Electrolysis of molten ionic compounds

4.4.3.2 · Chemical changes · revision notes

What is produced when a binary ionic compound (a metal combined with a non-metal) is electrolysed in the molten state: the metal forms at the cathode and the non-metal at the anode. Expect prediction questions and, at Higher tier, half equations.

Key facts

- Molten binary compound: metal at the cathode (−), non-metal at the anode (+)
- Cathode: $Pb^{2+} + 2e^- \rightarrow Pb$
- Halogens are diatomic: Cl_2, Br_2, I_2
- Lead bromide → lead + bromine
- Anode: $2Br^- \rightarrow Br_2 + 2e^-$
- Must be molten so the ions can move

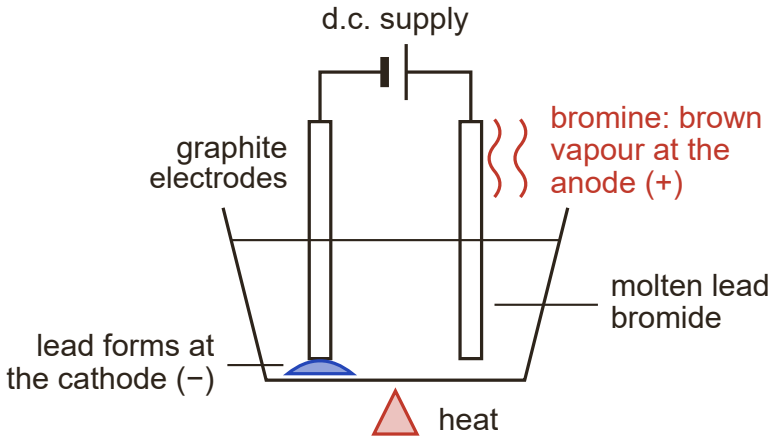
Notes

Molten binary ionic compounds

- A **binary ionic compound** is made of just two elements, a metal and a non-metal, e.g. lead bromide, $PbBr_2$.
- It must be heated until it melts, so the ions are free to move.
- With **inert electrodes** (e.g. graphite), the **metal** is produced at the **cathode** (negative) and the **non-metal** is produced at the **anode** (positive).
- This is simpler than a solution: there is no water, so only the two ions of the compound are present.

Example: lead bromide

- Lead ions, Pb^{2+}, move to the cathode, gain electrons and form lead, which appears as a silvery metal (molten at this temperature).
- Bromide ions, Br^{-}, move to the anode, lose electrons and form bromine, seen as brown vapour.



The solid must be melted first so that its ions can move. Do this in a fume cupboard.

- Bromine is toxic, so this is done in a fume cupboard.
- Anhydrous zinc chloride is a safer compound for practical work: it gives zinc at the cathode and chlorine at the anode.
- Overall: lead bromide → lead + bromine

More examples and half equations

- Molten sodium chloride → sodium (cathode) + chlorine (anode)
- Molten zinc chloride → zinc (cathode) + chlorine (anode)
- Molten potassium iodide → potassium (cathode) + iodine (anode)
- Molten aluminium oxide → aluminium (cathode) + oxygen (anode)
- Half equations for lead bromide: $Pb^{2+} + 2e^{-} \rightarrow Pb$ (cathode) and $2Br^{-} \rightarrow Br_2 + 2e^{-}$ (anode). Grade 7+ only
- Halogens form diatomic molecules, so two halide ions are needed for each molecule: $2Cl^{-} \rightarrow Cl_2 + 2e^{-}$. Grade 7+ only

How to answer each type of question

Predict the products at each electrode

2 marks | Grade 4

1. Split the compound into its metal ion and non-metal ion.
2. Metal at the cathode; non-metal at the anode.
3. Name the non-metal as an element: chlorine, not chloride.

Example. Molten calcium bromide is electrolysed using inert electrodes.
Name the product at (a) the cathode and (b) the anode.

Model answer.

(a) calcium (1)
(b) bromine (1)

Explain how the products form

4 marks | Grade 6

1. For each ion, say its charge and which electrode it moves to.
2. Say whether it gains or loses electrons there.
3. Name the element formed.

Example. Molten potassium iodide is electrolysed.
Explain how potassium and iodine are produced.

Model answer.

Potassium ions are positive, so they move to the cathode / negative electrode (1)
where they gain electrons to form potassium atoms (1)
Iodide ions are negative, so they move to the anode / positive electrode (1)
where they lose electrons to form iodine (molecules) (1)

Write the half equations

2 marks | Grade 7

1. Cathode: metal ion + electrons (equal to its charge) → metal atom.
2. Anode: two halide ions → halogen molecule + 2 electrons.
3. Check that atoms and charges balance.

Example. Molten zinc chloride is electrolysed.
Write half equations for the reactions at the cathode and at the anode.

Model answer.

Cathode: $Zn^{2+} + 2e^- \rightarrow Zn$ (1)
Anode: $2Cl^- \rightarrow Cl_2 + 2e^-$ (allow $2Cl^- - 2e^- \rightarrow Cl_2$) (1)

Don’t lose marks

- Writing 'chloride' or 'bromide' as the product at the anode instead of chlorine or bromine.
- Writing Br instead of Br_2 in a half equation.
- Putting the metal at the anode.
- Not balancing electrons: $2Br^- \rightarrow Br_2 + 2e^-$, not $+ e^-$.

More tips

Memory tricks

- Molten: the Metal goes to the cathode (M for molten, M for metal).
- Name change at the anode: chloride → chlorine, bromide → bromine, iodide → iodine, oxide → oxygen.
- The charge on the metal ion is the number of electrons in its half equation: Pb^{2+} needs $2e^-$.

Exam technique

- Say 'molten' or 'melted', not 'dissolved', when the question is about a molten compound.
- If asked why a fume cupboard is used, name the toxic product (e.g. bromine or chlorine).
- Describe observations precisely: 'brown vapour at the anode', 'silvery metal at the cathode'.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **State the products from molten lead bromide**
Lead is produced at the cathode and bromine at the anode.

Grade 4 — **Predict products for any molten binary compound**
The metal forms at the cathode and the non-metal forms at the anode.

Grade 5 — **Describe what is seen at each electrode**
For lead bromide, silvery lead forms at the cathode and brown bromine vapour at the anode.

Grade 6 — **Explain how each product forms**
Metal ions are attracted to the cathode and gain electrons; non-metal ions are attracted to the anode and lose electrons.

Grade 7 — **Write half equations for molten electrolysis**
For example, $Pb^{2+} + 2e^- \rightarrow Pb$ and $2Br^- \rightarrow Br_2 + 2e^-$.

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