IBDP HL Chemistry: Electrochemistry Worksheet

Total Marks: 50
Time: 90 minutes

SECTION A: Multiple Choice Questions (20 × 1 mark = 20 marks)

Instructions: Select the best answer for each question.

1. In a galvanic cell, which statement is correct?

- **(A)** Oxidation occurs at the cathode
- **(B)** The anode is the positive electrode
- **(C)** Electrons flow from the anode to the cathode through the external circuit
- **(D)** The electrolyte moves from anode to cathode

2. What is the standard cell potential ($E°_{cell}$) for a cell with $E°_{cathode} = +0.80\ V$ and $E°_{anode} = -0.44\ V$?

- **(A)** $+0.36\ V$
- **(B)** $+1.24\ V$
- **(C)** $-0.36\ V$
- **(D)** $+2.04\ V$

3. Which of the following is a secondary cell?

- **(A)** Leclanchè cell
- **(B)** Daniell cell
- **(C)** Lead-acid battery
- **(D)** Alkaline cell

4. In an electrolytic cell, the species that is oxidized is deposited at:

- **(A)** The anode
- **(B)** The cathode
- **(C)** Both anode and cathode
- **(D)** Neither electrode

5. Using Faraday's law, how many moles of electrons are transferred when 2 Faradays of charge pass through an electrolytic cell?

- **(A)** 0.5 mol
- **(B)** 1 mol
- **(C)** 2 mol
- **(D)** 4 mol

6. The relationship between $\Delta G°$, $E°_{cell}$, and n is:

- **(A)** $\Delta G° = nFE°_{cell}$
- **(B)** $\Delta G° = -nFE°_{cell}$
- **(C)** $\Delta G° = \dfrac{nFE°_{cell}}{2}$
- **(D)** $\Delta G° = nFE°_{cell} + RT$

7. A current of 2 A flows through an electrolytic cell for 1 hour. What is the total charge passed (in Coulombs)?

- **(A)** 2 C
- **(B)** 120 C
- **(C)** 3600 C
- **(D)** 7200 C

8. What is the primary advantage of a secondary cell over a primary cell?

- **(A)** Higher voltage
- **(B)** Can be recharged
- **(C)** Longer shelf life
- **(D)** Lower cost

9. In the Nernst equation, $E = E° - \frac{0.0592}{n} \log Q$, what does Q represent?

- **(A)** Equilibrium constant
- **(B)** Reaction quotient
- **(C)** Standard cell potential
- **(D)** Charge in Coulombs

10. Which statement about electrodes in a galvanic cell is true?

- **(A)** The cathode is where reduction occurs
- **(B)** The anode is where reduction occurs
- **(C)** Both electrodes undergo oxidation
- **(D)** The cathode has higher mass than the anode

11. For a spontaneous electrochemical process:

- **(A)** $E°_{cell} < 0$ and $\Delta G° > 0$
- **(B)** $E°_{cell} > 0$ and $\Delta G° < 0$
- **(C)** $E°_{cell} < 0$ and $\Delta G° < 0$
- **(D)** $E°_{cell} > 0$ and $\Delta G° > 0$

12. In electrolysis of aqueous NaCl using inert electrodes, what is produced at the anode?

- **(A)** Cl_2 and H_2O
- **(B)** Cl_2 only
- **(C)** O_2 and HCl
- **(D)** Na and Cl_2

13. How many grams of Cu can be deposited from a $CuSO_4$ solution using 4 Faradays of charge? (Molar mass of Cu = 64 g/mol)

- **(A)** 64 g
- **(B)** 128 g
- **(C)** 32 g
- **(D)** 256 g

14. The Gibbs free energy change is zero when:

- **(A)** The cell is at equilibrium ($E_{cell} = 0$)
- **(B)** The cell potential is maximum
- **(C)** Oxidation is complete
- **(D)** The anode dissolves completely

15. In a primary cell, which of the following is non-rechargeable?

- **(A)** Ni-Cd battery
- **(B)** Lead-acid battery
- **(C)** Alkaline battery
- **(D)** Lithium-ion battery

16. For the half-reaction: $Cr^{3+} + 3e^- \rightleftharpoons Cr$, how many moles of Cr are produced by 9 Faradays of charge?

- **(A)** 1 mol
- **(B)** 2 mol
- **(C)** 3 mol
- **(D)** 9 mol

17. Which factor does NOT affect the cell potential at non-standard conditions?

- **(A)** Concentration of ions
- **(B)** Temperature
- **(C)** The color of the electrode
- **(D)** Pressure (for gaseous species)

18. In an electrolytic cell, if 4 mol of electrons are transferred, how many Faradays of charge have passed?

- **(A)** 0.5 F
- **(B)** 1 F
- **(C)** 2 F
- **(D)** 4 F

19. The standard reduction potential for $Zn^{2+} + 2e^- \rightleftharpoons Zn$ is −0.76 V. This indicates:

- **(A)** Zn²⁺ is easily reduced
- **(B)** Zn is easily oxidized
- **(C)** Zn²⁺ is a strong oxidizing agent
- **(D)** Zn metal is a weak reducing agent

20. At equilibrium in an electrochemical cell:

- **(A)** $E_{cell} = E°_{cell}$
- **(B)** $E_{cell} = 0$
- **(C)** $\Delta G > 0$
- **(D)** $Q = 0$

SECTION B: Structured Questions (3 × 10 marks = 30 marks)

Question 1: Electrochemical Cell Analysis (10 marks)

A galvanic cell is constructed using a **Zn/Zn²⁺** electrode and a **Cu/Cu²⁺** electrode. The standard reduction potentials are:

- $Cu^{2+} + 2e^- \rightleftharpoons Cu \quad E° = +0.34 \ V$
- $Zn^{2+} + 2e^- \rightleftharpoons Zn \quad E° = -0.76 \ V$

The cell contains 1.0 M solutions of both ions at 25°C.

(a) Identify which electrode is the anode and which is the cathode. Explain your reasoning. **(2 marks)**

(b) Write the half-reactions occurring at each electrode and the overall cell reaction. **(3 marks)**

(c) Calculate the standard cell potential ($E°_{cell}$). **(2 marks)**

(d) Calculate $\Delta G°$ for this cell at 25°C using $\Delta G° = -nFE°_{cell}$, where $F = 96,500 \ C/mol$. Is the reaction spontaneous? **(3 marks)**

Question 2: Quantity of Electricity and Electrolysis (10 marks)

During the electrolysis of molten **NaCl**, a current of **5.0 A** is passed for **2 hours**.

(a) Calculate the total charge (in Coulombs) that passes through the cell. **(2 marks)**

(b) Determine the number of Faradays of charge. **(1 mark)**

(c) Write the half-reactions at the anode and cathode during the electrolysis of molten NaCl. **(2 marks)**

(d) Calculate the mass of **Na** deposited at the cathode. (Molar mass of Na = 23 g/mol) **(3 marks)**

(e) Calculate the volume of **Cl₂** gas produced at the anode at STP. **(2 marks)**

Question 3: Primary and Secondary Cells with Gibbs Free Energy (10 marks)

(a) Distinguish between **primary cells** and **secondary cells**, providing one example of each. **(3 marks)**

(b) A lead-acid battery has a standard cell potential of **2.0 V** and operates with $n = 2$ (moles of electrons transferred per mole of reaction). Calculate $\Delta G°$ for the discharge reaction. **(3 marks)**

(c) Explain why a secondary cell can be recharged while a primary cell cannot. Consider the reversibility of reactions in your answer. **(2 marks)**

(d) For an electrochemical cell at non-standard conditions, the Nernst equation is applied. If $E° = 0.50\ V$, $n = 2$, and $Q = 4$ (at 25°C), calculate the cell potential E_{cell}. Use $E = E° - \frac{0.0592}{n} log\ Q$. **(2 marks)**