Redox

This topic illustrates the relationship between electricity and chemical changes. Chemical reactions can be investigated by looking at electrode potentials.

a calculate oxidation numbers of elements in compounds and ions ☐

b describe and explain redox processes in terms of electron transfer and changes in oxidation number ☐

c use changes in oxidation numbers to help balance chemical equations ☐

6.1 Redox processes: electron transfer and changes in oxidation number (oxidation state)	a)	calculate oxidation numbers of elements in compounds and ions
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REDOX

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WHAT YOU NEED TO KNOW

Calculate oxidation numbers of elements in compounds and ions

Describe and explain redox processes in terms of electron transfer and changes in oxidation numbers

Use changes in oxidation numbers to help balance chemical equations

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REDOX

A redox reaction is a reaction in which electron transfer takes place.

Redox reactions form one of the largest groups in which we classify chemical changes.

In a redox reactions, oxidation and reduction will **always** occur together.

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REDOX DEFINITIONS

OXIDATION IS:	REDUCTION IS:
gain of oxygen	gain of hydrogen
loss of hydrogen	loss of oxygen
loss of electrons	gain of electrons
increase in oxidation state	decrease in oxidation state

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OXIDATION

1. Oxidation of an element:

$$S(s) + O_2(g) \longrightarrow SO_2(g)$$

2. Oxidation of a compound:

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$$

3. Oxidation using an indirect source of oxygen:

$$8KClO_3(s) + C_{12}H_{22}O_{11}(s) \longrightarrow 12CO_2(g) + 11H_2O(l) + 8KCl(s)$$

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SKILL CHECK

In each of the following equations, state which reactant has been oxidised:

(a) $PbO + H_2 \longrightarrow Pb + H_2O$

(b) $CO + Ag_2O \longrightarrow 2Ag + CO_2$

(c) $2Mg + CO_2 \longrightarrow 2MgO + C$

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REDUCTION

1. Reduction to an element:

$$2HgO(s) \longrightarrow 2Hg(l) + O_2(g)$$

2. Reduction of one element by another:

$$2CuO(s) + C(s) \longrightarrow 2Cu(s) + CO_2(g)$$

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SKILL CHECK

In each of the following equations, state which reactant has been reduced:

(a) $5CO + I_2O_2 \longrightarrow 5CO_2 + I_2$

(b) $2H_2S + SO_2 \longrightarrow 3S + 2H_2O$

(c) $CH_2{=}CH_2 + H_2 \longrightarrow CH_3CH_3$

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REDOX

There are two ways of finding out whether a substance has been oxidised or reduced during a chemical reaction:

1. electron transfer

2. changes in oxidation state

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HALF EQUATIONS

$$2Na(s) + Cl_2(g) \longrightarrow 2NaCl(s)$$

This reaction can be divided into two separate equations, one showing oxidation and the other reduction. These are known as half equations.

1. $Na \longrightarrow Na^+ + e^-$ (e- is lost)

Each sodium atom loses an electron from its outer shell. Sodium atoms have been oxidised.

2. $Cl_2 + 2e^- \longrightarrow 2Cl^-$ (e- is gained)

Each chlorine atom gains an electron to complete its outer shell. The chlorine atoms have been reduced.

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SKILL CHECK

Write two half-equations for the following reactions. For each half-equation state whether oxidation or reduction is occurring:

(a) $Cl_2 + 2I^- \longrightarrow I_2 + 2Cl^-$

(b) $2Mg + O_2 \longrightarrow 2MgO$

(c) $4Fe + 3O_2 \longrightarrow 2Fe_2O_3$

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BALANCING HALF EQUATIONS

A balanced ionic equation can be constructed by balancing the number of electrons lost and gained and then adding the two half equations together.

The electrons lost and gained in a redox reaction must be equal.

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SKILL CHECK

Zinc metal reacts with IO_3^- ions in acidic solution. Construct a balanced ionic equation for this reaction, using the two half-equations below:

$2IO_3^- + 12H^+ + 10e^- \longrightarrow I_2 + 6H_2O$

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

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OXIDATION NUMBERS

Oxidation number is the number of electrons that an individual atom within an ion or compound has either lost control of (+ve) or gained control of (-ve).

In simple ionic compounds, the non-metal is assigned a negative oxidation number and the metal is assigned a positive value.

In simple covalent compounds and complex ions, the most electronegative element is assigned a negative value and the least electronegative element is assigned a positive value.

The oxidation number of an uncombined element is 0. e.g. Na, Mg, Cu, O_2, N_2.

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OXIDATION NUMBERS

Certain elements (at least in our course) can usually be regarded as having a fixed value in all of their compounds. Examples of these follow.

- Group 1 elements are always +1.
- Group 2 elements are always +2.
- Group 3 elements are always +3.
- Fluorine is always -1.
- Oxygen is nearly always -2 unless it is combined with fluorine or when it is in the form of a peroxide or superoxide.

The total oxidation numbers of all atoms in a neutral compound always add up to 0.

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OXIDATION NUMBERS

The oxidation number of an atom in the form of a simple ion is equal to the charge on the ion. e.g.

- The oxidation number of potassium in the ion K^+ = +1
- The oxidation number of aluminium in the ion Al^{3+} = +3
- The oxidation number of nitrogen in the ion N^{3-} = -3
- The oxidation number of oxygen in the ion O^{2-} = -2

The total oxidation numbers of all the atoms in a complex ion always add up to the charge on the ion.

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SKILL CHECK

State the oxidation number of the bold atoms in these compounds or ions:

(a) $\mathbf{P}_2O_5$

(b) $\mathbf{S}O_4^{2-}$

(c) $Al_2\mathbf{Cl}_6$

(d) $\mathbf{Cl}O_2^-$

(e) $Ca\mathbf{C}O_3$

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OXIDISING AGENT

Increases the oxidation number of another atom.

An atom of the oxidising agent decreases in oxidation numbers.

The oxidising agent gets reduced - it gains electrons.

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SKILL CHECK

$2I^- + MnO_2 + 6H^+ + 2SO_4^{2-} \longrightarrow I_2 + Mn^{2+} + 2HSO_4^- + 2H_2O$

Which substance is the oxidising agent? Explain your answer.

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REDUCING AGENT

Decreases the oxidation number of another atom.

An atom of the reducing agent increases in oxidation numbers.

The reducing agent gets oxidized - it loses electrons.

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SKILL CHECK

$SO_2 + Br_2 + H_2O \longrightarrow SO_4^{2-} + Br^- + H^+$

Identify the reducing agent in this reaction. Explain your answer.

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