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VCE Chemistry ¾
Galvanic Cells [1.8]
Homework Solutions

Homework Outline:
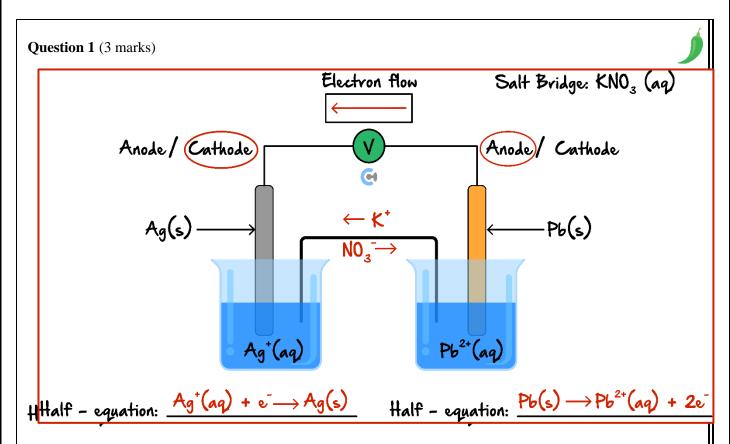
Compulsory Questions	Pg 2 — Pg 13
Supplementary Questions	Pg 14 — Pg 22

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Section A: Compulsory Questions (33 Marks)

Sub-Section [1.8.1]: Identify Electrodes, Salt Bridge/Electron Movement during Galvanic

Question 1 (3 marks)

Electron flow

Salt Bridge: KNO_3 (aq)

← [red arrow]

Anode / (Cathode)   (Anode) / Cathode

$Ag(s) \longrightarrow$ $\leftarrow Pb(s)$

$\leftarrow K^+$

$NO_3^- \rightarrow$

$Ag^+(aq)$ $Pb^{2+}(aq)$

Half – equation: $\underline{Ag^+(aq) + e^- \longrightarrow Ag(s)}$ Half – equation: $\underline{Pb(s) \longrightarrow Pb^{2+}(aq) + 2e^-}$
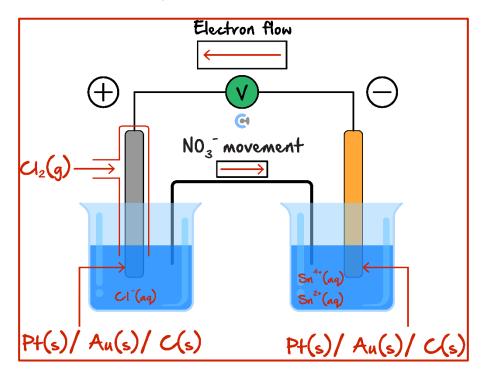
Use the provided diagram of a galvanic cell, write the half-equations, and label the cathode, anode, electron flow and salt bridge ion movement in the salt bridge.

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Question 2 (4 marks)

A reaction can occur between $Sn^{4+}(aq)/Sn^{2+}(aq)$ and $Cl_2(g)/Cl^-(aq)$. A galvanic cell template is shown below, with the polarities of the electrodes already indicated.

Electron flow

$Cl_2(g) \rightarrow$

NO_3^- movement

$Sn^{4+}(aq)$
$Sn^{2+}(aq)$

$Cl^-(aq)$

Pt(s)/ Au(s)/ C(s)   Pt(s)/ Au(s)/ C(s)

a. Write the balanced half-equation for the reaction occurring at the:

   i. Positive electrode. (0.5 marks)

$$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$$

   ii. Negative electrode. (0.5 marks)
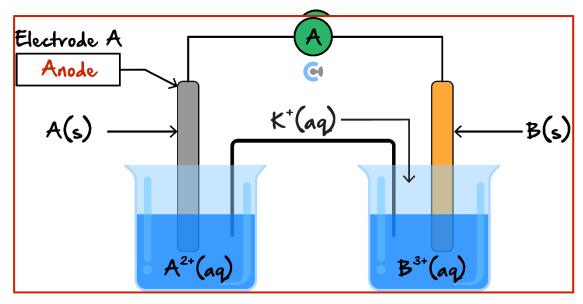
$$Sn^{2+}(aq) \rightarrow Sn^{4+}(aq) + 2e^-$$

b. Label suitable substances present in the electrolyte and the materials which make up each electrode in the diagram above. (1 mark)

c. Label the direction of electron flow and the movement of nitrate ions in the salt bridge in their respective boxes in the diagram above. (2 marks)

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Question 3 (3 marks)

The following galvanic cell is constructed.

Electrode A
Anode

A(s) $\longrightarrow$

$K^+(aq)$

$B(s)$

$A^{2+}(aq)$

$B^{3+}(aq)$

a. Label electrode *A* acting as the cathode or anode in the box provided above. (1 mark)

b. Write the overall reaction which takes place. (2 marks)
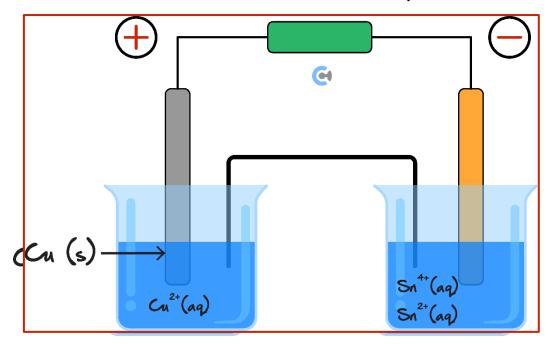
_____

$$3A(s) + 2B^{3+}(aq) \rightarrow 2B(s) + 3A^{2+}(aq)$$

_____

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Sub-Section [1.8.2]: Write Reactions in Galvanic Cells & Calculate the Maximum EMF Produced

Question 4 (3 marks)

A galvanic cell is constructed as shown below, with $1.0\ M$ of each of the electrolytes.

a. Label the polarities of the electrodes in the circles provided above. (1 mark)

b. Write the half-equation which occurs at the cathode. (1 mark)

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

c. Find the maximum theoretical EMF produced as the cell runs. (1 mark)

$$0.19\ V$$

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Question 5 (3 marks)

Ishan is investigating the Sn^{4+}/Sn^{2+} and Fe^{3+}/Fe^{2+} half-cells.

a. Write the half-equations for the galvanic cell. (2 marks)

Oxidation:

1. **Anode (oxidation):**
$$Sn^{2+}(aq) \rightarrow Sn^{4+}(aq) + 2e^-$$
(Sn^{2+} is oxidized to Sn^{4+}).

2. **Cathode (reduction):**
$$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$$

Reduction:

(Fe^{3+} is reduced to Fe^{2+}).

b. Calculate the EMF of the cell, given the concentration of the electrolytes is $1.0\,M$. (1 mark)

From standard electrode potentials ($E°$):

- $E°(Sn^{4+}/Sn^{2+}) = +0.15\,V$
- $E°(Fe^{3+}/Fe^{2+}) = +0.77\,V$

The EMF of the galvanic cell is calculated as:
$$EMF = E°(cathode) - E°(anode)$$
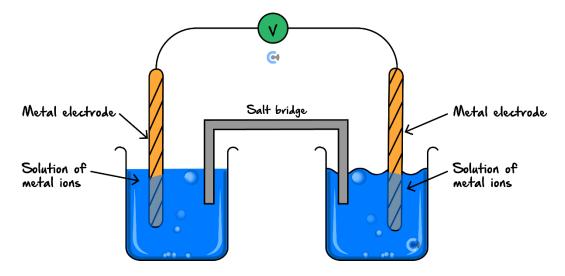$$EMF = 0.77 - 0.15 = 0.62\,V$$

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Question 6 (2 marks)

a. Four half-cells are constructed as follows:

- **Half-cell I:** An electrode of metal M in a 1.0 M solution of M^+ ions.

- **Half-cell II:** An electrode of metal N in a 1.0 M solution of N^+ ions.

- **Half-cell III:** An electrode of metal P in a 1.0 M solution of P^+ ions.

- **Half-cell IV:** An electrode of Q metal in a 1.0 M solution of Q^{2+} ions.

The half-cells are connected in pairs as shown below to form a series of galvanic cells.

For each cell, the polarity of the electrodes and the voltage generated are recorded:

Half-cells used	Positive electrode	Negative electrode	Voltage produced (V)
I and IV	M	Q	0.46
II and IV	Q	N	0.57
III and IV	Q	P	1.10
II and III	N	P	0.53

Which of the following alternatives lists the metals in order of increasing strength as reductants? (1 mark)

A. P, N, Q, M
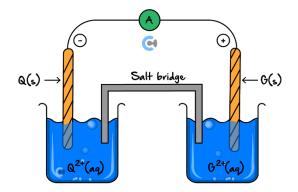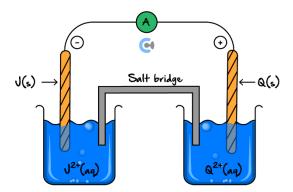
B. M, Q, N, P

C. Q, M, P, N

D. P, Q, N, M

b. The following diagrams represent combinations of four galvanic half-cells (G/G^{2+}, J/J^{2+}, Q/Q^{2+} and R/R^{2+}) that were investigated under standard conditions.
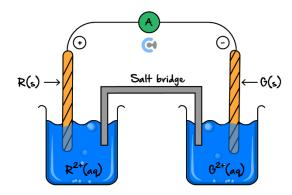
Each half-cell consisted of a metal electrode placed in a 1.0 M nitrate solution of the respective metal ion.

The diagrams show the polarity of the electrodes in each half-cell, as determined using an ammeter.

The results were then used to determine the order of the $E°$ values of the half-reactions.

Which of the following sequences the reductants from strongest to weakest? (1 mark)

A. J, Q, G, R
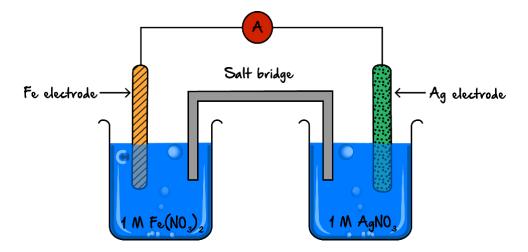
B. R, G, Q, J

C. R, J, Q, G

D. G, Q, J, R

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Sub-Section [1.8.3]: Identify & Explain Observations during Operation of Galvanic Cells

Question 7 (1 mark)

A galvanic cell is set up as shown in the diagram below.
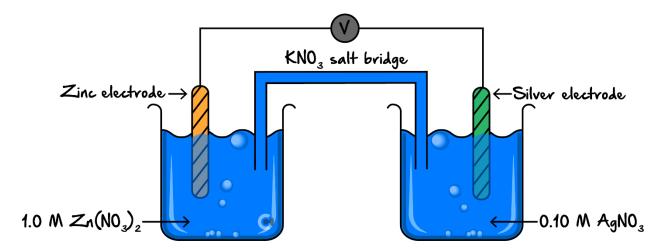

When this cell is operating:

A. Gas forms at the **Fe** electrode.

B. The mass of the **Fe** electrode decreases.

C. NO_3^- ions move towards the **Ag** electrode.

D. Electrons move from the **Ag** electrode to the **Fe** electrode.

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Question 8 (2 marks)

The following information applies to the two questions that follow.

a. Which one of the following statements about the cell above is true as the cell discharges? (1 mark)

    A. The zinc electrode is the cathode.

    B. The concentration of Ag^+ ions will decrease.

    C. The maximum voltage delivered by this cell will be $1.48\ V$.

    D. Electrons in the external circuit will flow from the zinc electrode to the silver electrode.

b. What should be observed at the zinc electrode as the cell discharges? (1 mark)

    A. No change will be observed at this electrode.

    B. The electrode will become thinner as zinc dissolves into the solution.

    C. Bubbles of gas will form at the zinc electrode.

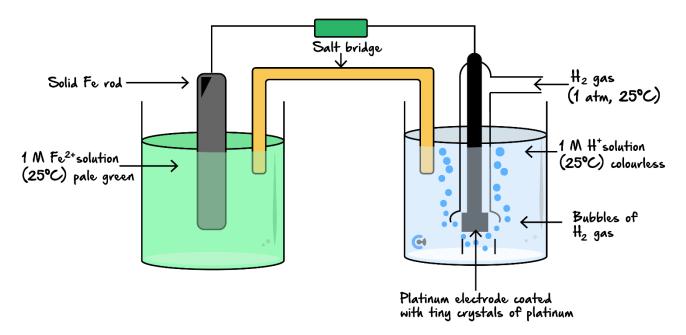   **D.** A layer of zinc nitrate crystals will deposit on the electrode.

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Question 9 (2 marks)

The following diagram shows a galvanic cell that is set up in a university laboratory.

The half-cell on the right is called the standard hydrogen electrode (SHE). It is the standard against which all standard redox potentials are compared. Hydrogen gas, H_2, is continually bubbled into this half-cell.

a. Which one of the following would occur at the platinum electrode when the cell discharges? (1 mark)

   A. Hydrogen gas would be reduced at the platinum electrode, forming H^+ ions.

   B. The platinum electrode would serve as the cathode in this cell and have negative polarity.

   C. The concentration of H^+ ions around the platinum electrode would increase.

   D. Electrons would flow from the iron electrode to the platinum electrode through the external circuit.

b. What is one change that would be expected in the Fe^{2+}/Fe half-cell as the cell discharges? (1 mark)

   A. The solution colour would change from pale green to a darker shade.

   B. Fe^{2+} ions would plate onto the iron electrode, increasing its mass.

   C. Bubbles of hydrogen gas would form at the iron electrode surface.

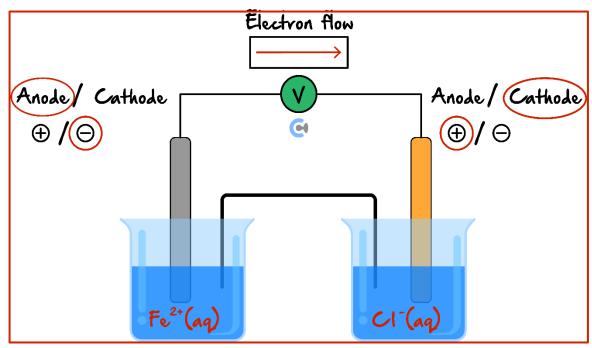   **D.** The pH of the solution would decrease due to an increase in H^+ ions.

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Sub-Section: The 'Final Boss'

Question 10 (10 marks)

Michelle is interested in the $Cl_2(g)/Cl^-(aq)$ and $Fe^{2+}(aq)/Fe(s)$ galvanic cell. A diagram has been provided below. Michelle knows that the left electrode loses mass as the experiment proceeds.

Electron flow

Anode / Cathode

$\oplus$ / $\ominus$

V

Anode / Cathode

$\oplus$ / $\ominus$

$Fe^{2+}(aq)$

$Cl^-(aq)$

a. Fill in the diagram above labelling the: (3 marks)

    i. Electron flow.

    ii. The ions present in each half-cell.

    iii. The anode and cathode and their respective polarities.

b. Calculate the EMF produced in the cell. (1 mark)

$$E^{\circ}_{cell} = E^{\circ}_{cathode} - E^{\circ}_{anode}$$

$$E^{\circ}_{cell} = +1.36 - (-0.44)$$
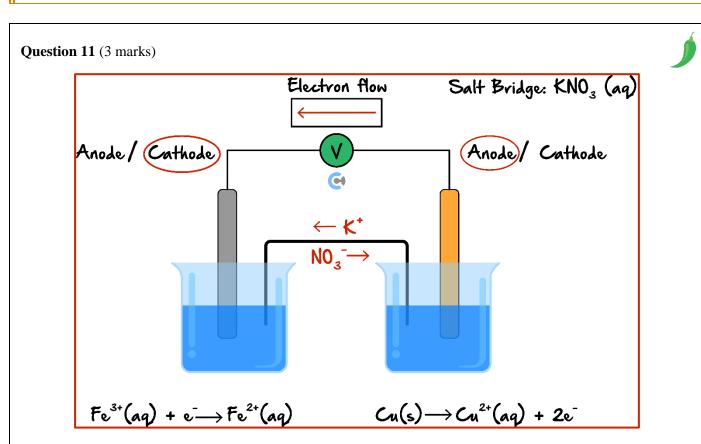
$$E^{\circ}_{cell} = 1.36 + 0.44 = 1.80 \, V$$

c. Michelle notices that the left half-cell begins to change in colour.

   i. Predict the colour change occurring. (1 mark)

   > Becomes more intensely green

   ii. Justify **part c.i**. (1 mark)

   > Iron solid is oxidising, therefore increasing the concentration of Fe^{2+} ions (1).
   > An increase in concentration results in a darker green colour. (2)

d. Michelle submerges the iron electrode in a solution of H^+ ions. Predict and justify the energy conversion which occurs. (2 marks)

   > Chemical $\rightarrow$ Thermal energy (1). This is because the oxidant and reductant
   > are in direct contact with each other (2).

e. The Fe^{2+}/Fe half-cell is connected to an unknown half-cell, and electrons flow from the unknown half-cell to the Fe^{2+}/Fe half-cell.

   Predict and justify whether the half-reaction occurring in the unknown half-cell is of a higher or lower $E°$ value than the $Fe^{2+}(aq)/Fe(s)$ half-cell. (2 marks)

   > Smaller (1). Electrons flow away from the unknown half-cell indicating that
   > it contains the anode (2). This means that it must have the lower $E°$ value.

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Section B: Supplementary Questions (26 Marks)

Sub-Section [1.8.1]: Identify Electrodes, Salt Bridge/Electron Movement during Galvanic

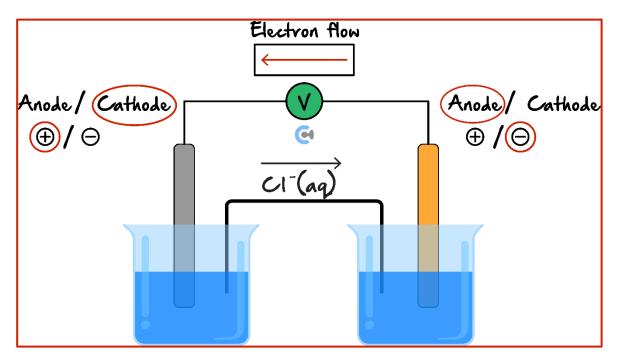**Question 11** (3 marks)

Use the provided diagram of a galvanic cell, and label the cathode, anode, electron flow and ion movement in the salt bridge.

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Question 12 (3 marks)

Use the provided galvanic cell diagram to label the cathode, anode, electrode polarities and electron flow.

Electron flow

Anode / Cathode

$\oplus$ / $\ominus$

V

$\overrightarrow{Cl^-(aq)}$

Anode / Cathode

$\oplus$ / $\ominus$
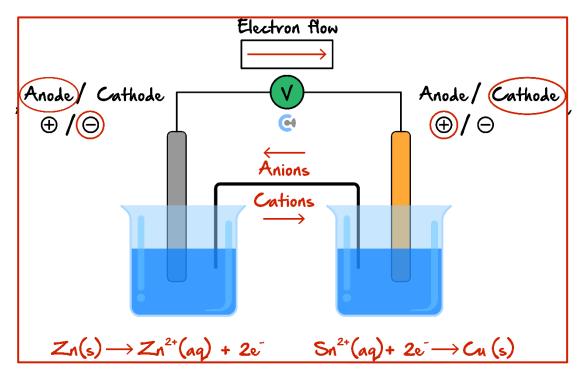
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Question 13 (3 marks)

Use the provided half-equations:

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

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

Draw the galvanic cell, labelling the anode, cathode, electron flow, ion movement in the salt bridge and electrode polarities.
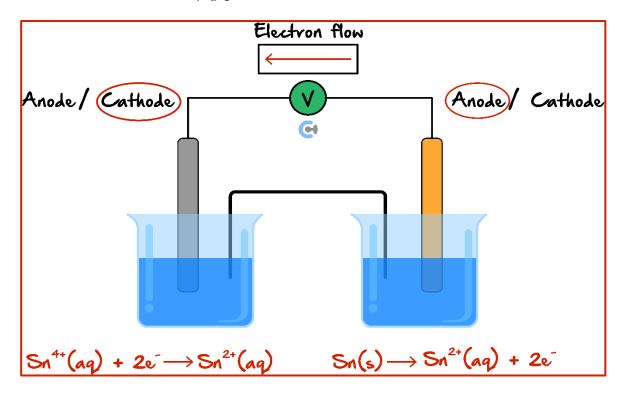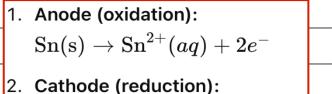

Electron flow →

Anode / Cathode
$\oplus$ / $\ominus$

V

Anode / Cathode
$\oplus$ / $\ominus$

← Anions

Cations →

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

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Sub-Section [1.8.2]: Write Reactions in Galvanic Cells & Calculate the Maximum EMF Produced

Question 14 (5 marks)

Matthias is interested in the Sn-Sn^{4+}(aq) galvanic cell.

Electron flow

Anode / **Cathode**   Anode / Cathode

$Sn^{4+}(aq) + 2e^- \longrightarrow Sn^{2+}(aq)$ $Sn(s) \longrightarrow Sn^{2+}(aq) + 2e^-$

a. Write the half-equations for this cell. (2 marks)

1. **Anode (oxidation):**
$$Sn(s) \rightarrow Sn^{2+}(aq) + 2e^-$$

2. **Cathode (reduction):**
$$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$$

b. Label the cathode, anode, their polarities and electron flow in the diagram above. (3 marks)

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Question 15 (7 marks)

Angel is curious about the Cu^{2+}/Cu^+ and Cr^{3+}/Cr^{2+} half-cell. The half-equation for the cells and their relative $E°$ values are provided.

$$Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq) \quad E° = -0.41\,V$$

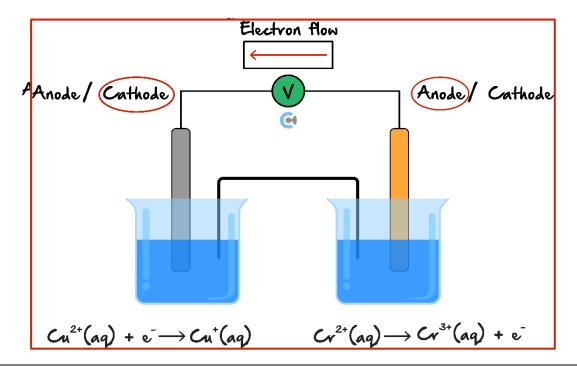$$Cu^{2+}(aq) + e^- \rightarrow Cu^+(aq) \quad E° = +0.15\,V$$

a. Write the half-equations for the galvanic cell. (2 marks)

Oxidation: $Cr^{3+}(aq) \rightarrow Cr^{2+}(aq) + e^-$
Reduction: $Cu^{2+}(aq) + e^- \rightarrow Cu^+(aq)$

b. Calculate the EMF of the cell. (2 marks)

$$E°_{cell} = 0.15 - (-0.41)$$

$$E°_{cell} = 0.15 + 0.41 = 0.56\,V$$

c. Label the galvanic cell in Angel's experiment. (3 marks)

Electron flow

Anode / Cathode   V   Anode / Cathode

$Cu^{2+}(aq) + e^- \longrightarrow Cu^+(aq)$ $Cr^{2+}(aq) \longrightarrow Cr^{3+}(aq) + e^-$

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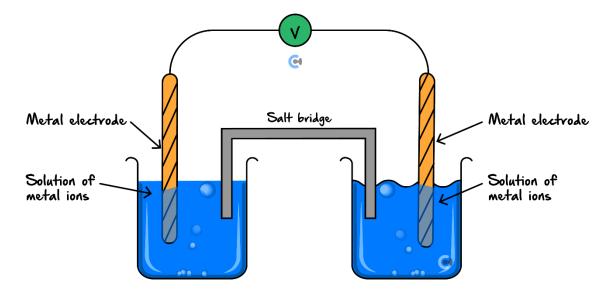VCE Chemistry ¾ Questions? Message +61 440 137 304

Question 16 (1 mark)

Four half-cells are constructed as follows.

- **Half-cell I:** An electrode of metal X in a 1.0 M solution of X^+ ions.

- **Half-cell II:** An electrode of metal Y in a 1.0 M solution of Y^+ ions.

- **Half-cell III:** An electrode of metal Z in a 1.0 M solution of Z^+ ions.

- **Half-cell IV:** An electrode of W metal in a 1.0 M solution of W^{2+} ions.

The half-cells are connected in pairs as shown below to form a series of galvanic cells.
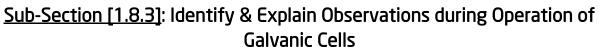

Half-cells used	Positive electrode	Negative electrode	Voltage produced (V)
I and IV	X	W	0.35
II and IV	W	Y	0.45
III and IV	W	Z	1.20
II and III	Y	Z	0.65

Which of the following alternatives lists the metals in order of increasing strength as reductants? (1 mark)

A. Z, Y, W, X

B. X, W, Y, Z

C. W, X, Z, Y

D. Z, W, X, Y

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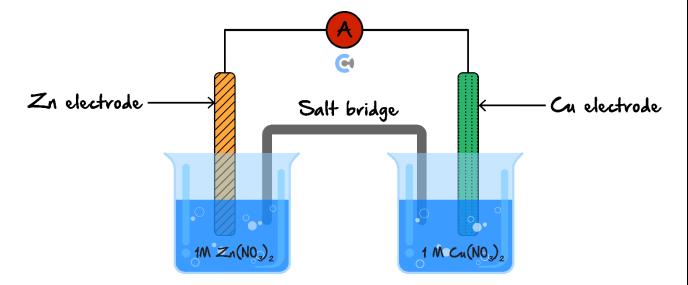## Sub-Section [1.8.3]: Identify & Explain Observations during Operation of Galvanic Cells

Question 17 (1 mark)

A galvanic cell is set up as shown in the diagram below with Zn/Zn^{2+} and Cu/Cu^{2+} half-cells.

When this cell is operating:

A. A gas forms at the Zn electrode.

B. The mass of the Cu electrode increases.

C. Zn^{2+} ions move towards the **s**alt bridge.

D. Electrons move from the Cu electrode to the Zn electrode.

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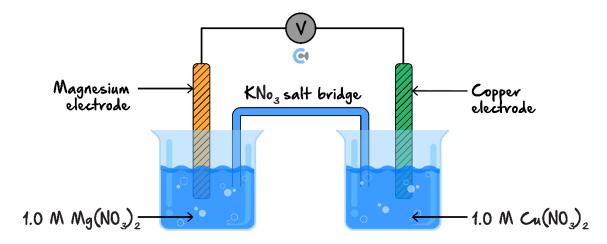VCE Chemistry ¾ Questions? Message +61 440 137 304

Question 18 (2 marks)

The following diagram is relevant to the two questions below.

a. Which one of the following statements about the cell above is true as the cell discharges? (1 mark)

    A. The copper electrode is the anode.

    B. The concentration of Mg^{2+} ions will increase.

    C. The maximum voltage delivered by this cell will be $2.71\ V$.

    D. Electrons in the external circuit will flow from the magnesium electrode to the copper electrode.

b. What should be observed at the magnesium electrode as the cell discharges? (1 mark)

    A. No change will be observed at this electrode.

    B. The electrode will become thinner as magnesium dissolves into the solution.

    C. Crystals will form over the surface of the electrode.

    D. Bubbles of gas will form over the surface of the electrode.
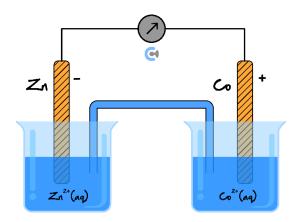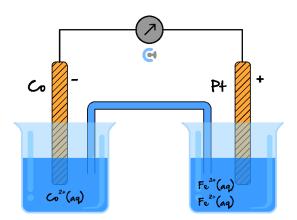
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Question 19 (1 mark)

Two standard galvanic cells are shown below.

On the basis of the polarity of the electrodes shown above, which one of the following reactions would **not** be expected to occur spontaneously? (1 mark)

A. $Co^{2+}(aq) + Zn(s) \rightarrow Co(s) + Zn^{2+}(aq)$

B. $2Fe^{3+}(aq) + Co(s) \rightarrow 2Fe^{2+}(aq) + Co^{2+}(aq)$

C. $2Fe^{3+}(aq) + Zn(s) \rightarrow 2Fe^{2+}(aq) + Zn^{2+}(aq)$

D. $2Fe^{2+}(aq) + Co^{2+}(aq) \rightarrow 2Fe^{3+}(aq) + Co(s)$

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