
NANYANG
GIRLS' HIGH
勤慎端樸

Redox

Reduction and Oxidation

Reactions

Reduction and Oxidation – Redox

What do I need to know about *reduction* and *oxidation*?

Reduction and Oxidation – Redox

Learning Outcomes

Candidates should be able to:

a) Define oxidation and reduction (redox) in terms of the gain or loss of oxygen or hydrogen.

b) Define redox in terms of electron transfer and changes in oxidation state.

c) Identify redox reactions in terms of oxygen / hydrogen gain / loss, electron gain / loss and changes in oxidation state.

d) Describe the use of aqueous potassium iodide and acidified potassium dichromate(VI) in testing for oxidising and reducing agents from the resulting colour changes.

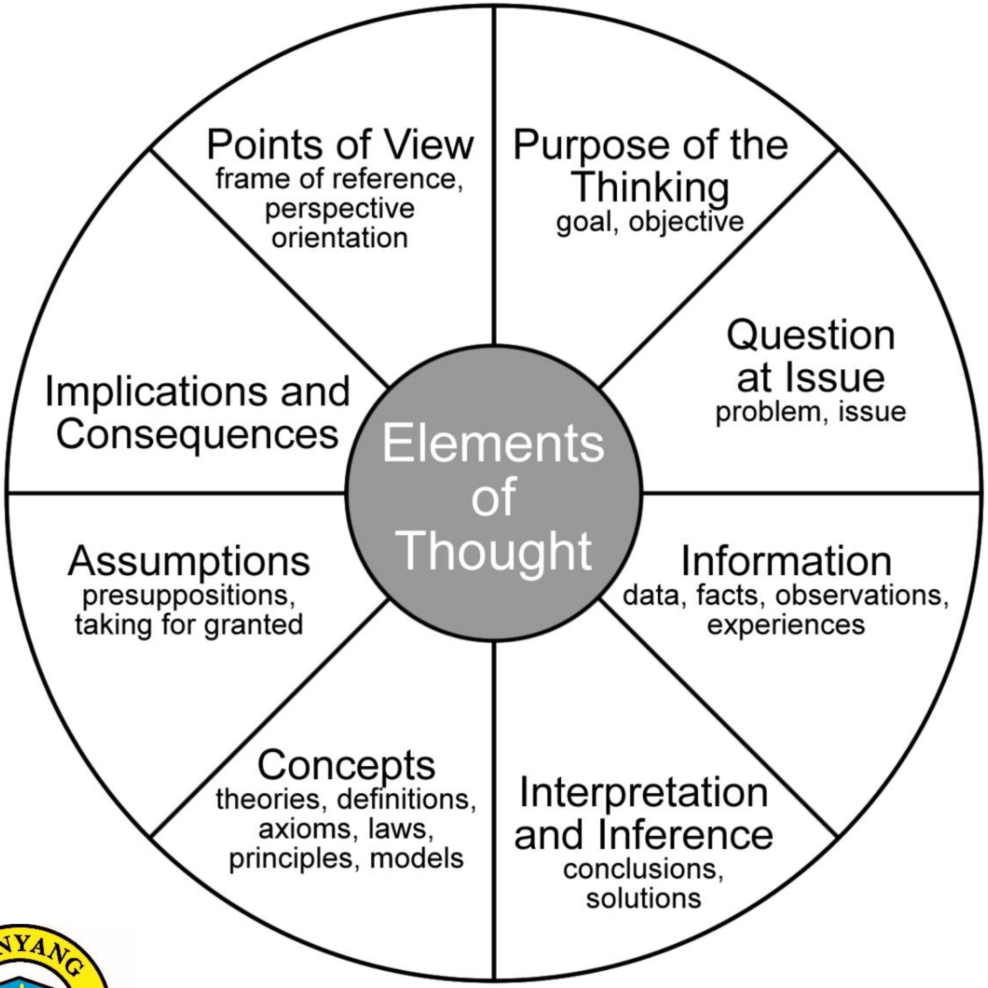
- Singapore Examinations and Assessment
- Board University of Cambridge International Examinations
- Ministry of Education Singapore

Reduction and Oxidation – Redox

What are the different ways of considering *reduction* and *oxidation*?

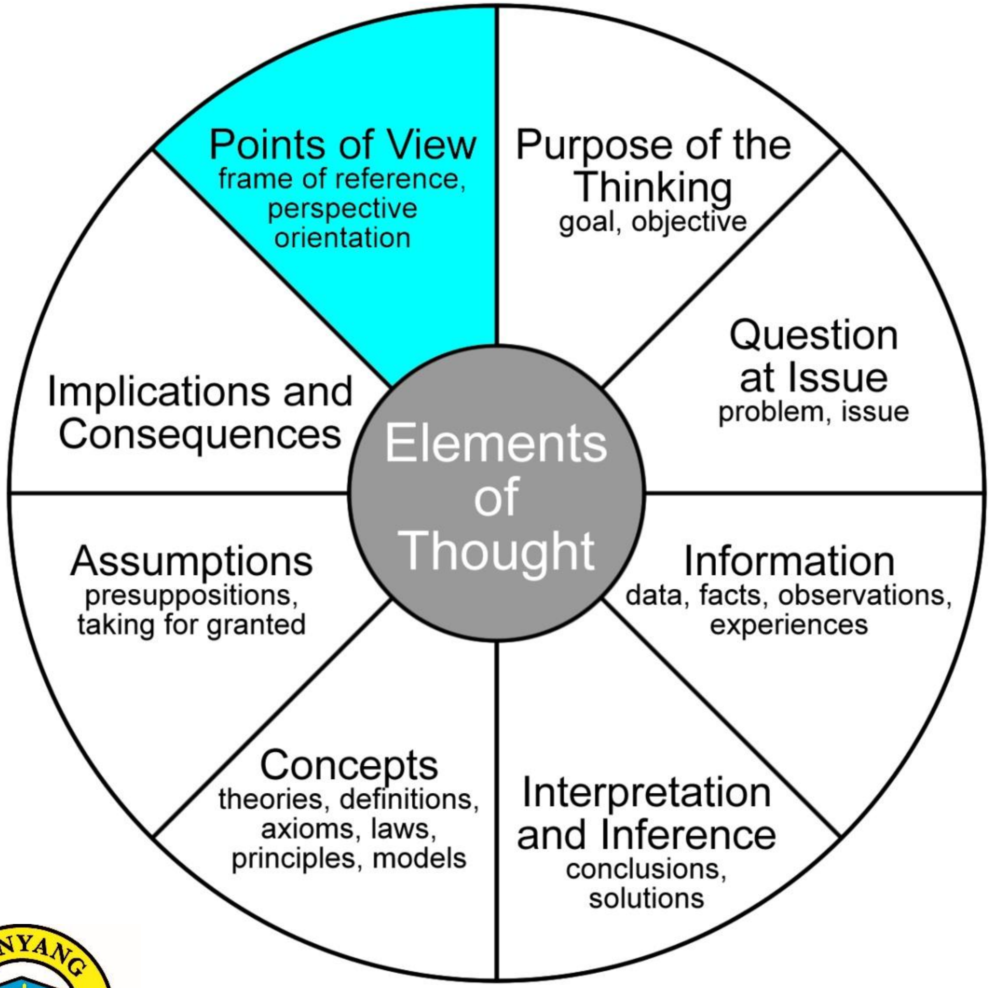
Reduction and Oxidation – Redox

Paul's Wheel of Reason



Reduction and Oxidation – Redox

Paul's Wheel of Reason



- **Oxidation:**
  → Gain of oxygen.
  → Loss of hydrogen.
  → Loss of electrons.
  → Increase in oxidation state.

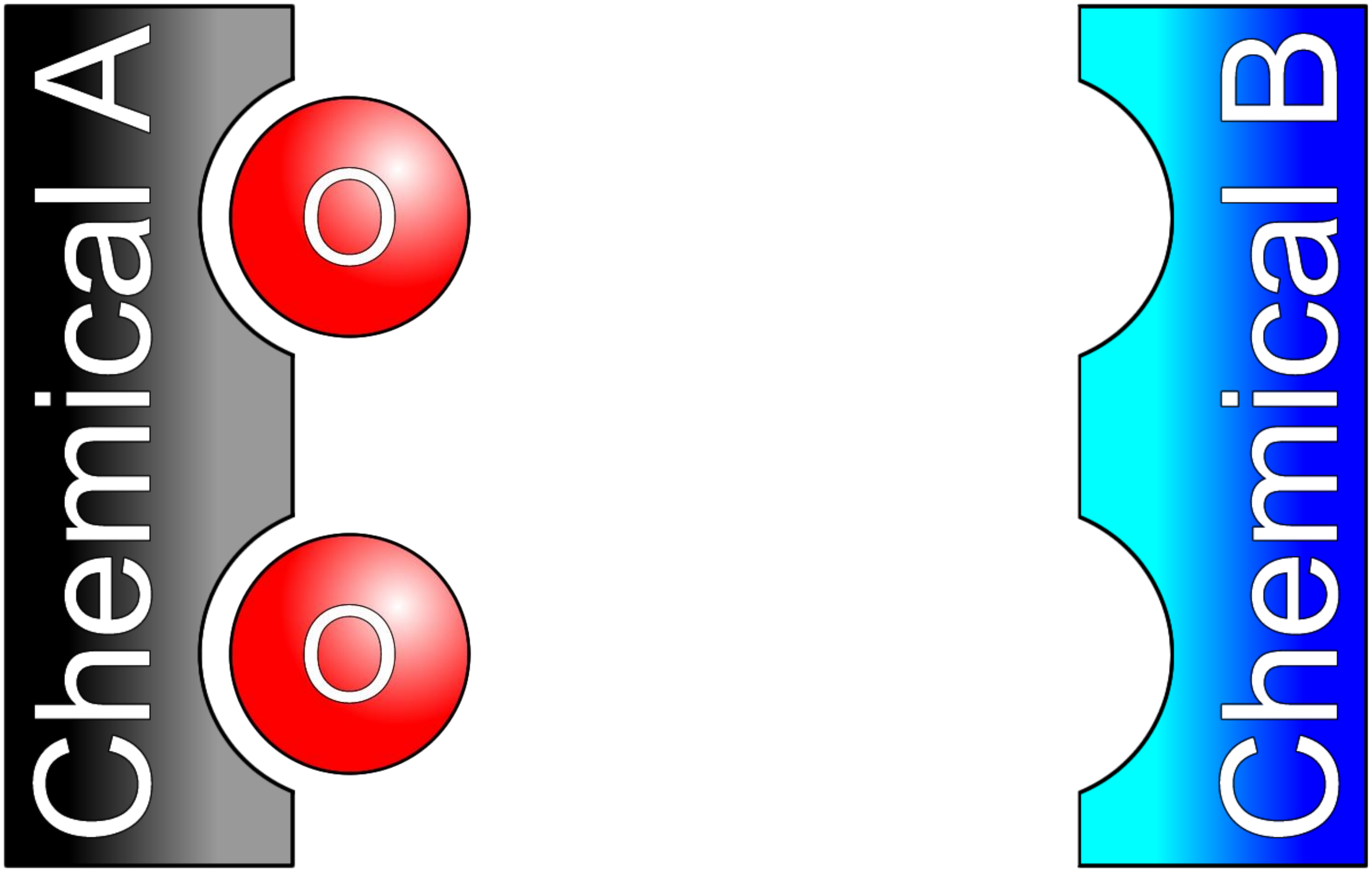
- **Reduction:**
  → Loss of oxygen.
  → Gain of hydrogen.
  → Gain of electrons.
  → Decrease in oxidation state.

Reduction and Oxidation – Redox

- *Oxidation* is the *gain* of *oxygen*.
- *Reduction* is the *loss* of *oxygen*.

- Oxidation: → Gain of oxygen.
- Reduction: → Loss of oxygen.

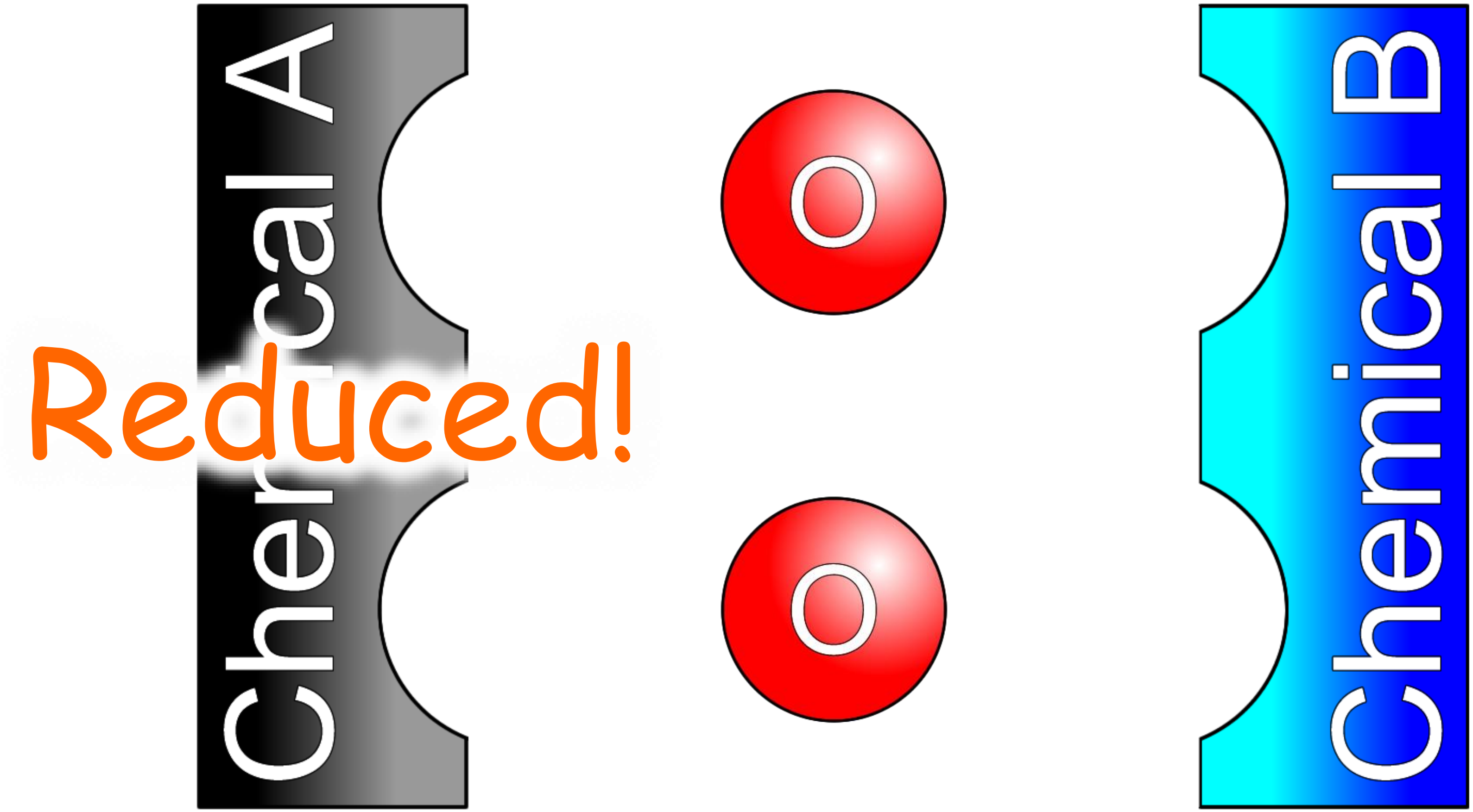
Reduction and Oxidation – Redox



- Oxidation: → Gain of oxygen.
- Reduction: → Loss of oxygen.

Reduction and Oxidation – Redox

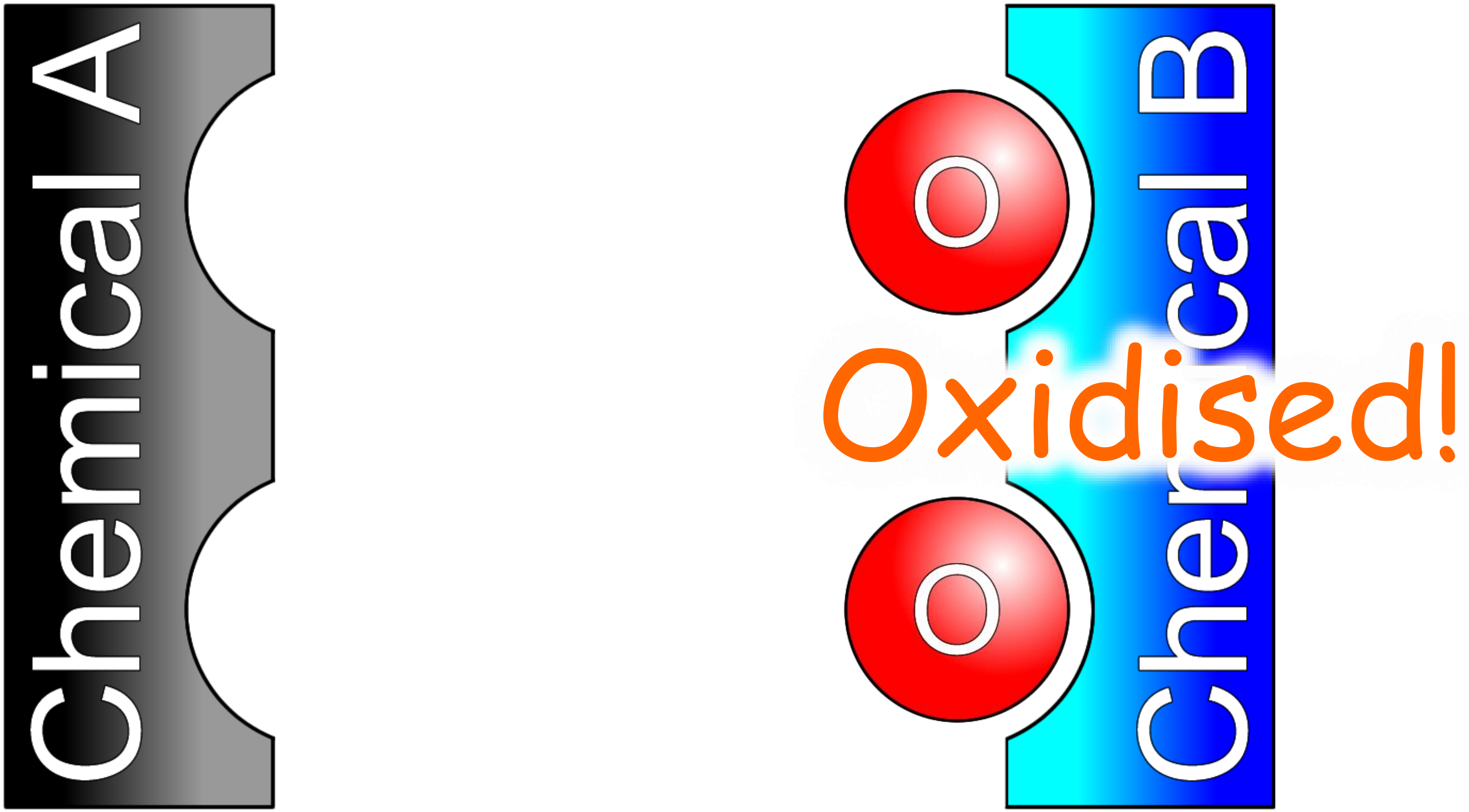
Reduction is the Loss of Oxygen



- Oxidation: → Gain of oxygen.
- Reduction: → Loss of oxygen.

Reduction and Oxidation – Redox

Oxidation is the Gain of Oxygen



- Oxidation: → Gain of oxygen.
- Reduction: → Loss of oxygen.

Reduction and Oxidation – Redox

Reduction is the Loss of Oxygen

Oxidation is the Gain of Oxygen

- Questions: What has been oxidised? What has been reduced?

$$Fe_2O_{3(s)} + 3CO_{(g)} \rightarrow 2Fe_{(s)} + 3CO_{2(g)}$$

$$CuO_{(s)} + H_{2(g)} \rightarrow Cu_{(s)} + H_2O_{(l)}$$

$$Fe_2O_{3(s)} + 2Al_{(s)} \rightarrow 2Fe_{(s)} + Al_2O_{3(s)}$$

- Oxidation: → Gain of oxygen.
- Reduction: → Loss of oxygen.

Reduction and Oxidation – Redox

Reduction is the Loss of Oxygen

Oxidation is the Gain of Oxygen

- Questions: What has been oxidised? What has been reduced?

$$Fe_2O_{3(s)} + 3CO_{(g)} \rightarrow 2Fe_{(s)} + 3CO_{2(g)}$$

- Carbon of CO has gained oxygen and is therefore oxidised.
- Iron of Fe_2O_3 has lost oxygen and is therefore reduced.

$$CuO_{(s)} + H_{2(g)} \rightarrow Cu_{(s)} + H_2O_{(l)}$$

- Hydrogen has gained oxygen and is therefore oxidised.
- Copper of CuO has lost oxygen and is therefore reduced.

$$Fe_2O_{3(s)} + 2Al_{(s)} \rightarrow 2Fe_{(s)} + Al_2O_{3(s)}$$

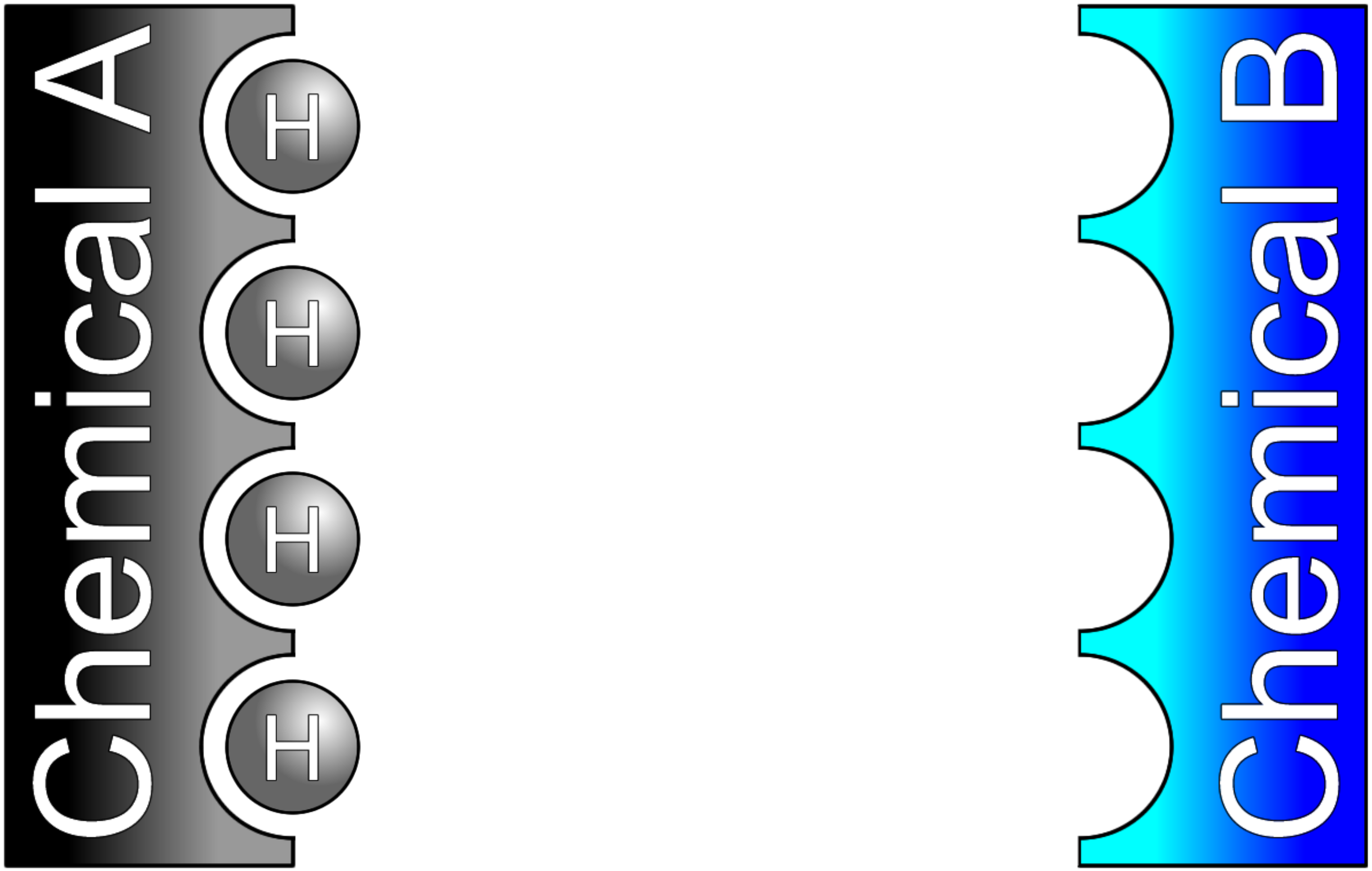
- Aluminium has gained oxygen and is therefore oxidised.
- Iron of Fe_2O_3 has lost oxygen and is therefore reduced.

- Oxidation: $\rightarrow$ Gain of oxygen.
- Reduction: $\rightarrow$ Loss of oxygen.

Reduction and Oxidation – Redox

- *Oxidation* is the *loss* of *hydrogen*.
- *Reduction* is the *gain* of *hydrogen*.

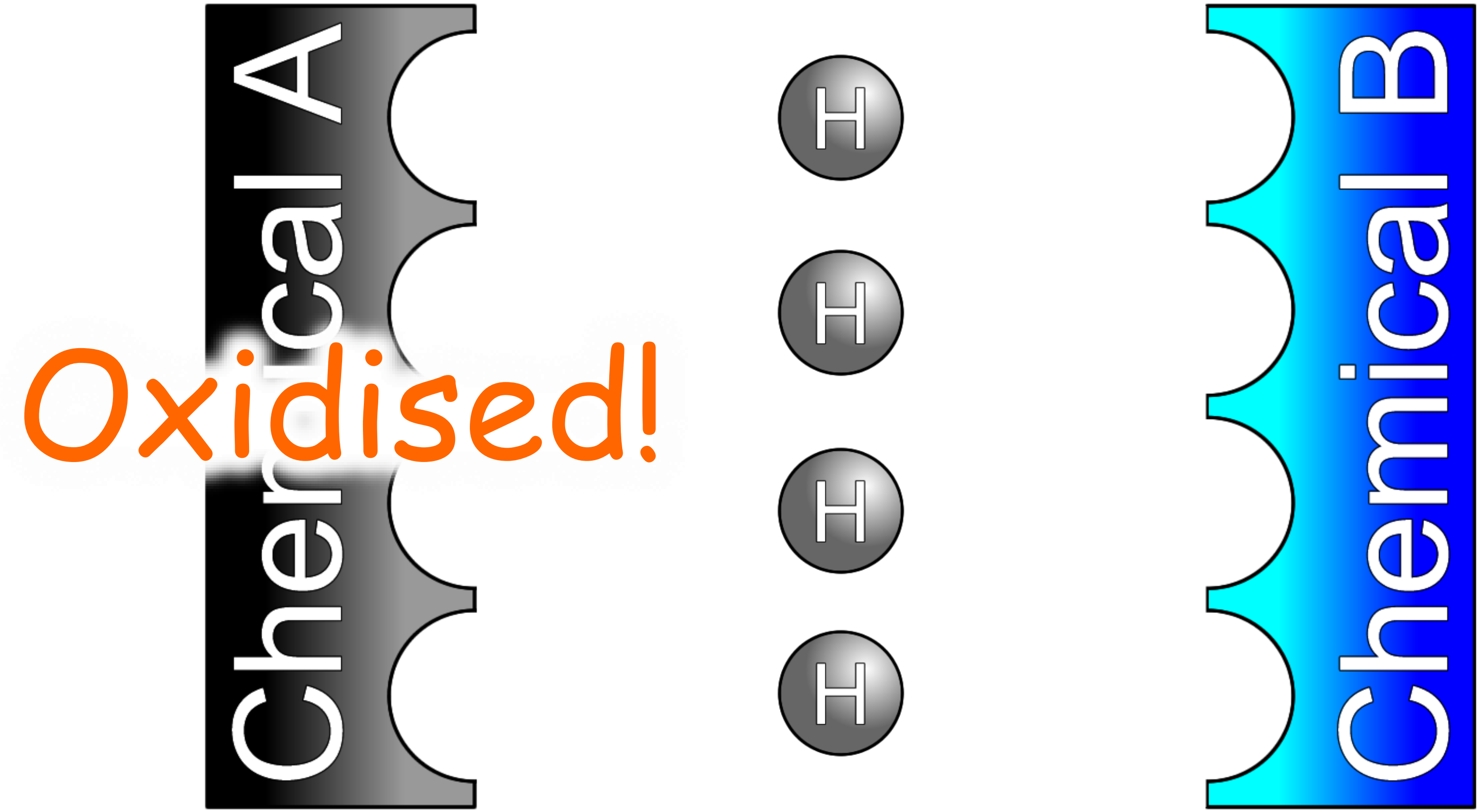
Reduction and Oxidation – Redox



- Oxidation: → Gain of oxygen. → Loss of hydrogen.
- Reduction: → Loss of oxygen. → Gain of hydrogen.

Reduction and Oxidation – Redox

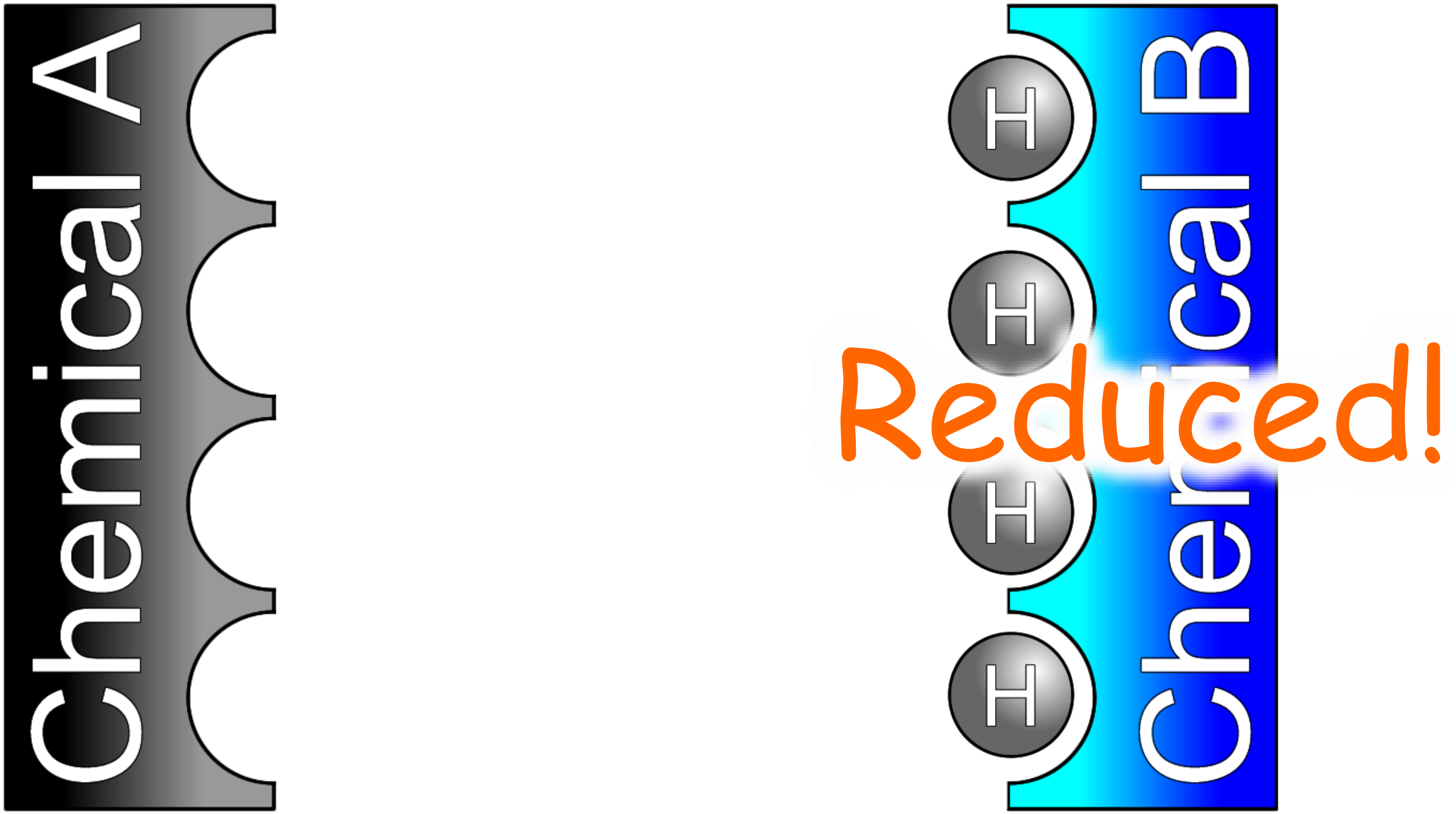
Oxidation is the Loss of Hydrogen



- Oxidation: → Gain of oxygen. → Loss of hydrogen.
- Reduction: → Loss of oxygen. → Gain of hydrogen.

Reduction and Oxidation – Redox

Reduction is the Gain of Hydrogen



- Oxidation: → Gain of oxygen. → Loss of hydrogen.
- Reduction: → Loss of oxygen. → Gain of hydrogen.

Reduction and Oxidation – Redox

Oxidation is the Loss of Hydrogen
Reduction is the Gain of Hydrogen

- Questions: What has been oxidised? What has been reduced?

$$H_2S_{(g)} + C\mathit{l}_{2(g)} \rightarrow S_{(s)} + 2HC\mathit{l}_{(g)}$$

$$C_2H_{4(g)} + H_{2(g)} \rightarrow C_2H_{6(g)}$$

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(\mathit{l})}$$

- Oxidation: → Gain of oxygen. → Loss of hydrogen.
- Reduction: → Loss of oxygen. → Gain of hydrogen.

Reduction and Oxidation – Redox

Oxidation is the Loss of Hydrogen

Reduction is the Gain of Hydrogen

- Questions: What has been oxidised? What has been reduced?

$$H_2S_{(g)} + Cl_{2(g)} \rightarrow S_{(s)} + 2HCl_{(g)}$$

- Sulfur of H_2S has lost hydrogen and is therefore oxidised.
- Chlorine has gained hydrogen and is therefore reduced.

$$C_2H_{4(g)} + H_{2(g)} \rightarrow C_2H_{6(g)}$$

- Carbon of C_2H_4 has gained hydrogen and is therefore reduced.
- H–H bond in H_2 breaks. Hydrogen loses hydrogen and is therefore oxidised.

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)}$$

- Hydrogen has gained oxygen and is therefore oxidised.
- Oxygen has gained hydrogen and is therefore reduced.

- Oxidation: → Gain of oxygen. → Loss of hydrogen.
- Reduction: → Loss of oxygen. → Gain of hydrogen.

Reduction and Oxidation – Redox

But what if the reaction does not involve oxygen or hydrogen?

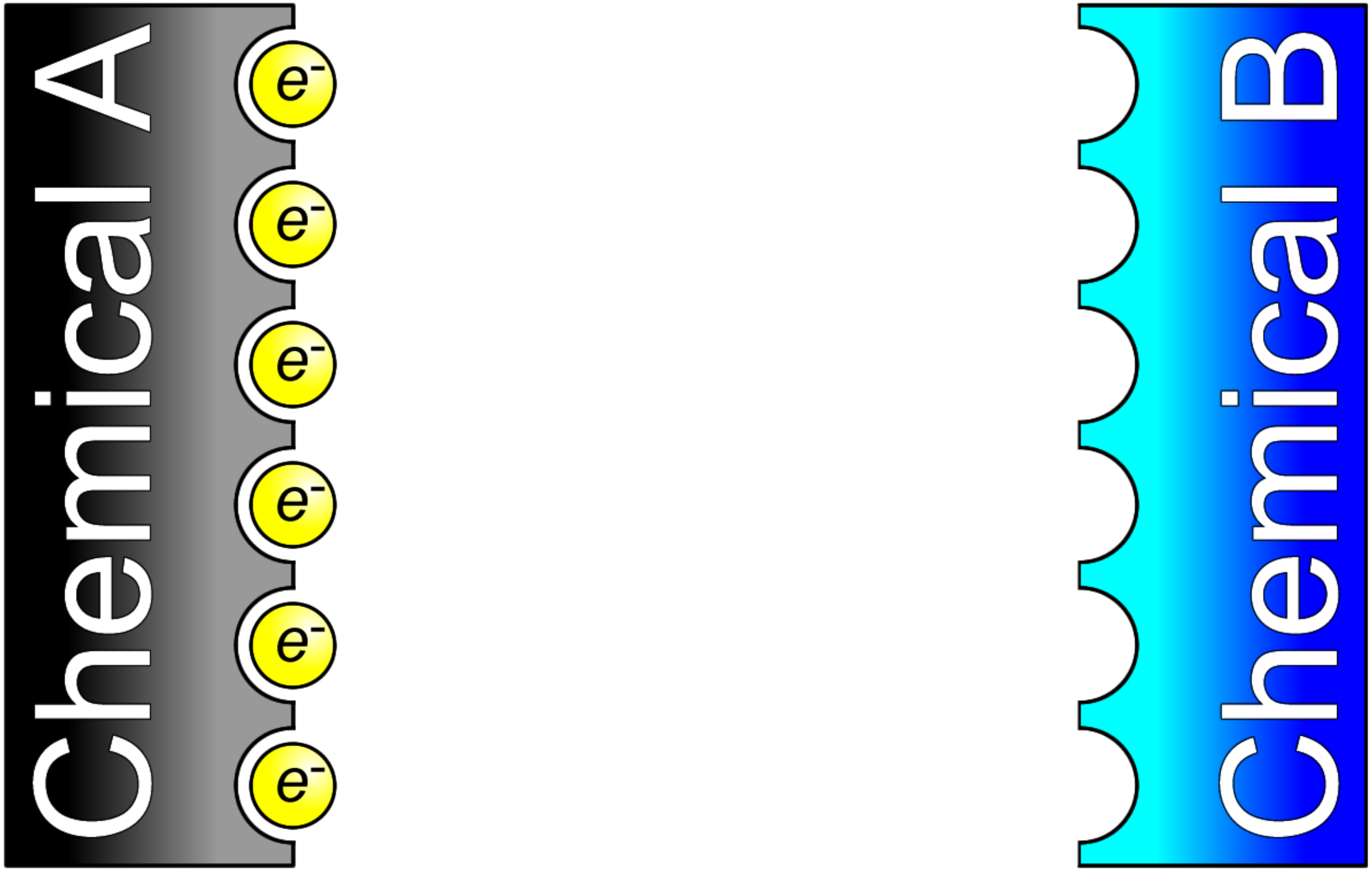
For example:

$$Mg_{(s)} + Cl_{2(g)} \rightarrow MgCl_{2(s)}$$

Reduction and Oxidation – Redox

- *Oxidation* is the *loss* of *electrons*.
- *Reduction* is the *gain* of *electrons*.

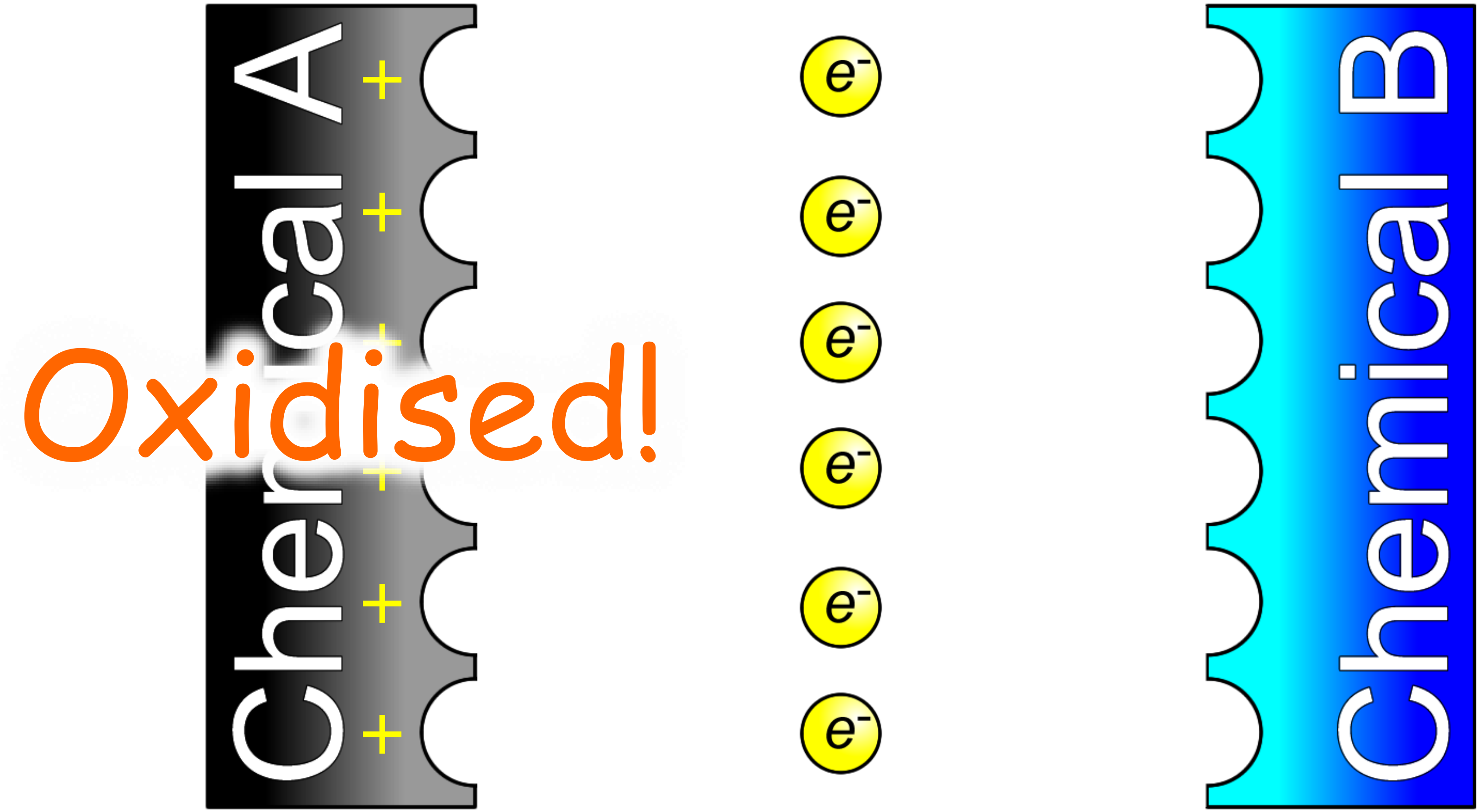
Reduction and Oxidation – Redox



- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons.

Reduction and Oxidation – Redox

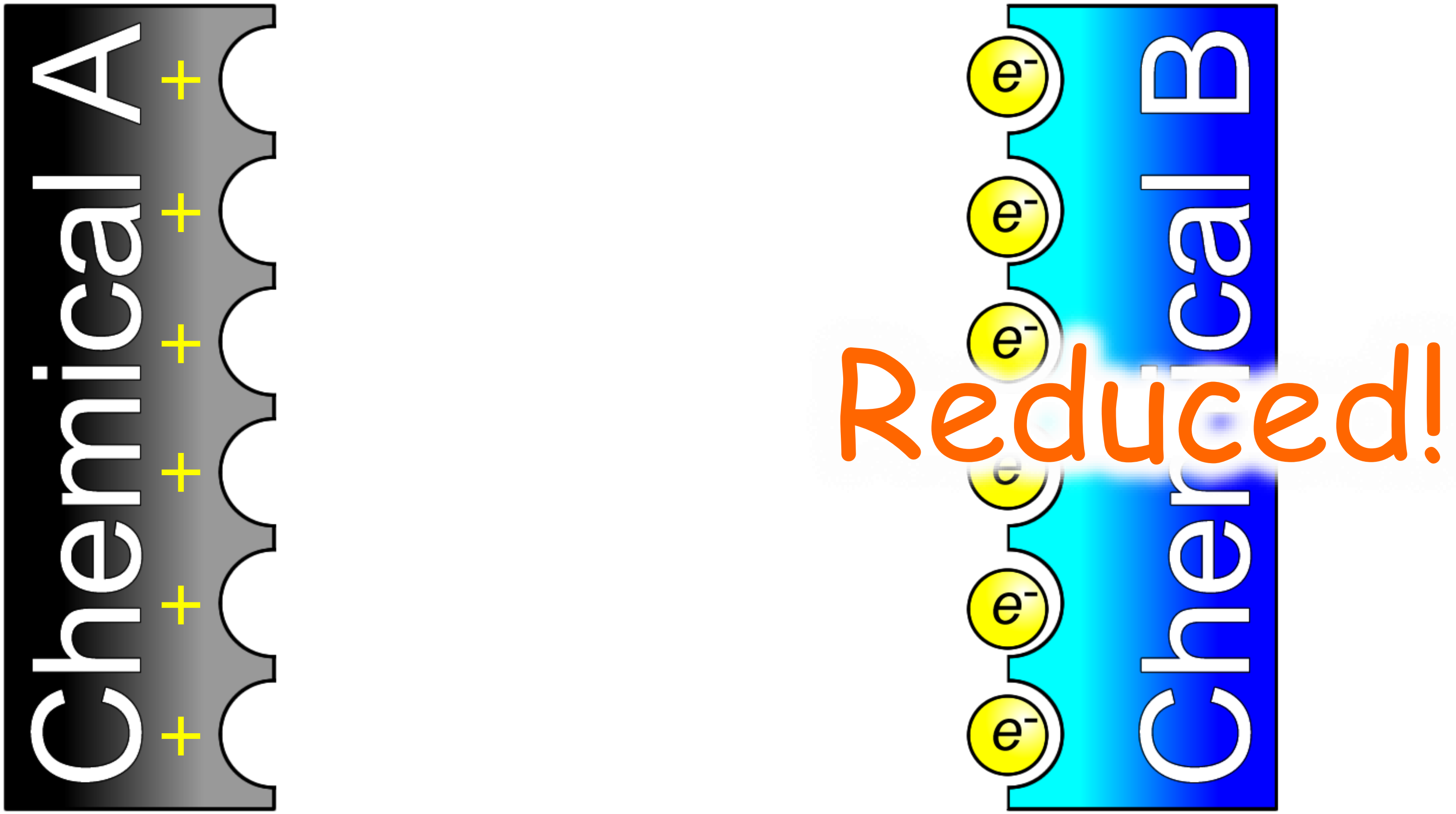
Oxidation is the Loss of Electrons



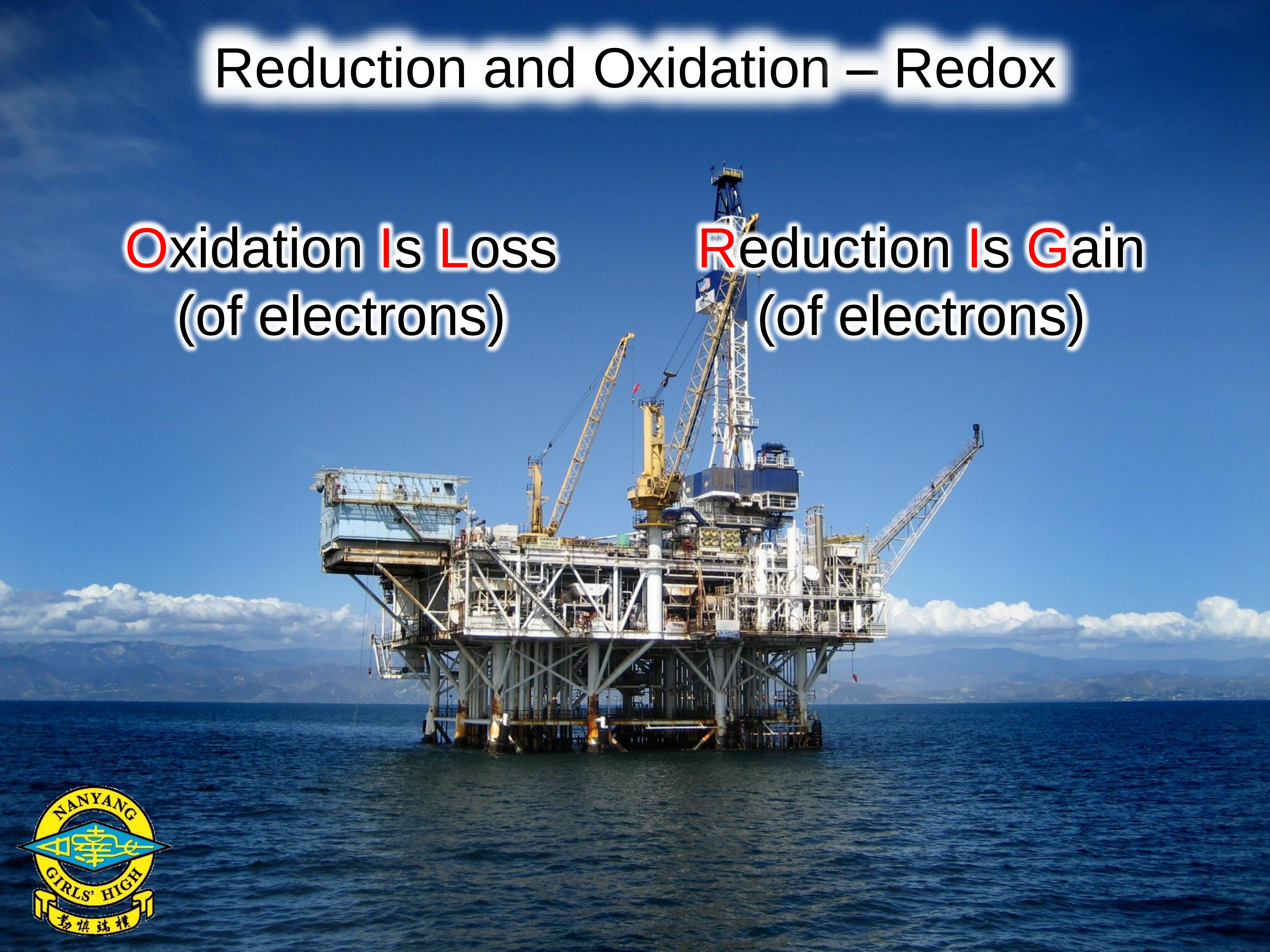
- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons.

Reduction and Oxidation – Redox

Reduction is the Gain of Electrons



- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons.


Reduction and Oxidation – Redox
Oxidation Is Loss
(of electrons)
Reduction Is Gain
(of electrons)
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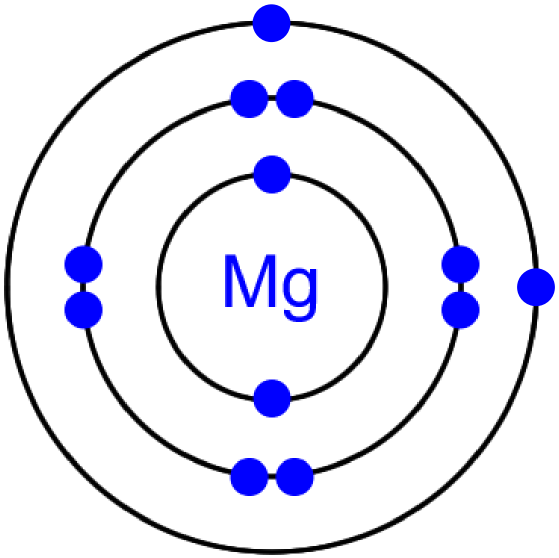
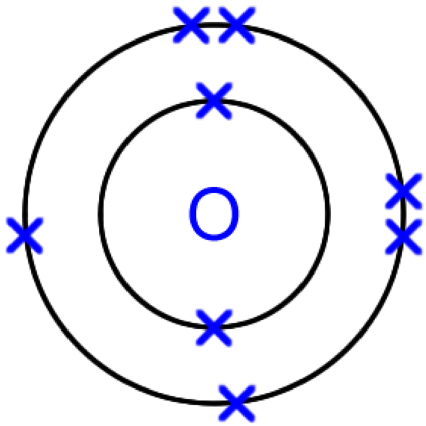
Reduction and Oxidation – Redox

Oxidation is the Loss of Electrons
Reduction is the Gain of Electrons



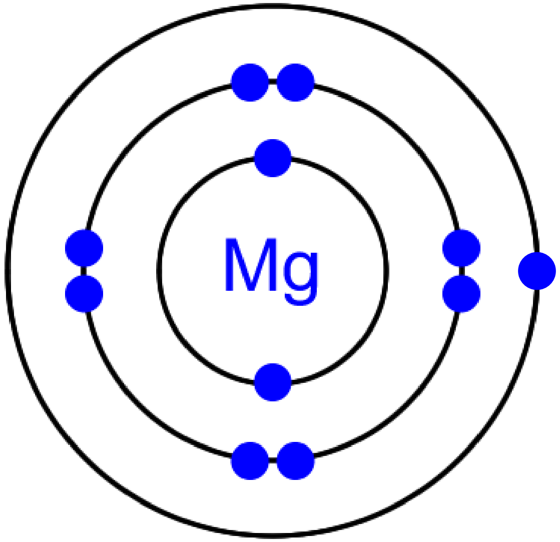


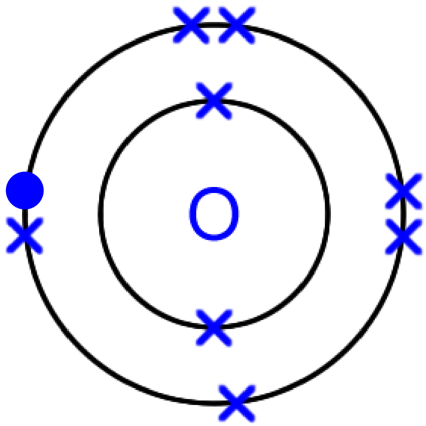
- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons.

Reduction and Oxidation – Redox

Oxidation is the Loss of Electrons

Reduction is the Gain of Electrons





- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons.

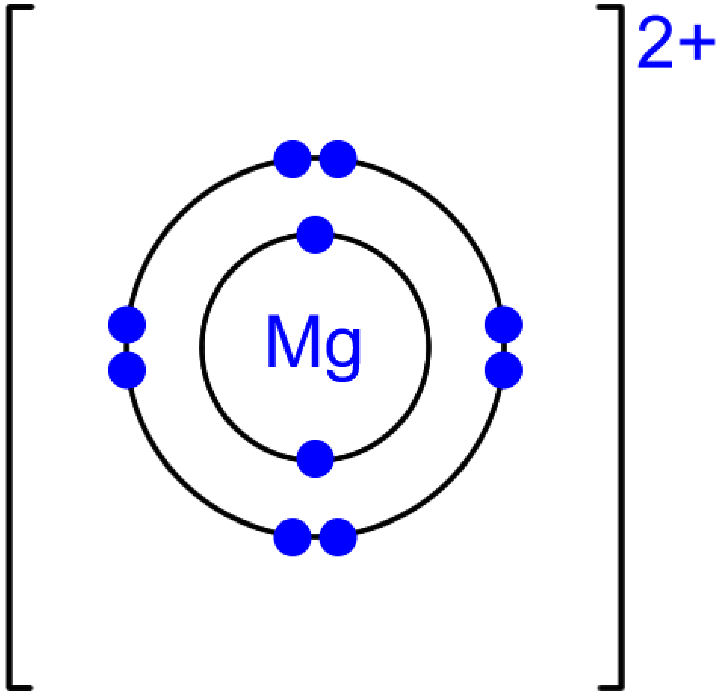
Reduction and Oxidation – Redox

Oxidation is the Loss of Electrons
Reduction is the Gain of Electrons

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons.

Reduction and Oxidation – Redox

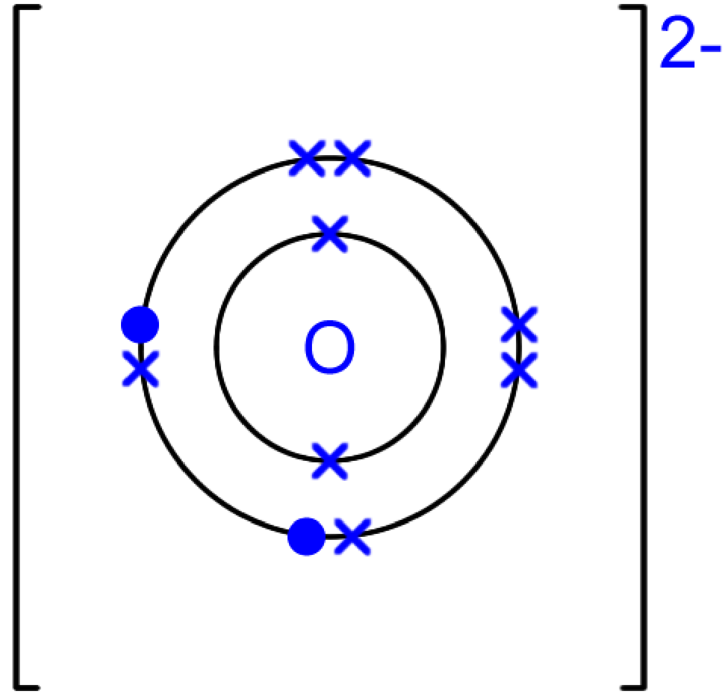
Oxidation is the Loss of Electrons
Reduction is the Gain of Electrons



Positive Magnesium Ion (Cation)

- Magnesium has lost electrons and has therefore been **oxidised**:

$$2Mg \rightarrow 2Mg^{2+} + 4e^{-}$$



Negative Oxide Ion (Anion)

- Oxygen has gained electrons And has therefore been **reduced**:

$$O_2 + 4e^{-} \rightarrow 2O^{2-}$$

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons.

Reduction and Oxidation – Redox

Oxidation is the Loss of Electrons

Reduction is the Gain of Electrons

- Questions: What has been oxidised? What has been reduced?

$$2Na_{(s)} + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$$

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons.

Reduction and Oxidation – Redox

Oxidation is the Loss of Electrons
Reduction is the Gain of Electrons

- Questions: What has been oxidised? What has been reduced?

$$2Na_{(s)} + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$$

$$2Na_{(s)} \rightarrow 2Na^{+}{}_{(s)} + 2e^{-}$$

- Sodium has lost electrons and has therefore been oxidised.

$$Cl_{2(g)} + 2e^{-} \rightarrow 2Cl^{-}{}_{(s)}$$

- Chlorine has gained electrons and has therefore been reduced.

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons.

Reduction and Oxidation – Redox

Oxidation is the Loss of Electrons
Reduction is the Gain of Electrons

- Questions: What has been oxidised? What has been reduced?

$$Cu_{(s)} + 2AgNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + 2Ag_{(s)}$$

$$Cu_{(s)} + 2Ag^{+}_{(aq)} \rightarrow Cu^{2+}_{(aq)} + 2Ag_{(s)}$$

Reduction and Oxidation – Redox

Oxidation is the Loss of Electrons

Reduction is the Gain of Electrons

- Questions: What has been oxidised? What has been reduced?

$$Cu_{(s)} + 2AgNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + 2Ag_{(s)}$$

$$Cu_{(s)} + 2Ag^{+}_{(aq)} \rightarrow Cu^{2+}_{(aq)} + 2Ag_{(s)}$$

$$Cu_{(s)} \rightarrow Cu^{2+}_{(aq)} + 2e^{-}$$

- Copper has lost electrons and has therefore been oxidised.

$$2Ag^{+}_{(aq)} + 2e^{-} \rightarrow 2Ag_{(s)}$$

- Silver ions have gained electrons and have therefore been reduced.

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons.

Reduction and Oxidation – Redox

Oxidation is the Loss of Electrons

Reduction is the Gain of Electrons

- Questions: What has been oxidised? What has been reduced?

$$Zn_{(s)} + CuSO_{4(aq)} \rightarrow ZnSO_{4(aq)} + Cu_{(s)}$$

$$Zn_{(s)} + Cu^{2+}{}_{(aq)} \rightarrow Zn^{2+}{}_{(aq)} + Cu_{(s)}$$

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons.

Reduction and Oxidation – Redox

Oxidation is the Loss of Electrons

Reduction is the Gain of Electrons

- Questions: What has been oxidised? What has been reduced?

$$Zn_{(s)} + CuSO_{4(aq)} \rightarrow ZnSO_{4(aq)} + Cu_{(s)}$$

$$Zn_{(s)} + Cu^{2+}_{(aq)} \rightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$$

$$Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e^{-}$$

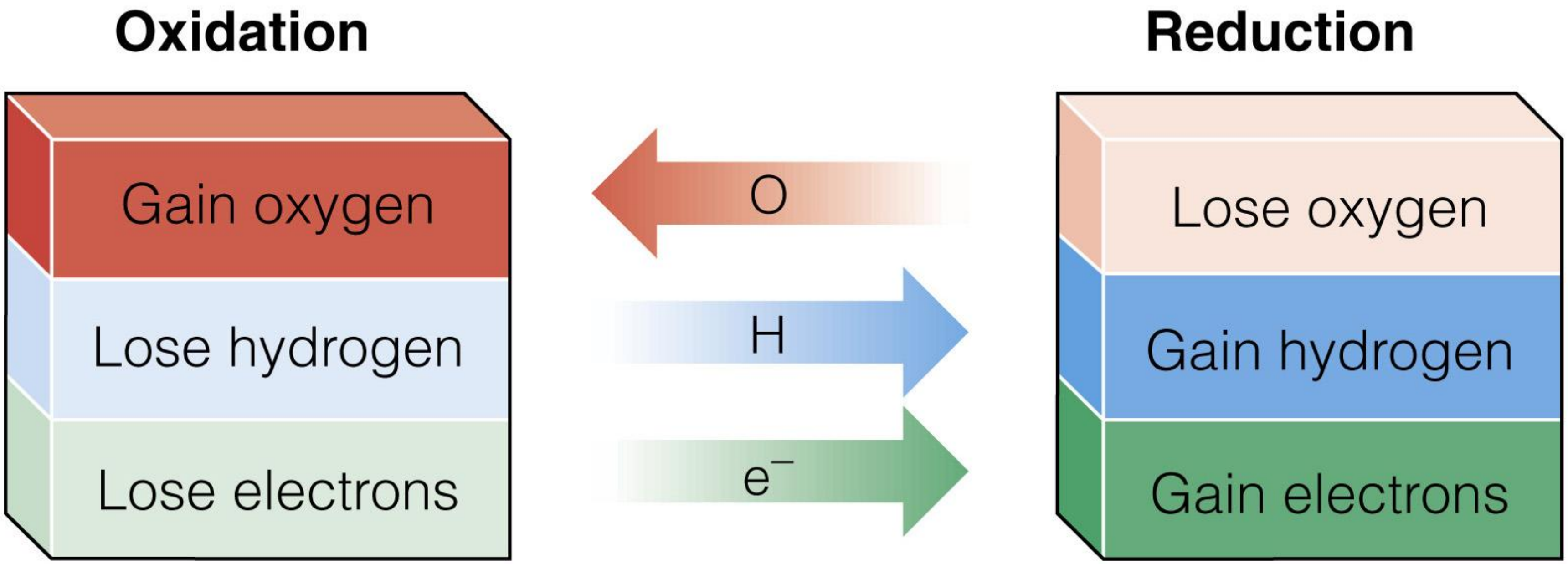
- Zinc has lost electrons and has therefore been oxidised.

$$Cu^{2+}_{(aq)} + 2e^{-} \rightarrow Cu_{(s)}$$

- Copper(II) ions have gained electrons and have therefore been reduced.

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons.

Reduction and Oxidation – Redox
Summary

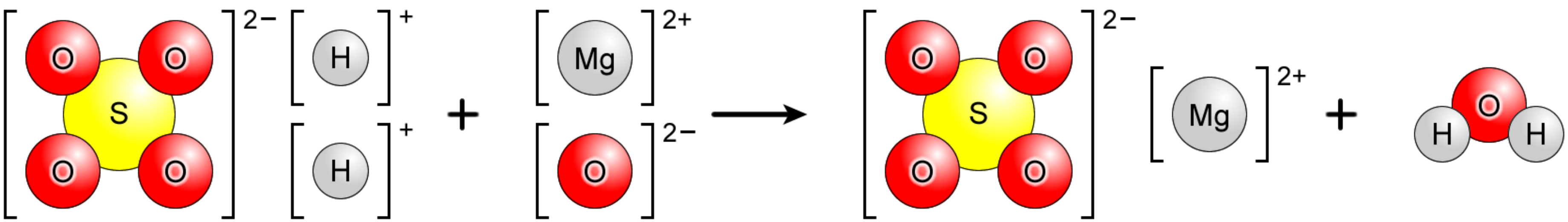


- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons.

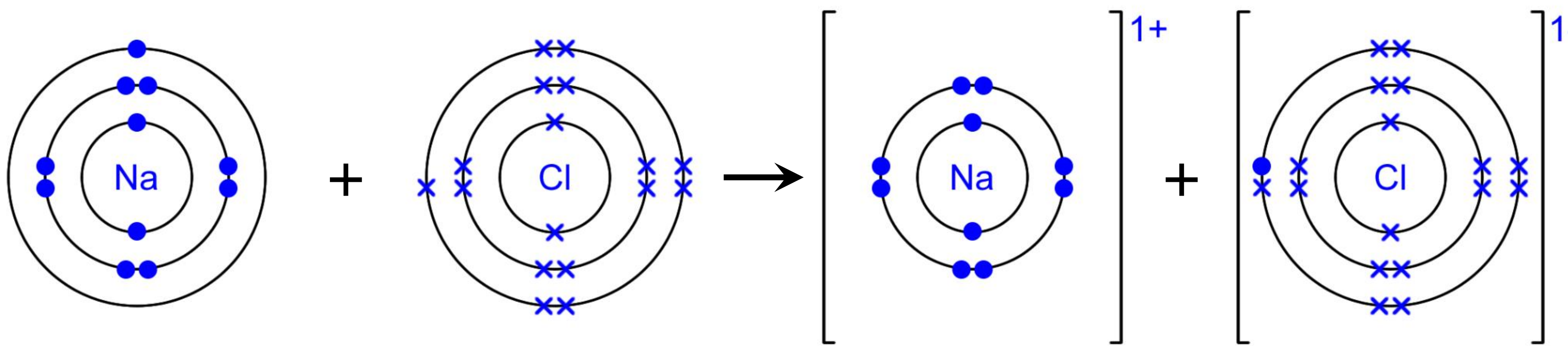
Reduction and Oxidation – Redox

Enduring Understanding

- Acid-base reactions involve the transfer of *H^+ ions*:



- Redox reactions involve the transfer of *electrons*:



- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons.

Reduction and Oxidation – Redox

But what if the reaction does not involve oxygen, hydrogen or the transfer of electrons?

For example:

$$C_{(s)} + 2Cl_{2(g)} \rightarrow CCl_{4(l)}$$

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Reduction and Oxidation – Redox

- *Oxidation* is the *increase* (↑) in oxidation state.

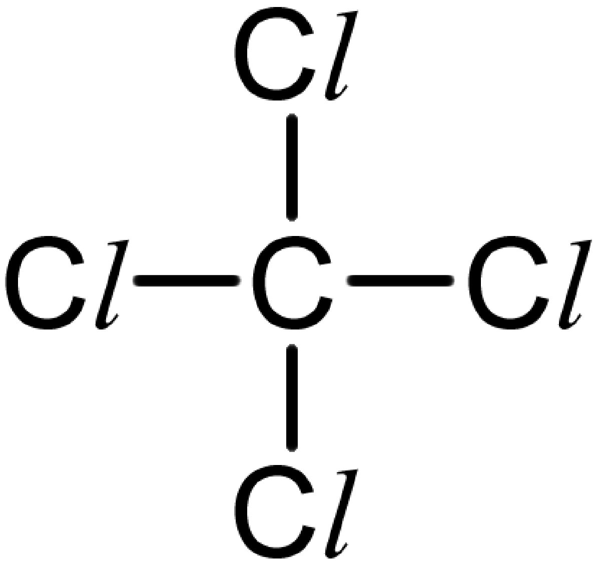
- *Reduction* is the *decrease* (↓) in oxidation state.

Reduction and Oxidation – Redox

Definition of Oxidation State

Oxidation state is the *hypothetical charge* that an atom would have if all bonds to atoms of different elements were completely *ionic*, with no covalent character (**note:** this is never true for real bonds). Oxidation states maybe positive, negative, or zero.

Reduction and Oxidation – Redox



- A molecule of the compound tetrachloromethane – CCl_4.

Note: This *does* really exist.

Reduction and Oxidation – Redox

Cl^-

Cl^- C^{4+} Cl^-

Cl^-

- The hypothetical structure of ionised tetrachloromethane. **Note:** This does *not* really exist.

- Carbon has an oxidation state of *+4* and chlorine has an oxidation state of *–1*.

Reduction and Oxidation – Redox

Oxidation is an Increase in Oxidation State

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidation is an Increase in Oxidation State

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

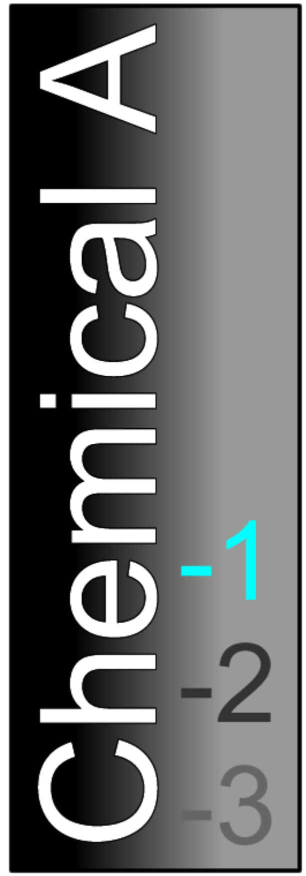
Reduction and Oxidation – Redox

Oxidation is an Increase in Oxidation State

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

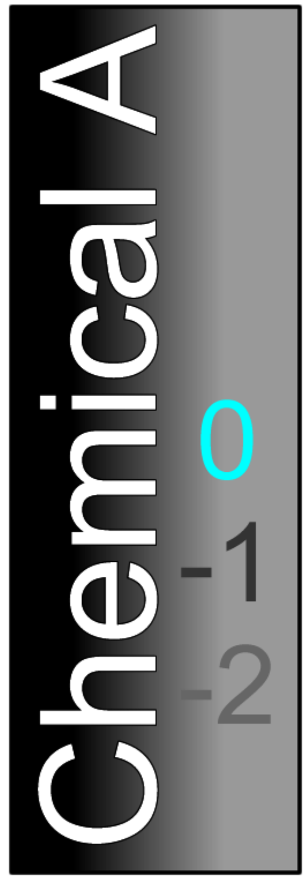
Oxidation is an Increase in Oxidation State



- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

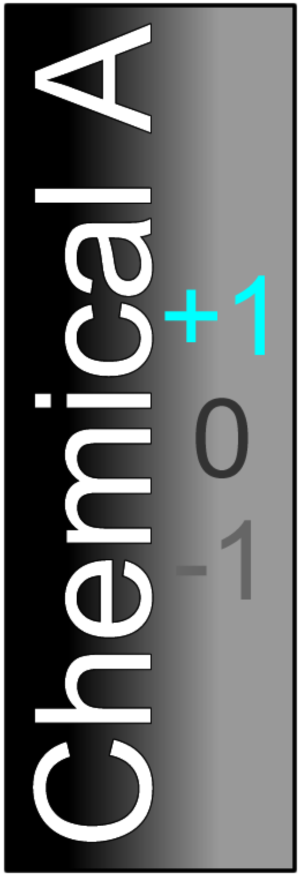
Oxidation is an Increase in Oxidation State



- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidation is an Increase in Oxidation State



- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidation is an Increase in Oxidation State

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidation is an Increase in Oxidation State

- If the oxidation state of a chemical element *increases* during a reaction, then it has been

Oxidised!

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Reduction is a Decrease in Oxidation State

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Reduction is a Decrease in Oxidation State

+3 Chemical B

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

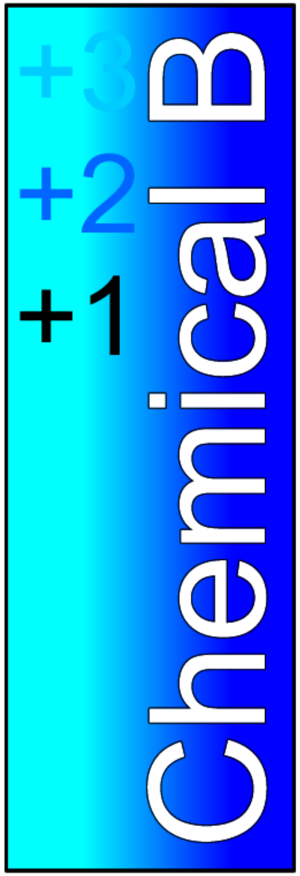
Reduction and Oxidation – Redox

Reduction is a Decrease in Oxidation State

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

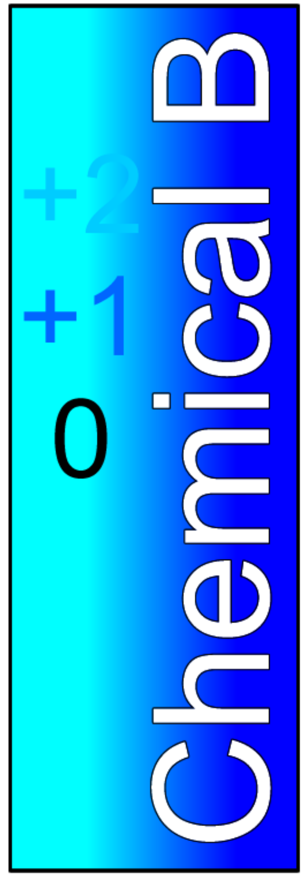
Reduction is a Decrease in Oxidation State



- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

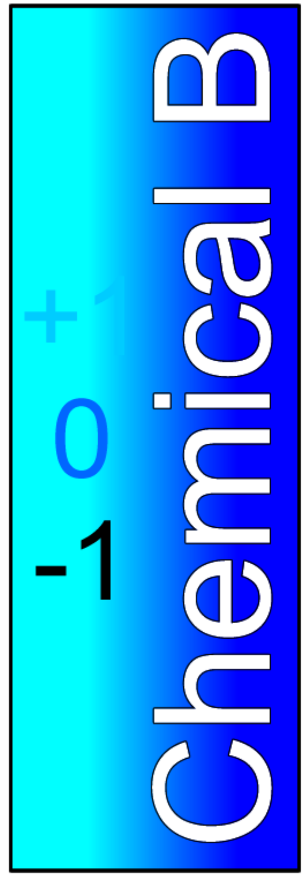
Reduction is a Decrease in Oxidation State



- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Reduction is a Decrease in Oxidation State



- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
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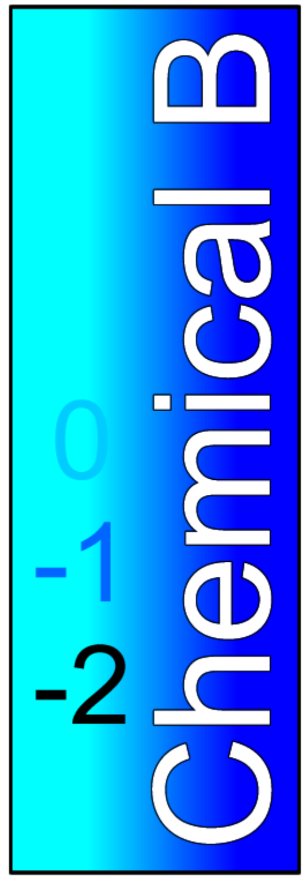
Reduction and Oxidation – Redox

Reduction is a Decrease in Oxidation State



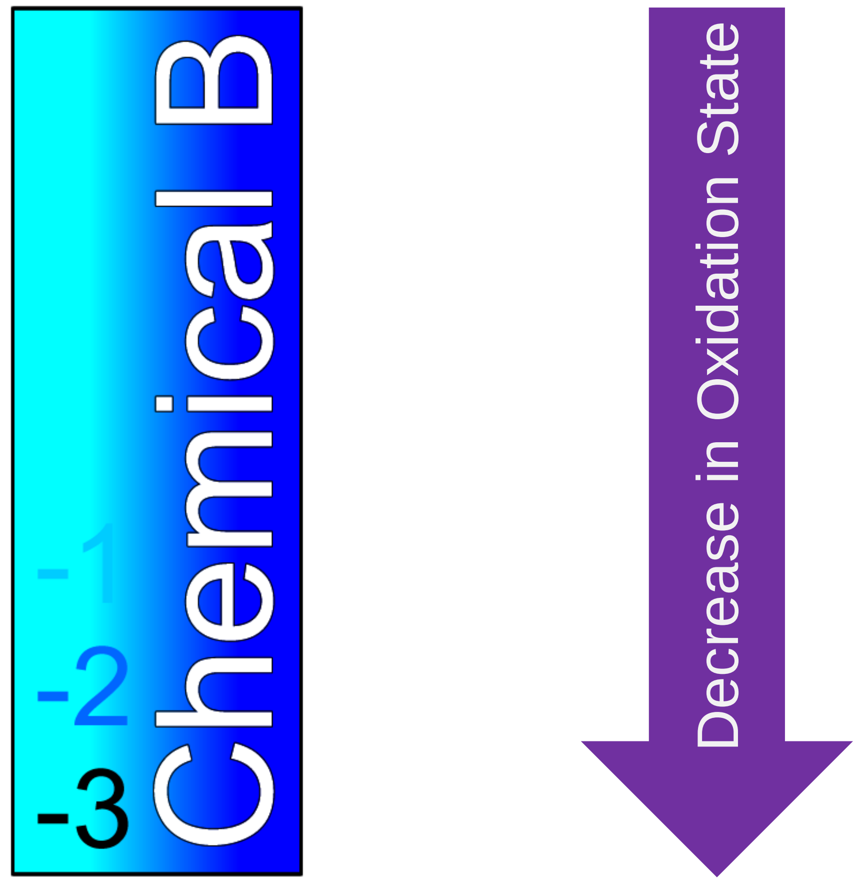
- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Reduction is a Decrease in Oxidation State

- If the oxidation state of a chemical element *decreases* during a reaction, then it has been

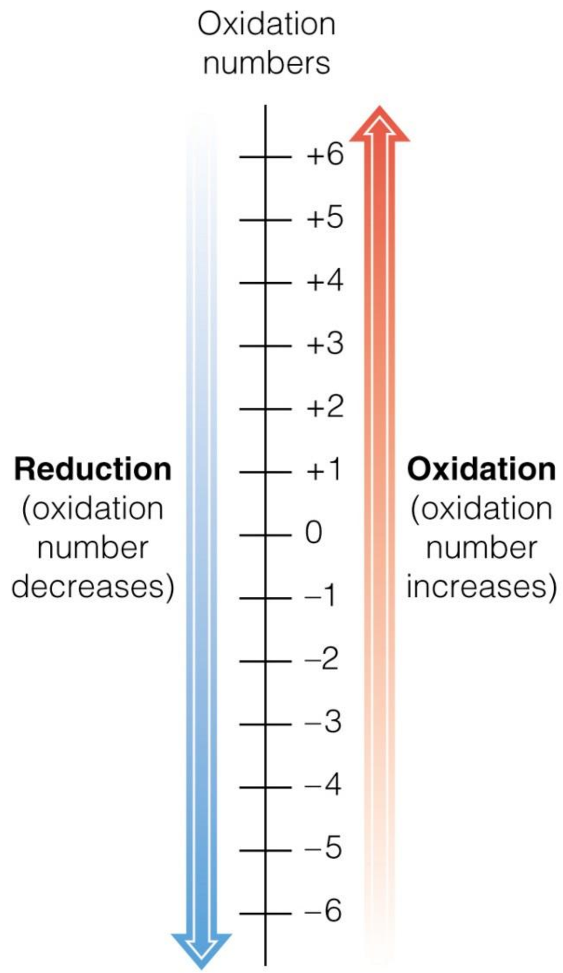
Reduced!



- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Summary



- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Okay, but how do I calculate oxidation states?

Reduction and Oxidation – Redox

Rules for Calculating Oxidation States

- The oxidation state (also referred to as the oxidation number) is an artificial construct invented by Chemists to help them understand redox better.

- The oxidation state is a number given to an *element*. This number is preceded by either a "+" sign or a "–" sign. In general, this number is the charge the atom of the element would have *if* it existed as an ion in the compound (even if the compound is a covalent compound).

Reduction and Oxidation – Redox

Rules for Calculating Oxidation States

- The oxidation state of a pure element is always ___.
- The oxidation state of a simple ion is equal to the _________ on the ion.
- The oxidation state of fluorine in a compound is always ___.
- The oxidation state of oxygen in a compound is always ___ unless it is combined with fluorine. Note: in hydrogen peroxide (H_2O_2), the oxidation state of oxygen is ___.
- The oxidation state of chlorine in a compound is always ___ unless it is combined with fluorine or oxygen.

Reduction and Oxidation – Redox

Rules for Calculating Oxidation States

- The oxidation state of a pure element is always __0__.
- The oxidation state of a simple ion is equal to the __charge__ on the ion.
- The oxidation state of fluorine in a compound is always __–1__.
- The oxidation state of oxygen in a compound is always __–2__ unless it is combined with fluorine. Note: in hydrogen peroxide (H_2O_2), the oxidation state of oxygen is __–1__.
- The oxidation state of chlorine in a compound is always __–1__ unless it is combined with fluorine or oxygen.

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Rules for Calculating Oxidation States

- The oxidation state of a Group 1 element in a compound is always ___.
- The oxidation state of a Group 2 element in a compound is always ___.
- The oxidation state of a Group 13 element in a compound is always ___.
- The oxidation state of hydrogen in a compound is always ___ unless it is combined with a reactive metal, in which case it is ___.

Reduction and Oxidation – Redox

Rules for Calculating Oxidation States

- The oxidation state of a Group 1 element in a compound is always __+1__.
- The oxidation state of a Group 2 element in a compound is always __+2__.
- The oxidation state of a Group 13 element in a compound is always __+3__.
- The oxidation state of hydrogen in a compound is always __+1__ unless it is combined with a reactive metal, in which case it is __–1__.

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Rules for Calculating Oxidation States

- The sum of the oxidation states of the elements in a compound is equal to the _________ carried by the compound.

- For example, the sulfate ion (formula: SO_4^{2-}) carries a charge of –2, so the sum of the oxidation states of the elements in the ion must add up to –2. Because the oxidation state of oxygen in a compound is known to be –2, the oxidation state of sulfur can be calculated.

Reduction and Oxidation – Redox

Rules for Calculating Oxidation States

- The sum of the oxidation states of the elements in a compound is equal to the __charge__ carried by the compound.

- For example, the sulfate ion (formula: SO_4^{2-}) carries a charge of –2, so the sum of the oxidation states of the elements in the ion must add up to –2. Because the oxidation state of oxygen in a compound is known to be –2, the oxidation state of sulfur can be calculated.

$$S + (4 \times O) = -2$$
$$S + (4 \times -2) = -2$$
$$S + (-8) = -2$$
$$S = -2 + 8$$
$$S = +6$$

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Calculating Oxidation States

- Questions: Calculate the oxidation states of the elements that have been underlined.

$\underline{O}_2$	$\underline{Cu}^{2+}$	$\underline{S}O_2$
$\underline{S}O_3$	$H_2\underline{S}$	$\underline{C}O_3^{2-}$
$\underline{V}_2O_5$	$\underline{I}O_4^{-}$	$\underline{Fe}Cl_3$
$\underline{P}O_4^{3-}$	$\underline{Mn}O_4^{-}$	$\underline{Cr}_2O_7^{2-}$

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Calculating Oxidation States

- Questions: Calculate the oxidation states of the elements that have been underlined.

$\underline{O}_2$ Pure Element	$\underline{Cu}^{2+}$ Charge on Ion	$\underline{S}O_2$ $S + (2 \times -2) = 0$
$\underline{S}O_3$ $S + (3 \times -2) = 0$	$H_2\underline{S}$ $S + (2 \times +1) = 0$	$\underline{C}O_3^{2-}$ $C + (3 \times -2) = -2$
$\underline{V}_2O_5$ $(2 \times V) + (5 \times -2) = 0$	$\underline{I}O_4^-$ $I + (4 \times -2) = -1$	$\underline{Fe}Cl_3$ $Fe + (3 \times -1) = 0$
$\underline{P}O_4^{3-}$ $P + (4 \times -2) = -3$	$\underline{Mn}O_4^-$ $Mn + (4 \times -2) = -1$	$\underline{Cr}_2O_7^{2-}$ $(2 \times Cr) + (7 \times -2) = -2$

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Calculating Oxidation States

- Questions: Calculate the oxidation states of the elements that have been underlined.

$\underline{O}_2 = 0$	$\underline{Cu}^{2+} = +2$	$\underline{S}O_2 = +4$
$\underline{S}O_3 = +6$	$H_2\underline{S} = -2$	$\underline{C}O_3^{2-} = +4$
$\underline{V}_2O_5 = +5$	$\underline{I}O_4^{-} = +7$	$\underline{Fe}Cl_3 = +3$
$\underline{P}O_4^{3-} = +5$	$\underline{Mn}O_4^{-} = +7$	$\underline{Cr}_2O_7^{2-} = +6$

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidation is an Increase in Oxidation State

Reduction is a Decrease in Oxidation State

- Question: By calculating oxidation states, deduce whether the underlined element has been oxidised or reduced during the reaction.

$$\underline{Mn}O_{2(s)} + 4HCl_{(aq)} \rightarrow \underline{Mn}Cl_{2(aq)} + 2H_2O_{(l)} + Cl_{2(g)}$$

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidation is an Increase in Oxidation State

Reduction is a Decrease in Oxidation State

- Question: By calculating oxidation states, deduce whether the underlined element has been oxidised or reduced during the reaction.

+4 Mn is Reduced +2

$$\underline{Mn}O_{2(s)} + 4HCl_{(aq)} \rightarrow \underline{Mn}Cl_{2(aq)} + 2H_2O_{(l)} + Cl_{2(g)}$$

Mn in MnO_2: $Mn + (2 \times -2) = 0$ $\therefore$ $Mn = +4$

Mn in $MnCl_2$: $Mn + (2 \times -1) = 0$ $\therefore$ $Mn = +2$

Mn is reduced from an oxidation state of +4 to +2.

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidation is an Increase in Oxidation State

Reduction is a Decrease in Oxidation State

- Question: By calculating oxidation states, deduce whether the underlined element has been oxidised or reduced during the reaction.

$$2\underline{S}_2O_3{}^{2-}{}_{(aq)} + I_{2(aq)} \rightarrow \underline{S}_4O_6{}^{2-}{}_{(aq)} + 2I^-{}_{(aq)}$$

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidation is an Increase in Oxidation State

Reduction is a Decrease in Oxidation State

- Question: By calculating oxidation states, deduce whether the underlined element has been oxidised or reduced during the reaction.

+2 S is Oxidised +2.5

$$2\underline{S}_2O_3{}^{2-}{}_{(aq)} + I_{2(aq)} \rightarrow \underline{S}_4O_6{}^{2-}{}_{(aq)} + 2I^-{}_{(aq)}$$

S in $S_2O_3{}^{2-}$: $(2 \times S) + (3 \times -2) = -2 \quad \therefore S = +2$

S in $S_4O_6{}^{2-}$: $(4 \times S) + (6 \times -2) = -2 \quad \therefore S = +2.5$

S is oxidised from an oxidation state of +2 to +2.5.

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidation is an Increase in Oxidation State

Reduction is a Decrease in Oxidation State

- Question: By calculating oxidation states, deduce whether the underlined element has been oxidised or reduced during the reaction.

$$\underline{Cr}_2O_7^{2-}{}_{(aq)} + 14H^+{}_{(aq)} + 6e^- \rightarrow 2\underline{Cr}^{3+}{}_{(aq)} + 7H_2O_{(l)}$$

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Reduction and Oxidation – Redox

Oxidation is an Increase in Oxidation State

Reduction is a Decrease in Oxidation State

- Question: By calculating oxidation states, deduce whether the underlined element has been oxidised or reduced during the reaction.

+6 Cr is Reduced +3

$$\underline{Cr}_2O_7^{2-}{}_{(aq)} + 14H^+{}_{(aq)} + 6e^- \rightarrow 2\underline{Cr}^{3+}{}_{(aq)} + 7H_2O_{(l)}$$

Cr in $Cr_2O_7^{2-}$: $(2 \times Cr) + (7 \times -2) = -2 \quad \therefore Cr = +6$

Cr in Cr^{3+}: $\therefore Cr = +3$

Cr is reduced from an oxidation state of +6 to +3.

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

A quick note about defining the term *redox reaction*.

Reduction and Oxidation – Redox

A *redox reaction* is defined as a reaction in which one chemical species is *oxidised* while another chemical species is *reduced* *at the same time* or *in the same chemical reaction*.

Reduction and Oxidation – Redox

Quick test! Are all chemical reactions redox reactions?

Reduction and Oxidation – Redox

Which of the following chemical reactions are redox?

1) $Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$

2) $H_2SO_{4(aq)} + 2NaOH_{(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)}$

3) $BaCl_{2(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2NaCl_{(aq)}$

4) $2KI_{(aq)} + Cl_{2(aq)} \rightarrow 2KCl_{(aq)} + I_{2(aq)}$

5) $2CO_{(g)} + 2NO_{(g)} \rightarrow 2CO_{2(g)} + N_{2(g)}$

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Which of the following chemical reactions are redox?

1) $Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$

- Redox Reaction: Magnesium is oxidised (0 to +2) while hydrogen is reduced (+1 to 0).

2) $H_2SO_{4(aq)} + 2NaOH_{(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)}$

- Neutralisation Reaction (not redox, no change in any oxidation state).

3) $BaCl_{2(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2NaCl_{(aq)}$

- Ionic Precipitation Reaction (not redox, no change in any oxidation state).

4) $2KI_{(aq)} + Cl_{2(aq)} \rightarrow 2KCl_{(aq)} + I_{2(aq)}$

- Redox Reaction: Iodide ions are oxidised (–1 to 0) while chlorine is reduced (0 to –1).

5) $2CO_{(g)} + 2NO_{(g)} \rightarrow 2CO_{2(g)} + N_{2(g)}$

- Redox Reaction: Carbon is oxidised (+2 to +4) while nitrogen is reduced (+2 to 0).

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

How can I tell which *Group* an element is from based upon its *oxidation states*?

Reduction and Oxidation – Redox

- The *highest positive oxidation state* exhibited by a chemical element reflects (*in theory*) the maximum number of electrons that a single atom *could* lose in order to form a positively charged ion with a Noble gas electronic configuration.

- This in turn indicates the total number of electrons present in the valence shell of a single atom of the element, and hence points to the Group of the Periodic Table that the element belongs to.

Reduction and Oxidation – Redox

- For example, consider a chemical element with a maximum positive oxidation state of *+6*.

- This means that a single atom of the element has *six* electrons in its valence shell which it could (*in theory*) lose in order to form an ion, X^{6+}, with the electronic configuration of a Noble gas.

- The chemical element therefore belongs to *Group 16* of the Periodic Table.

Reduction and Oxidation – Redox

What is a *disproportionation reaction*?

Reduction and Oxidation – Redox

Disproportionation Reactions

- *Disproportionation* is a special type of redox reaction in which an element undergoes both *oxidation* and *reduction* to form two different products.

Reduction and Oxidation – Redox

Disproportionation Reactions

- *Disproportionation* is a special type of redox reaction in which an element undergoes both *oxidation* and *reduction* to form two different products.

$$2H_2O_{2(l)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$$

Reduction and Oxidation – Redox

Disproportionation Reactions

- *Disproportionation* is a special type of redox reaction in which an element undergoes both *oxidation* and *reduction* to form two different products.

O is Reduced

–1 –2

$$2H_2O_{2(l)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$$

–1 0

O is Oxidised

This is a *disproportionation reaction*. Oxygen has been both *oxidised* from –1 to 0 and *reduced* from –1 to –2.

Reduction and Oxidation – Redox

Disproportionation Reactions

- *Disproportionation* is a special type of redox reaction in which an element undergoes both *oxidation* and *reduction* to form two different products.

$$Cu_2O_{(s)} + H_2SO_{4(aq)} \rightarrow Cu_{(s)} + CuSO_{4(aq)} + H_2O_{(l)}$$

Reduction and Oxidation – Redox

Disproportionation Reactions

- *Disproportionation* is a special type of redox reaction in which an element undergoes both *oxidation* and *reduction* to form two different products.

+1   Cu⁺ is Reduced   0

$$Cu_2O_{(s)} + H_2SO_{4(aq)} \rightarrow Cu_{(s)} + CuSO_{4(aq)} + H_2O_{(l)}$$

+1   Cu⁺ is Oxidised   +2

This is a *disproportionation reaction*. Copper(I) ions have been both *oxidised* from +1 to +2 and *reduced* from +1 to 0.

Reduction and Oxidation – Redox

What are
oxidising agents
and *reducing*
agents?

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

- One possible point of view…

Chemical **A** is the reducing agent.
Chemical **A** is oxidised.

Chemical **B** is reduced.

- Chemical **A** gives an electron to Chemical **B**.
- Chemical **B** gains an electron and is therefore *reduced*.
- Chemical **B** is *reduced* by Chemical **A**, therefore Chemical **A** is a *reducing agent*.
- Chemical **A** (the *reducing agent*) is *oxidised*.

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

- One possible point of view…

Chemical **A** is the reducing agent.
Chemical **A** is oxidised.

Chemical **B** is reduced.

- Chemical **A** gives an electron to Chemical **B**.
- Chemical **B** gains an electron and is therefore *reduced*.
- Chemical **B** is *reduced* by Chemical **A**, therefore Chemical **A** is a *reducing agent*.
- Chemical **A** (the *reducing agent*) is *oxidised*.

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

- Another possible point of view…

Chemical **A** is oxidised.

Chemical **B** is the oxidising agent.
Chemical **B** is reduced.

- Chemical **B** takes an electron from Chemical **A**.
- Chemical **A** loses an electron and is therefore *oxidised*.
- Chemical **A** is *oxidised* by Chemical **B**, therefore Chemical **B** is an *oxidising agent*.
- Chemical **B** (the *oxidising agent*) is *reduced*.

• Oxidation:	→ Gain of oxygen.	→ Loss of hydrogen.	→ Loss of electrons.	→ Increase in oxidation state.
• Reduction:	→ Loss of oxygen.	→ Gain of hydrogen.	→ Gain of electrons.	→ Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

- Another possible point of view…

Chemical **A** is oxidised.

Chemical **B** is the oxidising agent.
Chemical **B** is reduced.

- Chemical **B** takes an electron from Chemical **A**.
- Chemical **A** loses an electron and is therefore *oxidised*.
- Chemical **A** is *oxidised* by Chemical **B**, therefore Chemical **B** is an *oxidising agent*.
- Chemical **B** (the *oxidising agent*) is *reduced*.

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

- Compare…

I *give* you my pen…

…you *take* my pen.

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox
Oxidising Agents and Reducing Agents

- The *Oxidising* Agent is *Reduced*!

  → It loses oxygen.
  → It gains hydrogen.
  → It gains electrons.
  → Its oxidation state decreases.

- The *Reducing* Agent is *Oxidised*!

  → It gains oxygen.
  → It loses hydrogen.
  → It loses electrons.
  → Its oxidation state increases.

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- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

- Questions: What is the oxidising agent? What is the reducing agent?

$$2KI_{(aq)} + Cl_{2(aq)} \rightarrow I_{2(aq)} + 2KCl_{(aq)}$$

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

- Questions: What is the oxidising agent? What is the reducing agent?

Oxidised
∴ Reducing
Agent

–1 0

$$2KI_{(aq)} + Cl_{2(aq)} \rightarrow I_{2(aq)} + 2KCl_{(aq)}$$

0 –1

Reduced
∴ Oxidising Agent

Cl_2 is the oxidising agent. KI is the reducing agent.

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

- Questions: What is the oxidising agent? What is the reducing agent?

$$Ca_{(s)} + 2AgNO_{3(aq)} \rightarrow Ca(NO_3)_{2(aq)} + 2Ag_{(s)}$$

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

- Questions: What is the oxidising agent? What is the reducing agent?

Oxidised

∴ Reducing Agent

0 → +2

$$Ca_{(s)} + 2AgNO_{3(aq)} \rightarrow Ca(NO_3)_{2(aq)} + 2Ag_{(s)}$$

+1 → 0

Reduced

∴ Oxidising Agent

$AgNO_3$ is the oxidising agent. Ca is the reducing agent.

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

- Questions: What is the oxidising agent? What is the reducing agent?

$$2CuSO_{4(aq)} + 4KI_{(aq)} \rightarrow 2CuI_{(s)} + I_{2(aq)} + 2K_2SO_{4(aq)}$$

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

- Questions: What is the oxidising agent? What is the reducing agent?

Reduced

+2 ∴ Oxidising Agent +1

$$2CuSO_{4(aq)} + 4KI_{(aq)} \rightarrow 2CuI_{(s)} + I_{2(aq)} + 2K_2SO_{4(aq)}$$

–1 Oxidised 0

∴ Reducing Agent

$CuSO_4$ is the oxidising agent. KI is the reducing agent.

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Which elements in the Periodic Table are good oxidising agents? Which elements are good reducing agents?

Reduction and Oxidation – Redox

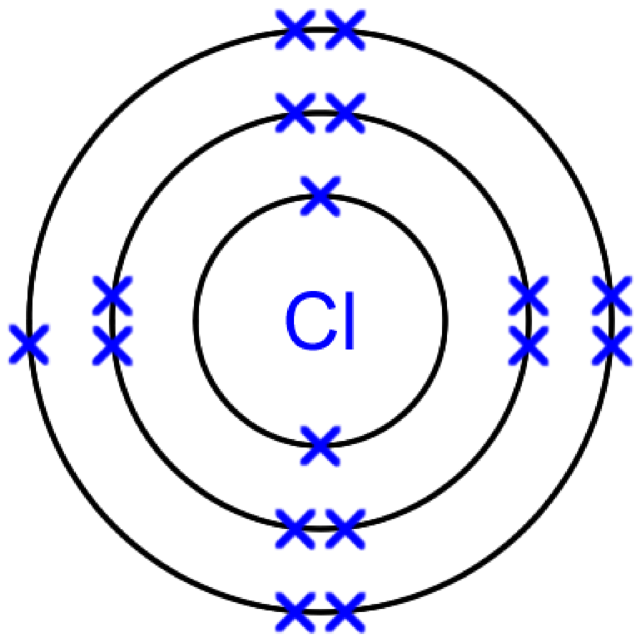
Oxidising Agents and Reducing Agents

- The strongest *oxidising agents* can be found in *Group 16* (*e.g.* oxygen) and *Group 17* (*e.g.* fluorine) of the Periodic Table. These reactive non-metals readily accept electrons in order to obtain a noble gas electronic configuration. By definition, the atom that gives electrons to a *Group 16* or *Group 17* element is *oxidised*, therefore the *Group 16* and *Group 17* non-metals are *good oxidising agents*.

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

- Chlorine has seven electrons in its valence shell.

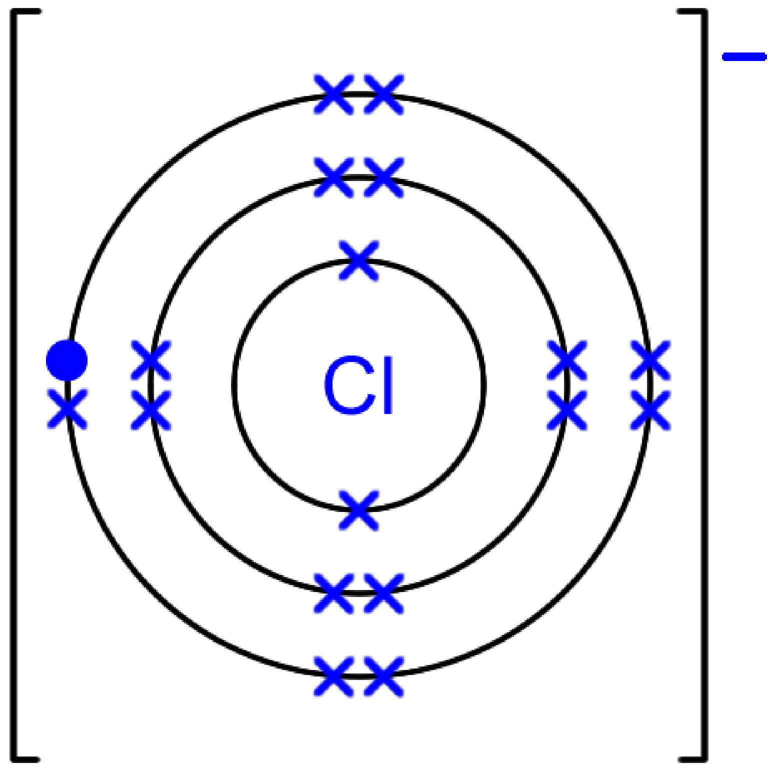


- Chlorine must *gain one electron* to complete its valence shell (full octet / Noble Gas electronic configuration).

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

- Chlorine removes an electron from another chemical.



- The other chemical has *lost an electron* and has therefore been *oxidised*. Chlorine is the *oxidising agent*.

Reduction and Oxidation – Redox

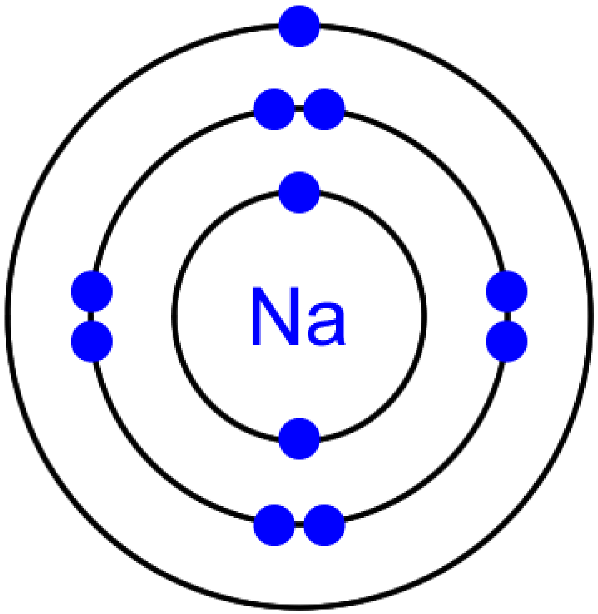
Oxidising Agents and Reducing Agents

- The strongest *reducing agents* can be found in *Group 1* (*e.g.* potassium) and *Group 2* (*e.g.* calcium) of the Periodic Table. These reactive metals readily give away their valence electrons in order to obtain a noble gas electronic configuration. By definition, the atom that accepts electrons from a *Group 1* or *Group 2* element is *reduced*, therefore the *Group 1* and *Group 2* metals are *good reducing agents*.

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

- Sodium has one electron in its valence shell.

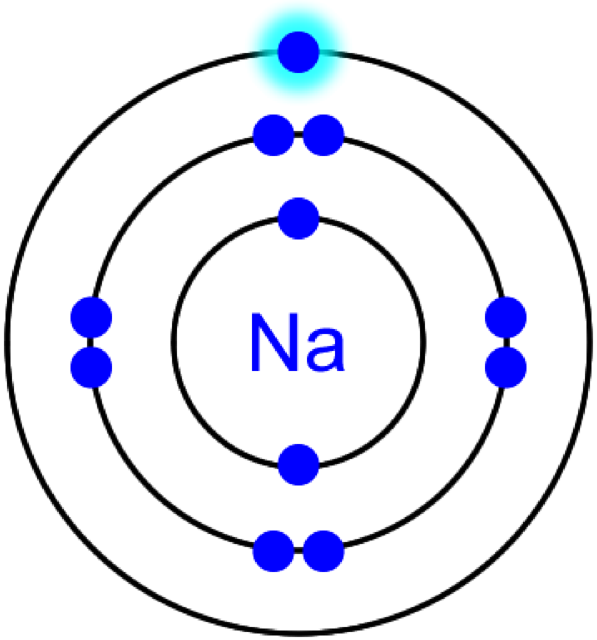


- Sodium must *lose one electron* to complete its valence shell (full octet / Noble Gas electronic configuration).

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

- Sodium has one electron in its valence shell.

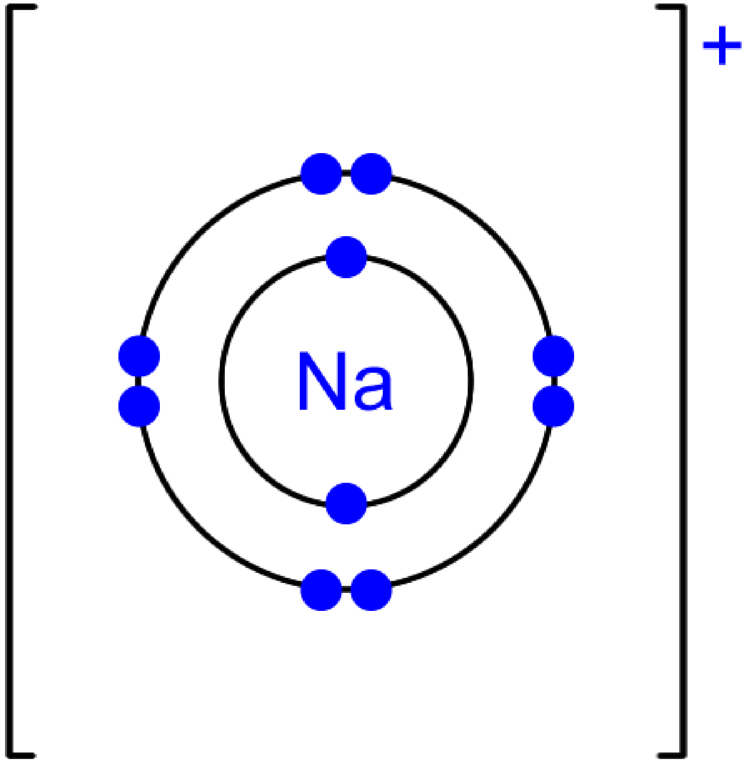


- Sodium must *lose one electron* to complete its valence shell (full octet / Noble Gas electronic configuration).

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

- Sodium gives an electron to another chemical.



- The other chemical *gains an electron* and is therefore *reduced*. Sodium is the *reducing agent*.

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

Reactivity Series of Metals

- Potassium
- Sodium
- Calcium
- Magnesium
- Aluminium
- Zinc
- Iron
- Copper
- Silver

Good / Strong Reducing Agents

Poor / Weak Reducing Agents

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Oxidising Agents and Reducing Agents

- Note: Hydrogen peroxide, H_2O_2, can be a good oxidising agent and also a good reducing agent depending upon the pH of the reaction.

- Under acidic conditions, hydrogen peroxide is reduced and therefore serves as an oxidising agent:

$$H_2O_{2(aq)} + 2H^+_{(aq)} + 2e^- \rightarrow 2H_2O_{(l)}$$

- Under alkaline conditions, hydrogen peroxide is oxidised and therefore serves as a reducing agent:

$$H_2O_{2(aq)} + 2OH^-_{(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)} + 2e^-$$

- The equation for the disproportionation reaction is:

$$2H_2O_{2(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$$

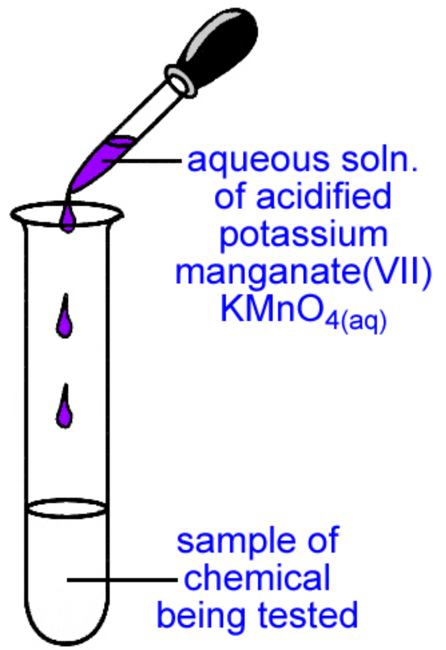
Reduction and Oxidation – Redox

How do I test for oxidising agents and reducing agents?

Reduction and Oxidation – Redox

Test for Reducing Agents

Using Acidified Potassium Manganate(VII)



$$MnO_4^-{}_{(aq)} + 8H^+{}_{(aq)} + 5e^- \rightarrow Mn^{2+}{}_{(aq)} + 4H_2O_{(l)}$$

Purple → Colourless

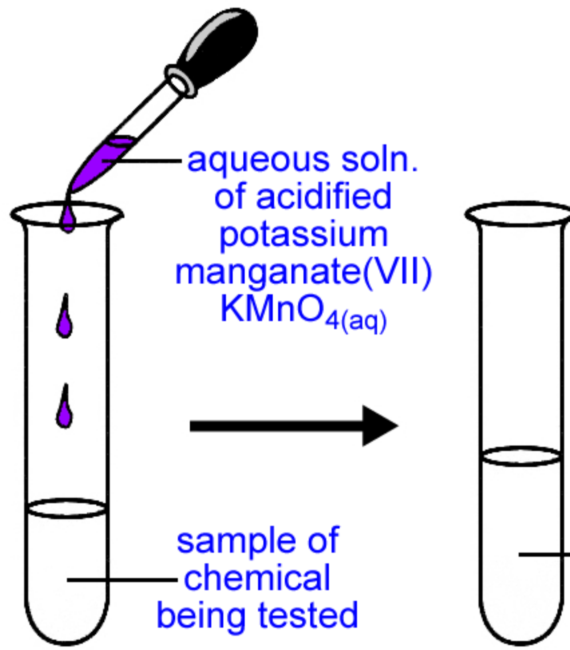
- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Test for Reducing Agents

Using Acidified Potassium Manganate(VII)

Result if the chemical being tested is a reducing agent:



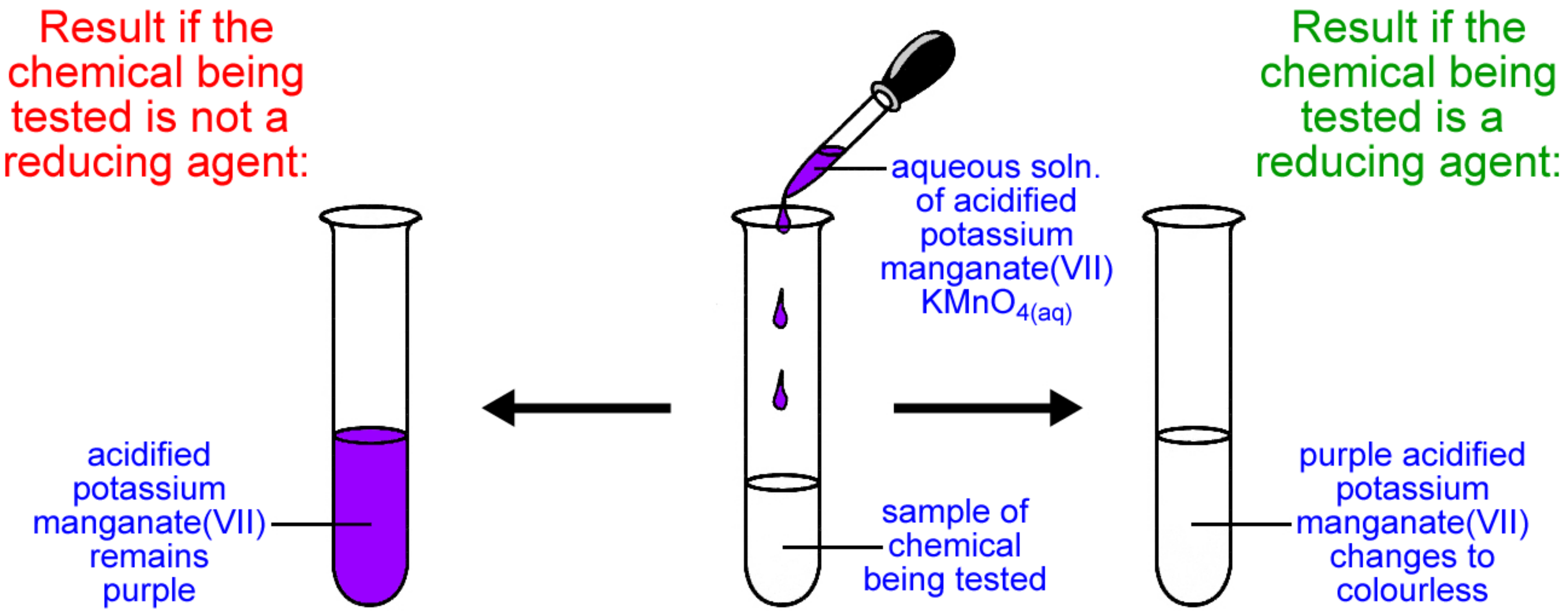
$$MnO_4^-{}_{(aq)} + 8H^+{}_{(aq)} + 5e^- \rightarrow Mn^{2+}{}_{(aq)} + 4H_2O_{(l)}$$

Purple — Colourless

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Test for Reducing Agents
Using Acidified Potassium Manganate(VII)



$$MnO_4^-{}_{(aq)} + 8H^+{}_{(aq)} + 5e^- \rightarrow Mn^{2+}{}_{(aq)} + 4H_2O_{(l)}$$

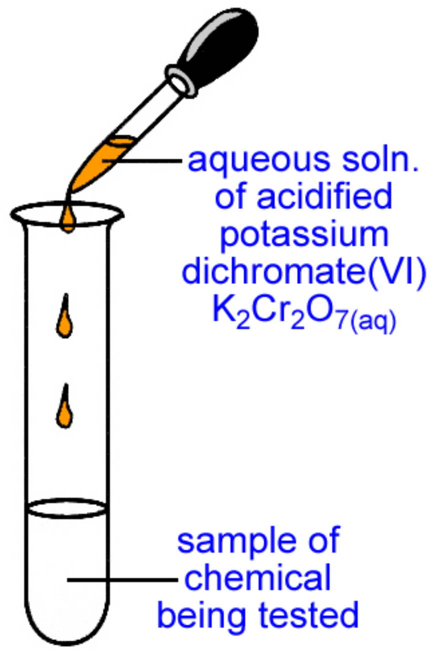
Purple — Colourless

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Test for Reducing Agents

Using Acidified Potassium Dichromate(VI)



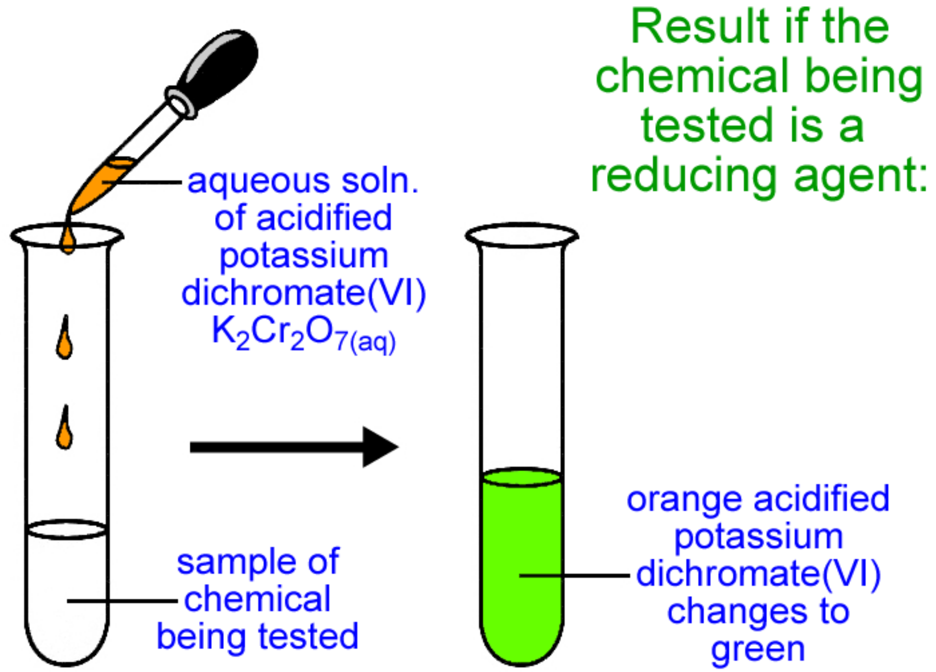
$$Cr_2O_7^{2-}{}_{(aq)} + 14H^+{}_{(aq)} + 6e^- \rightarrow 2Cr^{3+}{}_{(aq)} + 7H_2O_{(l)}$$

Orange Green

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Test for Reducing Agents
Using Acidified Potassium Dichromate(VI)



$$Cr_2O_7^{2-}{}_{(aq)} + 14H^+{}_{(aq)} + 6e^- \rightarrow 2Cr^{3+}{}_{(aq)} + 7H_2O_{(l)}$$

Orange ... Green

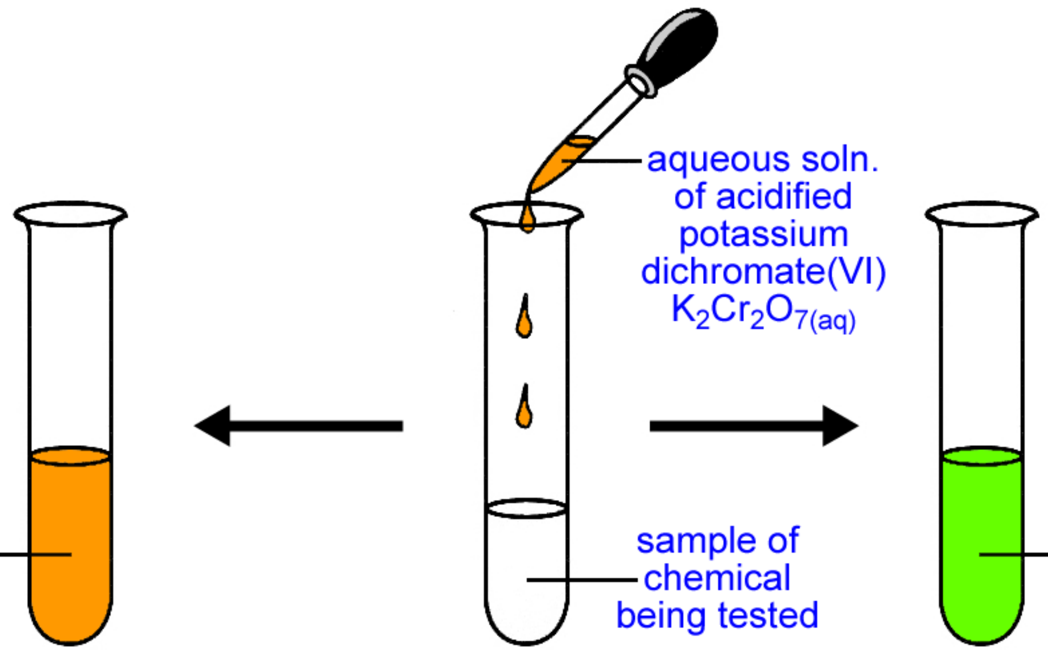
- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Test for Reducing Agents
Using Acidified Potassium Dichromate(VI)

Result if the chemical being tested is not a reducing agent:

Result if the chemical being tested is a reducing agent:



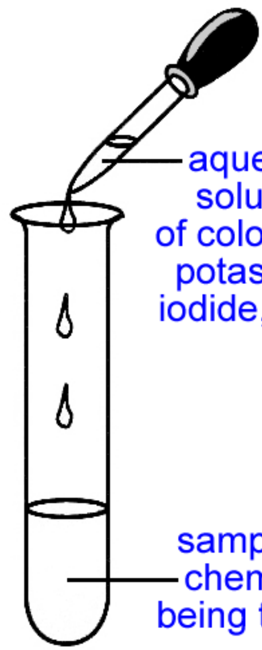
$$Cr_2O_7^{2-}{}_{(aq)} + 14H^+{}_{(aq)} + 6e^- \rightarrow 2Cr^{3+}{}_{(aq)} + 7H_2O_{(l)}$$

Orange — Green

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Test for Oxidising Agents
Using Aqueous Potassium Iodide



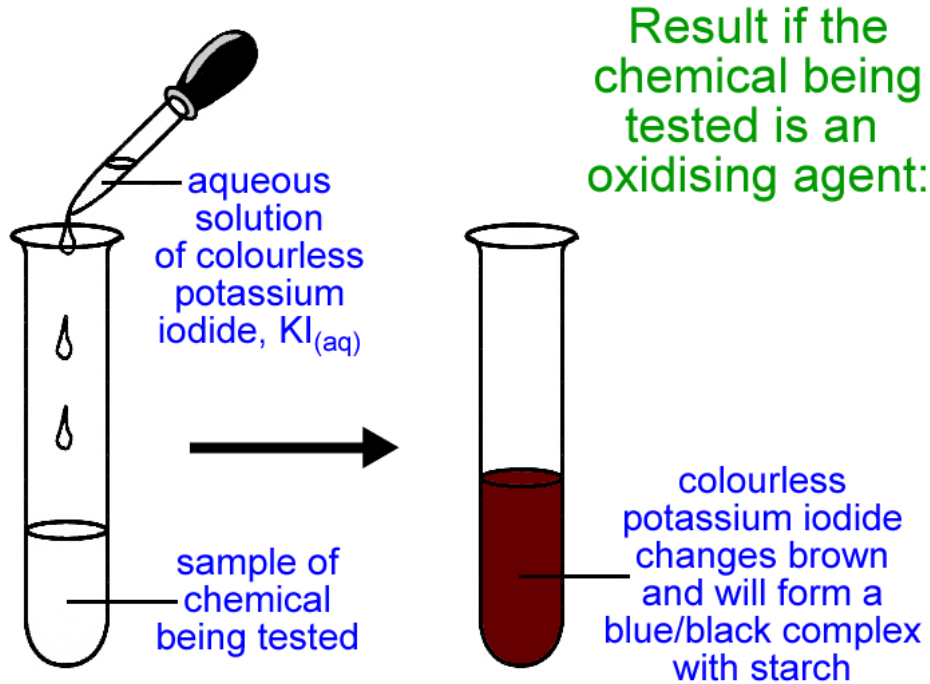
$$2I^{-}_{(aq)} \rightarrow I_{2(aq)} + 2e^{-}$$

Colourless Brown

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Test for Oxidising Agents
Using Aqueous Potassium Iodide



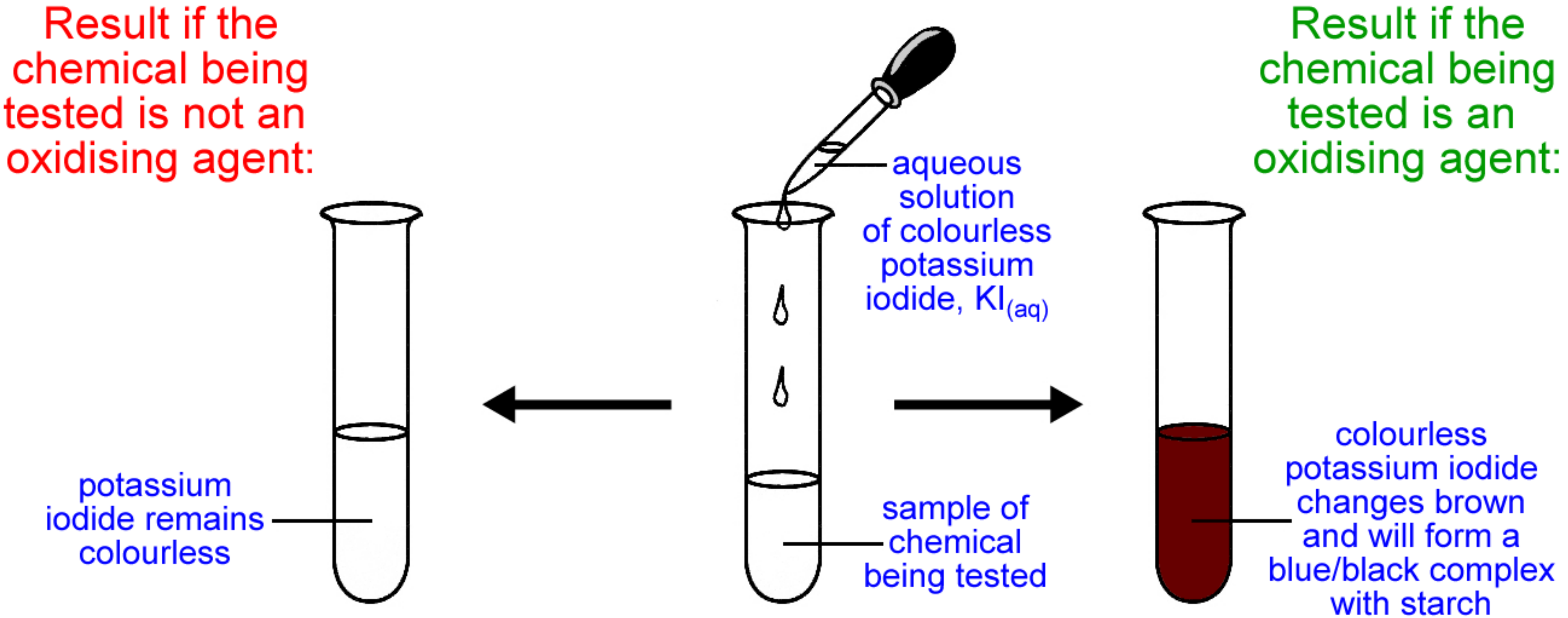
$$2I^{-}_{(aq)} \rightarrow I_{2(aq)} + 2e^{-}$$

Colourless Brown

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Test for Oxidising Agents
Using Aqueous Potassium Iodide



$$2I^{-}_{(aq)} \rightarrow I_{2(aq)} + 2e^{-}$$

Colourless Brown

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Test for Oxidising Agents
Using Aqueous Solutions of Iron(II) Salts

- Aqueous solutions of *iron(II) salts*, *e.g.* iron(II) sulfate ($FeSO_4$), can also be used to test for *oxidising agents*.
- In the presence of an oxidising agent, the *pale green* solution of *iron(II) ions* will be oxidised to form a *pale yellow* solution of *iron(III) ions*.

$$Fe^{2+}_{(aq)} \rightarrow Fe^{3+}_{(aq)} + e^{-}$$

- The presence of $Fe^{2+}_{(aq)}$ and $Fe^{3+}_{(aq)}$ can be confirmed through qualitative analysis by adding $NaOH_{(aq)}$.
$Fe^{2+}_{(aq)}$ will give a green precipitate of $Fe(OH)_{2(s)}$.
$Fe^{3+}_{(aq)}$ will give a reddish-brown precipitate of $Fe(OH)_{3(s)}$.

- Oxidation: → Gain of oxygen. → Loss of hydrogen. → Loss of electrons. → Increase in oxidation state.
- Reduction: → Loss of oxygen. → Gain of hydrogen. → Gain of electrons. → Decrease in oxidation state.

Reduction and Oxidation – Redox

Can I do any *titrations* using oxidising agents and reducing agents?

Reduction and Oxidation – Redox

Redox Titration

Reduction and Oxidation – Redox

Redox Titration

$$MnO_4^-{}_{(aq)} + 8H^+{}_{(aq)} + 5e^- \rightarrow Mn^{2+}{}_{(aq)} + 4H_2O_{(l)}$$

$$Fe^{2+}{}_{(aq)} \rightarrow Fe^{3+}{}_{(aq)} + e^-$$

Reduction and Oxidation – Redox

Redox Titration

$$MnO_4^{-}{}_{(aq)} + 8H^+{}_{(aq)} + 5e^- \rightarrow Mn^{2+}{}_{(aq)} + 4H_2O_{(l)}$$

$$Fe^{2+}{}_{(aq)} \rightarrow Fe^{3+}{}_{(aq)} + e^- \times 5$$

$$5Fe^{2+}{}_{(aq)} \rightarrow 5Fe^{3+}{}_{(aq)} + 5e^-$$

Reduction and Oxidation – Redox

Redox Titration

$$MnO_4^-{}_{(aq)} + 8H^+{}_{(aq)} + 5e^- \rightarrow Mn^{2+}{}_{(aq)} + 4H_2O_{(l)}$$

$$Fe^{2+}{}_{(aq)} \rightarrow Fe^{3+}{}_{(aq)} + e^- \times 5$$

$$5Fe^{2+}{}_{(aq)} \rightarrow 5Fe^{3+}{}_{(aq)} + 5e^-$$

$$MnO_4^-{}_{(aq)} + 5Fe^{2+}{}_{(aq)} + 8H^+{}_{(aq)} + 5e^-$$

$$\downarrow$$

$$Mn^{2+}{}_{(aq)} + 5Fe^{3+}{}_{(aq)} + 4H_2O_{(l)} + 5e^-$$

Reduction and Oxidation – Redox

Redox Titration

$$MnO_4^{-}{}_{(aq)} + 8H^{+}{}_{(aq)} + 5e^{-} \rightarrow Mn^{2+}{}_{(aq)} + 4H_2O_{(l)}$$

$$Fe^{2+}{}_{(aq)} \rightarrow Fe^{3+}{}_{(aq)} + e^{-} \times 5$$

$$5Fe^{2+}{}_{(aq)} \rightarrow 5Fe^{3+}{}_{(aq)} + 5e^{-}$$

$$MnO_4^{-}{}_{(aq)} + 5Fe^{2+}{}_{(aq)} + 8H^{+}{}_{(aq)} + \cancel{5e^{-}}$$
$$\downarrow$$
$$Mn^{2+}{}_{(aq)} + 5Fe^{3+}{}_{(aq)} + 4H_2O_{(l)} + \cancel{5e^{-}}$$

$$MnO_4^{-}{}_{(aq)} + 5Fe^{2+}{}_{(aq)} + 8H^{+}{}_{(aq)}$$
$$\downarrow$$
$$Mn^{2+}{}_{(aq)} + 5Fe^{3+}{}_{(aq)} + 4H_2O_{(l)}$$

Reduction and Oxidation – Redox

Redox Titration

- 1 mol of MnO_4^- ions react with 5 mol of Fe^{2+} ions.

- The reaction is described as *self indicating*, *i.e.* no indicator needs to be added. This is because the moment one drop of excess purple $KMnO_4$ is added to the flask, the solution turns a permanent pale pink colour.

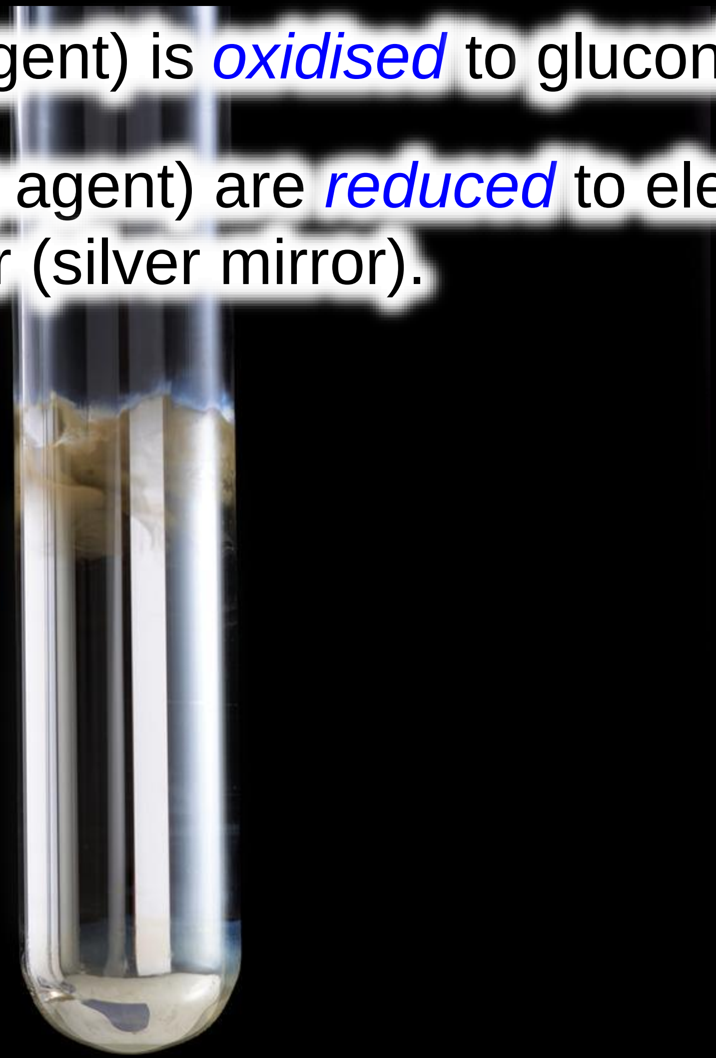
Reduction and Oxidation – Redox

I did the test for *reducing sugars* in Biology. What is the Chemistry behind that?

Reduction and Oxidation – Redox

Test for Reducing Sugars – Tollens' Reagent

- Glucose (reducing agent) is *oxidised* to gluconic acid.
- Silver ions (oxidising agent) are *reduced* to elemental silver (silver mirror).



Reduction and Oxidation – Redox

Test for Reducing Sugars – Tollens' Reagent

$$C_6H_{12}O_{6(aq)} + H_2O_{(l)} \rightarrow C_6H_{12}O_{7(aq)} + 2H^+_{(aq)} + 2e^-$$

$$Ag^+_{(aq)} + e^- \rightarrow Ag_{(s)}$$

Reduction and Oxidation – Redox

Test for Reducing Sugars – Tollens' Reagent

$$C_6H_{12}O_{6(aq)} + H_2O_{(l)} \rightarrow C_6H_{12}O_{7(aq)} + 2H^+_{(aq)} + 2e^-$$

$$Ag^+_{(aq)} + e^- \rightarrow Ag_{(s)} \times 2$$

becomes... $2Ag^+_{(aq)} + 2e^- \rightarrow 2Ag_{(s)}$

Reduction and Oxidation – Redox

Test for Reducing Sugars – Tollens' Reagent

$$C_6H_{12}O_{6(aq)} + H_2O_{(l)} \rightarrow C_6H_{12}O_{7(aq)} + 2H^+_{(aq)} + 2e^-$$

$$Ag^+_{(aq)} + e^- \rightarrow Ag_{(s)} \times 2$$

becomes... $2Ag^+_{(aq)} + 2e^- \rightarrow 2Ag_{(s)}$

combine $C_6H_{12}O_{6(aq)} + H_2O_{(l)} + 2Ag^+_{(aq)} + 2e^-$

$\downarrow$

$C_6H_{12}O_{7(aq)} + 2Ag_{(s)} + 2H^+_{(aq)} + 2e^-$

Reduction and Oxidation – Redox

Test for Reducing Sugars – Tollens' Reagent

$$C_6H_{12}O_{6(aq)} + H_2O_{(l)} \rightarrow C_6H_{12}O_{7(aq)} + 2H^+_{(aq)} + 2e^-$$

$$Ag^+_{(aq)} + e^- \rightarrow Ag_{(s)} \times 2$$

becomes... $2Ag^+_{(aq)} + 2e^- \rightarrow 2Ag_{(s)}$

combine

$$C_6H_{12}O_{6(aq)} + H_2O_{(l)} + 2Ag^+_{(aq)} + 2e^- \rightarrow C_6H_{12}O_{7(aq)} + 2Ag_{(s)} + 2H^+_{(aq)} + 2e^-$$

cancel e^-

$$C_6H_{12}O_{6(aq)} + H_2O_{(l)} + 2Ag^+_{(aq)} \rightarrow C_6H_{12}O_{7(aq)} + 2Ag_{(s)} + 2H^+_{(aq)}$$

Reduction and Oxidation – Redox

Test for Reducing Sugars – Benedict's / Fehling's Test

- Glucose (reducing agent) is *oxidised* to gluconic acid.
- Copper(II) ions (oxidising agent) are *reduced* to copper(I) ions (brick-red precipitate of copper(I) oxide).

Reduction and Oxidation – Redox

Test for Reducing Sugars – Benedict's / Fehling's Test

$$C_6H_{12}O_{6(aq)} + H_2O_{(l)} \rightarrow C_6H_{12}O_{7(aq)} + 2H^+_{(aq)} + 2e^-$$

$$Cu^{2+}_{(aq)} + e^- \rightarrow Cu^+_{(s)}$$

Reduction and Oxidation – Redox

Test for Reducing Sugars – Benedict's / Fehling's Test

$$C_6H_{12}O_{6(aq)} + H_2O_{(l)} \rightarrow C_6H_{12}O_{7(aq)} + 2H^+_{(aq)} + 2e^-$$

$$Cu^{2+}_{(aq)} + e^- \rightarrow Cu^+_{(s)} \times 2$$

becomes... $2Cu^{2+}_{(aq)} + 2e^- \rightarrow 2Cu^+_{(s)}$

Reduction and Oxidation – Redox

Test for Reducing Sugars – Benedict's / Fehling's Test

$$C_6H_{12}O_{6(aq)} + H_2O_{(l)} \rightarrow C_6H_{12}O_{7(aq)} + 2H^+_{(aq)} + 2e^-$$

$$Cu^{2+}_{(aq)} + e^- \rightarrow Cu^+_{(s)} \times 2$$

becomes... $2Cu^{2+}_{(aq)} + 2e^- \rightarrow 2Cu^+_{(s)}$

combine $C_6H_{12}O_{6(aq)} + H_2O_{(l)} + 2Cu^{2+}_{(aq)} + 2e^-$

$$\downarrow$$

$$C_6H_{12}O_{7(aq)} + 2Cu^+_{(s)} + 2H^+_{(aq)} + 2e^-$$

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Reduction and Oxidation – Redox

Test for Reducing Sugars – Benedict's / Fehling's Test

$$C_6H_{12}O_{6(aq)} + H_2O_{(l)} \rightarrow C_6H_{12}O_{7(aq)} + 2H^+_{(aq)} + 2e^-$$

$$Cu^{2+}_{(aq)} + e^- \rightarrow Cu^+_{(s)} \times 2$$

becomes... $2Cu^{2+}_{(aq)} + 2e^- \rightarrow 2Cu^+_{(s)}$

combine

$$C_6H_{12}O_{6(aq)} + H_2O_{(l)} + 2Cu^{2+}_{(aq)} + 2e^-$$
$$\downarrow$$
$$C_6H_{12}O_{7(aq)} + 2Cu^+_{(s)} + 2H^+_{(aq)} + 2e^-$$

cancel e^-

$$C_6H_{12}O_{6(aq)} + H_2O_{(l)} + 2Cu^{2+}_{(aq)}$$
$$\downarrow$$
$$C_6H_{12}O_{7(aq)} + 2Cu^+_{(s)} + 2H^+_{(aq)}$$

Reduction and Oxidation – Redox

What redox Chemistry takes place in a simple *battery*?

Reduction and Oxidation – Redox

Redox Reactions in Electrochemical Cells – Batteries

Reduction and Oxidation – Redox

Redox Reactions in Electrochemical Cells – Batteries

1) At one terminal of the battery (the *anode*) a chemical *loses electrons* and is therefore *oxidised*.

e.g. $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

2) The electrons flow through an external circuit (wires) where they do useful work, *e.g.* illuminate the screen on a hand phone. This movement of electrons is considered as the flow of electricity.

3) Electrons return to the other terminal of the battery (the *cathode*) where a chemical *gains* the *electrons* and is therefore *reduced*.

e.g. $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

Reduction and Oxidation – Redox

Presentation on
Redox

by Dr. Chris Slatter
christopher_john_slatter@nygh.edu.sg

Nanyang Girls' High School
2 Linden Drive
Singapore
288683

25th October 2016