National Certificate of Educational Achievement
TAUMATA MĀTAURANGA Ā-MOTU KUA TAEA

Exemplar for Internal Achievement Standard

Chemistry Level 3

This exemplar supports assessment against:

Achievement Standard AS91393

Demonstrate understanding of oxidation-reduction processes

An annotated exemplar is an extract of student evidence, with a commentary, to explain key aspects of the standard. It assists teachers to make assessment judgements at the grade boundaries.

New Zealand Qualifications Authority

To support internal assessment

	Grade Boundary: Low Excellence
1.	For Excellence, the student needs to demonstrate comprehensive understanding of oxidation reduction processes. This involves comparing and contrasting, and justifying, links between oxidation-reduction processes, observations, equations and calculations. This requires the consistent use of chemistry vocabulary, symbols, and conventions. This student has completed fully balanced equations (1) with correct calculations (2) and justifies the spontaneity of the reactions (3). The student has also compared and contrasted the oxidation-reduction processes in both electrochemical and electrolytic cells (4). For a more secure Excellence, the student could have elaborated further on the spontaneity of reactions, including the interpretation of E^{o} values. For example, linked the strengths of the reductants to the E^{o} values.

Student 1: Low Excellence
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Electrochemical Cell

Reduction at the cathode:
$H_2O_2 + 2H^+ + 2e \rightarrow 2H_2O$
The solution remains colourless as H_2O_2 and H_2O are both colourless.
This is a reduction reaction as the oxidation number of O decreases from -1 in H_2O_2 to -2 in H_2O. A decrease in oxidation number corresponds to reduction.
Each H_2O_2 gains two electrons. Gaining of electrons corresponds to reduction.

Oxidation at the anode:
$Fe^{2+} \rightarrow Fe^{3+} + e$
The solution turns from pale green Fe^{2+} to orange Fe^{3+}.
This is an oxidation reaction as the oxidation number of Fe increases from +2 in Fe^{2+} to +3 in Fe^{3+}. An increase in oxidation number corresponds to oxidation.
Each Fe^{2+} loses 1 electron, losing electrons corresponds to oxidation.

E°
An electrochemical cell is an apparatus that uses a spontaneous oxidation-reduction reaction to produce an electric current. It consists of two half cells connected by a conducting wire and a salt bridge.
For this reaction:
2 $E^\circ cell = E^\circ red - E^\circ ox = +1.77\ V - 0.77\ V = +1.00\ V$
3 As E°cell is positive, the reaction is spontaneous.
The most positive E° value will be the reduction reaction as these are reduction potentials.
The most positive E° value indicates the strongest oxidant so H_2O_2 is a stronger oxidant than Fe^{3+}. Therefore, H_2O_2 will be reduced.

Overall equation:
1 $2Fe^{2+}(aq) + H_2O_2(aq) + 2H^+(aq) \rightarrow 2H_2O(l) + 2Fe^{3+}(aq)$

Electolytic cell
From observations: The electrolysis of molten copper oxide produces bubbles of a colourless gas at one electrode and an orange solid is deposited at the other electrode.
Colourless gas is oxygen at the positive anode. Orange solid is copper and it is deposited at the negative cathode.

Reduction at the cathode (negative electrode)
$Cu^{2+} + 2e \rightarrow Cu$
The oxidation number of Cu decreases from +2 in Cu^{2+} to 0 in Cu.
Each Cu^{2+} gains 2 electrons.

Oxidation at the anode (positive electrode)
$2O^{2-} \rightarrow O_2 + 4e$
The bubbles of colourless gas are oxygen.
The oxidation number of O increases from -2 in O^{2-} to 0 in O_2.
Each O^{2-} loses 2 electrons.

1 **Overall equation**

$2Cu^{2+}(l) + 2O^{2-} (l) \rightarrow 2Cu (s) + O_2(g)$

3 **Energy requirements**

The battery provides push for electrons to move in the reverse direction to their natural tendency. The non-spontaneous reaction is forced to occur and electrical energy is consumed in order to produce a chemical reaction.

4

Electrochemical cell Reactions are spontaneous producing electrical energy.	Electrolytic cell The battery provides push for electrons to move in the reverse direction to their natural tendency. The non-spontaneous reaction is forced to occur and electrical energy is consumed in order to produce a chemical reaction.

	Grade Boundary: High Merit
2.	For Merit, the student needs to demonstrate in-depth understanding of oxidation-reduction processes. This involves making and explaining links between oxidation-reduction processes, observations, equations and calculations. This requires explanations that use chemistry vocabulary, symbols, and conventions. This student has identified what has been oxidised and reduced with reasons (1), and given balanced half equations for electrochemical and electrolytic cells (2). The student has also completed a correct reduction potential calculation for the electrochemical cell (3), explained the spontaneity of the reaction (4), and related species to the given observations (5). To reach Excellence, the student could ensure that both fully balanced equations are correct, and that they have elaborated on the spontaneity of reactions using E^o values.

Student 2: High Merit
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Electrochemical Cell

Reduction at the cathode:

2 $H_2O_2 + 2H^+ + 2e \rightarrow 2H_2O$

The solution remains colourless as H_2O_2 and H_2O are both colourless.

This is a reduction reaction as the oxidation number of O decreases from -1 in H_2O_2 to -2 in H_2O. A decrease in oxidation number corresponds to reduction.

Each H_2O_2 gains two electrons. Gaining of electrons corresponds to reduction.

Oxidation at the anode:

1 $Fe^{2+} \rightarrow Fe^{3+} + e$

The solution turns from pale green Fe^{2+} to orange Fe^{3+}.

This is an oxidation reaction as the oxidation number of Fe increases from +2 in Fe^{2+} to +3 in Fe^{3+}. An increase in oxidation number corresponds to oxidation.

Each Fe^{2+} loses 1 electron, losing electrons corresponds to oxidation.

E°

An electrochemical cell is an apparatus that uses a spontaneous oxidation-reduction reaction to produce an electric current. It consists of two half cells connected by a conducting wire and a salt bridge. The reaction is spontaneous creating electrical energy.

For this reaction:

3 E^ocell = E^ored - E^oox = +1.77 V- 0.77 V = +1.00 V

4 As E^ocell is positive, the reaction is spontaneous.

The most positive E° value will be the reduction reaction as these are reduction potentials

Overall equation:

$2Fe^{2+}(aq) + H_2O_2(aq) + H^+(aq) \rightarrow 2H_2O(l) + 2Fe^{3+}(aq)$

Electolytic cell

From observations: The electrolysis of molten copper oxide produces bubbles of a colourless gas at one electrode and an orange solid is deposited at the other electrode.

5 Colourless gas is oxygen at the positive anode. Orange solid is copper and it is deposited at the negative cathode.

Reduction at the cathode (negative electrode)

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

2 The oxidation number of Cu decreases from +2 in Cu^{2+} to 0 in Cu.

Each Cu^{2+} gains 2 electrons.

Oxidation at the anode (positive electrode)

1 $2O^{2-} \rightarrow O_2 + 4e$

The bubbles of colourless gas are oxygen.

The oxidation number of O increases from -2 in O^{2-} to 0 in O_2.

Each O^{2-} loses 2 electrons.

Overall equation

$2Cu^{2+}(l) + 2O^{2-}(l) \rightarrow 2Cu(s) + O_2(g)$

Energy requirements

The battery provides push for electrons to move in the reverse direction to their natural tendency. The non-spontaneous reaction is forced to occur and electrical energy is consumed in order to produce a chemical reaction.

	Grade Boundary: Low Merit
3.	For Merit, the student needs to demonstrate in-depth understanding of oxidation-reduction processes. This involves making and explaining links between oxidation-reduction processes, observations, equations and calculations. This requires explanations that use chemistry vocabulary, symbols, and conventions. This student has identified what has been oxidised and reduced with reasons (1) and given balanced half equations for electrochemical and electrolytic cells (2). The student has also completed a reduction potential calculation for the electrochemical cell (3), and related some species to given observations (4). For a more secure Merit, the student could relate all species to given observations, and included the correct unit for the calculation.

Student 3: Low Merit
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Electrochemical Cell

Reduction at the cathode:

2 $H_2O_2 + 2H^+ + e \rightarrow 2H_2O$

The reaction remains colourless.

1 This is a reduction reaction as the oxidation number of O decreases from -1 in H_2O_2 to -2 in H_2O. A decrease in oxidation number corresponds to reduction.

Oxidation at the anode:

$Fe^{2+} \rightarrow Fe^{3+} + e$

The solution turns from pale green Fe^{2+} to orange Fe^{3+}.

This is an oxidation reaction as the oxidation number of Fe increases from +2 in Fe^{2+} to +3 in Fe^{3+}. An increase in oxidation number corresponds to oxidation.

Each Fe^{2+} loses 1 electron, losing electrons corresponds to oxidation.

E°

For this reaction:

3 E°cell = E°red - E°ox = +1.77 - 0.77 = +1.00

The reaction is spontaneous.

Electolytic cell

From observations: The electrolysis of molten copper oxide produces bubbles of a colourless
4 gas at one electrode and an orange solid is deposited at the other electrode.

Colourless gas is oxygen at the positive anode. Orange solid is copper and it is deposited at the negative cathode.

2 **Reduction at the cathode (negative electrode)**

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

The oxidation number of Cu decreases from +2 in Cu^{2+} to 0 in Cu.

Each Cu^{2+} gains 2 electrons.

Oxidation at the anode (positive electrode)

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

The bubbles of colourless gas are oxygen.

Each O^{2-} loses 2 electrons.

This process requires electrical energy to make the non-spontaneous reaction happen.

	Grade Boundary: High Achieved
4.	For Achieved, the student needs to demonstrate understanding of oxidation-reduction processes. This involves describing oxidation-reduction processes and may involve calculations. This requires the use of chemistry vocabulary, symbols, and conventions. This student has identified what has been oxidised and reduced for electrochemical and electrolytic cells, with a description of either loss/gain of electrons or oxidation number (ON) changes (1). They have also made a reference to the requirement of energy for electrolytic cell (2) and reduction potentials for electrochemical cell (3). To reach Merit, the student could include correct half equations for all reactions.

Student 4: High Achieved
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Electrochemical Cell
Reduction at the cathode:
$H_2O_2 + e \rightarrow 2H_2O$
The reaction remains colourless.
① This is a reduction reaction as the oxidation number of O decreases from -1 in H_2O_2 to -2 in H_2O. A decrease in oxidation number corresponds to reduction.
Oxidation at the anode:
$Fe^{2+} \rightarrow Fe^{3+} + e$
The solution turns from pale green Fe^{2+} to orange Fe^{3+}.
This is an oxidation reaction as the oxidation number of Fe increases from +2 in Fe^{2+} to +3 in Fe^{3+}. An increase in oxidation number corresponds to oxidation.
Each Fe^{2+} loses 1 electron, losing electrons corresponds to oxidation.
E^o
For this reaction:
③ E^0 for H_2O_2 is the most positive (1.77) so it will be reduced.
The reaction is spontaneous creating electrical energy.

Electolytic cell
From observations: The electrolysis of molten copper oxide produces bubbles of a colourless gas at one electrode and an orange solid is deposited at the other electrode.
Colourless gas is oxygen at the positive anode. Orange solid is copper and it is deposited at the negative cathode.
Reduction at the cathode (negative electrode)
$Cu^{2+} + 2e \rightarrow Cu$
The oxidation number of Cu decreases from +2 in Cu^{2+} to 0 in Cu.
Each Cu^{2+} gains 2 electrons.
Oxidation at the anode (positive electrode)
$O^{2-} \rightarrow O_2 + 4e$
The bubbles of colourless gas are oxygen.
② Each O^{2-} loses 2 electrons.
This process requires electrical energy.

	Grade Boundary: Low Achieved
5.	For Achieved, the student needs to demonstrate understanding of oxidation-reduction processes. This involves describing oxidation-reduction processes and may involve calculations. This requires the use of chemistry vocabulary, symbols, and conventions. This student has identified what has been oxidised and reduced for electrochemical and electrolytic cells, with descriptions of either loss/gain of electrons or oxidation number (ON) changes (1), some reference to the requirement of energy for the electrolytic cell (2), and the reduction potentials for the electrochemical cell (3). For a more secure Achieved, the student could link oxidation number increase/decrease or loss/gain of electrons to oxidation and reduction processes.

Student 5: Low Achieved

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Electrochemical Cell

Reduction at the cathode:

$H_2O_2 \rightarrow 2H_2O$

The reaction remains colourless.

1 This is a reduction reaction as the oxidation number of O changes from -1 in H_2O_2 to -2 in H_2O

Oxidation at the anode:

$Fe^{2+} \rightarrow Fe^{3+} + e$

This is an oxidation reaction as the oxidation number of Fe increases from +2 in Fe^{2+} to +3 in Fe^{3+}. An increase in oxidation number corresponds to oxidation.

Each Fe^{2+} loses 1 electron, losing electrons corresponds to oxidation.

E°

3 E^0 for H_2O_2 is the most positive so it will be reduced. This reaction creates electrical energy.

Electolytic cell

From observations: The electrolysis of molten copper oxide produces bubbles of a colourless gas at one electrode and an orange solid is deposited at the other electrode.

Colourless gas is oxygen at the positive anode. Orange solid is copper and it is deposited at the negative cathode.

Reduction at the cathode (negative electrode)

$Cu^{2+} \rightarrow Cu$

The oxidation number of Cu goes from +2 in Cu^{2+} to 0 in Cu.

Each Cu^{2+} gains 2 electrons.

Oxidation at the anode (positive electrode)

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

The bubbles of colourless gas are oxygen.

Each O^{2-} loses 2 electrons.

2 This process requires external electrical energy.

	Grade Boundary: High Not Achieved
6.	For Achieved, the student needs to demonstrate understanding of oxidation-reduction processes. This involves describing oxidation-reduction processes and may involve calculations. This requires the use of chemistry vocabulary, symbols, and conventions. This student has identified what has been oxidised and reduced for electrochemical and electrolytic cells, with some reference to either loss/gain of electrons or oxidation number (ON) changes (1). To reach Achieved, the student could ensure that they have described all oxidation and reduction changes correctly, and made a reference to the requirement of energy for the electrolytic cell.

Student 6: High Not Achieved

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Electrochemical Cell

Reduction at the cathode:

$H_2O_2 \rightarrow 2H_2O$

This is a reduction reaction as the oxidation number of O changes from 0 in H_2O_2 to -2 in H_2O

1

Oxidation at the anode:

$Fe^{2+} \rightarrow Fe^{3+} + e$

This is an oxidation reaction as the oxidation number of Fe increases from +2 in Fe^{2+} to +3 in Fe^{3+}. An increase in oxidation number corresponds to oxidation.

Each Fe^{2+} loses 1 electron.

E°

E^0 for H_2O_2 is the most positive so it will be reduced. This reaction creates electrical energy.

Electolytic cell

From observations: The electrolysis of molten copper oxide produces bubbles of a colourless gas at one electrode and an orange solid is deposited at the other electrode. Colourless gas is oxygen at the positive anode. Orange solid is copper and it is deposited at the negative cathode.

Reduction at the cathode (negative electrode)

$Cu^{2+} \rightarrow Cu$

The oxidation number of Cu goes from +2 in Cu^{2+} to 0 in Cu.

Oxidation at the anode (positive electrode)

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

The bubbles of colourless gas are oxygen.

Each O^{2-} loses 2 electrons.