Dry Cells

Contents: Reading, questions and practical work concerning the nature of dry cells.

Time: 2 periods or more, depending on amount of practical work done.

Intended use: GCSE Chemistry and Integrated Science. Links with work on electrochemistry and electrochemical cells, tests for anions and cations and reactions of metals. May be particularly useful during revision.

Aims:

- To complement and revise work on electrochemical cells, and to revise work on tests for anions and cations
- To show the variety and importance of dry cells in everyday life
- To show the varied technology of dry cells
- To provide opportunities to practise skills in comprehension, collection of information and certain practical laboratory skills.

Requirements: Students' worksheets No. 706. If possible, a representative selection of dry cells. See below for practical work requirements.

Suggested use of the unit

The unit is in three parts:

Part 1 *Different kinds of cells.* An introductory survey at home or school of different types of dry cells.
Part 2 *How do different types of cells work?* A description of the construction and function of some common types of dry cell.
Part 3 *Practical investigation of a cell.*

The three parts are independent and it is not necessary to do all three parts if there is insufficient time.

The practical work in Part 3 can be used in a number of ways. It is principally intended as an investigative exercise to address the question, 'What's inside a dry cell?'. If it is used in this way, it should be attempted *before* Part 2, since Part 2 gives the answer to the question. It could alternatively be used *after* Part 2, as a way of *confirming* the identity of the dry cell contents. More notes on Part 3 appear below.

Notes on Part 1

This is intended as an opening exercise to give students an idea of the different types of dry cell in everyday use. It is best done at home, but students could be encouraged to bring different types of cells to school to enable the class to pool results. Alternatively, the teacher could provide a representative selection of cells. Ideally these should include all the different types described in Part 2.

Students are likely to find it difficult to distinguish between the different types of cell since classification is complicated by the range of sizes and brands encountered. The teacher may wish to draw things together at the end of the exercise.

Some of the more important types of dry cell are described in the table below.

Type of cell	*Voltage*	*Used for*	*Price (1985)*
zinc-carbon, ordinary quality (e.g. Ever Ready Blue Seal, Boots SP)	1.5V	torches, radios	£0.35 (SP2 size)
zinc-carbon, top quality (e.g. Ever Ready Silver Seal, Boots HP)	1.5V	cassette players, calculators, motorized toys	£0.50 (SP2 size)
alkaline-manganese (e.g. Duracell, Ever Ready Gold Seal, Boots Alkaline Power Cell)	1.6V	cassette players, motorized toys, other applications involving heavy continuous use	£1 (SP2 size)
silver oxide button cell	1.5V	calculators, watches	varies widely according to size
mercury oxide button cell	1.35V	hearing aids, photographic equipment	varies widely according to size
zinc-air button cell	1.5V	hearing aids	varies widely according to size
nickel-cadmium rechargeable	1.3V	applications involving heavy current discharge e.g. motorized toys, cassette players	£3.30 (SP2 size)

Q.3 Comparing 'value for money' is difficult, because the effective capacity of a cell depends on a number of factors. These include:

(a) The design and quality of manufacture
(b) The physical size of the cell
(c) The voltage at which the appliance ceases to work properly
(d) The age of the cell
(e) The rate at which the cell is discharged
(f) The period of time per day for which the cell is used
(g) The temperature.

Comparisons therefore give different results depending on the appliance in use, the time for which it runs, etc. In principle, however, comparisons can be made by running different batteries through the same cycle of operations under the same conditions, and comparing useful lifetimes.

Notes on Part 2

Q.4 In the zinc-carbon cell, the outer zinc casing is dissolved away during the cell reaction. Eventually holes appear and the electrolyte leaks out, though it may still be confined inside the outer steel container. In the alkaline manganese cell, the zinc is present as a powder, and is not part of the casing.

Q.5 See note on question 3 above.

Q.6 The main reason is simply size.

Q.8 This question is intended to remind students of the toxic nature of mercury compounds. Similar considerations apply to the rechargeable nickel-cadmium cell.

Q.9 Desirable features for the 'ideal' dry cell might include low cost, long lifetime for small size, ability to cope with heavy discharge for extended periods, ability to supply steady current, long shelf-life, etc.

Notes on Part 3

Depending on the ability of the students, the practical could be presented as a problem-solving exercise, with groups of students designing their own investigations. In this case, students need only be given page 6. Alternatively, students could be given pages 7 and 8, which include detailed instructions for the practical investigation.

The components of the zinc-carbon cell are:

Negative electrode — zinc
Black paste — mixture of manganese(IV) oxide and powdered carbon (positive electrode) with ammonium chloride and zinc chloride (electrolyte).

Using the suggested investigation, only partial identification of these components is possible. The teacher may care to suggest further tests to enable students to make a fuller identification.

Safety

The zinc casing contains very small quantities of toxic mercury, since quantities of mercury salts are added to the electrolyte to form an amalgam with the zinc case in order to inhibit corrosion. Students should wash their hands after practical work and be informed of the nature of the materials.

Warning Alkaline-manganese cells should *not* be opened for investigation. They contain 35 per cent potassium hydroxide solution, which is highly corrosive. Gas pressure can build up in the cell, causing the alkaline electrolyte to spurt out when the cell is opened.

Requirements for the investigation

Each group of students will need:

eye protection
100cm^3 beaker, test tubes, boiling tubes, filtering equipment, universal indicator paper, splints, wire wool, spatula, glass rod, half an ordinary zinc-carbon 1.5V cell.
(These should be prepared before the practical. The outer steel casing should be carefully prised off before clamping the inner cell in a vice and sawing it in half lengthways. Unused cells should be used since cell components change on discharge.)
newspaper to place on bench when dissecting cell (messy!)
hydrogen peroxide solution (20-volume)
dilute hydrochloric acid (2M)
dilute silver nitrate solution
dilute nitric acid (2M)
dilute sodium hydroxide (2M)
distilled water
access to tin snips or similar metal-cutting equipment.

In order to show that the casing is zinc, *clean* strips of the metal can be heated strongly in a crucible. This should be done as a demonstration *in the fume cupboard.* Yellow zinc oxide can be seen on the surface of the molten metal. The yellow colour disappears on cooling.

Further resources

Ever Ready Ltd will provide detailed information on the working of batteries. Technical Division, Ever Ready Ltd, Tanfield Lea, Stanley, Co. Durham DH9 9QF.

Duracell (UK) Ltd produce a useful pack called *Cells and Batteries.* It contains suggested experimental work, information, workcards and slides. From: Duracell (UK), Duracell House, Church Road, Lowfield Heath, Crawley, Sussex RH11 0PQ.

Acknowledgements Figure 1 supplied by Philips Consumer Electronics; Figures 3, 4 and 5 are reproduced with permission from the Duracell pack mentioned above.

DRY CELLS

On average each person in Britain uses somewhere between 8 and 15 dry cells each year. Dry cells are more commonly known as batteries. There are many different types, and in this unit we will look at some of them.

Part 1 Different kinds of cells

Look around your home, school or local electrical shop. See how many different kinds of batteries you can find. For each type of battery, try to find its voltage, what it is used for, and its price.

After completing your survey of batteries, answer questions 1 to 3.

Producing electricity

All electric cells have certain basic features (Figure 2). A **negative electrode** releases electrons. These electrons flow down a wire to a **positive electrode**, which accepts them. This flow of electrons is the electric current. The two electrodes are placed in an **electrolyte**. In the earliest cells, the electrolyte was a solution in water. These **wet cells** were a bit messy. **Dry cells** still have water in the electrolyte, but it is a paste rather than a solution.

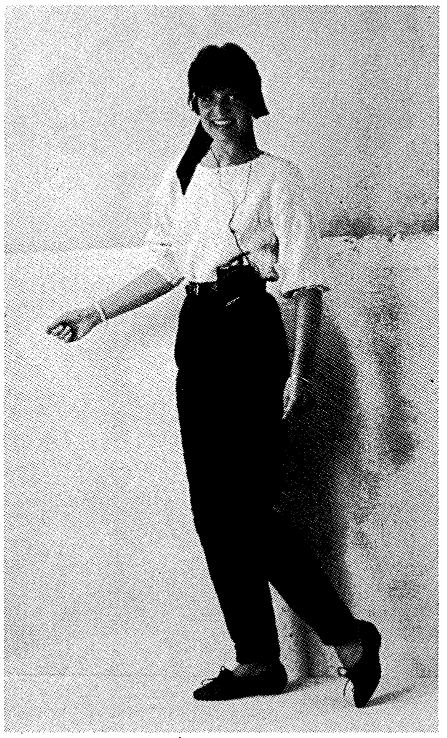

Figure 1 One popular use of the dry cell — in the personal stereo radio cassette

Questions

1. *Which is the commonest type of battery?*
2. *Why are some batteries cheaper than others?*
3. *How would you set about comparing 'value for money' of different batteries?*

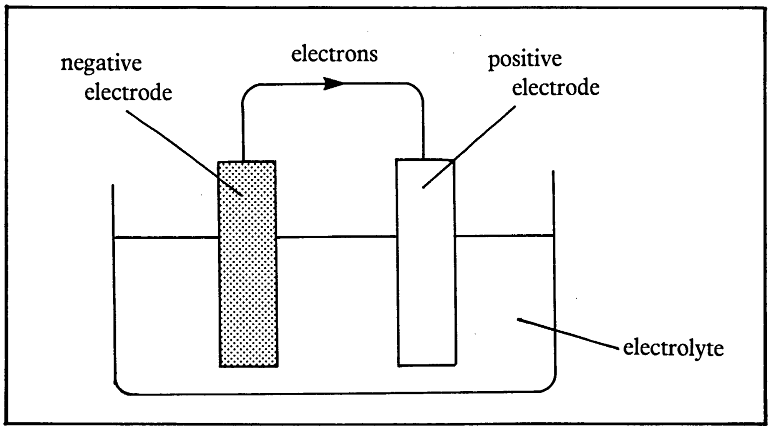

Figure 2 The basic features of an electric cell

Part 2 How do different types of cells work?

As you discovered in Part 1, there are many different types of cell, suitable for different uses. **Primary cells** are not rechargeable. Once used, they have to be thrown away. **Secondary cells** can be recharged.

The zinc-carbon cell (Leclanché cell)

This is the familiar round cell used in torches. It is the commonest and cheapest type of primary cell. Examples of common brands are Ever Ready Blue Seal and Silver Seal and Boots SP and HP. Figure 3 shows the main features of a zinc-carbon cell.

The reactions in the cell are rather complicated, but they can be summarised as shown below. The negative electrode is made of zinc. Zinc loses electrons to form zinc ions:

$$Zn \rightarrow Zn^{2+} + 2e^-$$

These electrons flow round the external circuit to the positive electrode. This is made from manganese(IV) oxide. Manganese(IV) oxide contains Mn^{4+} ions, which accept the electrons. They form Mn^{3+} ions.

$$2Mn^{4+} + 2e^- \rightarrow 2Mn^{3+}$$

The overall reaction in the cell is

$$Zn + 2Mn^{4+} \rightarrow Zn^{2+} + 2Mn^{3+}$$

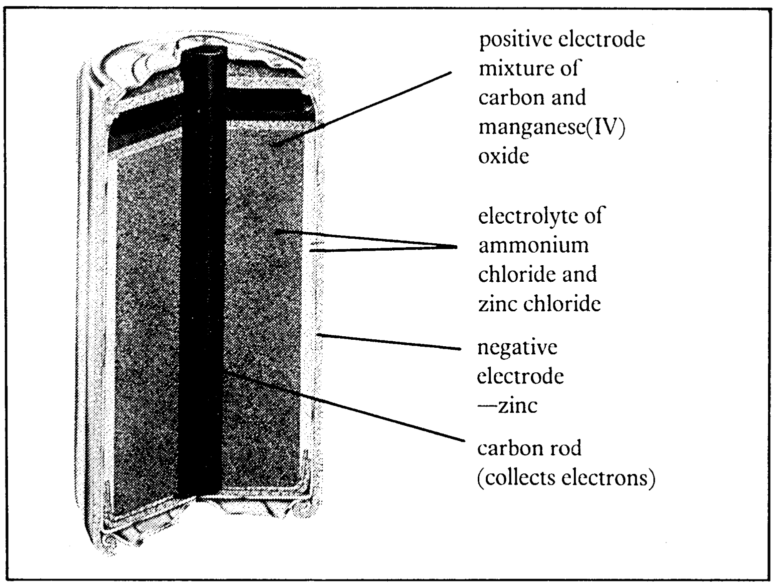

Figure 3 The zinc-carbon cell

Zinc-carbon cell

Voltage:	1.5V
Advantages:	Cheap
Disadvantages:	Comparatively short life. Zinc case dissolves away during reaction, causing leakages.
Uses:	Where the total power needed is fairly low, for example, torches and transistor radios.

The alkaline-manganese cell

This is an improvement on the zinc-carbon cell because it lasts longer. Examples of common brands are Duracell, Ever Ready Gold Seal and Boots Alkaline Powercell. Figure 4 shows the main features.

The basic chemical reaction in the alkaline cell is the same as for the zinc-carbon cell. The negative electrode is still zinc, but in a powdered form. The positive electrode is still manganese(IV) oxide, but in compressed pellet form. The zinc powder is on the inside, and the manganese(IV) oxide on the outside. The electrolyte is potassium hydroxide, which soaks both the zinc and the manganese(IV) oxide. The outer case is steel and is not part of the reaction, so it does not leak.

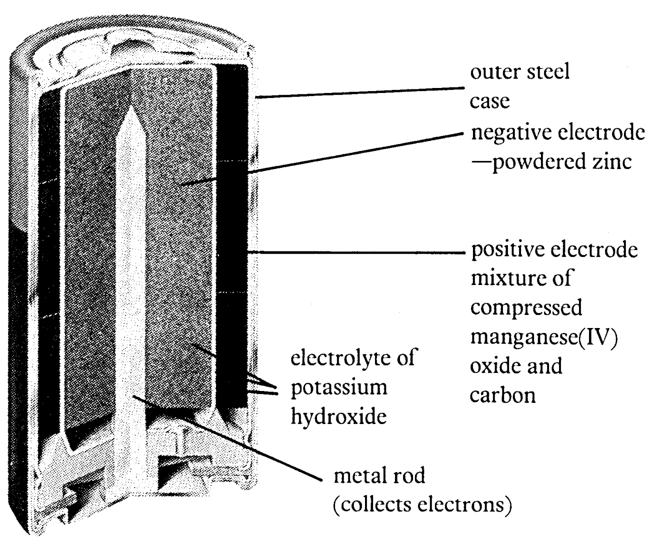

Figure 4 The alkaline manganese cell

Alkaline cell

Voltage:	1.6V
Advantages:	Lifetime 1.5 to 2 times that of zinc-carbon cell. Less likely to leak. Can be stored with little loss of lifetime.
Disadvantages:	Expensive
Uses:	Where there is a heavy or continuous use, for example, toys, cassette recorders.

Answer questions 4 and 5.

Questions

4 *Explain why zinc-carbon cells often leak when they are exhausted, but alkaline-manganese cells do not.*

5 *An alkaline-manganese cell is advertised as having 'up to three times the life of an ordinary cell'. Describe how you would try to test this claim.*

Button cells

Some appliances need a very small cell that has a long life and gives a steady current. These use a **mercury cell** or a **silver cell**, both of which have the button shape.

Once again the negative electrode is zinc powder, but the positive electrode is mercury(II) oxide or silver oxide. The electrolyte is potassium hydroxide solution. The top and bottom are nickel or steel. Figure 5 shows the details for a mercury cell.

As before, the zinc loses electrons, forming zinc ions. In a mercury cell, the electrons are accepted by mercury ions in the mercury oxide.

$$Hg^{2+} + 2e^{-} \rightarrow Hg$$

The overall reaction is

$$Zn + Hg^{2+} \rightarrow Zn^{2+} + Hg$$

The silver cell is very similar, but electrons are accepted by silver ions instead of mercury ions.

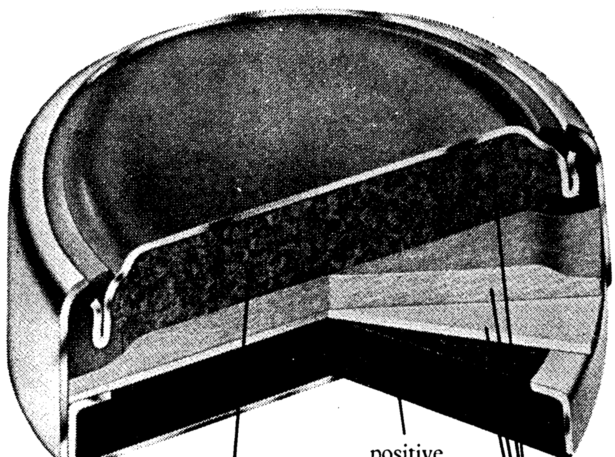

Figure 5 A mercury cell

Mercury oxide cell

Voltage:	1.35V
Advantages:	Small. Lasts for a long time giving a steady current. Can be stored with little loss of lifetime.
Disadvantages:	Expensive
Uses:	Where long life and steady current are important, for example, hearing aids.

Answer questions 6 to 8.

Questions

6 *Why are zinc-carbon cells unsuitable for use in digital watches?*

7 *Give two reasons why mercury button cells are unsuitable for use in torches.*

8 *Why is particular care needed when disposing of used mercury cells?*

Rechargeable cells

All the cells described so far have to be thrown away when they are run down. Rechargeable cells get over this problem. The most important type of rechargeable dry cell is the **nickel-cadmium cell**. These cells can be made in the familiar, round shape suitable for torches, calculators, cassette players, etc. The negative electrode is cadmium, which releases electrons. The positive electrode contains nickel ions, Ni^{4+}, which accept electrons, forming Ni^{2+}. The cell can be recharged over 500 times, but it is very expensive to buy in the first place. A special transformer is needed for recharging.

Cells for the future

Scientists are constantly looking for new, better cells. Some new developments are:

1 *Zinc-air cells* (1.5V) These last twice as long as the mercury cell. Used in hearing aids.

2 *Lithium cells* (3V or 1.5V) Long lasting and perform well at low temperatures. Used in watches and calculators.

3 *Sodium-sulphur cells* (2.1V) Under development for use in electrically powered vehicles. Rechargeable and relatively low cost but work at temperature of 350°C.

Answer questions 9 and 10.

Questions

9 *Describe the 'ideal dry cell' of the future. What features would it have?*

10 *What would life be like without dry cells? What important things would we have to do without?*

Part 3 Practical investigation of a cell

Safety warning Although zinc-carbon batteries can be quite safely opened, alkaline-manganese type batteries (Duracell, Ever Ready Gold Seal) should **not** be opened. They contain dangerously corrosive concentrated alkali.

In this investigation you will be looking at the commonest type of dry cell, the Leclanché cell. You will be trying to answer these questions.

1 What is the negative electrode made of?

2 What is the mixture that makes up the positive electrode and the electrolyte?

You will be given a dry cell which has been cut in half. Examine it carefully and compare it with Figure 6. Discuss with the rest of your group the tests you could do to answer the two questions above. When you have decided on a plan, discuss it with your teacher. Your teacher may let you try your own method, or alternatively you could follow the method given on pages 7 and 8.

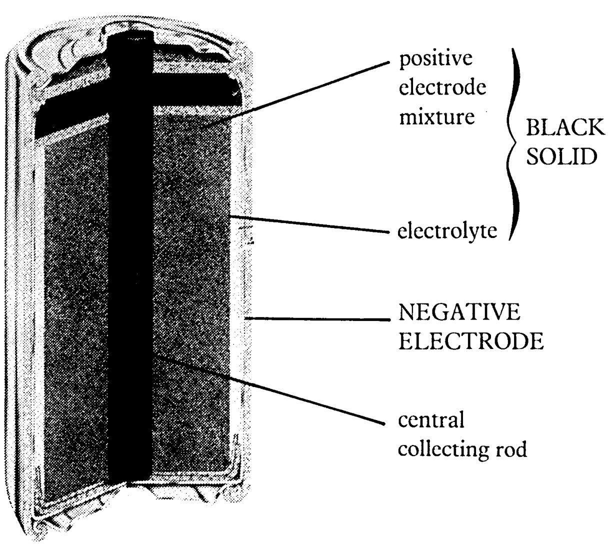

Figure 6 A dry cell

Experimental investigation of a dry cell

CAUTION Eye protection must be worn throughout this practical

1 The negative electrode

Use snips to cut a strip of the metal that makes up the negative electrode. The strip should be about 3-4cm^2 in area. Test it as described below.

(a) *Reaction with acid*

(i) Clean the strip of metal with wire wool and put it in a boiling tube. Add about 5cm^3 of dilute hydrochloric acid (**CARE**). Warm gently, but do not allow it to boil. A gas will be evolved. Hold your thumb over the end of the tube to collect some of the gas. Test the gas with a burning splint. What happens? What is the gas? What does this tell you about the metal?

(ii) After the metal has reacted with acid for a while, pour off 2cm^3 or 3cm^3 of the resulting solution into a test tube. Carefully and gradually add sodium hydroxide solution until the solution is neutral. You can test to see if it is neutral by removing drops on a glass rod and testing with universal indicator paper. When the solution is neutral, add a *few more* drops of sodium hydroxide solution. What happens? Now add excess sodium hydroxide solution. What happens now? What do these tests tell you about the metal that makes up the negative electrode?

(b) *Effect of heat*

Your teacher may demonstrate the effect of heating the metal.

2 The black solid/paste

The black pasty solid inside the battery is a mixture of two things:

(i) The electrolyte
(ii) The chemicals which act as the positive electrode, accepting electrons.

(a) *Separating the positive electrode materials from the electrolyte*

Place 2 spatula loads of the black paste in a 100cm^3 beaker. Add 50cm^3 of distilled water and stir thoroughly. Filter. Keep both the residue and the filtrate.

(b) *What is the residue?*

Place 2cm depth of hydrogen peroxide solution (**CARE**) in a test tube. Add 1 spatula measure of the residue. Hold a glowing splint at the mouth of the tube. What gas is evolved? Explain what has occurred. Does this help you to identify one of the substances in the residue?

(c) *What is the filtrate?*

The filtrate is a solution containing positive and negative ions.

(i) Place 2cm depth of filtrate in a test tube. Add about 1cm of dilute nitric acid (**CARE**). Now add a small amount of silver nitrate solution. Describe what happens. Use this result to identify a negative ion present in the filtrate mixture.

(ii) Divide the remainder of the filtrate into two portions. To one portion add sodium hydroxide solution (**CARE**), a few drops at first, then in excess. Describe what happens. Use this result to identify a positive ion present in the filtrate mixture.

(iii) To the other portion add an excess of sodium hydroxide solution, then warm gently (**GREAT CARE**. Hot sodium hydroxide solution is dangerously corrosive. Eye protection is essential.) What gas is given off? Use this result to identify another positive ion present in the filtrate mixture.

Safety warning Zinc-carbon cells contain traces of poisonous mercury. Wash your hands after the practical.