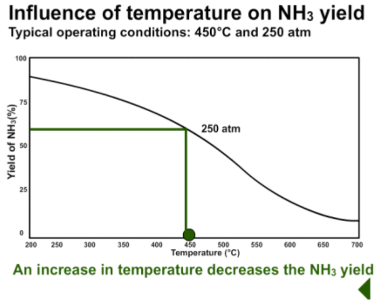
In the Haber Process the forward reaction is [**exo**/endo]thermic and the reverse is [exo/**endo**]thermic. This means that as nitrogen and hydrogen react with one another to form ammonia, heat is [absorbed/**released**], but as ammonia breaks up into hydrogen and nitrogen, heat is [**absorbed**/released]. According to Le Chatelier's principle, when a system which is in equilibrium is disturbed, it will respond in such a way as to counteract the disturbance. So if heat is added to a system in the Haber Process, the [exo/**endo**]thermic [forward/**reverse**] reaction is favoured to [**absorb**/release] some of that heat and so [**cool the system back down**/heat the system back up]. Both the forward and reverse reactions occur at [lower/**higher**] rates than before the heat was added, due to the additional kinetic energy of all the particles, but the [forward/**reverse**] reaction will have been speeded up to a greater extent than the [**forward**/reverse] reaction. So for a while, the system will not be in **equilibrium** as the [forward/**reverse**] reaction occurs more rapidly than the [**forward**/reverse] reaction. This will [in/**de**]crease the amount of ammonia present, and [**in**/de]crease the amount of hydrogen and nitrogen. After a while a new dynamic equilibrium is reached. The rates of forward and reverse reactions are again **equal** to one another, and the amounts of reactants and products will remain **constant**. However, compared to before the heat was added, there will now be [**less**/more] ammonia present at equilibrium. A new equilibrium constant, Kc, [higher than/**lower than**/the same as] that of the original equilibrium, is reached.

### *Cooling*

Cooling a system that is in equilibrium has two effects. Firstly, by [**de**/in]creasing the kinetic energy of all the molecules, it [**reduces**/increases] the rates of both the forward and reverse reactions. Secondly, it has the effect of disturbing the **equilibrium** by favouring the [**exo**/endo]thermic reaction until a new equilibrium is reached with [the same/**a different**] equilibrium constant.

If heat is removed from a system in the Haber Process, the [**exo**/endo]thermic [**forward**/reverse] reaction is favoured to [cool the system back down/**heat the system back up**]. For a while, the system will not be in **equilibrium** as the [**forward**/reverse] reaction occurs more rapidly than the [forward/**reverse**] reaction. This will [**in**/de]crease the amount of ammonia present, and [in/**de**]crease the amount of hydrogen and nitrogen. After a while a new dynamic equilibrium is reached. The rates of forward and reverse reactions are again **equal** to one another, and the amounts of reactants and products will remain **constant**. However, compared to before the system was cooled, there will now be [less/**more**] ammonia present at equilibrium. A new equilibrium constant, Kc, [**higher than**/lower than/the same as] that of the original equilibrium, is reached.

## *Optimum temperature*




In the Haber Process, we want to get a high ammonia yield. We want a dynamic equilibrium which makes as much ammonia product as possible. Consequently, we need to use a fairly [high/**low**] temperature. However, this causes a problem, namely **it causes both reactions to be slow, and so it takes a long time for equilibrium to be reached.** Therefore, a compromise is made, and a temperature of approximately 450°C is often used.

## *Units of pressure and temperature*

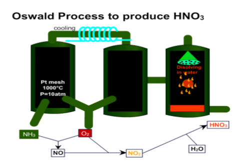
14 Complete for units of pressure.

| Unit | | Pressure at sea level at 0°C |
|---|---|---|
| **Name** | **Symbol** | |
| **bar** | **bar** | **1 bar** |
| **atmospheres** | **atm** | **1 atm** |
| **kilopascals** | **kPa** | **101,3 kPa** |
| **millimeters mercury** | **mm Hg** | **760 mm Hg** |

15 Kelvin is the SI (Standard International) unit for temperature. Complete for conversions.

| Temperature in degrees Celsius (°C) | Temperature in Kelvin (K) |
|---|---|
| 0 | **273** |
| **-273** | 0 |
| 100 | **373** |
| **-27** | 200 |
| 25 | **298** |

## Ostwald Process




16 What is the purpose of the Ostwald Process?
To produce **nitric acid ($HNO_3$)** from **ammonia ($NH_3$)**.

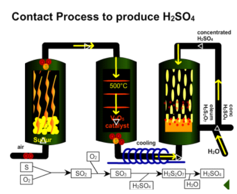
17 How is the product of the Ostwald Process useful for the fertiliser industry?
**Nitric acid can be used to make nitrate fertilisers.**

18 Why doesn't it matter that the platinum catalyst used is very expensive?
**It can be used over and over again because it is not used up. Catalysts speed up reactions without themselves being changed in the process.**

Complete.

| Step 1 | Step 2 | Step 3 |
|---|---|---|
| **$NH_3 + O_2$** ↓ **platinum** catalyst **NO** → | **$NO + O_2$** ↓ **$NO_2$** → | **$NO_2 + H_2O$** ↓ **$HNO_3$** |

## Contact Process




20 What is the purpose of the Contact Process?
To produce **sulfuric acid ($H_2SO_4$)** from **S + $O_2$**.

21 Name some uses of sulfuric acid. **manufacture of fertilisers, electrolyte in car batteries, as a dehydrating (a drying) agent**

22 Complete.

| Step 1 | Step 2 | Step 3 | Step 4 |
|---|---|---|---|
| **$S + O_2$** ↓ **$SO_2$** → | **$SO_2 + O_2$** ↓ **$V_2O_5$** catalyst **$SO_3$** → | **$SO_3 + H_2SO_4$** ↓ **$H_2S_2O_7$** → | **$H_2S_2O_7 + H_2O$** ↓ **$2H_2SO_4$** |

# BATTERIES MEMO

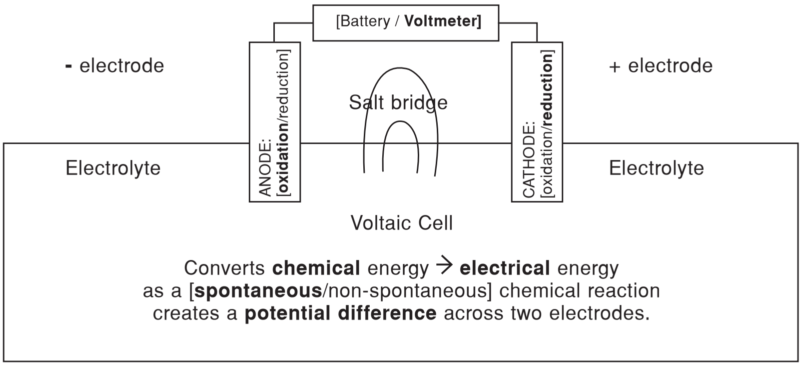
## Types of batteries

1 Complete / choose from the options to summarise the types of batteries.

| | Primary | Secondary |
|---|---|---|
| Rechargeable? | [rechargeable / **non-rechargeable**] | [**rechargeable** / non-rechargeable] |
| Voltaic / Electrolytic? | [**only voltaic** / voltaic and electrolytic] | [only voltaic / **voltaic and electrolytic**] |
| Name some examples | **Leclanche (zinc-chloride / dry) cell, mercury cell, alkaline cell** | **Lead acid, nickel-cadmium, nickel-metal hydride and lithium ion** |

## Voltaic cells

2 On the following diagram:
  a Add these labels: electrolyte, salt bridge, + electrode, - electrode
  b Complete / choose from the options to summarise the composition of a voltaic cell.




3 Answer concerning the salt bridge:
  a What is its purpose? **It completes the electric circuit and it prevents a build-up of charge in either half-cell, by allowing the movement of ions between them.**
  b What kind of substance must it be made of? **Ionic solution**
  c Why must it be made of this type of substance?
  **Ionic solutions consist of charged particles (ions) which are free to move under the influence of a potential difference, therefore they can conduct electricity.**

4 Choose from the options for a voltaic cell.

| VOLTAIC CELL | |
|---|---|
| **Anode** | **Cathode** |
| [**oxidation** / reduction] | [oxidation / **reduction**] |
| [positive / **negative**] | [**positive** / negative] |

5 Circle the correct option (True / False) for each of the following, referring to a **voltaic cell**.
  a A battery makes one electrode positive and the other negative, and this causes a chemical reaction to occur. [True / **False**]
  b A chemical reaction occurs, and this causes one electrode to be made positive and the other negative. [**True** / False]
  c As oxidation happens, chemicals lose electrons, which then go onto the anode, making it negative. [**True** / False]
  d The anode is made to be negative, and this makes chemicals lose electrons there, causing oxidation to happen. [True / **False**]
  e As reduction happens, chemicals accept electrons, taking them from the cathode, causing it to become positive. [**True** / False]
  f The cathode is made to be positive, and this makes chemicals gain electrons there, causing oxidation to happen. [True / **False**]

# Lead acid battery (Car battery)

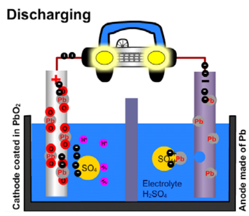
## *Overview*

6 A lead acid battery consists of [primary/**secondary**] cells.

7 Complete / choose from the options.

| | Discharging | Charging |
|---|---|---|
| | [electrolytic / **voltaic**] cells | [**electrolytic** / voltaic] cells |
| | [**produces** / requires] electrical energy | [produces / **requires**] electrical energy |
| Chemical reaction | [**spontaneous** / non-spontaneous] | [spontaneous / **non-spontaneous**] |
| | [**exothermic** / endothermic] | [exothermic / **endothermic**] |
| Energy conversion | **chemical** energy → **electrical** energy | **electrical** energy → **chemical** energy |
| Anode | [**Pb** / $PbO_2$] | [Pb / **$PbO_2$**] |
| Oxidation ½ reaction | $Pb \rightarrow Pb^{2+} + 2e^-$ | $PbSO_4 + 2H_2O \rightarrow PbO_2 + 4H^+ + SO_4^{2-} + 2e^-$ |
| Cathode | [Pb / **$PbO_2$**] | [**Pb** / $PbO_2$] |
| Reduction ½ reaction | $PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \rightarrow PbSO_4 + 2H_2O$ | $Pb^{2+} + 2e^- \rightarrow Pb$ |
| Net redox reaction | $PbO_2 + Pb + 4H^+ + 2SO_4^{2-} \rightarrow 2PbSO_4 + 2H_2O$ | $2PbSO_4 + 2H_2O \rightarrow PbO_2 + Pb + 4H^+ + 2SO_4^{2-}$ |

## *Discharging*




8 Complete the explanation by filling the gaps or choosing from the options. Do this before, or after, but not during, watching the animations. Mark during re-watching.

### *Overview*

When the lead acid battery is discharging it behaves as a set of [electrolytic/ **voltaic**] cells. Each lead acid battery consists of six cells. Only one of these is shown here. Each cell converts **chemical** energy into **electrical** energy, as a [**spontaneous**/non-spontaneous] chemical reaction [requires/**creates**] a potential difference across two electrodes. A lead acid battery has one electrode made of lead dioxide and another of lead. These are inside a **sulfuric** acid electrolyte.

### *Anode*

Lead atoms in the lead electrode are [**oxidised**/reduced]: they [gain/**lose**] two electrons each. This changes them into [**positively**/negatively/neutrally] charged lead [atoms/**ions**] of formula **$Pb^{2+}$**. Since [**oxidation**/reduction] occurs at this electrode, we call it the anode. The $Pb^{2+}$ ions move away from the electrode, leaving the electrons they had just lost behind on the electrode. This makes this electrode, the anode, [positively/**negatively**/neutrally] charged, creating a **potential difference** between it and the other electrode, which is positive relative to it. This causes electricity to flow between the two electrodes.

### *Cathode*

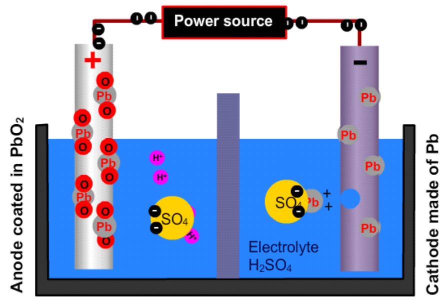
Electrons move from the [**lead**/lead dioxide] anode to the [lead/**lead dioxide**] cathode. There the electrons are [**accepted**/released] by positively charged **lead** ions in the lead dioxide electrode. The lead ions here have a [**4+**/2+] charge. Each lead [**4+**/2+] ion accepts two **electrons** and is reduced to a lead [4+/**2+**] ion. [Oxidation/**Reduction**] occurs at this electrode. It is therefore called the [**cathode**/ anode]. Because electrons are removed from the electrode in this way, it is charged [negatively/ **positively**]. These lead ions combine with **sulfate** ions from the sulfuric acid electrolyte to form **lead sulphate**. Hydrogen ions from the sulfuric acid electrolyte combine with **oxide** ions from the lead dioxide electrode to form **water**.

### *Overall reaction*
The overall reaction of the discharging lead acid battery is the reaction of **lead** and **lead dioxide** electrodes with **sulfuric** acid to form **lead sulfate** and **water**. This is a spontaneous, redox reaction which converts chemical into electric energy.

- It is spontaneous because **the reaction will occur on its own**: **you don't need to heat it or provide an external potential difference to force it to occur.**
- It is a redox reaction: it involves the transfer of **electrons** from one chemical to another.
- It converts **chemical** into **electrical** energy as **the chemical reaction creates a potential difference across the electrodes.**

## *Charging*
9 Complete the explanation by filling the gaps or choosing from the options. Do this before, or after, but not during, watching the animations.
Mark during re-watching.

**Charging**




### *Overview*
When the lead acid battery is charging it behaves as a set of [**electrolytic**/voltaic] cells. It converts **electrical** energy into **chemical** energy as a [spontaneous/**non-spontaneous**] chemical reaction is forced to occur due to an external potential difference being placed across two electrodes. To charge a lead acid battery, the lead dioxide electrode must be connected to the [**positive**/negative] terminal of an external power source, e.g. another battery. The lead electrode must be connected to the [positive/**negative**] terminal of this other battery. This pulls electrons from the [lead/**lead dioxide**] electrode and forces electrons into the [**lead**/lead dioxide] electrode. This causes the reactions which had occurred in the discharging reaction to take place [in the same direction/**in reverse**].

### *Anode*
The battery pulls electrons out of the electrode connected to its [**positive**/negative] terminal. Because of this, electrons are pulled out of the $Pb^{2+}$ ions in the **lead sulfate** around this electrode. This produces [$Pb^{2+}$/**$Pb^{4+}$**] ions. Because the [**$Pb^{2+}$**/$Pb^{4+}$] ions [gain/**lose**] electrons as they become $Pb^{4+}$ ions, [**oxidation**/reduction] is taking place. This electrode is therefore called the [**anode**/cathode]. Notice that in an electrolytic cell, such as this one, the anode is [**positively**/negatively] charged. This is opposite to the case of a voltaic cell. In an electrolytic cell the external **power supply (e.g. battery)** charges the anode positively, which forces oxidation to occur there.

### *Cathode*
The external battery [**pushes electrons into**/pulls electrons out of] the electrode connected to its negative terminal, charging that electrode [positively/**negatively**]. This forces lead ions, of formula **$Pb^{2+}$**, to accept two electrons each, changing them into lead atoms, of formula **Pb**. This is called [oxidation/**reduction**], since it involves **the acceptance of electrons**. Grey lead metal is formed through this reduction reaction. The electrode at which reduction happens is called the cathode. Therefore in an electrolytic cell, such as this one, the [positively/**negatively**] charged electrode is the cathode.

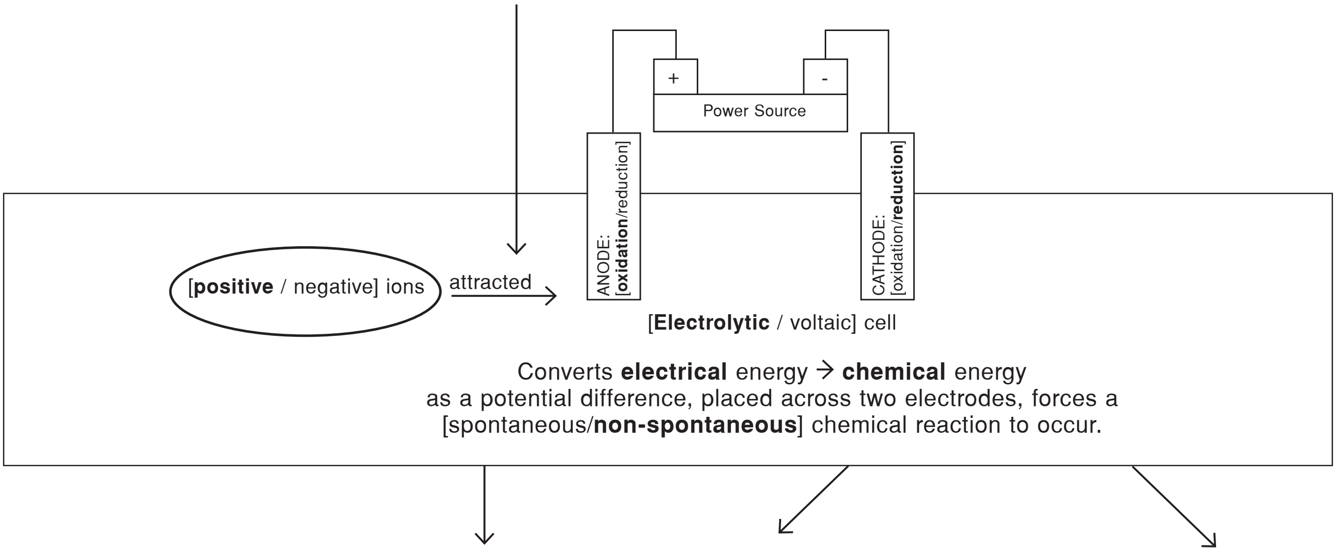
### *Overall reaction*
The overall reaction of the charging lead acid battery is the reaction of **lead** ions in lead sulfate to form **lead** at the cathode and **lead dioxide** at the anode. This is a non-spontaneous redox reaction which converts electrical into chemical energy.

- It is non-spontaneous because **the reaction will not occur on its own**: **you need to heat it or provide an external potential difference to force it to occur**.
- It is a redox reaction: it involves the transfer of **electrons** from one chemical to another.
- It converts **electrical** into **chemical** energy as **a potential difference forces a non-spontaneous chemical reaction to occur.**

# CHLOR-ALKALI MEMO

## Overview

1 Complete / choose from the options to summarise the purpose and process of the chlor-alkali industry.
Input: **Sodium chloride solution** (brine)




| | | | |
|---|---|---|---|
| Outputs: | **Chlorine : $Cl_2$** (g) | **Sodium hydroxide : NaOH** (aq) | Hydrogen: $H_2$ (g) |
| Uses: | **Bleach**<br>**Disinfectant**<br>**Used to make PVC** | **Soap-making**<br>**Water purification**<br>**Drain cleaning** | **Rocket fuel**<br>**Possible alternative car fuel**<br>**Needed for making plastics** |

2 Complete / choose from the options to summarise the types of chlor-alkali cells.

| | **Membrane** | **Diaphragm** | **Mercury** |
|---|---|---|---|
| **Cathode material** | carbon | carbon | **mercury** |
| **Input** | **brine (NaCl(aq)) and an electric potential difference (PD)** | | |
| **Oxidation ½ reaction at anode** | **$2Cl^-(aq) \rightarrow Cl_2 + 2e^-$** | | |
| **Reduction ½ reaction at cathode** | **$H_2O(\ell)$** reduced to **$H_2(g)+OH^-(aq)$** Since there are $Na^+$ ions present too, **NaOH** can be produced. | | **$Na^+$** reduced to **Na,** which then reacts with **$H_2O$** to form **NaOH** + **$H_2$** |
| **What divides the electrolyte into two half cells?** | **a semi-permeable membrane** | **a semi-permeable diaphragm** | **reduction ½ reaction occurs inside the liquid mercury cathode** |
| **Disadvantages** | | **diaphragm allows $Cl^-$ ions into the reduction ½ cell, contaminating the product with significant amounts of NaCl** | **mercury is poisonous** |

3 Choose from the options for an **electrolytic cell**.

| **ELECTROLYTIC CELL** | |
|---|---|
| **Anode** | **Cathode** |
| [**oxidation** / reduction] | [oxidation / **reduction**] |
| [**positive** / negative] | [positive / **negative**] |

4 Circle the correct option (True / False) for each of the following referring to an **electrolytic cell**.

a A battery makes one electrode positive and the other negative, and this causes a chemical reaction to occur. [**True** / False]

b A chemical reaction occurs, and this causes one electrode to be made positive and the other negative. [True / **False**]

c As oxidation happens, chemicals lose electrons, which then go onto the anode, making it positive. [True / **False]**

d The battery makes the anode positive, and this makes chemicals lose electrons there as the battery sucks electrons away from them, causing oxidation to happen. [**True** / False]

e As reduction happens, chemicals accept electrons, taking them from the cathode, causing it to become negative. [True / **False]**

f The battery makes the cathode negative, and this makes chemicals gain electrons there, causing reduction to happen. [**True** / False]

5 Link each element from Column A with its corresponding element in Column B. Write the letter from A next to each item in B in the last column.

| **Column A** | **Column B** | **A** |
|---|---|---|
| a anode | colour-remover | **k** |
| b cathode | a site at which the redox reactions of an electrochemical cell occur; often a rod | **c** |
| c electrode | a half reaction in which one chemical loses electrons, donating them to another chemical | **e** |
| d electrolyte | a half reaction in which one chemical gains electrons from another chemical | **f** |
| e oxidation | an electrode at which oxidation occurs | **a** |
| f reduction | a kind of reaction in which electrons are transferred from a reducing agent to an oxidising agent | **g** |
| g redox | attracted to water | **i** |
| h soap | an ionic solution, therefore able to conduct electricity | **d** |
| i hydrophilic | repelled by water | **j** |
| j hydrophobic | an electrode at which reduction occurs | **b** |
| k bleach | an organic chemical which is able to make fat dissolve | **h** |
| l chlorine ($Cl_2$) | a strong alkali; can be used to make soap; caustic soda | **m** |
| m sodium hydroxide | a substance which kills germs | **n** |
| n disinfectant | a dense green gas useful as bleach and disinfectant | **l** |

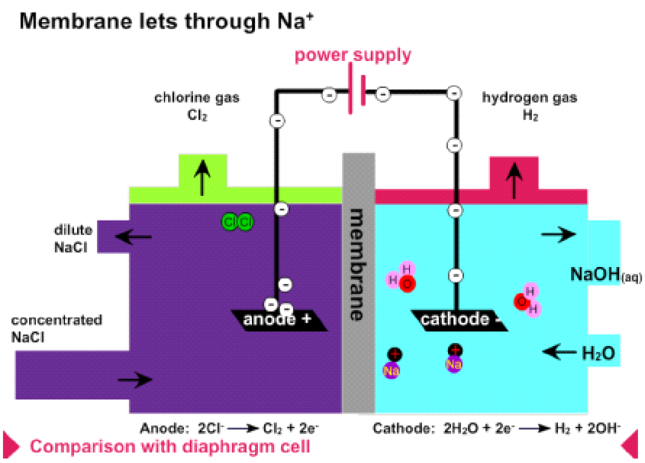
## Membrane Cell

6 Complete the explanation by filling the gaps or choosing from the options.
Do this before, or after, but not during, watching the animations.
Mark during re-watching.

### *Cell composition*

The membrane cell is a(n) [**electrolytic**/voltaic] cell. It consists of an external power supply (a battery), two **electrodes**, and **electrolytes**. The cell is divided into two halves. The two halves are separated by a semi-permeable membrane. Semi-permeable means **it only allows certain ions through**.

## Membrane cell



## *Electrolyte*
**Brine** serves as the electrolyte for the anode's half reaction. An electrolyte is **a solution which conducts electricity**. Brine consists of **sodium chloride** dissolved in water. When sodium chloride dissolves in water, its positively charged [**sodium**/chloride] ions are separated from its negatively charged [sodium/**chloride**] ions, and each ion is surrounded by **water**.

## *Anode*
The battery creates a **potential difference** across the electrodes. The positive terminal of the battery [**pulls electrons away from**/pushes electrons into] the electrode connected to it, charging the electrode [**positively**/negatively]. This attracts the [positively/**negatively**/neutrally] charged [sodium/**chloride**] ions in the brine. When these reach the electrode, the battery [**pulls an electron away from**/pushes electrons into] each of them. This converts them from [positively/**negatively**/neutrally] charged chloride ions into [positive/negative/**neutral**] chlorine atoms. These are unstable, so they bond covalently with one another in pairs, forming diatomic molecules of $\mathbf{Cl_2}$. This is what we often mean when we refer to chlorine. Chlorine is a dense green gas which bubbles away from this electrode and is collected. Chlorine was formed as chloride ions were stripped of electrons, so we call this half reaction [**oxidation**/reduction], which is the [gain/**loss**] of electrons. Each [chlorine atom/**chloride ion**] loses one electron to change it into a [**chlorine atom**/chloride ion]. The electrode at which oxidation occurs is called the [cathode/**anode**]. In an electrolytic cell, such as this, the battery charges the anode [**positively**/negatively].

## *Cathode*
The semi-permeable membrane allows [**positively**/negatively] charged sodium [**ions**/atoms] through into the other electrolytic half-cell. The electrode in this half-cell is connected to the negative terminal of the battery. The battery [pulls electrons away from/**pushes electrons into**] it, charging the electrode [positively/**negatively**/neutrally]. This causes water molecules to react at this electrode. The water molecules [lose/**accept**] the electrons. We say the water is [oxidised/**reduced**]. These electrons cause water to change into **hydrogen** gas ($H_2$) and [positively/**negatively**/neutrally] charged hydroxyl ions ($OH^-$). These hydroxyl ions are dissolved in water, as are the sodium ions which moved through the membrane. Sodium ions and hydroxyl ions are therefore present in the solution. We call this a sodium hydroxide solution. The electrode at which reduction occurs is called the [**cathode**/anode]. In an electrolytic cell, such as this, the battery charges the cathode [positively/**negatively**].

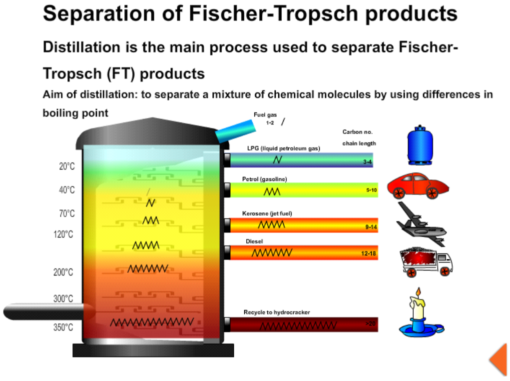
 

# PETROCHEMICALS MEMO

## Distillation

1 Why is distillation important in the petrochemical industry after the Fischer-Tropsch reaction?
**Distillation separates the hydrocarbon mixture resulting from the Fischer-Tropsch reaction into its components, which are more useful once isolated.**

2 Complete the explanation by filling the gaps or choosing from the options. Do this before, or after, but not during, watching the animations. Mark during re-watching.




Distillation is the separation of a mixture into its components by using their differences in **boiling** points. Boiling point is the **temperature** at which a substance boils. This is also the temperature at which it [freezes/melts/**condenses**/sublimes]. During condensation, a substance changes from **gas** to **liquid**. Long-chained hydrocarbons condense at [**higher**/lower] temperatures than short-chained hydrocarbons.

A distillation column has different temperatures throughout its height. At the bottom it is very [cold/**hot**]. It gets cooler and cooler [**higher up**/lower down]. The hydrocarbon mixture formed by the Fischer-Tropsch process is heated to over 350°C, making all its components vaporise, that is, turn to **gas**. This hot mixture is fed into the bottom of the **distillation** column.

Even though the temperature at the bottom of the column is hot, it is not hot enough to keep the [shortest/**longest**]-chained hydrocarbons in the gaseous phase. They **condense** and sink to the bottom. These hydrocarbons have more than 20 carbon atoms per molecule. They are then led off. They may be used, for example in **wax**, or they may be sent back to the **hydrocracker** to be split into shorter chains.

The [**shorter**/longer] hydrocarbons, still in the **gaseous** phase, rise. As they do so they come to cooler parts of the distillation column. At about 200°C, **diesel** condenses, and is led off. **Diesel** is made of a mixture of hydrocarbons having from 12 to 18 carbon atoms per molecule. It is used in some vehicles. At about 120°C, kerosene condenses. Kerosene is used as **jet** fuel. Kerosene is a mixture of hydrocarbons having 9 to 14 carbon atoms per molecule. At 40°C, **petrol** also called gasoline, condenses. It is made of a mixture of hydrocarbons having from 5 to 10 carbon atoms per molecule. This is used to power many vehicles. At 20°C **liquid petroleum gas** (LPG) condenses. LPG is often sold in gas bottles and might be used in gas heaters or stoves. It contains very [**short**/long] hydrocarbon chains which have only 3 or 4 carbon atoms per molecule. Even smaller molecules, consisting of only 1 or 2 carbon atoms per molecule, form **fuel gas**. This exits at the top of the distillation column, still in the **gaseous** phase.

So by cooling the heated hydrocarbon mixture to different **temperatures**, it is separated into its components as each component **condenses** at a different temperature, and therefore a different **height**, in the distillation column. A similar process is used in the separation of crude oil into its components. The temperatures used and products formed would, however, differ slightly from those given here.

## Hydrocracker

3 What is the purpose of the hydrocracker?
**To break long hydrocarbon chains into shorter chains when these are needed.**

4 Which chemical, in the presence of a catalyst, cracks the chains?
**Hydrogen**

## Methane, Ethane, Ethene, Wax

5 Give the formulae of:
a. Methane **$CH_4$** b. Ethane **$C_2H_6$** c. Ethene **$C_2H_4$**

6 Tick the relevant blocks in this table to show the classification of these chemicals.

| Chemical | Hydrocarbon? | Alkane? | Alkene? | Polymer? |
|---|---|---|---|---|
| Methane | ✓ | ✓ | | |
| Ethane | ✓ | ✓ | | |
| Ethene | ✓ | | ✓ | |
| Wax | ✓ | ✓ | ✓ | ✓ |

## General

7 Link each element from Column A with its corresponding element in Column B.
Write the letter from A next to each item in B in the last column.

| Column A | Column B | A |
|---|---|---|
| a hydrocarbons | bonds break | **e** |
| b alkanes | a single unit | **h** |
| c alkenes | energy needed to start a reaction | **k** |
| d adsorbed | consists of a long chain of repeated units | **g** |
| e dissociate | consist of only hydrogen and carbon atoms bonded together | **a** |
| f intramolecular | the process by which monomers bond with one another | **i** |
| g polymer | attaches to | **d** |
| h monomer | hydrocarbons with only single bonds | **b** |
| i polymerisation | between two atoms within a molecule | **f** |
| j catalyst | hydrocarbons with a double bond in them | **c** |
| k activation energy | a chemical which speeds up a reaction without itself being permanently changed by the reaction | **j** |

## Catalysts

8 Complete the explanation by filling the gaps or choosing from the options. Do this before, or after, but not during, watching the animations. Mark during re-watching.

A catalyst speeds up a reaction without itself being permanently **changed** by the reaction. It serves as a **binding** site for a reaction to take place. Reactants are **adsorbed** onto a catalyst surface. They then **dissociate**, breaking into their component atoms as their [inter/**intra**]molecular bonds break. The loosened [molecules/**atoms**] can then bond with other atoms to form a [reactant/**product**]. The catalyst allows this reaction to occur more easily than if it wasn't there. Reactants can only bond with one another if they can hit against one another with enough **energy** and the right **positioning**/**orientation** to stay together. We say they need **activation** energy in order to start them reacting. But if a catalyst holds the reactants in place to make reacting easier, the reactants need [more/**less**] energy to get to react. In other words, a catalyst [**reduces**/increases] the **activation** energy needed to cause a reaction. Because of this, the reaction will occur more [slowly/**quickly**] with a catalyst than without one.

# RESEARCH ASSIGNMENT

## Purpose
To get learners to extract, process, analyse, and synthesise information, and to communicate the results of these processes. They do this individually and collaboratively.

## Procedure

| Estimated time | Description | Resources |
|---|---|---|
| **Class time:**<br>**1 lesson** | • Explain the assignment to the learners.<br>• Divide learners into groups of four members each.<br>• Assign an industry to each group.<br>• Give each group their overarching controversial question (below), and allow them to conduct an initial brainstorm on this question, in their groups.<br>• Assign a number to each learner.<br>• Give each learner the learner sheets and guiding questions corresponding to their industry and learner number. | • Instructions (p.34)<br>• Overarching controversial questions (below)<br>• Guidance questions (p.34)<br>• Learner sheets (see p.34 for list) |
| **Homework:**<br>**2 hours** | • Learners read and summarise the information assigned to them.<br>• They answer their guiding questions in rough. | |
| **Class time:**<br>**2 lessons** | • Learners share information with one another.<br>• They draw a group mindmap.<br>• Learners discuss the group questions, given in the guidance table (p.34), and agree on their answer to the overarching controversial question. | Large sheets of paper (A3, A2 or A1)<br><br>Group guidance questions (p.34 ) |
| **Homework:**<br>**2-4 hours** | Learners prepare to present a presentation / write a report. | Notes: reports and presentations (pp. 35-36 ) |
| **Class time:**<br>**2 lessons** | • Each learner presents a section of a presentation / writes a section of a report, corresponding to their guiding questions (p.34), and related to their group's overarching controversial question (below).<br>• Collaboratively learners provide introductory and concluding statements in their presentation / report, which answers the overarching controversial question, and links the individuals' arguments to this.<br>• The teacher marks this work. | Rubrics (pp. 36-38) |

## Overarching controversial questions
Do you agree / disagree / partially agree with these statements? Justify your opinion.

### *The Fertiliser Industry*
In the future fewer South Africans will be able to live in cities because inorganic fertilisers are not sustainable.

### *The Battery Industry*
Battery technology has already changed our lifestyles hugely. In the future batteries are going to have an even bigger effect on us.

### *The Chlor-alkali Industry*
Chlor-alkali cells in general, and the membrane cell in particular, affect people's lives mainly for the better.

### *The Petrochemical Industry*
SASOL has contributed significantly to South Africa's development and prosperity in the past, and will continue to do so in the future.

## Learner instructions

You will work in a group of four learners. Your group's task is to answer one of the controversial questions on p. 33. You will do so by each writing part of a research report / presenting part of an oral presentation, and collaborating, as a group, on other parts.

1. Each learner in your group should have a number. Take the learner sheets, and note the guiding questions, corresponding to that number (see table below).
2. Read your learner sheets, and answer your guiding questions in rough.
3. Share what you have learnt with your group members. Draw a group mindmap. Discuss the group guidance questions (see table below). Discuss your controversial question.
4. Go through the notes on pages 35-36 and revise the information relevant to your topic. Your teacher may tell you to omit certain headings in the research report if time is limited. Note the rubrics.
5. Write a report / give an oral presentation. Collaboratively produce the introduction and conclusion. Individually produce the work related to your particular section.

## Guidance

| Industry | Learner | Guidance | Learner sheets |
|---|---|---|---|
| Fertiliser | 1 | How has the fertiliser industry developed? Where is it going? Is it sustainable? | F2,F8,F9 |
| | 2 | How have we developed faster ways to provide what plants need to grow? Why has our need for fertilisers increased? What are the consequences of this? | F4,F5,F7 |
| | 3 | The world needs more farmers. What do farmers need to know about fertilisers and farming to become financially successful and produce good crops? | F1,F3,F10 |
| | 4 | Does manufacturing fertilisers now create problems for the future? How does the fertiliser industry affect the environment? Is it sustainable? | F6,F11,F12 |
| | group | What do fertilisers have to do with people living in cities? What are inorganic fertilisers? Are they sustainable? Why/ why not? If they are not sustainable, will this affect city life? Why? / Why not? | |
| Battery | 1 | Explain the workings of an electrochemical cell. How have batteries developed over time? How do they affect our lives? | B1,B2,B10 |
| | 2 | Compare battery types. How do we use each? Discuss the strengths and weaknesses of each. How do you predict batteries will develop in the future? | B3,B4,B6 |
| | 3 | Different battery technologies have different uses and limitations. What are the challenges that the different technologies have faced and how have they tried to deal with these? Why have so many different technologies been developed? | B5,B7,B8 |
| | 4 | How can battery sustainability be improved? Refer to recycling, battery alternatives and correct battery handling, use and disposal. | B9,B11,B12 |
| | group | How has battery technology already changed our lifestyles? Is it sustainable? What possibilities are there for the future? Do you think these possibilities will affect us much? Why / why not? | |
| Chlor-alkali | 1 | How is salt electrolysed to form products? What are the consequences of this process? Who has benefited? How? Who has been harmed? How? | C1,C11,C12 |
| | 2 | Salt, caustic soda and many soaps contain sodium. What other links can be drawn between these three substances? Explain the history, sourcing, production and uses of each. Highlight the links between the three. | C2,C6,C7 |
| | 3 | Chlorine is found in ionic form in salt. Hydrogen is bonded to oxygen in water. Both Cl and H are common elements that affect our everyday lives. How are these elements used? Why are they so important to us? | C3,C4,C5 |
| | 4 | Discuss similarities, differences, strengths and weaknesses of the various cells used to electrolyse brine. Why have several techniques been developed? | C8,C9,C10 |
| | group | In what way do chlor-alkali cells improve our lives? Do they have any negative effects? How does the membrane cell differ from the rest? Does it improve our lives more than the other cells do? | |
| Petrochemical | 1 | Compare petrol and diesel referring to their structures and their economic viability as fuels. How does our dependence on these affect the environment? | P1,P5,P6 |
| | 2 | Why does the petrochemical industry consist of so many different types of industrial processes? Identify some of these processes. Explain how they work. What products are formed? What are the products' uses? | P4,P8,P9 |
| | 3 | Fossil fuels are natural sources of energy. Give two examples of fossil fuels. Explain what they are and how we obtain them. How do they affect our lives? | P2,P3,P7 |
| | 4 | The petrochemical industry is big business. How and why is this so? Who are the role players in South Africa and why are they so influential in everyday life? | P10,P11,P12 |
| | group | How has and does SASOL contribute to South Africa's development and prosperity? Is the industry sustainable? What changes in energy usage do you think might happen in the future? Why? Will SASOL's contribution to South Africa change? If so, how and why? If not, why not? | |

# Researching and presentation notes

## *Research*

- **Do not** copy information directly from your sources. This is plagiarism, which is wrong. As you read, write a list of keywords. Then put away your sources and use your keywords to help you to explain what you have read, using your own words.
- Interpret the findings and state conclusions. Form an **opinion of your own**. Make suggestions and recommendations of your own.

## *Oral presentation*

- Imagine you are teaching the class this topic. How can you be **interesting and informative**? You cannot cover everything, so carefully **choose what you will present**.
- **Plan** what you will say. Choose only a few main arguments. Each **argument** should consist of:
  - a **claim** (a statement) and
  - **backing** (support to convince people the claim is true).

  Where appropriate, also give **counterarguments** (arguments against your view point), and **rebuttals** to these (how you would answer back against these counterarguments).
  Use appropriate **linking words** to make your argument clear, logical and cohesive. Some linking words you could use are: firstly, secondly, as we have seen, on one hand, on the other hand, consequently, therefore, however, because, in the past, in the future, at present, instead, even though, in summary.
- **Practice** your presentation. Speak, don't read. Time yourself. Listen to yourself. Are you interesting and clear? Are you enthusiastic? Are you speaking clearly and confidently? Be sure to make eye contact with your audience.
- Use appropriate language. **Do not read** off notes. **Do not recite** a prepared speech. Talk to the class about what you have found and what you have learned as if you are **teaching** the material.

## *Written report*

- **Check** your writing for spelling and grammar errors. Check if your writing is logical, clear and cohesive (links together well). Correct your draft and rewrite it.
- Make sure you **reference** your sources. See the notes on how to do a reference list (**p.36**).

## *Report headings*

### *Abstract*

A **summary** of your main argument. 200 words or fewer. No references.

### *Title page*

**Title**, authors' **names**, **date** of completion. Include here which group member was responsible for which section.

### *Introduction*

What is the research **question**? Why is this **important**? What topics will be dealt with, and in what **sequence**? (How is the argument which follows structured?)

### *Report of the research project*

Each paragraph should deal with one main idea, or **argument**. Each argument should consist of:
- a **claim** (a statement) and
- **backing** (support to convince people the claim is true).

Where appropriate, also give **counterarguments** (arguments against your view point), and **rebuttals** to these (how you would answer back against these counterarguments).
Use appropriate **linking words** to make your argument clear, logical and cohesive. Some linking words you could use are: firstly, secondly, as we have seen, on one hand, on the other hand, consequently, therefore, however, because, in the past, in the future, at present, instead, even though, in summary.

***Conclusion***

The research question is **answered**. This answer is supported with a brief **summary** of the strongest arguments given in the report. Suggestions for **additional research** are given.

***References***

A list of resources used. For more than one author, write '&' before the last one.

**Books**

Author's surname, Initial. (Year of publication). Title. City of publication: Publisher.

**Journals / Magazines**

Author's surname, Initial. (Year of publication). Title. Journal, Volume (Number), Pages.

**Web sources**

Author's surname, Initial. (Year of publication). Title. [Online]. Available from URL. [Date of retrieval].

**Example**

Black, J. (2001). Battery manufacturers in South Africa. [Online]. Available from http://www.howstuffworks.com/Batteries/South Africa.htm. [22 September 2010].

Naidoo, P. G. (1992). Teaching Physical Sciences in the South African classroom. Science Education, 1(1), 34-36.

Smith, D., Green, R. S. & Gumede, A. (1986). Chemicals and their uses. Cape Town: First Publishers.

**Appendix**

Include:

- a **glossary** of the terms relevant to the project.
- relevant **diagrams** or pictures.
- a **mind map** or flow diagram that was used to plan the research report.

## Rubrics

### *Oral presentation*

| Group mark | Not achieved | Moderate | Adequate/ Substantial | Outstanding |
|---|---|---|---|---|
| • The group presented its answer to the controversial question **clearly** and **convincingly**. | 0 | 1 | 2 | 3 |
| • The group supported its answer to the controversial question **thoroughly** and **logically**. | 0 | 1 | 2 | 3 |
| • The collaborative and individual sections of the presentation were **well integrated** and **linked** to make a **cohesive** whole. | 0 | 1 | 2 | 3 |
| **Individual mark** | | | | |
| • A highly enthusiastic learner. The presentation is interesting, capturing attention. | 0 | 1 | 2 | 3 |
| • Accurate information was presented. It is clear that the learner has mastered the content. | 0 | 1 | 2 | 3 |
| • Arguments are clear and logical. Claims are supported thoroughly and logically. | 0 | 1 | 2 | 3 |
| • Counterarguments and rebuttals are included in a fair-minded manner. | 0 | 1 | 2 | 3 |
| • The learner is able to converse in a scientific language. | 0 | 1 | 2 | 3 |
| • The learner presents the topic without reading. He/she keeps to time limits. | 0 | 1 | 2 | 3 |
| • The most important and relevant content was presented. This is done in a well-organised sequence. | 0 | 1 | 2 | 3 |
| **Total** | **/30** | | | |

## *Written report*

| Criterion | Level Descriptors | | | | |
|---|---|---|---|---|---|
| **Abstract**<br>(6 marks)<br><br>(Group mark) | No abstract is included or abstract is not appropriate or abstract is relevant but none of the statements are satisfactory. | Any one of: Research concept is stated clearly. Essential research findings are summarised. Conclusion is stated. Fewer than 200 words are used. | Any two of: Research concept is stated clearly. Essential research findings are summarised. Conclusion is stated. Fewer than 200 words are used. | Any three of: Research concept is stated clearly. Essential research findings are summarised. Conclusion is stated. Fewer than 200 words are used. | Research concept is stated clearly. Essential research findings are summarised. Conclusion is stated. Fewer than 200 words are used. |
| | **0-1 marks** | **2-3 marks** | **4 marks** | **5 marks** | **6 marks** |
| **Title page**<br>(1 mark)<br><br>(Group mark) | No title page is included or title page is inappropriate or title page is incomplete. | The following are given: Research report title. Authors' names. Completion date. A list of which learner was responsible for which section. | | | |
| | **0 marks** | **1 mark** | | | |
| **Introduction**<br>(7 marks)<br><br>(Group mark) | No introduction or introduction is inappropriate or it is relevant but not satisfactory. | Any one of the following: The research question is given. It is clear why the research is important. The argument sequence is mapped out. | Any two of the following: The research question is given. It is clear why the research is important. The argument sequence is mapped out. | All of the following: The research question is given. It is clear why the research is important. The argument sequence is mapped out. | |
| | **0-1 marks** | **2-3 marks** | **4-5 marks** | **6-7 marks** | |
| **Report**<br>(20 marks)<br><br>(Individual mark) | No report is included or the report is inappropriate or the report is relevant but not satisfactory, or plagiarism is present. | Any one of the following is appropriate: Findings are in learner's own words. Scientific terms and concepts are correctly used. Resources used / consulted are cited. The report is well researched. The guiding questions are answered thoroughly and correctly. | Any two of the following are appropriate: Findings are in learner's own words. Scientific terms and concepts are correctly used. Resources used / consulted are cited. The report is well researched. The guiding questions are answered thoroughly and correctly. | Any three of the following are appropriate: Findings are in learner's own words. Scientific terms and concepts are correctly used. Resources used / consulted are cited. The report is well researched. The guiding questions are answered thoroughly and correctly. | More than three of the following are appropriate: Findings are in learner's own words. Scientific terms and concepts are correctly used. Resources used / consulted are cited. The report is well researched. The guiding questions are answered thoroughly and correctly. |
| | **0-2 marks** | **3-6 marks** | **7-10 marks** | **11-14 marks** | **15-20 marks** |

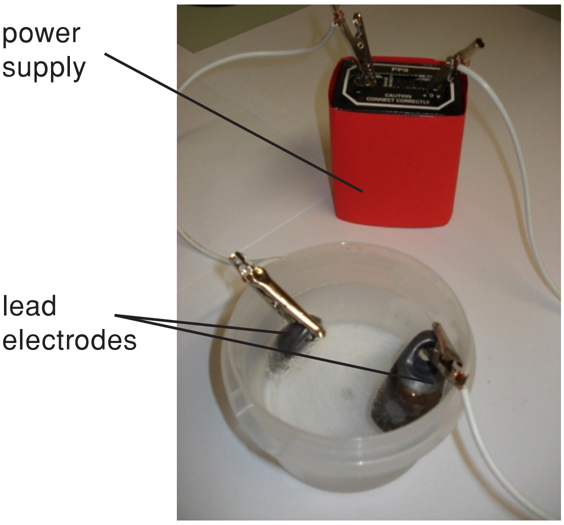
| | | | | | |
|---|---|---|---|---|---|
| **Argument quality** (12 marks)<br><br>(Individual mark) | Claims are not clear and not thoroughly and logically supported. Counterarguments and rebuttals are not given, or not suitable. Linking words are lacking and used inappropriately. | Any one of: Claims are clear and thoroughly and logically supported. Counterarguments and rebuttals are given and integrated well in a coherent, fair-minded manner. Linking words are used logically to hold the argument cohesively together. | Any two of: Claims are clear and thoroughly and logically supported. Counterarguments and rebuttals are given and integrated well in a coherent, fair-minded manner. Linking words are used logically to hold the argument cohesively together. | All three of: Claims are clear and thoroughly and logically supported. Counterarguments and rebuttals are given and integrated well in a coherent, fair-minded manner. Linking words are used logically to hold the argument cohesively together. | |
| | **0-2 marks** | **3-6 marks** | **7-9 marks** | **10-12 marks** | |
| **Conclusion** (7 marks)<br><br>(Group mark) | No conclusion is included or the conclusion is inappropriate or the conclusion is relevant but not satisfactory. | Any one of: The research question is answered clearly. This is supported by a brief summary of the strongest arguments. Suggestions for further research are given. | Any two of: The research question is answered clearly. This is supported by a brief summary of the strongest arguments. Suggestions for further research are given. | All three of: The research question is answered clearly. This is supported by a brief summary of the strongest arguments. Suggestions for further research are given. | |
| | **0-1 marks** | **2-3 marks** | **4-5 marks** | **6-7 marks** | |
| **References** (4 marks)<br><br>(Group mark) | No reference list is included, or none of the sources is appropriately referenced. | Any one of: Appropriate resources are cited. The reference list is appropriately extensive. Sources are all correctly referenced. | Appropriate resources are cited. The reference list is appropriately extensive. Some, but not all, resources are correctly referenced. | All three of: Appropriate resources are cited. The reference list is appropriately extensive. Sources are all correctly referenced. | |
| | **0 marks** | **1 mark** | **2 marks** | **3-4 marks** | |
| **Appendix** (3 marks)<br><br>(Group mark) | No appendix is included or the appendix is inappropriate or it is relevant but not satisfactory. | Any one of: Relevant terms are correctly explained. Relevant diagrams/ pictures are included. There is a relevant concept map / flow diagram. | Any two of: Relevant terms are correctly explained. Relevant diagrams/ pictures are included. There is a relevant concept map / flow diagram. | Relevant terms are correctly explained. Relevant diagrams/ pictures are included. There is a relevant concept map / flow diagram. | |
| | **0 marks** | **1 mark** | **2 marks** | **3 marks** | |
| **Writing quality** (10 marks)<br><br>(Individual mark) | There are very many grammatical, spelling, typographic and / or scientific errors. | There are a significant number of grammatical, spelling, typographic and / or scientific errors. | There are a fair number of grammatical, spelling, typographic and / or scientific errors. | There are few grammatical, spelling, typographic and / or scientific errors. | There are no grammatical, spelling, typographic, or scientific errors. |
| | **0-1 mark** | **2-4 marks** | **5-6 marks** | **7-8 marks** | **9-10 marks** |
| | | | **Total /70** | | |

# CELL CHARGE AND DISCHARGE

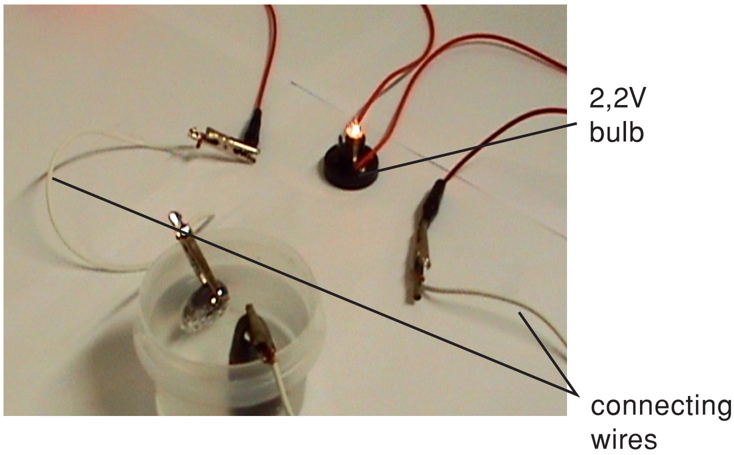
## Instructions
- Read these investigation instructions, results and theory.
- Watch the accompanying movie.
- Answer the questions.
- Perform the investigation yourself for enrichment.

## Investigation instructions and results

### *Apparatus*



Charging cell



Discharging cell

### *Method*
- **Charging**. Charge the cell for various times.
  Treatments differ in charge time:
  A: 1 minute B: 2 minutes C: 3 minutes
  D: 4 minutes E: 5 minutes F: 6 minutes
- **Discharging**. After each charge period, connect a 2,2V bulb to allow for discharge. Measure the time period for which the bulb shines.

### *Background theory*
A secondary cell is rechargeable. While it is discharging it behaves as a voltaic cell. Chemical energy is converted into electrical energy. This happens as a spontaneous redox reaction occurs at the electrodes, causing a potential difference to develop across them.

While the cell is being charged it behaves as an electrolytic cell. Electrical energy is converted into chemical energy. For this to happen, the cell must be connected to an external power supply. This causes a potential difference to form across the electrodes. This forces a non-spontaneous chemical reaction to occur. This chemical reaction is the reverse of the spontaneous discharge reaction. In this way the chemicals are restored to their original state, ready to react spontaneously during the next discharge.

# Questions

## *Variables*

Complete / Give the:

1 **Independent** variable. ______________________________

(Cause. What the investigator made different between the treatments.)

2 **Indicator** of the **dependent** variable. ______________________________

(Measurement of effect. What the investigator measures to show the investigation outcome.)

3 ______________________________ variable. **A cell's discharge time.**

(Effect. Different between the treatments because they had been treated differently from the start.)

4 **Controlled** variables (list at least three). (Must be kept the same between treatments for a fair test.)

______________________________

______________________________

## *Focus question*

Complete:

5 How does ______________________________ affect ______________________________?

[independent variable] [dependent variable]

## *Hypothesis*

6 Guess what the answer to the focus question might be. ______________________________

______________________________

7 Justify your hypothesis, referring to the background theory. ______________________________

______________________________

______________________________

## *Table*

8 Circle the correct options to complete general rules for drawing a table.

*Optional* *Headings*

| | Dependent variable / **Independent variable** / Indicator of dependent variable | Dependent variable / Independent variable / **Indicator of dependent variable** |
|---|---|---|
| A | **Values showing how investigator treated** | Values showing how investigator treated treat- |
| B | **treatments differently** / Measurements | ments differently / **Measurements** |
| C | made to show investigation outcome | **made to show investigation outcome** |
| D | | |

*Body*

9 Units (e.g. min or s) should be given only in the [heading / body] of the table.

10 The abbreviation for the unit seconds is [sec / s].

11 Calculate the averages for each treatment.

The effect of a cell's charge time on its discharge time

| | Charge time (min) | Time bulb shines (s) | |
|---|---|---|---|
| | | Raw data (3 repetitions) | Average |
| A | 1 | 4,5 ; 4,7 ; 4,6 | |
| B | 2 | 6,0 ; 5,9 ; 5,5 | |
| C | 3 | 6,4 ; 6,4 ; 6,7 | |
| D | 4 | 6,9 ; 6,9 ; 6,9 | |
| E | 5 | 7,3 ; 7,9 ; 7,0 | |
| F | 6 | 8,1 ; 8,4 ; 7,5 | |

## *Graph*

12 Represent the findings graphically.

Check. Have you: Tick if done:

- given a suitable graph heading? ☐
- plotted the independent variable on the x ( — ) axis? ☐
- plotted the indicator of the dependent variable on the y ( | ) axis? ☐
- labelled each axis and given units where appropriate? ☐
- accurately plotted data points with small circled dots? ☐
- drawn a smooth trend line? ☐

## *Conclusion*

13 Answer the focus question in your own words. ______________________________

______________________________

14 Complete for a shorter way of writing the conclusion.

Increasing ______________________________ [increases / decreases / doesn't affect]
[independent variable]

______________________________ [dependent variable]

## *Discussion*

15 Was your hypothesis shown to be correct or incorrect? ______________________________

16 Suggest a reason for your findings, referring to the background theory.

______________________________

______________________________

______________________________

## *Further investigation*

Design another investigation of your own, using the guidance given below.
It must have a different focus question to the previous investigation.

### *Variables*

Complete / Give the:

17 **Independent** variable. ______________________________

**Dependent** variable. **A cell's discharge time.**

18 **Controlled** variables. (Must be kept the same between treatments for a fair test.)
Compared to the previous investigation, give one variable which:

a must be constant between treatments here, but not previously

______________________________

b must not be constant between treatments here, but must be previously

______________________________

### *Focus question*

Complete:

19 How does ______________________ affect ______________________?
[independent variable] [dependent variable]

### *Method*

20 Treatments differ in : ______________________:

A: ______________________ C: ______________________

B: ______________________ D: ______________________

21 Explain what you would do in this investigation.

______________________________

______________________________

______________________________

______________________________

### *Table*

22 Fill in headings and values showing how you will treat the treatments differently.
Include units in headings where appropriate.
Leave empty spaces where you could fill data in after taking measurements.

| | | |
|---|---|---|
| A | | |
| B | | |
| C | | |
| D | | |

# RATE OF ELECTROLYSIS

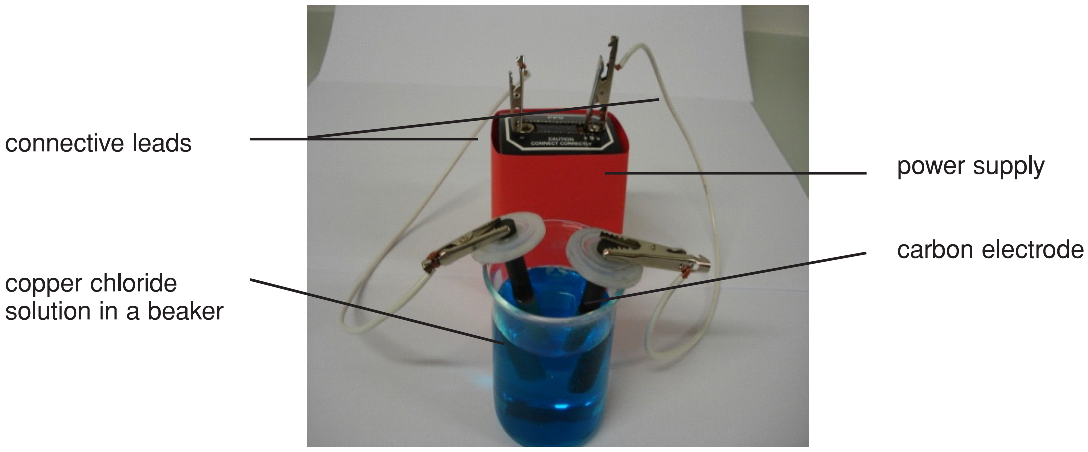
## Instructions

- Read this investigation information.
- Watch the accompanying movie section by section as you answer the questions.
- Perform the investigation yourself.

## Investigation information

### *Apparatus*

- Carbon electrodes. You could get these from dismantled cells.
- Copper chloride solution in a beaker.
- A power supply (e.g. battery) and connective leads.




### *Background theory*

Chlorine is a dense green gas with a characteristic sharp smell. It is a very strong oxidising agent, which makes it a powerful bleach and disinfectant. Chlorine can be produced by the electrolysis of chlorine-containing compounds. During electrolysis, a compound may be decomposed into its component elements. This happens as electrical energy is converted into chemical energy in an electrolytic cell. An electrolytic cell consists of an external power supply (e.g. battery) connected to two electrodes which are placed in an electrolyte. The electrodes are conductive rods. An electrolyte is an ionic solution which conducts electricity. When an electric potential difference is placed across the two electrodes, a redox reaction occurs at each electrode. This redox reaction decomposes the electrolyte into its component elements or into simpler component compounds.

Copper chloride solution ($CuCl_2(aq)$) contains chloride ions ($Cl^-(aq)$). These can be oxidised to chlorine molecules ($Cl_2$). This is seen by bubbles of chlorine gas forming at the positively charged electrode. The electrode where oxidation occurs is called the anode. Copper chloride solution also contains copper ions ($Cu^{2+}(aq)$). During the electrolytic process, these are reduced to copper atoms, which precipitate on the negatively charged electrode. The electrode where reduction occurs is called the cathode. The blue colour of the copper chloride solution becomes lighter in colour and the mass of the cathode increases as the copper ions in solution are reduced to copper which gathers on the cathode.

Electrolysis rate means the extent to which electrolysis occurs in a certain time. It can be measured by the change in reactants and / or products per time.

## Questions

### *Planning possibilities*

Watch the movie introduction about the planning possibilities of the investigation.

You want to investigate how various factors affect the rate of electrolysis.

1 Suggest various factors which might affect the rate of electrolysis and which you could alter in this investigation. These are possible **independent** variables.

________________________________________

________________________________________

________________________________________

2 **Rate of electrolysis** is the **dependent** variable for this investigation.

Give possible **focus questions** for this investigation.

These can be written in the form:

How does [independent variable] affect [dependent variable]?

________________________________________

________________________________________

________________________________________

3 Complete for three possible indicators of the dependent variable (rate of electrolysis).

| Indicator of rate of electrolysis | If I see ________, I would deduce that the rate of electrolysis was **high** | If I see ________, I would deduce that the rate of electrolysis was **low** |
|---|---|---|
| | | |
| | | |
| | | |

Watch the rest of the movie.

### *Focus question*

4 Give the focus question of the investigation performed in the movie.

How does ____________________ affect ____________________?

[independent variable] [dependent variable]

## *Treatments*

5 Describe the treatments.

______________________________________________________________________

______________________________________________________________________

(give a general description of what is common between the treatments)

A: ____________________ B: ____________________

C: ____________________ D: ____________________

(list specific differences between the treatments)

6 In which variable do they differ from one another? (Choose.) [Dependent / Independent]

## *Controlled variables*

7 List variables which must be the same between the different treatments for a fair test.

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

## *Results*

8 Tabulate the results either shown in the movie, or, preferably, from your own experiment.

Raw data table:

| | **Electrode mass (g)** | | |
|---|---|---|---|
| | **Initial** | **Final** | **Change** |
| | | | |
| | | | |
| | | | |
| | | | |

Processed data table:

| | **Change in electrode mass due to copper deposition (g)** |
|---|---|
| | |
| | |
| | |
| | |

Check. Have you: Tick if done:

- completed the table headings suitably? ☐
- headed the first columns with the independent variable? ☐
- given units, where appropriate, in the headings, not body, of the table? ☐
- filled in all treatment details in the first column? ☐
- filled in initial and final mass readings (processed data table) ☐
- correctly calculated and recorded mass change values (raw and processed data tables)? ☐

## *Graph*

9 Represent the findings graphically.

Check. Have you: Tick if done:

- given a suitable graph heading? ☐
- plotted the independent variable on the x ( ___ ) axis? ☐
- plotted the indicator of the dependent variable on the y ( | ) axis? ☐
- labelled each axis and given units where appropriate? ☐
- accurately plotted data and drawn a smooth trend line ☐

## *Conclusion*

10 Answer the focus question in your own words.

______________________________________________

______________________________________________

11 Complete for a shorter way of writing the conclusion.

Increasing ______________________________ [increases / decreases / doesn't affect]

[independent variable]

______________________________ [dependent variable]

## *Discussion*

12 Suggest a reason for your findings, referring to the background theory.

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

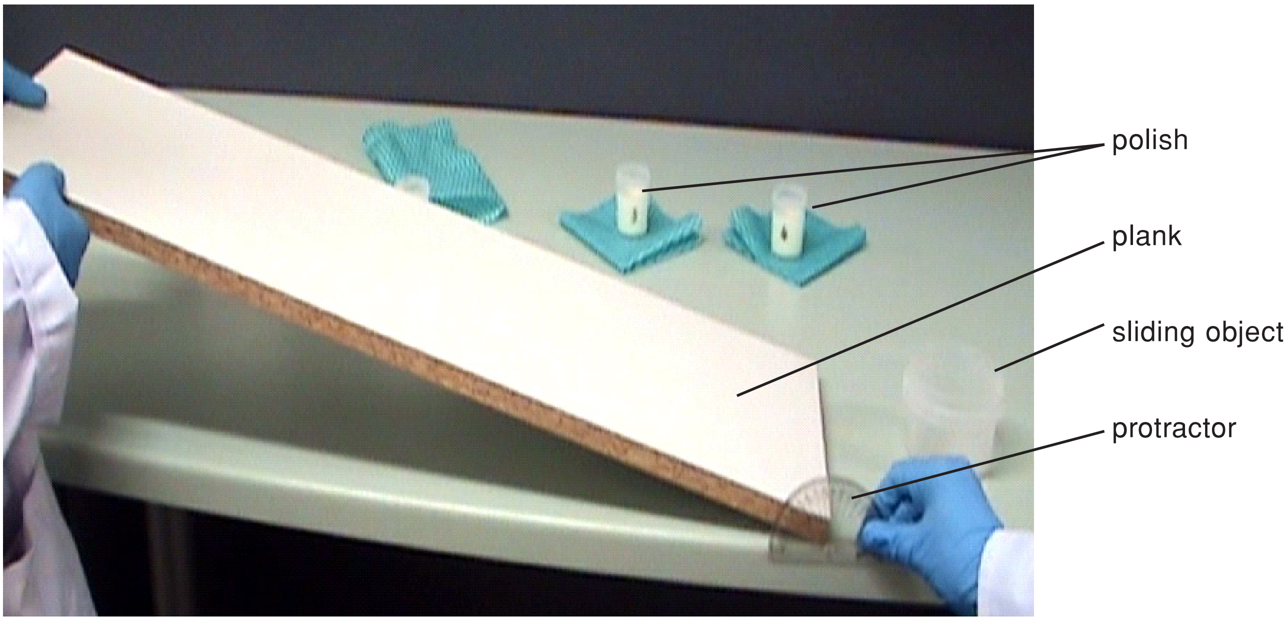
______________________________________________

# PROPERTIES OF FLOOR WAX

## Instructions
- Read these investigation instructions, results and theory.
- Watch the accompanying movie.
- Answer the questions.
- Perform the investigation yourself for enrichment.

## Investigation instructions and results

### *Apparatus*
- Four different kinds of floor polish prepared by mixing molten candle wax in paraffin wax. Treatments differ in amount of candle wax dissolved in paraffin to make the polish:
    - A: 4 g candle wax / 20 ml paraffin
    - B: 8 g candle wax / 20 ml paraffin
    - C: 12 g candle wax / 20 ml paraffin
    - D: 16 g candle wax / 20 ml paraffin
- Four planks.
- An object to slide down the planks.
- A protractor.




### *Method*
- Smear some polish onto each plank.
- Place the sliding object on one plank at a time.
- Lift one end of the plank gradually until the object begins to slide.
- Measure the angle the plank makes to the horizontal when in this position.

### *Results*
The effect of a polish's amount of candle wax on the amount of friction it gives

| | Mass candle wax / 20ml paraffin (g) | Minimum angle causing sliding (° to horizontal) | |
|---|---|---|---|
| | | Raw data (3 repetitions) | Average |
| A | 4 | 16, 16, 16 | 16 |
| B | 8 | 20, 16, 18 | 18 |
| C | 12 | 26, 22, 30 | 26 |
| D | 16 | 46, 45, 47 | 46 |

### *Background theory*

Candle wax is made of long-chained alkanes, and liquid paraffin of short-chained alkanes. Both are sometimes called paraffins, since they are both alkanes. Candle wax can be called paraffin wax. Alkanes are hydrocarbons with only single bonds. Hydrocarbons consist of only carbon and hydrogen atoms. Longer chained hydrocarbons have a higher viscosity than shorter chained hydrocarbons. Viscosity means resistance to flow. Long chained hydrocarbons tangle up with one another, making it difficult for them to flow over one another, making their viscosity high. Their viscosity may be so high that they cannot flow at all: they are solids, not liquids.

Heating a solid can melt it. This decreases its viscosity, changing it from solid to liquid. When candle wax is melted, it can mix with paraffin. This mixture is called a solution.

Friction is a force which resists motion. It results from surfaces rubbing against one another. The amount of friction is affected by how hard the two rubbing surfaces are pressed together, and how rough each surface is. Therefore the friction between an object and the surface it is resting on can be reduced by making the object lighter, tilting the surface, or by making the surfaces smoother. Some polish might make a surface smoother.

## Questions

### *Variables*

Complete / Give the:

1 **Independent** variable. ______________________________
(Cause. What the investigator made different between the treatments.)

2 **Indicator** of the **dependent** variable. ______________________________
(Measurement of effect. What the investigator measures to show the investigation outcome.)

3 ______________________________ variable: **Amount of friction the polish gives.**
(Effect. Different between the treatments because they had been treated differently from the start.)

4 **Controlled** variables (list at least three). (Must be kept the same between treatments for a fair test.)

______________________________

______________________________

### *Focus question*

Complete:

5 How does ______________________________ affect ______________________________?
[independent variable] [dependent variable]

### *Theory*

6 What is friction? ______________________________

7 How can friction between two surfaces be reduced?

______________________________

8 Why do we want polish with more friction?

______________________________

9 How does candle wax differ from paraffin?

Candle wax ______________________________

whereas paraffin ______________________________.

## *Graph*

10 Represent the findings graphically. Only plot the average values.

Check. Have you: | Tick if done:

- given a suitable graph heading? ☐
- plotted the independent variable on the x ( —— ) axis? ☐
- plotted the indicator of the dependent variable on the y ( | ) axis? ☐
- labelled each axis and given units where appropriate? ☐
- accurately plotted data points with small circled dots? ☐
- drawn a smooth trend line? ☐

11 It would be wrong to make this graph's line cut the origin (0,0). Why?

______________________________________________

______________________________________________

## *Interpretation*

12 Circle the correct option to analyse the data.

| Amount of candle wax | Minimum angle causing sliding | Amount of friction polish gives |
|---|---|---|
| high was found to cause → | a [higher / lower] sliding angle indicates → | [more / less] friction |
| low was found to cause → | a [higher / lower] sliding angle indicates → | [more / less] friction |

13 Interpret the results in your own words.

______________________________________________

______________________________________________

## *Conclusion*

14 Answer the focus question in your own words.

______________________________________________

______________________________________________

15 Complete for a shorter way of writing the conclusion.

Increasing ______________________________ [independent variable]

[increases / decreases / doesn't affect] ______________________________ [dependent variable]

## *Discussion*

16 Suggest a reason for your findings, referring to the background theory.

______________________________________________

______________________________________________

______________________________________________

## *Further investigation*

Design another investigation of your own, using the guidance given below.
It must have a different focus question from the previous investigation.

### *Variables*

Complete / Give the:

17 **Independent** variable. ______________________________

**Dependent** variable. **Amount of friction polish gives.**

18 **Controlled** variables. (Must be kept the same between treatments for a fair test.)
Compared to the previous investigation, give one variable which:

a must be constant between treatments here, but not previously

______________________________________________

b must not be constant between treatments here, but must be previously

______________________________________________

### *Focus question*

Complete:

19 How does ______________________ affect ______________________?
[independent variable] [dependent variable]

### *Method*

20 Treatments differ in : ______________________________

A: ______________________ C: ______________________

B: ______________________ D: ______________________

### *Table*

21 Fill in headings and values showing how you will treat the treatments differently.
Include units in headings where appropriate.
Leave empty spaces where you could fill in data after taking measurements.

| | | |
|---|---|---|
| A | | |
| B | | |
| C | | |
| D | | |

# CELL CHARGE AND DISCHARGE MEMO

## Purpose

- Learners are guided through the basic aspects of an experimental investigation.
- Learners plan an additional investigation of their own.

## Suggested teaching approach

| Estimated time | Description | Resources |
|---|---|---|
| Class time:<br>1 lesson | • Explain the necessary theory about batteries and about the scientific method.<br>• Show learners the movie or perform the investigation yourself.<br>• Discuss the investigation. Refer to: variables, focus question, hypothesis, results, conclusion, discussion. | Cell charge and discharge movie<br>Worksheet (p.39) |
| Homework time:<br>½ hour | • Learners answer questions 1-16 in writing. | Worksheet (p.39) |
| Class time:<br>½ lesson | • Go through the answers to questions 1-16 with the learners.<br>• Conduct a class discussion on further investigation possibilities (questions 17-22). Note that a number of possibilities could be correct: not only the one suggested here. | Memo<br>Worksheet |
| Homework time:<br>½ hour | • Learners answer questions 17-22 in writing. | Worksheet |

Check the learners' work.
Additional time should be allowed if you want to perform the experiment in class.

## Practical tips

- Make sure you use a low-voltage (2,2V) bulb. An LED will also work, but takes a long time to discharge the cell.
- Allow the cell to charge for a while before you begin collecting data. $PbO_2$ forms in this time.
- Short-circuit the cell by placing a wire across the electrodes, before each charge.

## Suggested answers to questions

### *Variables*

1 **Independent** variable: **A cell's charge time.**
(Cause. What the investigator made different between the treatments.)

2 **Indicator** of the **dependent** variable. **Time bulb shines**
(Measurement of effect. What the investigator measures to show the investigation outcome.)

3 **Dependent** variable. A cell's discharge time.
(Effect. Different between the treatments because they had been treated differently from the start.)

4 **Controlled** variables (list at least three). (Must be kept the same between treatments for a fair test.)
**concentration of electrolyte (sulfuric acid solution); PD during changing; temperature; distance between electrodes; surface area of electrodes; types of substances used for electrodes and electrolyte**

### *Focus question*

5 How does **a cell's charge time** [independent variable] affect **its discharge time**? [dependent variable]

### *Hypothesis*

6 Guess what the answer to the focus question might be.
**The learner should give his/her guess.**

7 Justify your hypothesis, referring to the background theory.
**The learner should justify his/her hypothesis, referring to theory.**

## Table

8 Circle the correct options to complete general rules for drawing a table.

| *Optional* | **Dependent variable** / **Independent variable** / **Indicator of dependent variable** | **Dependent variable** / **Independent variable** / **Indicator of dependent variable** |
|---|---|---|
| A | **Values showing how investigator treated** | Values showing how investigator treated treat- |
| B | **treatments differently** / Measurements | ments differently / **Measurements** |
| C | made to show investigation outcome | **made to show investigation outcome** |
| D | | |

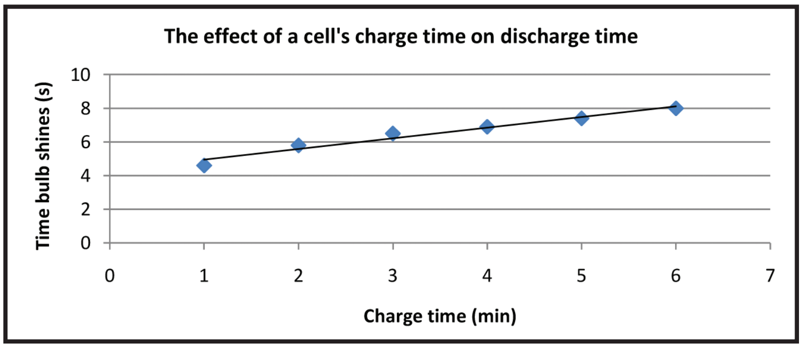
9 Units (e.g. min or s) should be given only in the [**heading** / body] of the table.
10 The abbreviation for the unit seconds is [sec / **s**].
11 Calculate the averages for each treatment:

The effect of a cell's charge time on its discharge time

| | **Charge time (min)** | **Time bulb shines (s)** | |
|---|---|---|---|
| | | **Raw data (3 repetitions)** | **Average** |
| A | 1 | 4,5 ; 4,7 ; 4,6 | **4,6** |
| B | 2 | 6,0 ; 5,9 ; 5,5 | **5,8** |
| C | 3 | 6,4 ; 6,4 ; 6,7 | **6,5** |
| D | 4 | 6,9 ; 6,9 ; 6,9 | **6,9** |
| E | 5 | 7,3 ; 7,9 ; 7,0 | **7,4** |
| F | 6 | 8,1 ; 8,4 ; 7,5 | **8,0** |

## Graph

12 Represent the findings graphically.




Check. Has the learner: — Tick if done:

- given a suitable graph heading? ☐
- plotted the independent variable on the x ( —— ) axis? ☐
- plotted the indicator of the dependent variable on the y ( | ) axis? ☐
- labelled each axis and given units where appropriate? ☐
- accurately plotted data points with small circled dots? ☐
- drawn a smooth trend line? ☐

## Conclusion

13 Answer the focus question in your own words.
**The longer you charge the battery, the longer the light shines (the longer the battery can discharge). A battery's discharge time is directly proportional to its charge time.**
14 Complete for a shorter way of writing the conclusion.
Increasing **a cell's charge time**[**increases** / decreases / doesn't affect] **its discharge time**.

## Discussion

15 Was your hypothesis shown to be correct or incorrect? **Depends on learner's hypothesis.**
16 Suggest a reason for your findings, referring to the background theory.

**The charging process restores chemicals to the state they need to be in to restart the discharge process. The longer the charging time the more chemicals can be restored to the state needed for the discharge process, and therefore the longer the subsequent discharge time can be. Of course, this is only up to a point. If the battery is already fully charged — with all its chemicals restored to the state ready for discharge — then charging it longer doesn't help: it won't discharge for longer because it has reached its capacity already.**
**We can also explain this in terms of energy. Charging converts electrical to chemical energy. This chemical energy can then be converted back into electrical energy during discharging. The longer the period of charging, the more electrical energy is stored as chemical energy, and therefore the more chemical energy is present to be able to be converted back into electrical energy during discharging. Again, this is only up to a limit.**

## *Further investigation: Possible answer*

Design another investigation of your own, using the guidance given below.
It must have a different focus question to the previous investigation.
**Note that there are other answers which could be correct too.**

### *Variables*

Complete / Give the:

17 **Independent** variable. **A cell's electrolyte concentration**
**Dependent** variable. **A cell's discharge time.**

18 **Controlled** variables. (Must be kept the same between treatments for a fair test.)
Compared to the previous investigation, give one variable which:
a must be constant between treatments here, but not previously **the cell's charge time**.
b must not be constant between treatments here, but must be previously
**the electrolyte concentration (or whatever learner chose as their dependent variable here).**

### *Focus question*

Complete:

19 How does **a cell's electrolyte concentration** [independent variable] affect **its discharge time**? [dependent variable]

### *Method*

20 Treatments differ in: **electrolyte concentration**
**Note: these values are only suggestions: any reasonable values are acceptable:**
A: **0,1 M $H_2SO_4$(aq)**
B: **0,5 M $H_2SO_4$(aq)**
C: **1 M $H_2SO_4$(aq)**
D: **1,5 M $H_2SO_4$(aq)**

21 Explain what you would do in this investigation.
**Mix different concentrations of sulfuric acid solutions.**
**Charge each cell for a certain amount of time (e.g. 1 minute).**
**Record the time for discharge for each cell.**

### *Table*

22 Fill in headings and values showing how you will treat the treatments differently.
Include units in headings where appropriate.
Leave empty spaces where you could fill data in after taking measurements.

**The effect of a cell's electrolyte concentration on its discharge time**

| | Electrolyte concentration (M) | Time bulb shines (s) |
|---|---|---|
| A | **0,1** | |
| B | **0,5** | |
| C | **1** | |
| D | **1,5** | |

# RATE OF ELECTROLYSIS MEMO

## Purpose

- Learners design, perform, and report on an experimental investigation using readily-available equipment.

## Structure

- During the first part of the worksheet and movie learners explore numerous investigation possibilities, and think through the design of these possible experiments. During the last part of the movie, learners observe how to perform a specific investigation. After this, they should preferably practically perform this investigation, or any of the other variations they had previously planned. Alternatively, they could complete the worksheet by referring to what was done in the movie.

## Suggested teaching approach

| Estimated time | Description | Resources |
|---|---|---|
| Class time:<br>1 lesson | · Explore planning possibilities.<br>· Discuss set-up and theory.<br>· Set up electrolytic cells. Either prescribe a specific investigation to perform, e.g. that performed in the movie, or give learners the freedom to investigate any feasible question from those previously discussed. | Rate of electrolysis movie<br>Electrodes, $CuCl_2$, cells, wires, scale |
| Homework:<br>½ lesson | · Learners answer questions 1-7 in writing. | Worksheet (pp.43-46) |
| Overnight | · Allow to stand for about 2 hours.<br>· Remove cathodes from the electrolytes. Allow to dry overnight. | Well ventilated area |
| Class time:<br>1 lesson | · Collect data.<br>· Learners answer questions 8-12 in writing. | Scale<br>Worksheet |
| Class time:<br>½ lesson | · Go through answers. | Memo |

## Practical preparation and tips

- You need: carbon rods (you could get these from dismantled batteries), copper chloride solution electrolyte in a beaker, a power supply (e.g. battery) and connective leads.
- If you cannot get copper chloride, use blue window cleaner.
- To measure electrode mass, you need a mass scale. Be sure to measure each cathode's initial mass and to mark each one clearly. Be careful not to dislodge any copper from the cathodes during or after the experiment. Allow to dry thoroughly before measuring the final masses.
- Electrolyte colour change is a poor practical indicator of rate of electrolysis of $CuCl_2(aq)$, since it is very difficult to see the difference between most colour changes which might occur.

## Suggested answers to questions

### *Planning possibilities*

Watch the movie introduction about the planning possibilities of the investigation.
You want to investigate how various factors affect the rate of electrolysis.

1 Suggest various factors which might affect the rate of electrolysis, which you could alter in this investigation. These are possible **independent** variables.
**temperature of solution, concentration of solution, time left in solution, potential difference used, surface area of electrodes, distance between electrodes, volume of solution**

2 **Rate of electrolysis** is the **dependent** variable for this investigation.
Give possible **focus questions** for this investigation.
These can be written in the form:
How does [independent variable] affect [dependent variable]?
**How does temperature of solution affect rate of electrolysis?**

**How does concentration of solution affect rate of electrolysis?**
**How does time left in solution affect rate of electrolysis?**
**How does potential difference used affect rate of electrolysis?**
**How does surface area of electrodes affect rate of electrolysis?**
**How does distance between electrodes affect rate of electrolysis?**
**How does volume of solution affect rate of electrolysis?**

3 Complete for three possible indicators of the dependent variable (rate of electrolysis):

| Indicator of electrolysis rate | If I see ________, I would deduce that the rate of electrolysis was high | If I see ________, I would deduce that the rate of electrolysis was low |
|---|---|---|
| **colour of solution after a certain time** | **pale blue after e.g. 2,5 hours** | **still dark blue after e.g. 2,5 hours** |
| **volume of chlorine gas formed in a certain time** | **much chlorine gas would be formed in e.g. 5 minutes.** | **little chlorine gas would be formed in e.g. 5 minutes.** |
| **mass of copper precipitated on electrode in a certain time** | **electrode would have gained a lot of mass, due to copper precipitation, in e.g. 2,5 hours.** | **electrode would have gained little mass, due to copper precipitation, in e.g. 2,5 hours.** |

Watch the rest of the movie.

## *Focus question*

4 Give the focus question of the investigation performed on the movie.
How does **potential difference** affect **rate of electrolysis**?

## *Treatments*

5 Describe the treatments.
**Four electrolytic cells are used, with the following potential differences across their electrodes:**
A: **1,5V** B: **3V**
C: **4,5V** D: **6V**

6 In which variable do they differ from one another? (Choose:) [Dependent / **Independent**]

## *Controlled variables*

7 List variables which must be the same between the different treatments for a fair test:
**temperature of solution, concentration of solution, time left in solution, surface area of electrodes, distance between electrodes, volume of solution**

## *Tables*

8 Tabulate the results either shown in the movie, or, preferably, from your own experiment.
**Note: if learners use data from their own experiment, then their values will differ from those given here.**

Raw data table: The effect of potential difference on rate of electrolysis

| **Potential difference (V)** | **Electrode mass (g)** | | |
|---|---|---|---|
| | Initial | Final | Change |
| **1,5** | **6,50** | **6,90** | **0,40** |
| **3** | **6,50** | **7,33** | **0,83** |
| **4,5** | **6,51** | **7,93** | **1,42** |
| **6** | **6,57** | **8,17** | **1,60** |

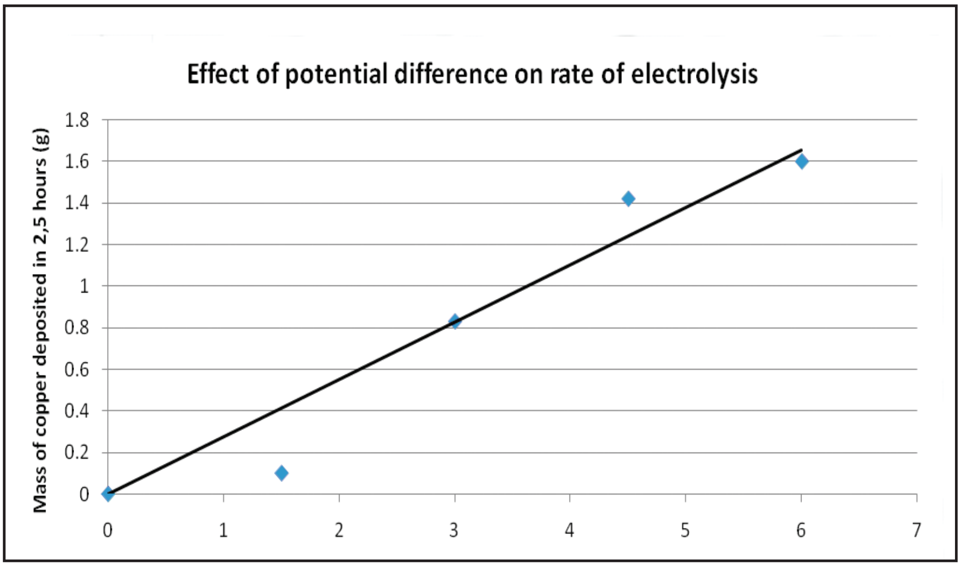
Processed data table: The effect of potential difference on rate of electrolysis

| **Potential difference (V)** | **Change in electrode mass due to copper deposition (g)** |
|---|---|
| **1,5** | **0,40** |
| **3** | **0,83** |
| **4,5** | **1,42** |
| **6** | **1,60** |

Check. Has the learner: Tick if done:
- completed the table headings suitably? ☐
- headed the first columns with the independent variable? ☐
- given units, where appropriate, in the headings, not body, of the table? ☐
- filled in all treatment details in the first column? ☐
- filled in initial and final mass readings (processed data table) ☐
- correctly calculated and recorded mass change values (raw and processed data tables)? ☐

## *Graph*

9 Represent the findings graphically.




Check. Has the learner: Tick if done:
- given a suitable graph heading? ☐
- plotted the independent variable on the x ( —— ) axis? ☐
- plotted the indicator of the dependent variable on the y ( | ) axis? ☐
- labelled each axis and given units where appropriate? ☐
- accurately plotted data and drawn a smooth trend line? ☐

## *Conclusion*

10 Answer the focus question in your own words.
**A higher potential difference causes the electrolytic reaction rate to be higher.**

11 Complete for a shorter way of writing the conclusion:
Increasing **potential difference** [**increases** / decreases / doesn't affect] **rate of electrolysis**.
[independent variable] [dependent variable]

## *Discussion*

12 Suggest a reason for your findings, referring to the background theory.
**A higher potential difference is associated with a greater delivery of electrical energy to the circuit. In an electrolytic cell electrical energy is converted into chemical energy. A higher rate of delivery of electrical energy to the cell results in a higher rate of chemical reaction. Therefore the rate of electrolysis increases with an increased potential difference.**

# PROPERTIES OF FLOOR WAX MEMO

## Purpose

- Learners are guided through the basic aspects of an experimental investigation.
- Learners plan an additional investigation of their own.

## Suggested teaching approach

| Estimated time | Description | Resources |
|---|---|---|
| Class time:<br>1 lesson | • Explain the necessary theory about wax and about the scientific method.<br>• Show learners the movie or perform the investigation yourself.<br>• Discuss the investigation. Refer to: variables, focus question, hypothesis, results, conclusion, discussion. | Properties of floor wax movie<br>Worksheet (p.47-50) |
| Homework:<br>½ lesson | • Learners answer questions 1-16 in writing. | Worksheet |
| Class time:<br>1 lesson | • Go through the answers to questions 1-16 with the learners.<br>• Conduct a class discussion on further investigation possibilities (questions 17-22). Note that a number of possibilities could be correct, not only the one suggested here. | Memo<br>Worksheet |
| Homework:<br>½ lesson | • Learners complete worksheet questions 17-22. | Worksheet |

Check learners' work.
Additional time should be allowed if you wish to perform the experiment in class.

## Practical preparation and tips

- You need: a candle, paraffin, a measuring cylinder, a stove / hot plate, heat-resistant containers (e.g. beakers) containers to store the polish in, cloths, planks, a protractor, a sliding object.
- If you cut a standard candle into 1cm strips, each piece will have a mass of approximately 4g.
- Do not heat the paraffin. Add hot, molten candle wax to the paraffin and mix.
- You will probably find quite a lot of variation in your data. You will also probably find it difficult to decide when to stop tilting the plank, especially for the higher wax content polishes. This provides an excellent opportunity for you to discuss limitations, experimental error, variation in data, reliability and validity, with your learners.

## Suggested answers to questions

### *Variables*

1 **Independent** variable. **A polish's amount of candle wax**
(Cause. What the investigator made different between the treatments.)
2 Indicator of the dependent variable. **Minimum angle causing sliding**
(Measurement of effect. What the investigator measures to show the investigation outcome.)
3 **Dependent** variable. **Amount of friction the polish gives**
(Effect. Different between the treatments because they had been treated differently from the start.)
4 **Controlled** variables (list at least three). (Must be kept the same between treatments for a fair test.)
**Thickness of layer of polish applied.** **Mass of sliding objects.**
**Material type and degree of smoothness of planks.** **Temperature.**
**Material type and degree of smoothness of sliding objects' bottom surfaces.**

### *Focus question*

5 How does **a polish's amount of candle wax** affect **the amount of friction the polish gives**?

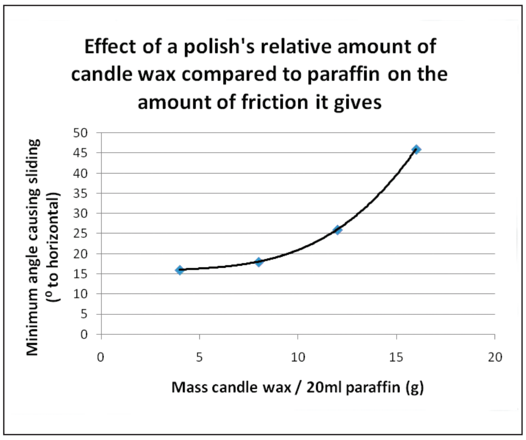
### *Theory*

6 What is friction? **A force which resists motion.**
7 How can friction between two surfaces be reduced? **By making the object lighter, tilting the surface, or by making the surfaces smoother.**

8 Why do we want polish with more friction? **Friction reduces slipping. We want to shine and waterproof a floor with polish, but don't want this to make us slip.**
9 How does candle wax differ from paraffin?
- Candle wax **consists of longer hydrocarbon chains**.
- whereas paraffin wax **consists of shorter hydrocarbon chains**.

## *Graph*

10 Represent the findings graphically.




Check. Has the learner: — Tick if done:
- given a suitable graph heading? ☐
- plotted the independent variable on the x ( —— ) axis? ☐
- plotted the indicator of the dependent variable on the y ( | ) axis? ☐
- labelled each axis and given units where appropriate? ☐
- accurately plotted data points with small circled dots? ☐
- drawn a smooth trend line? ☐

11 It would be wrong to make this graph's line cut the origin (0,0). Why? **The sliding object would not slide at 0° to the horizontal if the polish contained 0g candle wax.**

## *Interpretation*

12 Circle the correct option to analyse the data.

| Amount of candle wax | | Minimum angle causing sliding | | Amount of friction polish gives |
|---|---|---|---|---|
| high | was found to cause → | a [**higher** / lower] sliding angle | indicates → | [ **more** / less ] friction |
| low | was found to cause → | a [higher / **lower**] sliding angle | indicates → | [ more / **less** ] friction |

13 Interpret the results in your own words.
**The more candle wax there is in the polish the more friction the polish gives.**

## *Conclusion*

14 Answer the focus question in your own words.
**In learner's words. E.g. More candle wax, more friction.**
15 Complete for a shorter way of writing the conclusion.
**Increasing a polish's amount of candle wax [increases** / decreases / doesn't affect]
**the amount of friction the polish gives.**

## *Discussion*

16 Suggest a reason for your findings, referring to the background theory.
**The candle wax consists of longer-chained hydrocarbons. It is therefore more viscous than the paraffin, and so is more sticky, and therefore gives more friction.**

## *Further investigation: Possible answer*

Design another investigation of your own, using the guidance given below.
It must have a different focus question from the previous investigation.
**Note that there are other answers which could be considered correct too.**

### *Variables*

Complete / Give the:
17 **Independent** variable. **Temperature**
**Dependent** variable. **Amount of friction polish gives.**
18 **Controlled** variables. (Must be kept the same between treatments for a fair test.)
Compared to the previous investigation, give one variable which:
a must be constant between treatments here, but not previously.
**amount of candle wax compared to paraffin**
b must not be constant between treatments here, but must be previously
**temperature (or whatever learner chose as their dependent variable here).**

### *Focus question*

Complete:
19 How does **temperature** [independent variable] affect **amount of friction polish gives?** [dependent variable]

### *Method*

20 Treatments differ in : **temperature**
**Note: these values are only suggestions: any reasonable values are acceptable:**
A: **10°C**
B: **25°C**
C: **50°C**
D: **80°C**

### *Table*

Fill in headings and values showing how you will treat the treatments differently.
Include units in headings where appropriate.
Leave empty spaces where you could fill data in after taking measurements.

**The effect of floor polish's temperature on the amount of friction it gives**

| | Temperature (°C) | Minimum angle causing sliding (° to horizontal) |
|---|---|---|
| A | **10** | |
| B | **25** | |
| C | **50** | |
| D | **80** | |

# GLOSSARY

| | |
|---|---|
| **Activation energy** | The energy required to start a reaction. |
| **Adsorption** | A process where something bonds to a solid. |
| **Alkali** | Soluble base. Has a pH greater than 7. Tastes bitter and feels soapy. |
| **Alkane** | A hydrocarbon which has only single bonds. |
| **Alkene** | A hydrocarbon with one double bond between two of its carbon atoms. |
| **Anode** | An electrode at which oxidation occurs. |
| **Apparatus** | Equipment. |
| **Battery** | A group of voltaic cells. |
| **Bleach** | Colour-remover. |
| **Boiling point** | Temperature at which a substance boils. Equals its condensation point. |
| **Brine** | Salt water. Dissociated sodium ions and chloride ions surrounded by water. |
| **Catalyst** | A chemical which speeds up a reaction by lowering the reaction's activation energy. It is not used up by the reaction. |
| **Cathode** | An electrode at which reduction occurs. |
| **Chlorine** | A dense green gas which is useful as bleach and disinfectant. |
| **Chloralkali industry** | The industry which manufactures chlorine and sodium hydroxide from the electrolysis of sodium chloride. |
| **Closed** | (Chemical system) Chemicals do not either enter or leave the system. |
| **Conclusion** | The answer to an investigation's question, as shown by the investigation's data. Might be written as: [dependent variable] [increases/decreases] with increased [independent variable]. |
| **Condensation** | Changing from the gaseous to the liquid phase. |
| **Contact Process** | The industrial process by which sulfuric acid ($H_2SO_4$) is formed from sulfur, oxygen and water. |
| **Controlled variable** | Variable which is kept the same between treatments for the whole investigation. Cannot be the independent or dependent variables. |
| **Crude oil** | A mixture of hydrocarbons of various lengths. Crude oil is mined. Later it is separated into its components, e.g. by distillation. |
| **Data** | Measurements. |
| **Dependent variable** | Effect. Variable which becomes different between the treatments because they had been treated differently from the start. |
| **Desorption** | A process where something separates from a solid. |
| **Detergent** | An inorganic chemical which is able to make fat dissolve in water. |
| **Diaphragm** | A dividing membrane. Made of asbestos in the diaphragm cell. |
| **Diesel** | A mixture of hydrocarbons having 12-18 carbon atoms per molecule. Fuel. |
| **Direct Proportion** | As the independent variable is increased, the dependent variable increases by the same factor. |
| **Discussion** | A written discussion of the trends in the data, and a suggested explanation, in terms of the background theory. |
| **Disinfectant** | Germ killer. |
| **Dissociation** | Breaking apart. |
| **Distillation** | The process of separating a mixture due to components different boiling points. |
| **Distillation column** | A large container which is hottest at the bottom, and gets cooler and cooler with height. Used for distillation. |
| **Dynamic equilibrium** | A state which can be reached when a reversible reaction occurs in a closed system. Both the forward and reverse reactions occur at the same rate as one another. The amounts of reactants and products remain constant. |
| **Electrode** | A site at which the redox reactions of an electrochemical cell occur. Often a rod. |

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| **Electrolysis** | A non-spontaneous chemical reaction in which a compound is broken down into simpler component substances as an electric current passes through it. |
| **Electrolyte** | An ionic solution. Such a solution is able to conduct electricity. |
| **Electrolytic cell** | Consists of an external power source (e.g. battery), connected to two electrodes placed in an electrolyte. Electrical energy is converted to chemical energy. |
| **Endothermic** | A reaction which absorbs more energy than it releases. |
| **Exothermic** | A reaction which releases more energy than it absorbs. |
| **Experimental investigation** | A way of finding an answer to a cause-effect question. Two or more treatments are used. These differ only in the independent variable at the start. Because of this they might get to differ in the dependent variable, which is measured. |
| **Fischer-Tropsch reaction** | The second step in making hydrocarbons, e.g. petrol, from coal. Carbon monoxide and hydrogen react to form water and hydrocarbons. |
| **Focus question** | A question which guides everything done in an experimental investigation. Might be written as: How does [independent variable] affect [dependent variable]? |
| **Gasification** | The first step in making hydrocarbons, e.g. petrol, from coal. Carbon dioxide and water vapour react to form carbon monoxide and hydrogen gas. |
| **Haber Process** | The industrial process by which ammonia ($NH_3$) is formed from $N_2$ and $H_2$. |
| **Halogen** | Very reactive non-metals found next to the noble gases on the periodic table. |
| **Hydrocarbon** | An organic compound consisting only of bonded hydrogen and carbon atoms. |
| **Hydrocracking** | Hydrogen reacts with long-chained hydrocarbons, in the presence of a catalyst, to split the hydrocarbon into shorter chains. |
| **Hydrophilic** | 'Water loving'. Attracted to water. |
| **Hydrophobic** | 'Water fearing'. Repelled by water. |
| **Hypothesis** | A guessed answer to the focus question. It must be informed by background theory. It is then tested by doing an experimental investigation. |
| **Independent variable** | Cause. Variable the investigator makes different between the treatments from the start. |
| **Indicator** | A specific way of varying, measuring or showing up a general variable. |
| **Inert** | Unreactive. |
| **Inverse proportion** | As the independent variable is increased, the dependent variable decreases by the same factor. |
| **Ionic bridge** | An ionic solution connecting the two half cells in a voltaic cell. Necessary for a complete electric circuit and to prevent the build-up of ions in either half cell. |
| **Kerosene** | A mixture of hydrocarbons with 9-14 C atoms per molecule. Aeroplane (jet) fuel. |
| **Le Chatelier's Principle** | When a system which is in equilibrium is disturbed, it will respond in such a way as to counteract the disturbance. |
| **Lead acid battery** | A car battery. A secondary cell with lead and lead dioxide electrodes in a sulfuric acid electrolyte. |
| **Liquid petroleum gas** | (LPG) A mixture of hydrocarbons having 3-4 carbon atoms per molecule. Sold as bottled gas for heating and cooking. |
| **Membrane** | A thin sheet or film which lets only certain ions through. |
| **Mercury** | A poisonous silver metal which is a liquid at room temperature. |
| **Mercury cell** | A chlor-alkali cell which has a mercury cathode. |
| **Method** | Steps followed to find an answer to a focus question in an investigation. |
| **Mixture** | Consists of two or more pure substances not chemically bonded to one another. |
| **Monomer** | A building block which is repeated multiple times within a polymer. |
| **Nitrate** | A compound containing the compound ion $NO_3^-$. Can be absorbed by plants. |
| **Nitrite** | A compound containing the compound ion $NO_2^-$. Can be absorbed by plants. |
| **Nitrogen** | An element which is found in all proteins. Exists in the elemental form as $N_2$, which forms 78% of air. Plants cannot absorb $N_2$. |
| **Non-polar** | Having no distortion in electron distribution. |

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| **Non-spontane-ous** | Does not happen on its own. |
| **Ostwald Process** | The industrial process by which nitric acid ($HNO_3$) is formed from ammonia ($NH_3$) and oxygen ($O_2$) |
| **Oxidation** | A half reaction in which one chemical loses electrons to another chemical. |
| **Oxidising agent** | A chemical which causes another to get oxidised while it is itself reduced. |
| **Petrol** | A mixture of hydrocarbons having 5-10 carbon atoms per molecule. Fuel. |
| **Polar** | Having a distortion in electron distribution. Having + and - ends. |
| **Polymer** | A long-chained organic compound made of many monomers bonded together. |
| **Polymerisation** | The process of forming a polymer from many reacting monomers. |
| **Pressure** | Force per area. In gases, pressure is related to the rate at which particles hit against the sides of their container. Measured in bars, atmospheres (atm), kiloPascals (kPa) and millimetres of mercury (mm Hg). |
| **Primary cell** | A voltaic cell which cannot be recharged. |
| **Pure substance** | A substance which has its own chemical and physical properties. May be an element or a compound. |
| **Redox** | A kind of reaction in which electrons are transferred. |
| **Reducing agent** | A chemical which causes another to get reduced while it is itself oxidised. |
| **Reduction** | A half reaction in which one chemical gains electrons from another chemical. |
| **Reversible** | A reaction which can occur in both the forward and reverse directions. |
| **Secondary cell** | A rechargeable cell. Voltaic during discharging. Electrolytic during charging. |
| **Semi-permeable** | Allows some substances through but blocks others. |
| **Soap** | An organic chemical able to make fat dissolve in water. Made from animal fat and sodium hydroxide. Molecules have hydrophilic heads and hydrophobic tails. |
| **Sodium hydroxide** | A strong alkali (soluble base). Can be used to make soap. Also called caustic soda. |
| **Spontaneous** | Happens on its own: without needing to be heated, for example. |
| **STP** | Standard temperature and pressure: 273 K and 101,3 kPa. A reference state. |
| **Temperature** | A measure of particles' average kinetic energy. Measured in degrees Celsius (°C) or Kelvin (K). |
| **Treatments** | Groups which are treated differently in one way (the independent variable) at the start of an investigation. There must always be at least two treatments in an experiment. |
| **Uniform scale** | A scale with equally spaced increases, e.g. 5 kg increase every centimetre. |
| **Unit** | Measurement scale, e.g. seconds (s). |
| **Variables** | Properties which may vary (change) in quantity (how much) and / or quality (what like). |
| **Viscosity** | Resistance to flow |
| **Voltaic cell** | An electrochemical cell which converts chemical to electrical energy. A spontaneous chemical reaction creates a potential difference. |
| **x-axis** | Horizontal axis. |
| **y-axis** | Vertical axis. |

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