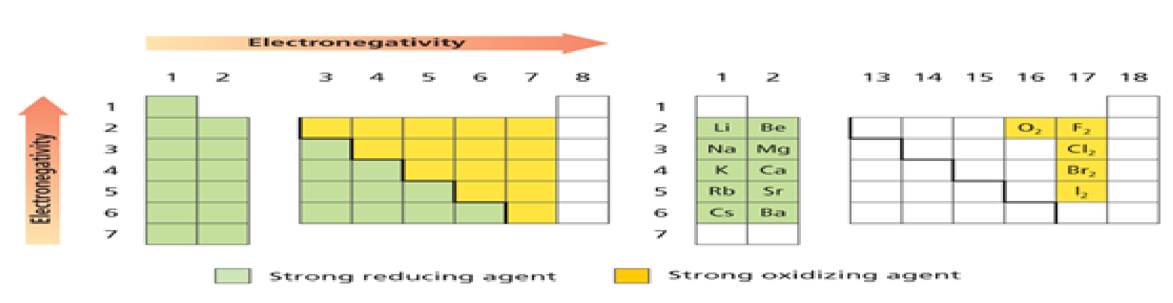


Rules for Determining Oxidation Numbers

Rule	Example	$n_{element}$
1. The oxidation number of an uncombined atom is zero.	Na, O_2, Cl_2, H_2	0
2. The oxidation number of a monatomic ion is equal to the charge of the ion.	Ca^{2+}	+2
	Br^-	−1
3. The oxidation number of the more-electronegative atom in a molecule or a complex ion is the same as the charge it would have if it were an ion.	N in NH_3	−3
	O in NO	−2
4. The oxidation number of the most-electronegative element, fluorine, is always −1 when it is bonded to another element.	F in LiF	−1
5. The oxidation number of oxygen in compounds is always −2 except in peroxides, such as hydrogen peroxide (H_2O_2), where it is −1. When it is bonded to fluorine, the only element more electronegative than oxygen, the oxidation number of oxygen is positive.	O in NO_2	−2
	O in H_2O_2	−1
6. The oxidation number of hydrogen in most of its compounds is +1, except in metal hydrides; then, the oxidation number is −1.	H in NaH	−1
7. The oxidation numbers of group 1 and 2 metals and aluminum are positive and equal to their number of valence electrons.	K	+1
	Ca	+2
	Al	+3
8. The sum of the oxidation numbers in a neutral compound is zero.	$CaBr_2$	(+2) + 2(−1) = 0
9. The sum of the oxidation numbers of the atoms in a polyatomic ion is equal to the charge of the ion.	SO_3^{2-}	(+4) + 3(−2) = −2

Standerd Reductin Potentials

Half-Reaction	$E°$ (V)	Half-Reaction	$E°$ (V)
$Li^+ + e^- \rightarrow Li$	−3.0401	$Cu^{2+} + e^- \rightarrow Cu^+$	+0.153
$Ca^{2+} + 2e^- \rightarrow Ca$	−2.868	$Cu^{2+} + 2e^- \rightarrow Cu$	+0.3419
$Na^+ + e^- \rightarrow Na$	−2.71	$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$	+0.401
$Mg^{2+} + 2e^- \rightarrow Mg$	−2.372	$I_2 + 2e^- \rightarrow 2I^-$	+0.5355
$Be^{2+} + 2e^- \rightarrow Be$	−1.847	$Fe^{3+} + e^- \rightarrow Fe^{2+}$	+0.771
$Al^{3+} + 3e^- \rightarrow Al$	−1.662	$NO_3^- + 2H^+ + e^- \rightarrow NO_2 + H_2O$	+0.775
$Mn^{2+} + 2e^- \rightarrow Mn$	−1.185	$Hg_2^{2+} + 2e^- \rightarrow 2Hg$	+0.7973
$Cr^{2+} + 2e^- \rightarrow Cr$	−0.913	$Ag^+ + e^- \rightarrow Ag$	+0.7996
$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$	−0.8277	$Hg^{2+} + 2e^- \rightarrow Hg$	+0.851
$Zn^{2+} + 2e^- \rightarrow Zn$	−0.7618	$2Hg^{2+} + 2e^- \rightarrow Hg_2^{2+}$	+0.920
$Cr^{3+} + 3e^- \rightarrow Cr$	−0.744	$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$	+0.957
$S + 2e^- \rightarrow S^{2-}$	−0.47627	$Br_2(l) + 2e^- \rightarrow 2Br^-$	+1.066
$Fe^{2+} + 2e^- \rightarrow Fe$	−0.447	$Pt^{2+} + 2e^- \rightarrow Pt$	+1.18
$Cd^{2+} + 2e^- \rightarrow Cd$	−0.4030	$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	+1.229
$PbI_2 + 2e^- \rightarrow Pb + 2I^-$	−0.365	$Cl_2 + 2e^- \rightarrow 2Cl^-$	+1.35827
$PbSO_4 + 2e^- \rightarrow Pb + SO_4^{2-}$	−0.3588	$Au^{3+} + 3e^- \rightarrow Au$	+1.498
$Co^{2+} + 2e^- \rightarrow Co$	−0.28	$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	+1.507
$Ni^{2+} + 2e^- \rightarrow Ni$	−0.257	$Au^+ + e^- \rightarrow Au$	+1.692
$Sn^{2+} + 2e^- \rightarrow Sn$	−0.1375	$H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$	+1.776
$Pb^{2+} + 2e^- \rightarrow Pb$	−0.1262	$Co^{3+} + e^- \rightarrow Co^{2+}$	+1.92
$Fe^{3+} + 3e^- \rightarrow Fe$	−0.037	$S_2O_8^{2-} + 2e^- \rightarrow 2SO_4^{2-}$	+2.010
$2H^+ + 2e^- \rightarrow H_2$	**0.0000**	$F_2 + 2e^- \rightarrow 2F^-$	+2.866

CHAPTER 14: Redox Reactions & Electrochemistry

Part 1:Redox Reactions

- **An oxidation-reduction reaction or redox reaction** involves the transfer of electrons from one atom to another.
- **Oxidation** is defined as the loss of electrons from atoms of a substance. $Na \rightarrow Na^+ + e^-$
- **Reduction** is defined as the gain of electrons by the atoms of a substance. $Cl_2 + 2e^- \rightarrow 2Cl^-$
- The **oxidation number** of an atom in an ionic compound is the number of electrons lost or gained by the atom when it forms an ion.
- When an atom or ion is **reduced**, the numerical value of its oxidation number decreases.
- When an atom or ion is **oxidized**, its oxidation number increases.
- Oxidation numbers are tools that scientists use to keep track of the movement of electrons in a redox reaction.
- The substance that **oxidizes** another substance by accepting its electrons is called an **oxidizing agent.**
- The oxidizing agent is the substance that is reduced in a redox reaction.
- The substance that reduces another substance by losing its electrons is the **reducing agent**.
- The reducing agent is the substance that is oxidized in a redox reaction.
- A **half-reaction** is one of the two parts of a redox reaction—the oxidation half of the reduction half.

1 Which of the following is an oxidation reaction?
CH 14
A $I_2 \rightarrow 2I^-$
B $Cl_2 \rightarrow 2Cl^-$
C $Ag^+ \rightarrow Ag$
D $Fe^{+2} \rightarrow Fe^{+3}$
When an atom or ion is oxidized, its oxidation number increases. →D

2 What happened to the chlorine in the following reaction: $Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$
CH 14
A Oxidation **B** Reduction
C Neutralization **D** Decomposition
When an atom or ion is reduced, the numerical value of its oxidation number decreases. →B

3 Which is true about the following half reaction? $Zn \rightarrow Zn^{+2} + 2e^-$
CH 14
A Zinc is a reducing agent
B Zinc atom gained an electron
C Zinc is an oxidizing agent
D It's the reduction half reaction
The reducing agent is the substance that is oxidized in a redox reaction. →A

4 What type of elements have a (+) oxidation number?
CH 14
A Noble gas **B** Metal
C Non-metal **D** Metalloid
Metals have (+) oxidation numbers →B

5 What type of elements have a (-) oxidation number?
CH 14
A Noble gases **B** Alkali Metals
C Non-metals **D** Alkaline Earth metals
Non-Metals have (-) oxidation numbers →C

6 Increasing in oxidation number is
CH 14
A Reduction **B** Oxidation
C Oxidation and reduction **D** Electroplating
Increasing in oxidation number is oxidation. →B

7 Increasing in oxidation number is
CH 14
A Reduction **B** Oxidation
C Oxidation and reduction **D** Electroplating
Decreasing in oxidation number is reduction. →A

8 What is the oxidation number of Cu^{+2}
CH 14
A 0 **B** +2
C -2 **D** +1
Oxidation numbers of an element = the charge of it. →B

9 What is the oxidation number of N^{-3}
CH 14
A 0 **B** +3
C -3 **D** +1
Oxidation numbers of an element = the charge of it. →C

10 What is the oxidation number of C in CO_3^{-2}
CH 14
A -2 **B** -4
C +4 **D** +1
-2 = (1 x oxidation no. of C) + (3 x 2)
oxidation no. of C = +4 →C

11 What is the oxidation number of Oxygen O in hydrogen peroxide H_2O_2
CH 14
A -2 **B** +1
C +2 **D** -1
Oxidation number of O in peroxides = -1 →D

12 What is the oxidation number of Hydrogen H in Lithium hydride LiH
CH 14
A –2 **B** +1
C +2 **D** –1
Oxidation number of H in Hydrides = -1 →D

13 How does the oxidation number change in sodium in the following equation? $2Na(s) + I_2(l) \rightarrow 2NaI(s)$
CH 14
A It changes from 0 to –1
B It changes from +1 to 0
C It changes from –1 to 0
D It changes from 0 to +1
It changes from 0 to +1 →D

15 In the following reaction, what is the oxidizing agent? $Li(s) + Br_2 \rightarrow 2LiBr$
CH 14
A Li **B** Br_2
C LiBr **D** Br^-
Br_2 is the oxidizing agent, because reduction happened to it. →B

16 In the following reaction, what is the reducing agent? $CuCl_2(aq)$ $Ni(s) \rightarrow NiCl_2(aq) + Cu(s)$
CH 14
A Cu **B** $NiCl_2$
C Ni **D** $CuCl_2$
Ni is the reducing agent, because oxidaton happened to it. →C

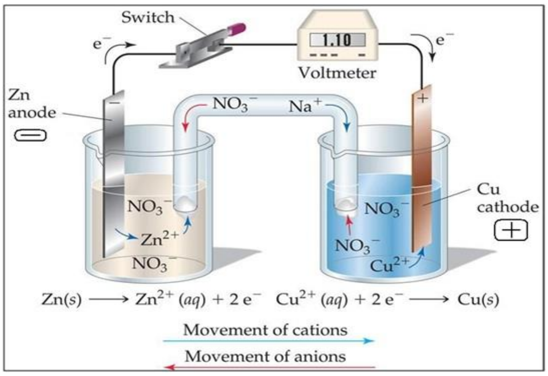
CHAPTER 14: Redox Reactions & Electrochemistry

Part 2: Voltaic Cells (Galvanic Cells)

•**Electrochemistry** is the study of the redox processes by which chemical energy is converted to electrical energy and vice versa.
•An electrochemical cell consists of two parts called half-cells, in which the separate oxidation and reduction reactions take place.

Voltaic Cells

.• **A voltaic cell** is a type of electrochemical cell that converts chemical energy to electrical energy **by a spontaneous redox reaction.**
•**The electrode** where oxidation takes place is called the **anode**.
• **The cathode** is the electrode where reduction occurs.
•**Electric potential energy** is a measure of the amount of current that can be generated from a voltaic cell to do work.
• **A salt bridge** is a pathway to allow the passage of ions from one side to another so that ions do not build up around the electrodes.



$$E_{cell} = E^o_{\ Cathode} - E^o_{\ Anode}$$

• The tendency of a substance to gain electrons is its **reduction potential.**
• **Cell potentials** can be used to determine if a proposed reaction under standard conditions will be spontaneous.
• If the calculated potential is positive, the reaction is **spontaneous.**
• If the calculated potential is negative, the reaction is **not spontaneous.**

The **standard hydrogen electrode** consists of a small sheet of platinum immersed in hydrochloric acid solution that = 0 V

17 **The study of redox processes by which chemical energy is converted to electrical energy …**
CH14
A Analytical chemistry
B Atomic chemistry
C Biochemistry
D Electrochemistry
Electrochemistry is the study of the redox processes by which chemical energy is converted to electrical energy and vice versa. →D

18 **In the electrochemical cell: The cathode electrode experiences …**
CH 14
A Electrolysis **B** Neutralization
C Reduction **D** Oxidation
The cathode is the electrode where reduction occurs. →C

19 **In the voltaic(galvanic) cell the ions transfer through the ...**
CH14
A Cathode **B** Elevator
C Wire **D** Salt bridge
A salt bridge is a pathway to allow the passage of ions from one side to another so that ions do not build up around the electrodes. →D

20 **The voltaic cell is a type of ... cells**
CH 14
A Electromagnetic **B** Electrochemical
C Electrothermal **D** Chemical
A voltaic cell is a type of electrochemical cell that converts chemical energy to electrical energy →B

21 **An electric current forms from a chemical reactions in …**
CH 14
A Corrosion resistance **B** Electrolytic cells
C Galvanization **D** Voltaic cells
A voltaic cell is a type of electrochemical cell that converts chemical energy to electrical energy →D

22 **The energy that pushes or drives electrons from the electrochemical anode toward its cathode …**
CH 14
A Electric potential energy
B Cathode potential
C Anode potential
D Potential difference of the voltaic cell
Cell potentials can be used to determine if a proposed reaction under standard conditions will be spontaneous. →A

23 **The tendency of a substance to gain electrons ...**
CH 14
A Oxidation potential **B** Reduction potential
C Electrode potential **D** Cell potential
The tendency of a substance to gain electrons is its reduction potential. →B

24 **Standard reduction potential is ...**
CH 14
A 1 V **B** -1.1 V
C 0 V **D** -1 V
The standard hydrogen electrode consists of a small sheet of platinum immersed in hydrochloric acid solution that = 0 V →C

25 **Which of the following formulas represents the formula for cell potential …**
CH14
A $E_{cell} = E_{cathode} + E_{anode}$
B $E_{cell} = E_{anode} - E_{cathode}$
C $E_{cell} = E_{anode} + E_{cathode}$
D $E_{cell} = E_{cathode} - E_{anode}$
Cell potentials = $E_{cathode} - E_{anode}$ →D

26 **Calculate the cells potential**
$Cu^{+2}(aq) + Al(s) \rightarrow Cu(s) + Al^{+3}(aq)$
$E_{Cu} = +0.34V$, $E_{Al} = -1.66V$
CH 14
A 1 V **B** -1 V
C 2 V **D** -2 V
Cell potentials = Ecathode - Eanode
Cell potentials = $E_{Cu} - E_{Al}$
= 0.34 - (-1.66) = 2V →C

27 **If the reaction is spontaneous then the cell potential must be…**

CH 14

A	Negative	**B**	Positive
C	High	**D**	Low

If the calculated potential is positive, the reaction is spontaneous. →B

28 **If E^0_{cu2+}= +0.3 V , E^0_{Sn2+} = -0.1 V , then the cell reaction of Sn(s) + Cu^{2+}(aq) → Sn^{2+}(aq) +Cu(s)…**

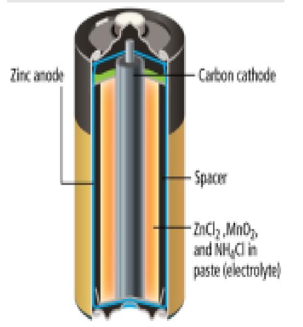
CH 14

A	Spontaneous.	**B**	Nonspontaneous.
C	Reverse.	**D**	Incomplete.

Cell potentials = $E_{Cu} – E_{Sn}$
= 0.34 - (-0.1) = +0.44V →A

Part.3: Batteries

•**A battery** is one or more voltaic cells in a single package that generates an electric current.



Zinc-carbon dry cell

Dry Cells

•A dry cell is an electrochemical cell in which the electrolyte is a moist paste.
The paste in a ***zinc-carbon cell*** consists of zinc chloride, manganese (IV) oxide, ammonium chloride, and a small amount of water.

• The anode is the zinc shell.

• The cathode is a carbon rod, but reduction occurs in the paste.

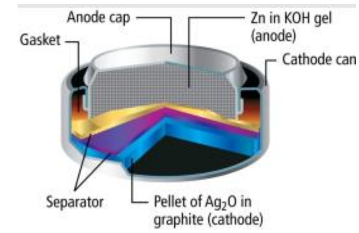
Alkaline cell

In the alkaline cell, zinc is in a powdered form and mixed with potassium hydroxide is contained in a steel case.

• Alkaline batteries are small and more useful in small devices.

Silver batteries

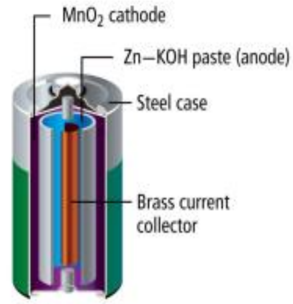
Silver batteries are similar to alkaline but smaller.



Silver button battery

• **Primary** batteries produce electric energy by means of redox reactions that are not easily reversed.

• **Secondary batteries** depend on reversible redox reactions and are rechargeable.



Alkaline battery

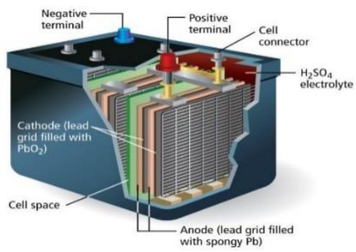
Lead-Acid Storage Battery

•Lead-acid storage batteries are common in automobiles.

• The electrolyte solution is sulfuric acid, hence the name.

• The anode consists of grids of porous lead.

• The cathode consists of lead grids filled with lead (IV) oxide.



Lithium Batteries

• Lithium is the lightest known metal and has the lowest the standard reduction potential of the metallic elements.

• Lithium batteries can be either primary or secondary.

Fuel Cells

A fuel cell is a voltaic cell in which the oxidation of fuel is used to produce electric energy.

•How a fuel cell works

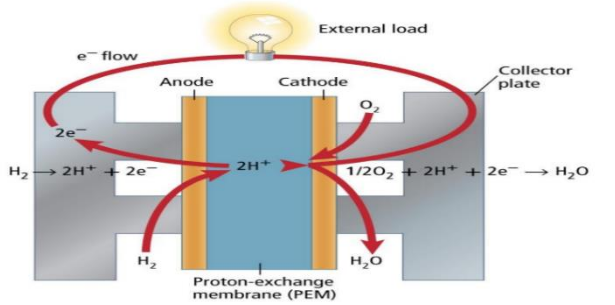
- Potassium hydroxide is often the electrolyte
- The oxidation half-reaction

$2H_2(g) + 4OH^- \rightarrow 4H_2O + 4e^-$

- The reduction of half-reaction

$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$

- When combined, the equation is the same as burning hydrogen in oxygen to form water.



29 **One or more voltaic cells in a single package that generates electric current…**

CH 14

A	Thermochemical cell.	**B**	Magnetic cell.
C	Hydroelectric cell.	**D**	Battery.

battery is one or more voltaic cells in a single package that generates an electric current. →D

30 **In a Zinc-Carbon Battery , the cathode is..**

CH 14

A	A carbon rod	**B**	Zinc
C	KOH	**D**	Copper case

zinc-carbon cell
• The anode is the zinc shell.
• The cathode is a carbon rod, but reduction occurs in the paste. →A

31 **To produce an electric energy by means of reversible redox reactions, we use…**

CH 14

A	Alkaline battery.	**B**	Dry cell.
C	Secondary battery.	**D**	Silver battery

Secondary batteries depend on reversible redox reactions and are rechargeable. →C

32 **Lithium is used in battery manufacturing of mobile phone because it is …**

CH14

A The largest reduction potential
B The cheapest known element.
C The lightest known element.
D The most available element

Lithium is used in battery manufacturing of mobile phone because it is the lightest known element. →C

CHAPTER 14: Redox Reactions & Electrochemistry

33 **When reacting, which cell depends on its reversible reaction?**
CH 14
A Alkaline battery. **B** Dry cell.
C Secondary battery. **D** Silver battery
Secondary batteries depend on reversible redox reactions and are rechargeable. →C

34 **Batteries that can be used more than once are also called____.**
CH 14
A Primary batteries **B** Dry cell.
C Secondary battery. **D** Tertiary batteries
Secondary batteries can be used more than once →C

Part 4: Electrolytic Cells

- The use of electrical energy to bring about a chemical reaction is called **electrolysis.**
- **An electrochemical cell** in which electrolysis occurs is called an electrolytic cell.

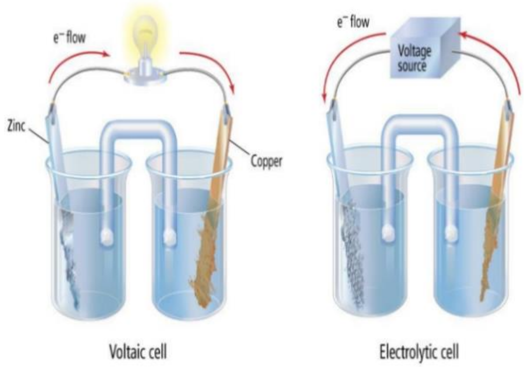
Applications of Electrolysis

Electrolysis of water is one method of obtaining hydrogen gas for commercial use.

Objects can be **electroplated** with a metal such as silver.

The cathode is the object to be electroplated, where reduction occurs.

The anode is a bar of silver, where silver is oxidized and silver ions are transferred to the cathode.



35 **The use of electrical energy to bring about a chemical reaction is...**
CH 14
A Refinement **B** Electrolysis.
C Distillation. **D** Galvanization
The use of electrical energy to bring about a chemical reaction is called electrolysis. →B

36 **What is required to drive a nonspontaneous reaction in an electrolytic cell?**
CH 14
A Electrodes **B** Additional ions
C An energy source **D** An electrolyte
The use of electrical energy to bring about a chemical reaction is called electrolysis. →C

37 **In an electrolytic cell, oxidation takes place**
CH14
A At the anode.
B At the cathode.
C Via the salt bridge.
D At the positive electrode.
In an electrolytic cell, oxidation takes place at the anode. →A

38 **In an electrolytic cell, reduction takes place**
CH14
A At the anode.
B At the cathode.
C Via the salt bridge.
D At the positive electrode.
In an electrolytic cell, oxidation takes place at the cathode. →B

39 **Which of the following applications is NOT an applications of electrolysis ...**
CH 14
A Down's cell. **B** Hall-Heroult process
C Halogenation process **D** Electroplating.
Halogenation process is NOT an applications of electrolysis. →C

40 **To get chlorine we should use…**
CH 14
A Down's cell. **B** Hall-Heroult process
C Halogenation process **D** Electroplating.
To get chlorine we should use Down's cell. →A

41 **Electrolysis of H_2O results in what products?**
CH 14
A H^+ and OH^- **B** H_2O_2 and O_2
C NaOH and H_2 **D** H_2 and O_2
Electrolysis of H_2O results are H_2 and O_2 →D

42 **In an electrolytic cell, the anode**
CH 14
A Can be either positively or negatively charged.
B Is not charged.
C Is positively charged.
D Is negatively charged.
In an electrolytic cell, the anode is positively charged. →C

43 **In an electrolytic cell, the cathode**
CH 14
A Can be either positively or negatively charged.
B Is not charged.
C Is positively charged.
D Is negatively charged.
In an electrolytic cell, the cathode is negatively charged. →D

44 **Which is the source of energy for an electrolytic cell?**
CH14
A The reaction occurring in the electrolytic cell
B An external direct-current source, such as a battery
C Ion migration in the electrolyte
D Electron migration in the electrolyte
The source of energy for an electrolytic cell is An external direct-current source, such as a battery. →B

45 **What is needed to create chemical changes in an electrolytic cell?**
CH 14
A Gravity **B** High temperatures
C Electricity **D** A fuel cell
To create chemical changes in an electrolytic cell we need electricity. →C

46 **What type of process is the electrolysis reaction?**
CH 14
A Electrode reaction **B** Spontaneous
C Dry cell reaction **D** Nonspontaneous
The type of process in the electrolysis reaction is nonspontaneous. →D