Oxidation and reduction in terms of electrons

4.4.1.4 · Chemical changes · revision notes

Higher tier only. Oxidation and reduction described in terms of electrons, used to write ionic equations for displacement reactions and to say which species are oxidised and which are reduced. Usually 2 to 3 mark questions.

Key facts

- OIL RIG: Oxidation Is Loss, Reduction Is Gain (of electrons)
- Metal ion + electrons → metal atom: reduction
- $Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$
- Electrons on the left of a half equation = reduction; on the right = oxidation
- Metal atom → metal ion + electrons: oxidation
- $Mg + Cu^{2+} \rightarrow Mg^{2+} + Cu$
- Spectator ion: an ion that does not change, left out of the ionic equation

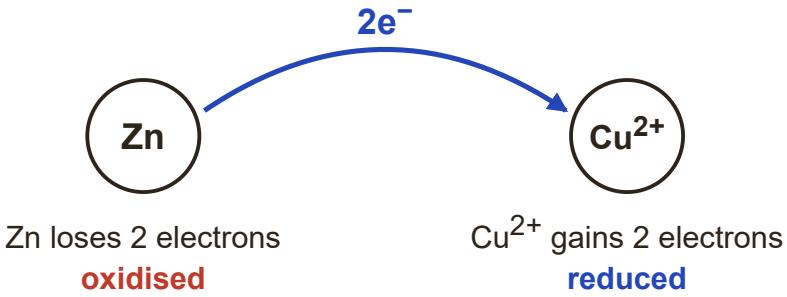
Notes

OIL RIG

- **Oxidation Is Loss** of electrons. **Reduction Is Gain** of electrons.
- A metal atom that loses electrons to form a positive ion is oxidised: $Zn \rightarrow Zn^{2+} + 2e^-$.
- A metal ion that gains electrons to form an atom is reduced: $Cu^{2+} + 2e^- \rightarrow Cu$.
- Non-metals work the same way: chlorine gaining electrons is reduced ($Cl_2 + 2e^- \rightarrow 2Cl^-$); bromide ions losing electrons are oxidised.
- The electrons lost by one species are gained by another, so oxidation and reduction always happen together: a **redox** reaction.

Ionic equations for displacement reactions

- In a displacement reaction in solution, the negative ion (e.g. sulfate) does not change. It is a **spectator ion** and is left out of the ionic equation.
- Full equation: $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$
- Ionic equation: $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$
- Zinc atoms lose electrons, so zinc is oxidised. Copper(II) ions gain electrons, so they are reduced.



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

OIL RIG: the species that loses electrons is oxidised; the one that gains them is reduced.

- Halogen displacement works the same way: $Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$. Chlorine is reduced and bromide ions are oxidised.

Building and balancing an ionic equation

- Write the two half equations, one for the species losing electrons and one for the species gaining them.
- Multiply them so the number of electrons is the same in both, then add them and cancel the electrons.
- Example: $Al \rightarrow Al^{3+} + 3e^-$ (× 2) and $Cu^{2+} + 2e^- \rightarrow Cu$ (× 3). Both now involve 6 electrons, giving $2Al + 3Cu^{2+} \rightarrow 2Al^{3+} + 3Cu$. Grade 9+ only
- Check: the number of each atom and the total charge must be the same on both sides.

How to answer each type of question

Which species is oxidised? Explain in terms of electrons 2 marks Grade 6

1. Look at each species: has it lost electrons (charge becomes more positive) or gained electrons?
2. Loss of electrons = oxidised; gain of electrons = reduced.
3. Name the species exactly, e.g. 'iron atoms' or 'copper(II) ions'.

Example. $Fe + Cu^{2+} \rightarrow Fe^{2+} + Cu$
Which species is oxidised? Explain your answer in terms of electrons.

Model answer.

Iron / iron atoms (1)

because they lose electrons (to form Fe^{2+} ions) (1)

Complete a half equation and explain a reduction

3 marks | Grade 7

1. Balance the atoms, then add electrons to make the charges equal on both sides.
2. Say which species gains electrons and link it to reduction.

Example. Chlorine reacts with potassium iodide solution:

$Cl_2 + 2I^- \rightarrow 2Cl^- + I_2$

(a) Complete the half equation: $2I^- \rightarrow I_2 +$ .....

(b) Explain why chlorine is reduced in this reaction.

Model answer.

(a) $2e^-$ (1)

(b) Each chlorine molecule gains (two) electrons to form chloride ions (1)

Gain of electrons is reduction (1)

Write an ionic equation for a displacement reaction

2 marks | Grade 8

1. Split the soluble ionic compounds into their ions.
2. Cross out the ions that are the same on both sides (spectator ions).
3. Balance the atoms and check the total charge is the same on both sides.

Example. Magnesium reacts with silver nitrate solution:

$Mg + 2AgNO_3 \rightarrow Mg(NO_3)_2 + 2Ag$

Write the ionic equation for this reaction.

Model answer.

Correct species: $Mg + Ag^+ \rightarrow Mg^{2+} + Ag$ (1)

Balanced: $Mg + 2Ag^+ \rightarrow Mg^{2+} + 2Ag$ (1)

Don’t lose marks

- Mixing up the two definitions: gain of oxygen and loss of electrons are both oxidation.
- Leaving spectator ions such as SO_4^{2-} or NO_3^- in an ionic equation.
- Not balancing charge: $Mg + Ag^+ \rightarrow Mg^{2+} + Ag$ has 1+ on the left but 2+ on the right.
- Using the wrong number of electrons, e.g. $Cu^{2+} + e^- \rightarrow Cu$.
- Saying 'copper is reduced' in a displacement reaction: it is the copper ions that gain electrons.
- Writing e instead of e^- in a half equation: the electron must carry its negative charge.

More tips

Memory tricks

- OIL RIG: Oxidation Is Loss, Reduction Is Gain.
- Charge goes up (e.g. 0 to 2+) = electrons lost = oxidised. Charge goes down (e.g. 2+ to 0, or 0 to 1−) = electrons gained = reduced.
- In a metal displacement reaction, the more reactive metal is always the one that is oxidised.
- Electrons go on whichever side makes the total charges equal.

Exam technique

- If the question says 'in terms of electrons', use 'loses electrons' or 'gains electrons', not oxygen.
- Name the species with its charge where you can, e.g. 'Cu^{2+} ions are reduced'.
- Write the half equations first: they make the ionic equation easier to build and to check.
- If asked for state symbols in an ionic equation, solid metals are (s) and ions in solution are (aq): $Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$.

What each grade needs

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

Grade 5

Define oxidation and reduction using electrons

Oxidation is the loss of electrons and reduction is the gain of electrons (OIL RIG).

Grade 6

Identify the species oxidised and reduced

An atom that becomes a positive ion is oxidised; a positive ion that becomes an atom is reduced.

Grade 7

Write half equations for displacement reactions

For example, $Mg \rightarrow Mg^{2+} + 2e^{-}$ and $Cu^{2+} + 2e^{-} \rightarrow Cu$.

Grade 8

Write ionic equations for displacement reactions

Leave out the spectator ions, e.g. $Mg + Cu^{2+} \rightarrow Mg^{2+} + Cu$.

Grade 9

Balance ionic equations with different ion charges

Match the electrons lost and gained, e.g. $2Al + 3Cu^{2+} \rightarrow 2Al^{3+} + 3Cu$.

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