(1) Which statement describes the redox reaction that occurs when an object is electroplated?
A) It is spontaneous and requires an electric current.
B) It is spontaneous and produces an electric current.
C) It is non-spontaneous and produces an electric current.
D) It is non-spontaneous and requires an electric current.

Base your answers to questions 2 and 3 on the diagram below which represents the electroplating of a metal fork with Ag(s).

![Diagram of electroplating](image)

(2) Which equation represents the half-reaction that takes place at the fork?
A) \( \text{Ag}^+ + e^- \rightarrow \text{Ag(s)} \)
B) \( \text{Ag}^+ + \text{NO}_3^- \rightarrow \text{AgNO}_3 \)
C) \( \text{AgNO}_3 \rightarrow \text{Ag}^+ + \text{NO}_3^- \)
D) \( \text{Ag(s)} \rightarrow \text{Ag}^+ + e^- \)

(3) Which part of the electroplating system is provided by the fork?
A) the anode, which is the negative electrode
B) the cathode, which is the positive electrode
C) the cathode, which is the negative electrode
D) the anode, which is the positive electrode

(4) A standard zinc half-cell is connected to a standard copper half cell by means of a wire and a salt bridge. Which electronic equation represents the oxidation reaction that takes place?
A) \( \text{Cu}^{2+} + 2e^- \rightarrow \text{Cu}^0 \)
B) \( \text{Zn}^{2+} + 2e^- \rightarrow \text{Zn}^0 \)
C) \( \text{Cu}^0 - 2e^- \rightarrow \text{Cu}^{2+} \)
D) \( \text{Zn}^0 - 2e^- \rightarrow \text{Zn}^{2+} \)

(5) A battery consists of which type of cells?
A) electroplating
B) electrochemical
C) electromagnetic
D) electrolytic

The diagram below shows the electrolysis of fused KCl.

![Diagram of electrolysis](image)

(6) What occurs when the switch is closed?
A) Positive ions migrate toward the anode, where they lose electrons.
B) Positive ions migrate toward the cathode, where they lose electrons.
C) Positive ions migrate toward the cathode, where they gain electrons.
D) Positive ions migrate toward the anode, where they gain electrons.

(7) Reduction occurs at the cathode in
A) neither electrolytic cells nor voltaic cells
B) both electrolytic cells and voltaic cells
C) electrolytic cells, only
D) voltaic cells, only

(8) Which energy conversion occurs in an operating electrolytic cell?
A) electrical energy to chemical energy
B) thermal energy to nuclear energy
C) chemical energy to electrical energy
D) nuclear energy to thermal energy

(9) In a chemical cell, electrical energy will be produced when
A) neither oxidation nor reduction occurs
B) energy is required for the reaction to occur
C) energy is produced when the reaction occurs
D) both oxidation and reduction occur

(10) A voltaic cell differs from an electrolytic cell in that in a voltaic cell
A) neither oxidation nor reduction occurs
B) energy is required for the reaction to occur
C) energy is produced when the reaction occurs
D) both oxidation and reduction occur
(11) Which statement describes one characteristic of an operating electrolytic cell?

A) It produces electrical energy.
B) It undergoes a spontaneous redox reaction.
C) It uses radioactive nuclides.
D) It requires an external energy source.

Base your answer to the following question on the diagram below which represents a chemical cell at 298 K and 1 atmosphere.

(12) Which species represents the cathode?

A) Cu²⁺  B) Zn  C) Zn²⁺  D) Cu

(13) Which procedure requires the use of an external electric current to force a redox reaction to occur?

A) electrolysis  B) saponification  C) distillation  D) polymerization

A student collects the materials and equipment below to construct a voltaic cell:

• two 250-mL beakers
• wire and a switch
• one strip of magnesium
• one strip of copper
• 125 mL of 0.20 M Mg(NO₃)₂(aq)
• 125 mL of 0.20 M Cu(NO₃)₂(aq)

(14) Which additional item is required for the construction of the voltaic cell?

A) an anode  B) a battery  C) a cathode  D) a salt bridge

The diagram below shows a key being plated with copper in an electrolytic cell

CuSO₄(aq)  Copper electrode  Battery

(15) Given the reduction reaction for this cell:

Cu²⁺(aq) + 2e⁻ → Cu(s)

This reduction occurs at

A) B, which is the anode  B) A, which is the cathode  C) B, which is the cathode  D) A, which is the anode

Base your answer to the following question on the diagram below of an electrolytic cell in which the electrodes are tin and copper.

(16) When the switch is closed, what will happen to the two electrodes?

A) A will dissolve and B will become coated with copper.  B) A will dissolve and B will become coated with tin.
C) B will dissolve and A will become coated with copper.  D) B will dissolve and A will become coated with tin.

(17) A voltaic cell spontaneously converts

A) electrical energy to chemical energy  B) electrical energy to nuclear energy  C) chemical energy to electrical energy  D) nuclear energy to electrical energy
(18) Given the redox reaction in an electrochemical cell:

\[ \text{Ni(s)} + \text{Pb}^{2+}(\text{aq}) \leftrightarrow \text{Ni}^{2+}(\text{aq}) + \text{Pb(s)} \]

A salt bridge is used to connect

A) \( \text{Pb}^{2+}(\text{aq}) \) and \( \text{Pb(s)} \)
B) \( \text{Ni(s)} \) and \( \text{Pb(s)} \)
C) \( \text{Pb}^{2+}(\text{aq}) \) and \( \text{Ni}^{2+}(\text{aq}) \)
D) \( \text{Ni(s)} \) and \( \text{Ni}^{2+}(\text{aq}) \)

(19) In an electrolytic cell, the anode is always the

A) positive electrode, where oxidation occurs
B) negative electrode, where reduction occurs
C) negative electrode, where oxidation occurs
D) positive electrode, where reduction occurs

(20) What is indicated when a chemical cell's voltage \( (E^0) \) has dropped to zero?

A) The cell reaction has reached equilibrium.
B) The concentration of the products has decreased.
C) The concentration of the reactants has increased.
D) The cell reaction has completely stopped.

(21) Which statement describes where the oxidation and reduction half-reactions occur in an operating electrochemical cell?

A) Oxidation and reduction both occur at the cathode.
B) Oxidation occurs at the anode, and reduction occurs at the cathode.
C) Oxidation occurs at the cathode, and reduction occurs at the anode.
D) Oxidation and reduction both occur at the anode.

A diagram of a chemical cell and an equation are shown below.

\[ \text{Pb(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Pb}^{2+}(\text{aq}) + \text{Cu(s)} \]

(22) When the switch is closed, electrons will flow from

A) the \( \text{Pb(s)} \) to the \( \text{Cu(s)} \)
B) the \( \text{Cu}^{2+}(\text{aq}) \) to the \( \text{Cu(s)} \)
C) the \( \text{Pb}^{2+}(\text{aq}) \) to the \( \text{Pb(s)} \)
D) the \( \text{Cu(s)} \) to the \( \text{Pb(s)} \)

(23) Explain the purpose of the battery in this cell.

Electroplating is an electrolytic process used to coat metal objects with a more expensive and less reactive metal. The diagram below shows an electroplating cell that includes a battery connected to a silver bar and a metal spoon. The bar and spoon are submerged in AgNO\(_3\)(aq).
Base your answers to questions 24 and 25 on the information below.

The diagram and balanced ionic equation below represent a voltaic cell with copper and silver electrodes and the reaction that occurs when the cell is operating.

\[
\text{Cu(s) + 2Ag}^+(aq) \rightarrow \text{Cu}^{2+}(aq) + 2\text{Ag(s)}
\]

(24) Describe the direction of electron flow in the external circuit in this operating cell.

(25) State the purpose of the salt bridge in this voltaic cell.

(26) What is the oxidation number of nitrogen in NO(g)?

(27) Explain, in terms of activity, why HCl(aq) reacts with Zn(s), but HCl(aq) does not react with Cu(s).
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Examples: – The battery provides the electrical energy necessary for the reaction to occur.

Acceptable responses include, but are not limited to: • The salt bridge allows for the migration of ions between the half-cells. • The salt bridge prevents polarization of the half-cells maintains electrical neutrality

Acceptable responses include, but are not limited to: • The salt bridge allows for the migration of ions between the half-cells. • The salt bridge prevents polarization of the half-cells maintains electrical neutrality

+2

Acceptable responses include, but are not limited to: • Zinc is more active than hydrogen, but copper is less active than hydrogen. • On Table J, Zn is above H₂, and Cu is below H₂.

Acceptable responses include, but are not limited to: • Electrons flow from the copper electrode to the silver electrode through the wires and voltmeter. • The e⁻ flow is from Cu to Ag in the external circuit from anode to cathode