SOLUTIONS

ST ANDREW'S SECONDARY SCHOOL

NAME | TEACHING GROUP

CHEMISTRY (G3) **6092**

14.1 Electrolytic Cells
Assessment for Learning

ELECTROLYSIS

1 [B]

At anode (ions attracted: Cl^- & OH^-)
- [Cl^-] > [OH^-]: concentration effect applies.
- Thus, Cl^- ions are selectively discharged over OH^- ions, and lose e^- to form Cl_2 gas.
- Oxidation: 2 Cl^- (aq) → Cl_2 (g) + 2 e^-

At cathode (ions attracted: M^{2+} & H^+)
- M forms M^{2+}; valency = 2, based on MCl_2.
- Position of M is lower than H in the reactivity series: between Cu & Ag.
- Thus, M^{2+} ions are selectively discharged over H^+ ions, and gain e^- to form solid M.
- Reduction: M^{2+} (aq) + 2 e^- → M (s)

2 [A]
- Position of Cu is lower than H in the reactivity series.
- Thus, Cu^{2+} ions are selectively discharged over H^+ ions, and gain e^- to form Cu metal at cathode.
- This led to the increase in mass of the cathode.

3 [A]
- Negative electrode (cathode) attracts all 3 cations in the electrolyte (Cu^{2+}, H^+, Mg^{2+}).
- Position of Cu is the lowest amongst them in the reactivity series.
- Thus, Cu^{2+} ions are selectively discharged over H^+ and Mg^{2+} ions, and gain e^- to form Cu metal at cathode.

4 *None of the options is the correct answer...*

Option **A**: Ba^{2+} ions gain electrons at the ~~anode~~ *cathode*.
Option **B**: Ba^{2+} ions ~~lose~~ *gain* electrons at the cathode.
Option **C**: Cl^- ions ~~gain~~ *lose* electrons at the anode.
Option **D**: Cl^- ions lose electrons at the ~~cathode~~ *anode*.

5 [C]
- Position of Cu is lower than H in the reactivity series.
- Thus, Cu^{2+} ions are selectively discharged over H^+ ions, and gain e^- to form Cu metal at cathode.
- [Cu^{2+}] continues to decrease during the electrolysis, causing the blue colour of the solution to fade.

Option **A**: A pink-brown solid is deposited at the ~~anode~~ *cathode*.
Option **B**: Bubbles form at the ~~negative~~ *positive* electrode. (O_2 evolved: OH^- are discharged)
Option **D**: The negative electrode becomes ~~smaller~~ *bigger.* (size increases due to Cu deposited)

6 [B]

<u>At anode (ions attracted: Cl^- & OH^-)</u>

- $[Cl^-] > [OH^-]$: concentration effect applies.
- Thus, Cl^- ions are selectively discharged over OH^- ions, and lose e^- to form Cl_2 gas.
- Cl_2 formed dissolves back into solution: $Cl_2 + H_2O \rightarrow HCl + HOCl$ (OCl^- bleaches litmus).

<u>At cathode (ions attracted: Na^+ & H^+)</u>

- Position of Na is higher than H in the reactivity series.
- Thus, H^+ ions are selectively discharged over Na^+ ions, and gain e^- to form H_2 gas.
- $[H^+]$ decreases as the reaction progresses: $[H^+] < [OH^-]$. Litmus turns blue colour.

7 [A]

- X forms at negative electrode ⇒ X is a cation ⇒ X is metallic / ~~H^+~~ (molten compound) ⇒ X is a metal.
- Y forms at positive electrode ⇒ Y is an anion ⇒ Y is a non-metal.

8 [B]

- Bulb lights = Circuit is closed = Electrolyte used.
- Gas produced at each electrode: Cathode = H_2 ; Anode = O_2 / Cl_2.

9 [C]

- Oxidation occurs at anode. With a diatomic molecule formed at the anode, the electrodes used cannot be active, ie. inert.
- X^- ions: X has a valency of 1, X is a halogen (Group VII).
- To selectively discharge X_2,electrolyte used must be concentrated.

10 [B]

- Reduction occurs at the cathode; Oxidation occurs at the anode.
- Note the use of inert electrodes.

Eqn 2: (At anode) As inert electrodes are used, ions in the electrolyte are involved in electrolysis. Hence, OH^- ions (in the electrolyte) undergo oxidation.

Eqn 3: (At cathode) As Cu is lower than H in the reactivity series, Cu^{2+} ions are selectively discharged. Hence, Cu^{2+} ions (not H^+) undergo reduction.

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CHEMISTRY (G3) **6092**

14.2 Simple Cells
Assessment for Learning

ELECTROLYSIS

1 [D]

- The further apart two metals are in the reactivity series, the greater the voltage produced.

2 [B]

- The further apart two metals are in the reactivity series, the greater the voltage produced.
- Using a porous membrane allows certain ions to pass through, usually H^+. This ensures electrical conduction within the electrolyte (ie. closed circuit) while preventing both solutions used from mixing.

3 [B]

Statement 1 is correct: Mg/Ag is further apart compared to Mg/Cu.
Statement 2 is correct: Both positive and negative ions are required for electrical conduction.
Statement 3 is **wrong**: 'Amount of e^-' varies with the valency of the metal. Consider Na & *Al*.
Na is more reactive than *Al*. Each mole of Na loses 1 mole of e^-, whereas each mole of *Al* loses 3 moles of e^-.

4 [D]

- Zn/Cu: As Zn is more reactive than Cu, it undergoes oxidation and loses e^- to form Zn^{2+} ions.

Option **A**: Electrons move through the ~~electrolyte~~ *external circuit*.
Option **B**: Mass of the zinc electrode ~~increases~~ *decreases*.
Option **C**: ~~The electrolyte changes its colour to blue.~~ *No change in the colour of the electrolyte*.

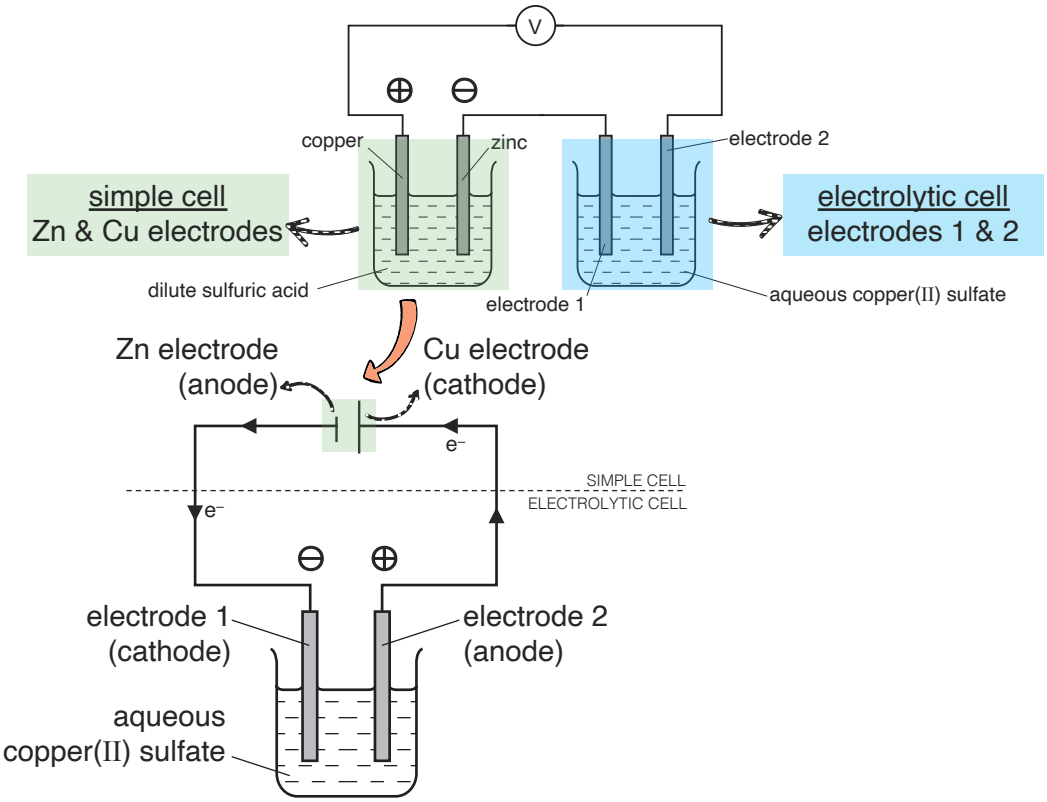
5 [D]

- Electrolyte must contain mobile ions serving as mobile charge carriers that conduct electricity in a complete circuit.

Option **A**: *Electrodes of the same metal used.*
(With both electrodes having the same electric potential energy (same metal), no electricity is being produced as there is no e^- flow between them (ie. pd = 0 V).)
Option **B**: *Solid NaCl used.*
(As the ions in the crystal lattice are still held in their fixed positions, they are not mobile and cannot conduct electricity.)
Option **C**: *Liquid C_2H_5OH (ethanol) used.*
(As ethanol molecules are covalently-bonded, they are electrically neutral. Hence, they will not be attracted to the electrodes and cannot conduct electricity.)

6 [B]

- This electrical circuit may be considered as having the cell with Zn/Cu electrodes as a battery (simple cell) connected to the cell with electrodes 1 and 2 (electrolytic cell).
- Zn is more reactive than Cu: Zn loses electrons to electrode 1: electrode 1 identified as the negatively-charged cathode of an electrolytic cell.
- Since electrode 1 is the cathode, electrode 2 will be the positively-charged anode of an electrolytic cell.



At electrode 1 (e^- rich):	Reduction occurs. Cu^{2+} ions are selectively discharged instead of H^+ ions.
[Cathode]	$\Rightarrow Cu^{2+} + 2\ e^- \rightarrow Cu$
At electrode 2:	Oxidation occurs. To complete the circuit, e^- are lost to the Cu electrode.
[Anode]	OH^- ions are selectively discharged instead of SO_4^{2-} ions.
	$\Rightarrow 4\ OH^- \rightarrow O_2 + 2\ H_2O + 4\ e^-$

7 [C]

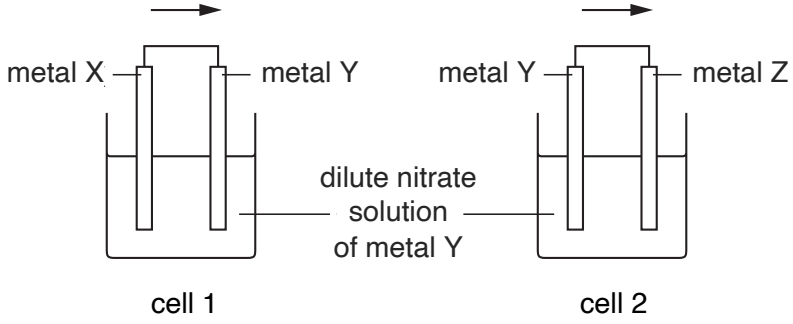
- e^- travels from the more reactive metal electrode to the less reactive metal electrode.
- Metal X undergoes oxidation to form ions by losing its e^-.

Option **A**: Copper is the ~~anode~~ *cathode*.
Option **B**: Mass of the copper electrode ~~decreases~~ *remains the same*.
Option **D**: Metal X is ~~below~~ *above* copper in the reactivity series.

Replace questions **8 – 10** *with the following*:

Use the information provided below to answer questions **8** – **10**.

Metals X, Y and Z form two simple cells using dilute nitrate solution of metal Y as electrolyte, as shown in the diagrams. The arrows represent the directions of electron flow in each cell.



8 Which set of metals would lead to the electron flow in the directions shown?

	X	Y	Z
A	Cu	Zn	Mg
B	Mg	Cu	Zn
C	Mg	Zn	Cu
D	Zn	Mg	Cu

9 Which statement about the observation made in cell 1 is correct?

A Effervescence is observed at the metal X electrode.
B Size of the metal X electrode decreases.
C Size of the metal Y electrode increases.
D The electrolyte changes colour.

10 Which statement about the observation made in cell 2 is correct?

A A grey solid is deposited at the metal Z electrode.
B Effervescence is observed at the metal Z electrode.
C Size of the metal Y electrode increases.
D The electrolyte changes colour.

8 [C]

- Direction of e^- flow in both cells: X → Y → Z.
- Arrange the 3 metals (Mg, Zn, Cu) according to their positions in the reactivity series.

9 [B]

- e^- flows from the more reactive metal electrode to the less reactive metal electrode.
- Metal X undergoes oxidation to form ions by losing its e^-: $X \rightarrow X^{2+} + 2\ e^-$.

Option **A**: Effervescence is observed at the ~~metal X~~ *metal Y* electrode.
Option **C**: Size of the metal Y electrode ~~increases~~ *remains constant*.
Option **D**: ~~The electrolyte changes colour.~~ *Colour of the electrolyte remains unchanged.*

10 [B]

- e^- flows from the more reactive metal electrode to the less reactive metal electrode.
- Metal Y undergoes oxidation to form ions by losing its e^-: $Y \rightarrow Y^{2+} + 2\ e^-$.
- H^+ ions are selectively reduced instead of Y^{2+} (aq) to form H_2 gas as the effervescence observed.

Option **A**: A grey solid is deposited at the metal Z electrode. *There will not be any solid deposited.*
Option **C**: Size of the metal Y electrode ~~increases~~ *decreases*.
Option **D**: ~~The electrolyte changes colour.~~ *Colour of the electrolyte remains unchanged.*

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CHEMISTRY (G3) 6092

14.3 Practical Applications of Electrochemistry
Assessment for Learning

ELECTROLYSIS

1 [D]
- The more reactive metal undergoes oxidation instead.
- Describes 'Sacrificial protection': amount of sacrificial metal does not affect the reaction.

2 [D]
- Na reacts explosively in solution.
- Na is too reactive a metal to allow Na^+ ions be selectively discharged at the cathode during electroplating.

3 [B]
- Cu from the impure anode will move towards the cathode made of pure Cu.

4 [A]
- Hydrogen is oxidised at the negatively-charged anode: H_2 (g) + 2 OH^- (aq) → 2 H_2O (l) + 2 e^-.
- Oxygen is reduced at the positively-charged cathode: O_2 (g) + 2 H_2O (l) + 4 e^- → 4 OH^- (aq).

5 [B]
- It is expensive to produce H_2 gas sustainably/ renewably through the electrolysis of water. (Note: H_2 gas produced from the cracking of hydrocarbons should **not** be considered 'renewable'.)
- Also, H_2 gas must be liquefied under high pressure for storage and transportation before refuelling. To achieve this, special equipment must be used, which increases costs.

Option **A**: The hydrogen fuel cell produces ~~less~~ *more* energy compared to combustion of fossil fuels in engines.
Option **C**: ~~The hydrogen gas used is highly flammable.~~ *All fuels are flammable.*
Option **D**: The product formed is ~~an environmental pollutant~~ *harmless to the environment*.

6 [D]
- Cathode (–ve terminal): Article to be electroplated (steel key)
- Anode (+ve terminal): Metal (copper)

7 [B]
- Al_2O_3 must be in the molten state for electrolysis to occur.
- The Al metal formed should be in its molten state before it flows out of the apparatus.

Option **A**: Both aluminium and aluminium oxide are in the liquid states, with aluminium formed at the ~~anode~~ *cathode*.

8 [B]
- At anode: As concentrated sodium chloride solution (brine) is used, [Cl^-] >> [OH^-]. Cl^- ions are selectively discharged at the anode to form Cl_2 gas. 2 Cl^- → Cl_2 + 2 e^-
- At cathode: The position of H is lower than Na in the reactivity series. H^+ ions are selectively discharged at the cathode to form H_2 gas. 2 H^+ + 2 e^- → H_2

9 [B]

- Article to be electroplated must be the negatively-charged cathode.
- Between the two allotropes of carbon, only graphite is conductive.

10 [C]

Statement 1 is correct: Cu undergoes oxidation as it is the positively-charged anode.
$Cu \rightarrow Cu^{2+} + 2\ e^-$

Statement 2 is **wrong**: $[Cu^{2+}]$ remains constant.

Statement 3 is correct: The position of Cu is lower than H in the reactivity series. Cu^{2+} ions are selectively discharged instead of H^+ ions at the cathode.