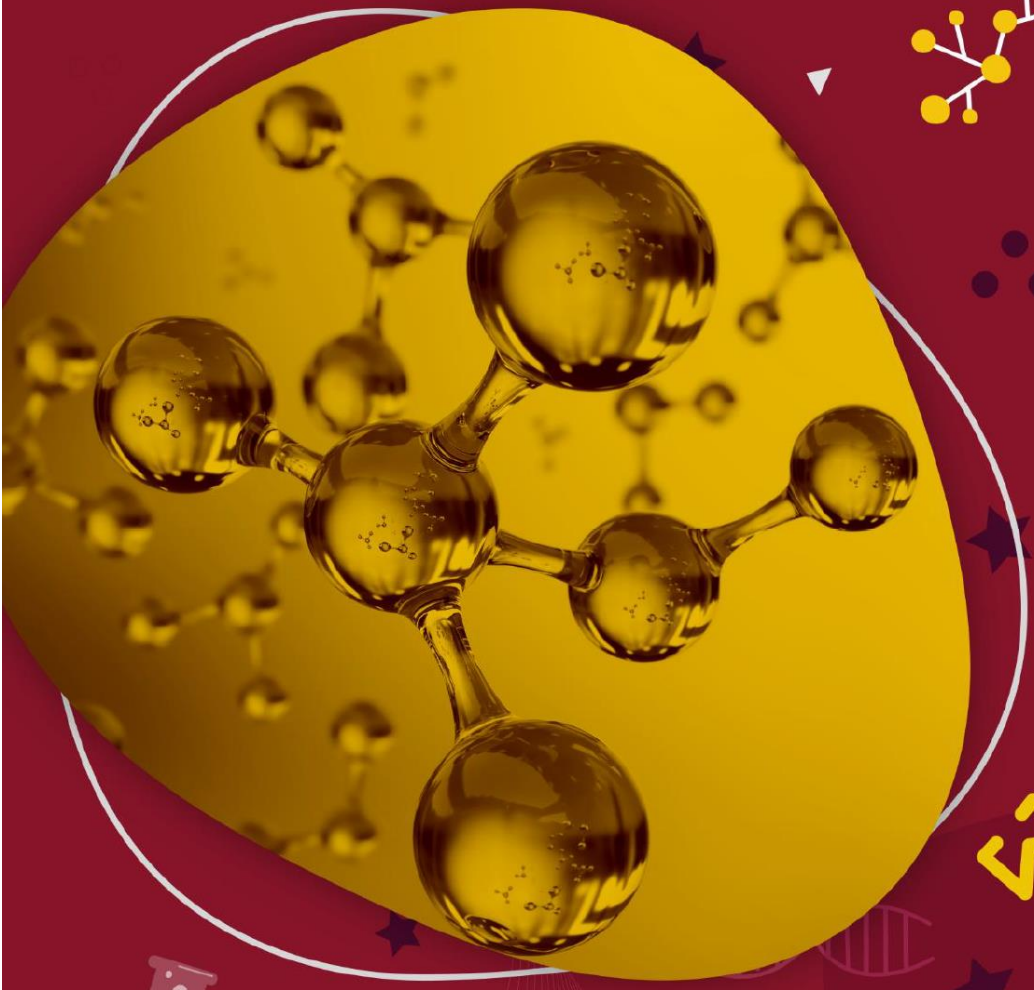
CHEMISTRY

12 Advanced

Mr. Hesham Eltoukhy

Electrochemistry



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My dear students

Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy

In your hands are papers in chemistry for grade 12 advanced. Here is a detailed explanation of the contents and method of study.

Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy

These papers contain a complete explanation of everything in the book, in addition to all the book's questions and previous year's questions, knowing that they do not replace the textbook, and the papers consist of three parts.

Part One (Explanation and Questions)

Detailed explanation with questions on each objective.

Part Two (Questions with answers)

Additional questions on each section with answer key at the end of each section.

Part Three (Exams of last years)

Last year's exam questions with answer key at the end of each exam.

Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy
Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy
Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy
Mr. Hesha Eltoukhy
Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy
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Part One (Explanation and Questions)

Detailed explanation with questions on each objective.

Sec. (1) Voltaic Cells

Electrochemistry: the study of oxidation and reduction processes in which chemical energy is converted into electrical energy and vice versa.

Electrochemical processes are useful in industry, and in biological functions.

Electrochemical Cells

Electrochemical cell: a device that uses a redox reaction to produce electrical energy or uses electrical energy to cause a chemical reaction.

Types of electrochemical cells

voltaic cell	electrolytic cell
Convert chemical energy into electrical energy	Convert electrical energy into chemical energy

Voltaic cell: a type of electrochemical cell that converts chemical energy into electrical energy through a spontaneous redox reaction.

An electrochemical cell consists of two parts called a half-cell.

Half-cell reaction: the reaction that takes place in each half of a cell.

The voltaic cell is named by the scientist (Alessandro Volta) and the corresponding shape resembles one of the first cells of Alessandro Volta.

The Volta cell consists of zinc and copper discs arranged in alternate layers, separated by pieces of cloth or cardboard dipped in an acidic solution.

The intensity of the current increases with the increase in the number of zinc and copper discs.



Electrode: a material that conducts electricity.

The electrode is a metallic strip or graphite stem that conducts electrons in and out of solution in the half-cell.

Anode: the electrode at which the oxidation reaction takes place.

Cathode: the electrode at which the reduction reaction takes place.

$Zn_{(s)} + Cu^{2+}_{(aq)} \rightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$

- half-reactions
  - oxidation (lose electrons): $Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e^-$
  - reduction (gain electrons): $Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$
- $2e^-$ transfers from Zn to Cu^{2+}
- the products: Zn^{2+} and Cu

But does this reaction occur when the oxidation half-reaction is separated from the reduction half-reaction?



zinc electrode in1M zinc sulfate solution



copper electrode in 1M copper sulfate solution

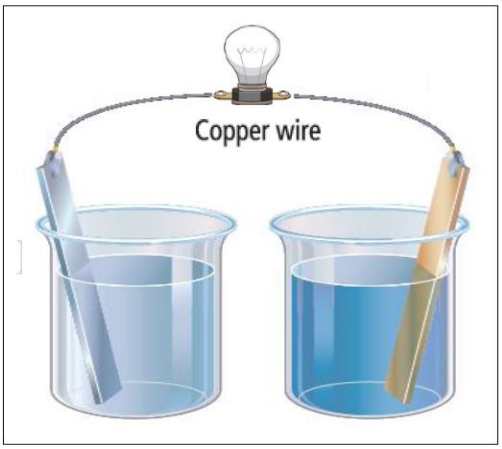
There is a problem? → There is no way to transfer electrons from Zn atoms to Cu^{2+} ions

Solve the problem → The zinc and copper electrodes are connected to a metal wire, where the wire acts as a path for the transmission of electrons.

What happens when the electrodes are connected to a metallic wire?

The lamp does not light

The metallic wire connecting the zinc and copper electrodes provides a path for the transfer of electrons, but the transfer of electrons does not occur.



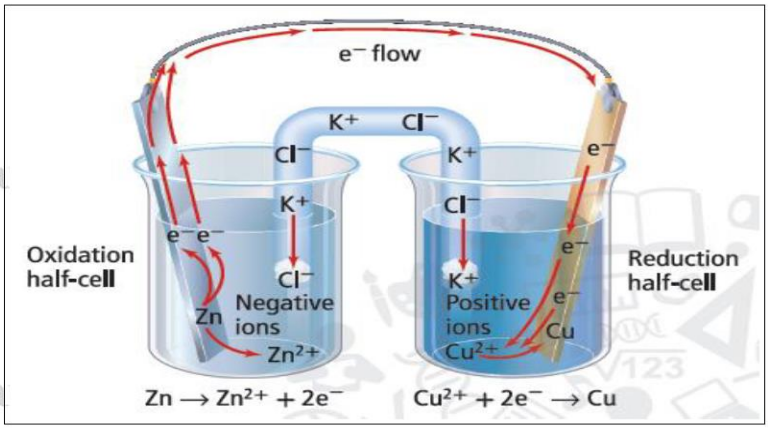
There is another problem? → **Zn^{2+} ions accumulate around the Zn electrode, Cu^{2+} ions are accumulated around the Cu electrode, and the charge accumulation prevents the reaction from continuing.**

Solve the problem → **Use a salt bridge.**

Salt Bridge: A pathway to maintain solution neutrality by allowing the passage of ions from one side to another.

What is a salt bridge made of?

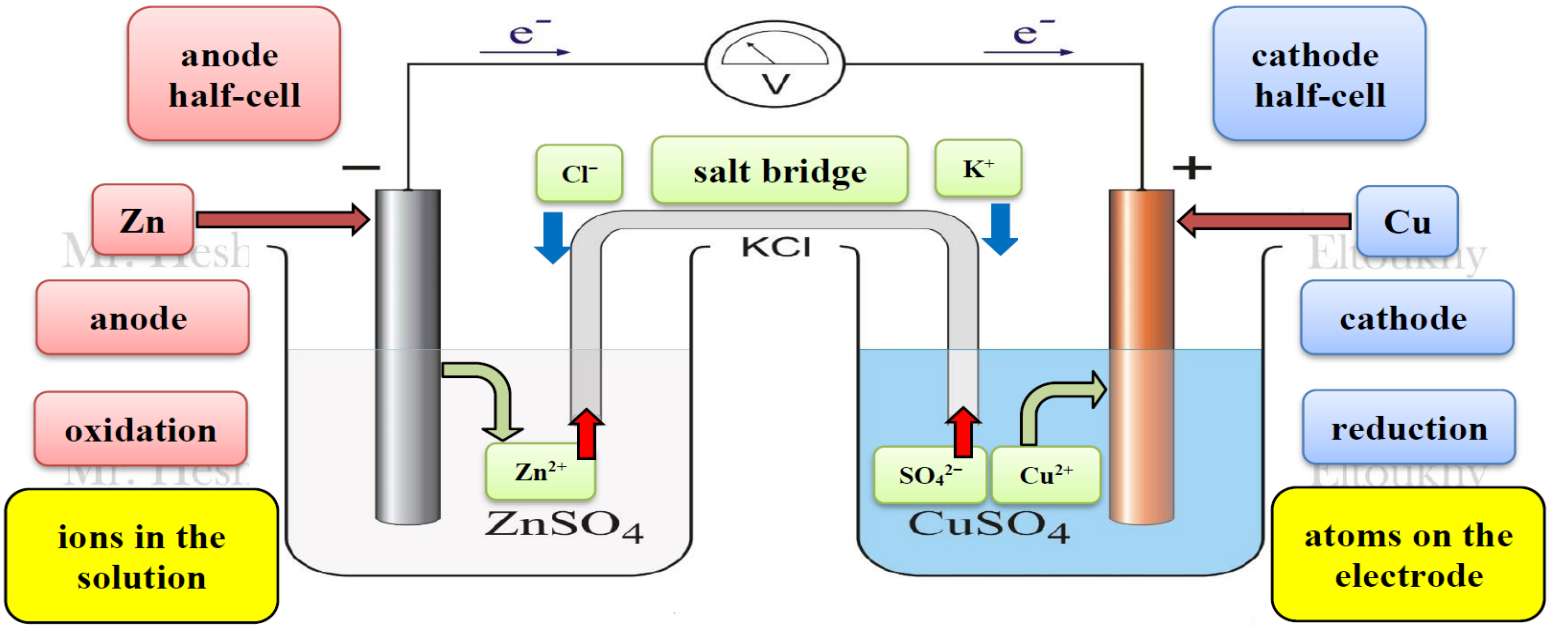
It consists of a tube containing a conductive salt solution such as KCl that holds the salt in place using an agar gel.



The agar gel in the brine allows the ions to move through it, while not allowing the two solutions to mix.

Salt bridge functions

- **Passage of ions from one side to another**
- **Maintain the balance of the solution**
- **Do not allow the two solutions to mix**



if the metal wire and the salt bridge are in place

the oxidation and reduction process starts spontaneously

oxidation: $Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e^-$

reduction: $Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$

Zn atoms turns to Zn^{2+} ions

Cu^{2+} ions are reduced by electrons

electrons travel through the metal wire to the Cu electrode

$CuSO_4$ solution dissociates into Cu^{2+} and SO_4^{2-}

There is a problem?

The concentration of Zn^{2+} ions increase in half-cell of the anode, the concentration of SO_4^{2-} ions increase in half-cell of the cathode.

The role of the salt bridge comes

an exchange of ions occurs in half of the anode cell.

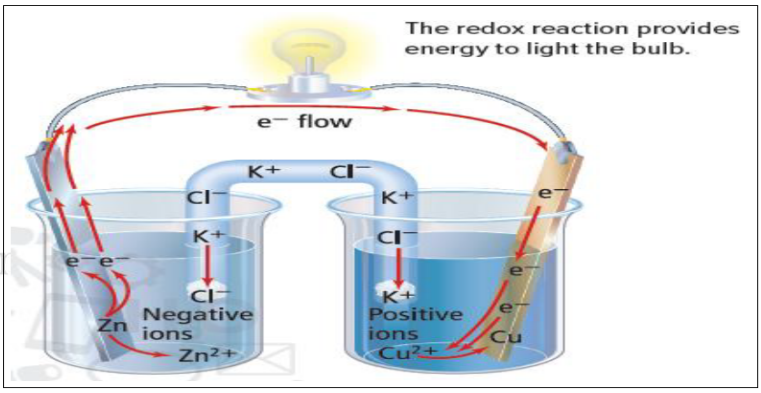
positive ions enter the salt bridge and negative ions leave it.

an exchange of ions occurs in half of the cathode cell.

negative ions enter the salt bridge and positive ions leave it.

What results from the flow of electrons through the wire, and the flow of ions through the salt bridge?

Electric current.



How do the electrode masses and ion concentrations change in the cell?

- **anode electrode mass decreases (Zn)**
- **cathode electrode mass increases (Cu)**
- **anode solution ion concentration increases (Zn^{2+})**
- **cathode solution ion concentration decreases (Cu^{2+})**

The movement of electrons and ions in the cell

- **Electrons move through the metal wire from the anode to the cathode.**
- **Positive ions move across the salt bridge (from the anode half-cell towards the the cathode half-cell).**
- **Negative ions move across the salt bridge (from the cathode half-cell towards the anode half-cell).**

Oxidation half-reaction	$Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e^-$
Reduction half-reaction	$Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$
Overall reaction	$Zn_{(s)} + Cu^{2+}_{(aq)} \rightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$

anode **cathode**

Cell notation

reactant | product || reactant | product

$Zn \mid Zn^{2+} \parallel Cu^{2+} \mid Cu$

A voltaic cell expressed by the reaction, answer the questions (1-3).

$Pb^{2+} + Mg \rightarrow Pb + Mg^{2+}$

1) What is the equation for the reaction of the anode?

a. $Mg^{2+} + 2e^- \rightarrow Mg$

b. $Mg \rightarrow Mg^{2+} + 2e^-$

c. $Pb^{2+} + 2e^- \rightarrow Pb$

d. $Pb \rightarrow Pb^{2+} + 2e^-$

2) What is the equation for the reaction of the cathode?

a. $Mg^{2+} + 2e^- \rightarrow Mg$

b. $Mg \rightarrow Mg^{2+} + 2e^-$

c. $Pb^{2+} + 2e^- \rightarrow Pb$

d. $Pb \rightarrow Pb^{2+} + 2e^-$

3) What is the cell notation?

a. $Pb^{2+} \mid Pb \parallel Mg \mid Mg^{2+}$

b. $Mg^{2+} \mid Mg \parallel Pb \mid Pb^{2+}$

c. $Pb \mid Pb^{2+} \parallel Mg^{2+} \mid Mg$

d. $Mg \mid Mg^{2+} \parallel Pb^{2+} \mid Pb$

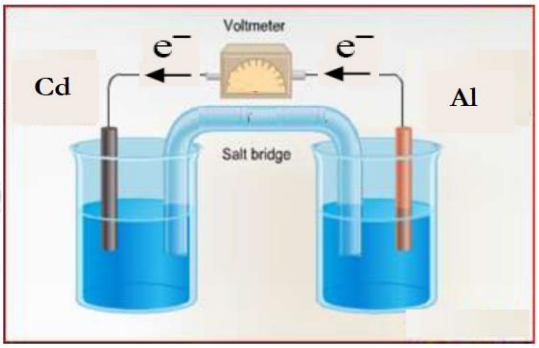
4) Depending on the corresponding cell, what reaction occurs at the anode?

a. $Al \rightarrow Al^{3+} + 3e^-$

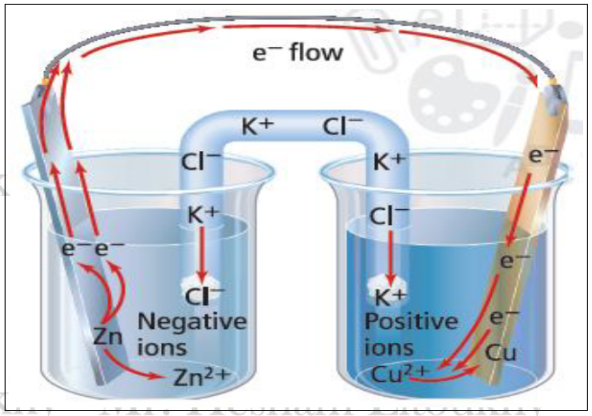
b. $Al^{3+} + 3e^- \rightarrow Al$

c. $Cd \rightarrow Cd^{2+} + 2e^-$

d. $Cd^{2+} + 2e^- \rightarrow Cd$



Using the corresponding figure, answer the questions (5-7).



5) What is the anode reaction?

a. $Cu \rightarrow Cu^{2+} + 2e^-$ b. $Cu^{2+} + 2e^- \rightarrow Cu$

c. $Zn \rightarrow Zn^{2+} + 2e^-$ d. $Zn^{2+} + 2e^- \rightarrow Zn$

6) What happens to the cathode electrode mass?

a. increase b. decrease

c. does not change d. cannot be determined

7) What is the cell notation?

a. $Cu \mid Cu^{2+} \parallel Zn^{2+} \mid Zn$ b. $Cu^{2+} \mid Cu \parallel Zn \mid Zn^{2+}$

c. $Zn \mid Zn^{2+} \parallel Cu^{2+} \mid Cu$ d. $Zn^{2+} \mid Zn \parallel Cu \mid Cu^{2+}$

8) In the voltaic cell represented by, what is oxidized and what is reduced when the cell releases current?

$Al \mid Al^{3+} \parallel Cu^{2+} \mid Cu$

a. oxidation: Al^{3+}, reduction: Cu b. oxidation: Al, reduction: Cu^{2+}

c. oxidation: Cu^{2+}, reduction: Al d. oxidation: Cu, reduction: Al^{3+}

9) What is the equation for the reaction at the cathode of the voltaic cell in which the reaction takes place?

$Ba + Sn^{2+} \rightarrow Ba^{2+} + Sn$

a. $Ba \rightarrow Ba^{2+} + 2e^-$ b. $Ba^{2+} + 2e^- \rightarrow Ba$

c. $Sn \rightarrow Sn^{2+} + 2e^-$ d. $Sn^{2+} + 2e^- \rightarrow Sn$

10) A voltaic cell is made using chromium and iron (II) as in the reaction, what phrase describes this cell?

$2Cr_{(s)} + 3Fe^{2+}_{(aq)} \rightarrow 2Cr^{3+}_{(aq)} + 3Fe_{(s)}$

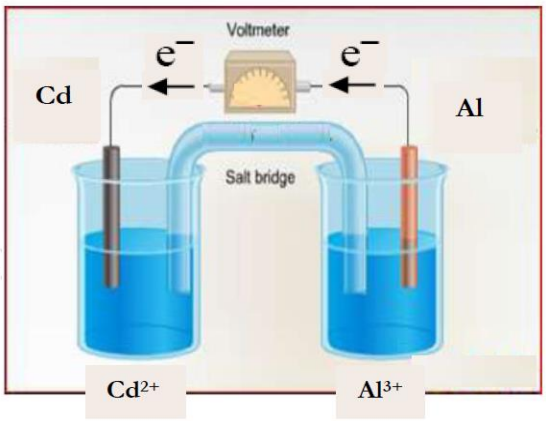
a. electrons flow from the iron electrode to the chromium electrode

b. heat energy is released

c. negative ions move across the salt bridge from the chromium half-cell to the iron half-cell

d. negative ions move across the salt bridge from the iron half-cell to the chromium half-cell

Using the corresponding figure, answer questions (11-14)



11) What is the reaction of the anode?

a. $Cd^{2+} + 2e^- \rightarrow Cd$

b. $Cd \rightarrow Cd^{2+} + 2e^-$

c. $Al^{3+} + 3e^- \rightarrow Al$

d. $Al \rightarrow Al^{3+} + 3e^-$

12) What is the reaction of the cathode?

a. $Cd^{2+} + 2e^- \rightarrow Cd$

b. $Cd \rightarrow Cd^{2+} + 2e^-$

c. $Al^{3+} + 3e^- \rightarrow Al$

d. $Al \rightarrow Al^{3+} + 3e^-$

13) What is the overall reaction of the cell?

a. $2Al^{3+} + 3Cd \rightarrow 2Al + 3Cd^{2+}$

b. $2Al + 3Cd^{2+} \rightarrow 2Al^{3+} + 3Cd$

c. $2Al + 3Cd \rightarrow 2Al^{3+} + 3Cd^{2+}$

d. $2Al^{3+} + 3Cd^{2+} \rightarrow 2Al + 3Cd$

14) What is the cell notation?

a. $Al^{3+} \mid Al \parallel Cd \mid Cd^{2+}$

b. $Cd \mid Cd^{2+} \parallel Al^{3+} \mid Al$

c. $Al \mid Al^{3+} \parallel Cd^{2+} \mid Cd$

d. $Cd^{2+} \mid Cd \parallel Al \mid Al^{3+}$

15) Which of the following options occurs in the voltaic cell that has the notation?

$Al \mid Al^{3+} \parallel Fe^{2+} \mid Fe$

a. reduction: Fe^{2+}

b. reduction: Al^{3+}

c. reduction: Al

d. oxidation: Fe

11	d	12	a	13	b	141	c	15	a

Voltaic cells and energy

The potential energy of the electrode depends on its position or configuration.

Electrical potential is a measure of the amount of current that can be generated from a voltaic cell to do work.

When can an electric charge move between two points? → If there is a difference in electrical energy between them.

What are the two points between which charge moves in an electrochemical cell? → The two electrodes (anode and cathode).

What is the result of the difference in electrical potential between the electrodes? → Electromotive force (EMF)

Electrons generated at the anode (oxidation) are pushed to the cathode (reduction) by electromotive force (EMF).

What is the electromotive force called, and what is its unit? → The cell potential, the unit is volts.

What does it mean that the electric potential difference of a voltaic cell is an indication of the energy available to move electrons from the anode to the cathode? → The higher the potential difference, the more energy is available to move the electrons.



Roller Coaster

It has gravitational potential energy (PE) at the highest point and converted into kinetic energy (KE) at the lowest point.

The greater the difference in height between the top of the track and the bottom, the higher the kinetic energy.

Voltaic Cell

The energy of electrons flowing from the anode to the cathode is determined by the electrical potential energy difference between the two electrodes. The cell voltage is determined by comparing the difference between the tendency of both electrodes to gain electrons. The greater the potential energy difference between the two electrodes, the greater the cell voltage.

Calculation of electrochemical cell potentials

Reduction potential (E): The tendency of a material to gain electrons.

Why the reduction potential of an electrode can't be determined directly? → **Because the reduction half-reaction must be combined with the redox half-reaction.**

What is the potential output when the two halves of the reaction are coupled together, and what is its unit? → **The electric potential difference, and its unit is volts.**

Zinc-copper cell

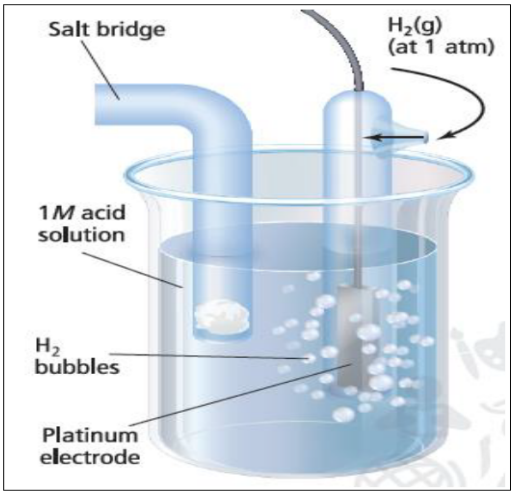
zinc atoms (Zn) are oxidized	copper ions (Cu^{2+}) are reduced
zinc has a lower tendency to gain electrons	copper has a greater tendency to gain electrons
zinc has lower reduction potential	copper has higher reduction potential

The redox reaction occurs spontaneously only when electrons flow from zinc to copper.

Standard Hydrogen Electrode

Standard Hydrogen Electrode

- It consists of a small plate of platinum immersed in a solution of hydrochloric acid at a concentration of 1M
- Hydrogen H_2 gas is pumped into the solution at standard conditions
  - 25 °C
  - 1 atm
- The standard reduction potential of a standard hydrogen electrode is zero.



The standard hydrogen electrode functions as an "oxidation half-reaction" or "reduction half-reaction" depending on the half-cell connected to it.

$H_{2(g)} \rightarrow 2H^+_{(aq)} + 2e^-$ (oxidation) $\quad E^\circ_{H_2} = 0.0\ V$

$2H^+_{(aq)} + 2e^- \rightarrow H_{2(g)}$ (reduction) $\quad E^\circ_{H_2} = 0.0\ V$

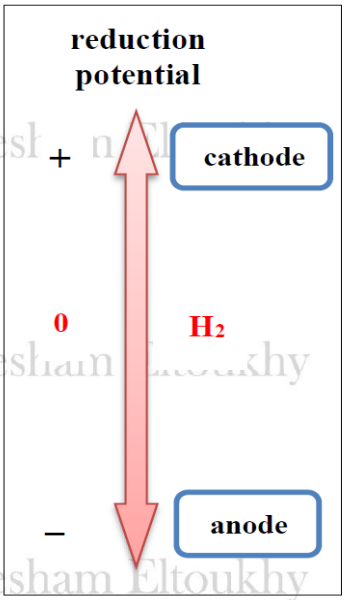
Half-cell potentials

To determine the reduction potential of the elements, the half-cell of the element is connected to the hydrogen half-cell.

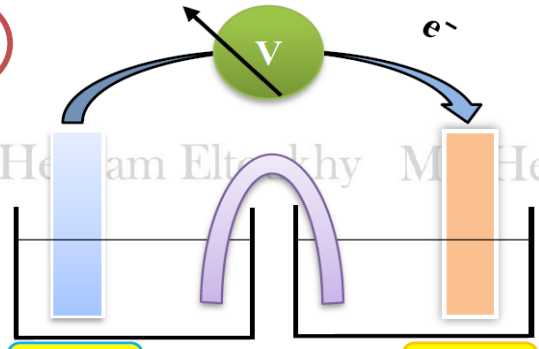
The half-cell that is more reducible than hydrogen will reduce and have a positive reduction potential.

The half-cell that is less reducible than hydrogen will oxidize and have a negative reduction potential.

The electrode with higher reduction potential is the cathode, and the electrode with lower reduction potential is the anode.



1



H_2 | X

anode | cathode

less | more

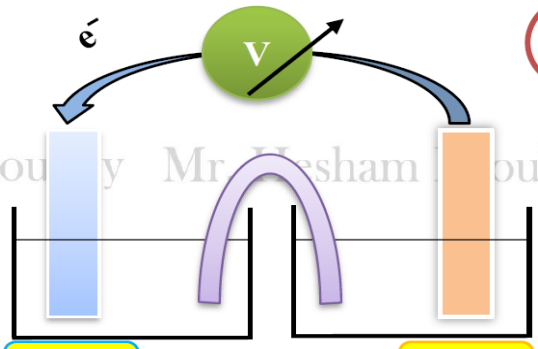
reduction potential

0 | +

$H_{2(g)} \rightarrow 2H^+_{(aq)} + 2e^-$

$H_2 \mid H^+ \parallel X^+ \mid X$

2



H_2 | Y

cathode | anode

more | less

reduction potential

0 | –

$2H^+_{(aq)} + 2e^- \rightarrow H_{2(g)}$

$Y \mid Y^+ \parallel H^+ \mid H_2$

The electrode is measured under standard conditions of 1atm, 25°C and dipped in a 1M solution.

The reduction potential at standard conditions is denoted by the symbol E°

The half-reactions are recorded in the table as reduction reactions.

Standard Reduction Potentials

not required to memorize

Half-Reaction	E^0 (V)	Half-Reaction	E^0 (V)
$Li^+ + e^- \rightleftarrows Li$	−3.0401	$Cu^{2+} + e^- \rightleftarrows Cu^+$	+0.153
$Ca^{2+} + 2e^- \rightleftarrows Ca$	−2.868	$Cu^{2+} + 2e^- \rightleftarrows Cu$	+0.3419
$Na^+ + e^- \rightleftarrows Na$	−2.71	$O_2 + 2H_2O + 4e^- \rightleftarrows 4OH^-$	+0.401
$Mg^{2+} + 2e^- \rightleftarrows Mg$	−2.372	$I_2 + 2e^- \rightleftarrows 2I^-$	+0.5355
$Be^{2+} + 2e^- \rightleftarrows Be$	−1.847	$Fe^{3+} + e^- \rightleftarrows Fe^{2+}$	+0.771
$Al^{3+} + 3e^- \rightleftarrows Al$	−1.662	$NO_3^- + 2H^+ + e^- \rightleftarrows NO_2 + H_2O$	+0.775
$Mn^{2+} + 2e^- \rightleftarrows Mn$	−1.185	$Hg_2^{2+} + 2e^- \rightleftarrows 2Hg$	+0.7973
$Cr^{2+} + 2e^- \rightleftarrows Cr$	−0.913	$Ag^+ + e^- \rightleftarrows Ag$	+0.7996
$2H_2O + 2e^- \rightleftarrows H_2 + 2OH^-$	−0.8277	$Hg^{2+} + 2e^- \rightleftarrows Hg$	+0.851
$Zn^{2+} + 2e^- \rightleftarrows Zn$	−0.7618	$2Hg^{2+} + 2e^- \rightleftarrows Hg_2^{2+}$	+0.920
$Cr^{3+} + 3e^- \rightleftarrows Cr$	−0.744	$NO_3^- + 4H^+ + 3e^- \rightleftarrows NO + 2H_2O$	+0.957
$S + 2e^- \rightleftarrows S^{2-}$	−0.47627	$Br_2(l) + 2e^- \rightleftarrows 2Br^-$	+1.066
$Fe^{2+} + 2e^- \rightleftarrows Fe$	−0.447	$Pt^{2+} + 2e^- \rightleftarrows Pt$	+1.18
$Cd^{2+} + 2e^- \rightleftarrows Cd$	−0.4030	$O_2 + 4H^+ + 4e^- \rightleftarrows 2H_2O$	+1.229
$PbI_2 + 2e^- \rightleftarrows Pb + 2I^-$	−0.365	$Cl_2 + 2e^- \rightleftarrows 2Cl^-$	+1.35827
$PbSO_4 + 2e^- \rightleftarrows Pb + SO_4^{2-}$	−0.3588	$Au^{3+} + 3e^- \rightleftarrows Au$	+1.498
$Co^{2+} + 2e^- \rightleftarrows Co$	−0.28	$MnO_4^- + 8H^+ + 5e^- \rightleftarrows Mn^{2+} + 4H_2O$	+1.507
$Ni^{2+} + 2e^- \rightleftarrows Ni$	−0.257	$Au^+ + e^- \rightleftarrows Au$	+1.692
$Sn^{2+} + 2e^- \rightleftarrows Sn$	−0.1375	$H_2O_2 + 2H^+ + 2e^- \rightleftarrows 2H_2O$	+1.776
$Pb^{2+} + 2e^- \rightleftarrows Pb$	−0.1262	$Co^{3+} + e^- \rightleftarrows Co^{2+}$	+1.92
$Fe^{3+} + 3e^- \rightleftarrows Fe$	−0.037	$S_2O_8^{2-} + 2e^- \rightleftarrows 2SO_4^{2-}$	+2.010
$2H^+ + 2e^- \rightleftarrows H_2$	**0.0000**	$F_2 + 2e^- \rightleftarrows 2F^-$	+2.866

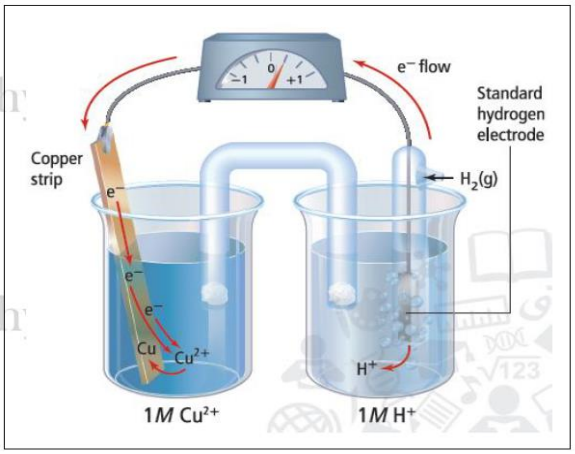
Copper-Hydrogen cell

Electrons flow from the hydrogen electrode to the copper electrode.

E° value measured in voltmeters +0.342 V

Cu^{2+} ions at the copper electrode gain electrons more easily than the H^+ ions at the standard hydrogen electrode.

Copper ions have a reduction potential greater than hydrogen ions.



Copper represents the cathode.

Hydrogen represents the anode.

The hydrogen reduction potential is zero, so the copper reduction potential is positive.

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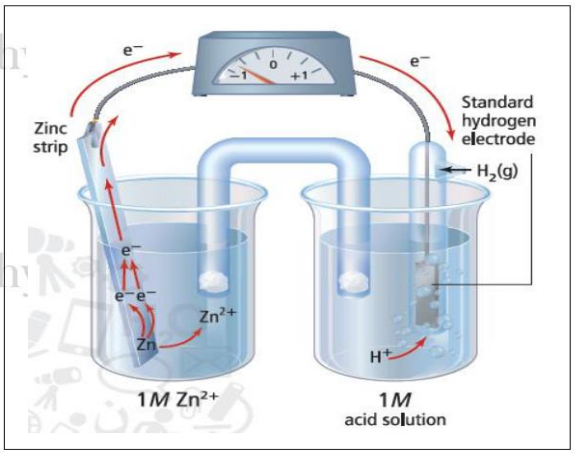
Zinc-Hydrogen cell

Electrons flow from the zinc electrode to the hydrogen electrode.

E° value measured in voltmeters –0.762 V

H^+ ions at the standard hydrogen electrode gain electrons more easily than Zn^{2+} ions at the zinc electrode.

Hydrogen ions have a greater reduction potential than zinc ions.



Zinc represents the anode.

Hydrogen represents the cathode.

The hydrogen reduction potential is zero, so the zinc reduction potential is negative.

Electrochemical cell potential calculation

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

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quantity		unit
symbol	meaning	
E°_{cell}	standard overall potential of the cell	volt (V)
$E^{\circ}_{cathode}$	standard half-cell reduction potential of the reduction	volt (V)
E°_{anode}	standard half-cell reduction potential of the oxidation	volt (V)

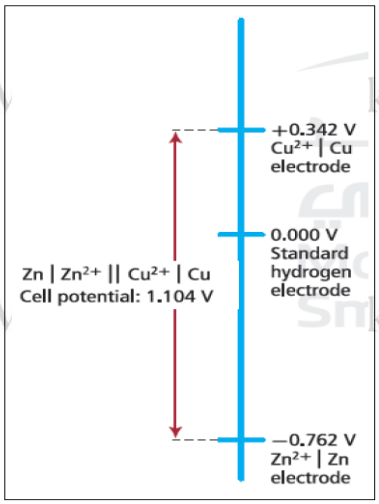
The value of the voltaic cell potential is always positive, so that electrons flow spontaneously from the anode to the cathode.

Example

Calculating the potential of a copper-zinc cell

$$E^{\circ}_{cell} = E^{\circ}_{Cu^{2+}|Cu} - E^{\circ}_{Zn^{2+}|Zn}$$

$$= +0.342 - (-0.762) = +1.104\ V$$



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How to determine the anode and the cathode?

1. Direction of movement of electrons.
2. Half-reactions.
3. Overall reactions.
4. Cell notation.
5. Reduction potential.

Study the following half-reduction reactions and answer questions (16-18)

half-reaction نصف التفاعل	$I_{2(s)} + 2e^- \rightarrow 2I^-_{(aq)}$	$Fe^{2+}_{(aq)} + 2e^- \rightarrow Fe_{(s)}$
potential الجهد	+0.536 V	–0.447 V

16) What is the standard cell potential?

a. –0.983 V b. –0.089 V

c. +0.983 V d. +0.089 V

17) What is the overall cell reaction?

a. $Fe^{2+}_{(aq)} + I_{2(s)} \rightarrow Fe_{(s)} + 2I^-_{(aq)}$

b. $Fe^{2+}_{(aq)} + 2I^-_{(aq)} \rightarrow Fe_{(s)} + I_{2(s)}$

c. $Fe_{(s)} + 2I^-_{(aq)} \rightarrow Fe^{2+}_{(aq)} + I_{2(s)}$

d. $Fe_{(s)} + I_{2(s)} \rightarrow Fe^{2+}_{(aq)} + 2I^-_{(aq)}$

18) What is the cell notation?

a. $I_2 \mid I^- \parallel Fe \mid Fe^{2+}$

b. $Fe \mid Fe^{2+} \parallel I_2 \mid I^-$

c. $I^- \mid I_2 \parallel Fe^{2+} \mid Fe$

d. $Fe^{2+} \mid Fe \parallel I^- \mid I_2$

19) What is the balanced equation for the spontaneous cell reaction that occurs in the cell with the following reduction half-reactions?

half-reaction نصف التفاعل	$Mg^{2+}_{(aq)} + 2e^- \rightarrow Mg_{(s)}$	$2H^+_{(aq)} + 2e^- \rightarrow H_{2(g)}$
potential الجهد	–2.37 V	0.0 V

a. $Mg + 2H^+ \rightarrow Mg^{2+} + H_2$

b. $Mg^{2+} + H_2 \rightarrow Mg + 2H^+$

c. $Mg^{2+} + 2H^+ \rightarrow Mg + H_2$

d. $Mg + H_2 \rightarrow Mg^{2+} + 2H^+$

Based on the values of the reduction potentials of the tin-mercury voltage cell, answer questions (20-24).

half-reaction نصف التفاعل	$Sn^{2+} + 2e^- \rightarrow Sn$	$Hg^{2+} + 2e^- \rightarrow Hg$
potential الجهد	–0.138 V	+0.851 V

20) What is oxidized and what is reduced?

a. oxidation: Sn^{2+}, reduction: Hg
b. oxidation: Sn, reduction: Hg^{2+}
c. oxidation: Hg^{2+}, reducing: Sn
d. oxidation: Hg, reducing: Sn^{2+}

21) What are the reactions that takes place at the anode and at the cathode?

choice	anode reaction	cathode reaction
a.	$Hg^{2+} + 2e^- \rightarrow Hg$	$Sn \rightarrow Sn^{2+} + 2e^-$
b.	$Sn \rightarrow Sn^{2+} + 2e^-$	$Hg^{2+} + 2e^- \rightarrow Hg$
c.	$Sn^{2+} + 2e^- \rightarrow Sn$	$Hg \rightarrow Hg^{2+} + 2e^-$
d.	$Hg \rightarrow Hg^{2+} + 2e^-$	$Sn^{2+} + 2e^- \rightarrow Sn$

22) What is the balanced equation for the overall cell reaction?

a. $Hg_{(s)} + Sn^{2+}_{(aq)} \rightarrow Hg^{2+}_{(aq)} + Sn_{(s)}$
b. $Hg_{(s)} + Sn_{(s)} \rightarrow Hg^{2+}_{(aq)} + Sn^{2+}_{(aq)}$
c. $Hg^{2+}_{(aq)} + Sn_{(s)} \rightarrow Hg_{(s)} + Sn^{2+}_{(aq)}$
d. $Hg^{2+}_{(aq)} + Sn^{2+}_{(aq)} \rightarrow Hg_{(s)} + Sn_{(s)}$

23) What is the value of the cell potential (V)?

a. +0.713
b. –0.713
c. +0.989
d. –0.989

24) If there is a sodium sulfate solution in the brine. In which direction do the sulfate ions move?

a. towards the Hg electrode
b. do not move
c. towards the cathode half-cell
d. towards the Sn half-cell

25) What is the balanced chemical equation for a standard cell that has the following notation?

$Sn \mid Sn^{2+} \parallel Ag^{+} \mid Ag$

a. $Sn^{2+} + 2Ag^{+} \rightarrow Sn + 2Ag$

b. $Sn + 2Ag \rightarrow Sn^{2+} + 2Ag^{+}$

c. $Sn^{2+} + 2Ag \rightarrow Sn + 2Ag^{+}$

d. $Sn + 2Ag^{+} \rightarrow Sn^{2+} + 2Ag$

26) What does the cell notation when the next half of the cell is attached to the standard hydrogen electrode ($E^{\circ}_{H_2} = 0.0$ V)?

$Hg^{2+} \mid Hg$	$E^{\circ} = +0.851$ V

a. $2H^{+} \mid H_2 \parallel Hg \mid Hg^{2+}$

b. $H_2 \mid 2H^{+} \parallel Hg^{2+} \mid Hg$

c. $Hg^{2+} \mid Hg \parallel H_2 \mid 2H^{+}$

d. $Hg \mid Hg^{2+} \parallel 2H^{2+} \mid H_2$

27) What is the value of the cell potential (V) that has the following cell notation?

a. +2.16

b. –2.16

c. +1.22

d. –1.22

cell notation ترميز الخلية	$S^{2-} \mid S \parallel Au^{+} \mid Au$	
reduction potential جهد الاختزال	$E^{\circ}_{S} = -0.47$ V	$E^{\circ}_{Au} = +1.69$ V

28) What are the electrodes make up a cell where $E^{\circ}_{cell} = +0.05$ V?

a. Ag, Cu

b. Mg, Cu

c. Hg, Ag

d. Hg, Mg

electrode القطب	potential الجهد
Ag	+0.80 V
Hg	+0.85 V
Cu	+0.34 V
Mg	–2.37 V

29) What is the potential of the cell in which the following reaction takes place?

cell reaction تفاعل الخلية	$2Ag^{+}_{(aq)} + Pb_{(s)} \rightarrow Pb^{2+}_{(aq)} + 2Ag_{(s)}$	
reduction potential جهد الاختزال	$E^{\circ}_{Ag} = +0.799$ V	$E^{\circ}_{Pb} = -0.126$ V

a. +0.925 V b. –0.925 V

c. +0.673 V d. –0.673 V

Study the following half-reduction reactions and answer questions (30-32)

half-reaction نصف التفاعل	$Co^{2+}_{(aq)} + 2e^{-} \rightarrow Co_{(s)}$	$Cr^{3+}_{(aq)} + 3e^{-} \rightarrow Cr_{(s)}$
potential الجهد	–0.28 V	–0.744 V

30) What is the standard cell potential?

a. –0.464 V b. –1.024 V

c. +0.464 V d. +1.024 V

31) What is the overall cell reaction?

a. $2Cr^{3+} + 3Co^{2+} \rightarrow 2Cr + 3Co$

b. $2Cr + 3Co \rightarrow 2Cr^{3+} + 3Co^{2+}$

c. $2Cr^{3+} + 3Co \rightarrow 2Cr + 3Co^{2+}$

d. $2Cr + 3Co^{2+} \rightarrow 2Cr^{3+} + 3Co$

32) What is the cell notation?

a. $Co \mid Co^{2+} \parallel Cr^{3+} \mid Cr$

b. $Cr \mid Cr^{3+} \parallel Co^{2+} \mid Co$

c. $Co^{2+} \mid Co \parallel Cr \mid Cr^{3+}$

d. $Cr^{3+} \mid Cr \parallel Co \mid Co^{2+}$

Answer Key							
29	a	30	c	31	d	32	b

Using standard reduction potential

How do electrons flow in a voltaic cell? → **From half of the cell with low reduction potential (anode) to half of cell with high reduction potential (cathode).**

What results from the flow of electrons in the voltaic cell? → **It causes a positive potential to the cell.**

the spontaneity of a reaction

if the cell potential is positive → **the reaction is spontaneous**

spontaneous

reactants ⇄ products

non-spontaneous

if the cell potential is negative → **the reaction is non-spontaneous**

non-spontaneous

reactants ⇄ products

spontaneous

How to determine the anode and the cathode?

half-reactions without reduction potential

oxidation	reduction
$X \rightarrow X^+ + e^-$	$Y^+ + e^- \rightarrow Y$
X: anode	Y^+: cathode

half-reactions with reduction potential

$X^+ + e^- \rightarrow X$ $\quad E^\circ_X = \ldots\ldots V$

$Y^+ + e^- \rightarrow Y$ $\quad E^\circ_Y = \ldots\ldots V$

$E^\circ_X < E^\circ_Y$

X: anode $\quad$ Y^+: cathode

Overall redox reaction

$X + Y^+ \rightarrow X^+ + Y$

X: anode $\quad$ Y^+: cathode

cell notation

$X \mid X^+ \parallel Y^+ \mid Y$

X: anode $\quad$ Y^+: cathode

33) What is the cell potential for the following balanced redox reaction, and is the reaction spontaneous or not?

cell reaction تفاعل الخلية	$Sn_{(s)} + Cu^{2+}_{(aq)} \rightarrow Sn^{2+}_{(aq)} + Cu_{(s)}$	
reduction potential جهد الاختزال	$E^{\circ}_{Sn} = -0.1375$ V	$E^{\circ}_{Cu} = +0.3419$ V

choice	E°_{cell} (V)	spontaneity
a.	+0.4794	non-spontaneous
b.	+0.4794	spontaneous
c.	–0.4794	non-spontaneous
d.	–0.4794	spontaneous

34) What is the cell potential for the following balanced redox reaction, and is the reaction spontaneous or not?

cell reaction تفاعل الخلية	$2SO_4^{2-}{}_{(aq)} + Co^{2+}_{(aq)} \rightarrow Co_{(s)} + S_2O_8^{2-}{}_{(aq)}$	
reduction potential جهد الاختزال	$E^{\circ}_{SO_4^{2-}} = +2.01$ V	$E^{\circ}_{Co} = -0.28$ V

choice	E°_{cell} (V)	spontaneity
a.	+2.29 V	spontaneous
b.	+2.29 V	non-spontaneous
c.	–2.29 V	spontaneous
d.	–2.29 V	non-spontaneous

35) What is the cell potential for the following balanced redox reaction, and is the reaction spontaneous or not?

cell notation ترميز الخلية	$Al \mid Al^{3+} \parallel Hg^{2+} \mid Hg$	
reduction potential جهد الاختزال	$E^{\circ}_{Al} = -1.662$ V	$= +0.851$ V E°_{Hg}

choice	E°_{cell} (V)	spontaneity
a.	+2.513	spontaneous
b.	+2.513	non-spontaneous
c.	–2.513	spontaneous
d.	–2.513	non-spontaneous

36) What is the cell potential for the following balanced redox reaction, and is the reaction spontaneous or not?

cell reaction تفاعل الخلية	$Mg_{(s)} + Pb^{2+}_{(aq)} \rightarrow Mg^{2+}_{(aq)} + Pb_{(s)}$	
reduction potential جهد الاختزال	$E^{\circ}_{Mg} = -2.372$ V	$E^{\circ}_{Pb} = -0.1262$ V

choice	E°_{cell} (V)	spontaneity
a.	–2.4982	non-spontaneous
b.	+2.4982	spontaneous
c.	–2.2458	non-spontaneous
d.	+2.2458	spontaneous

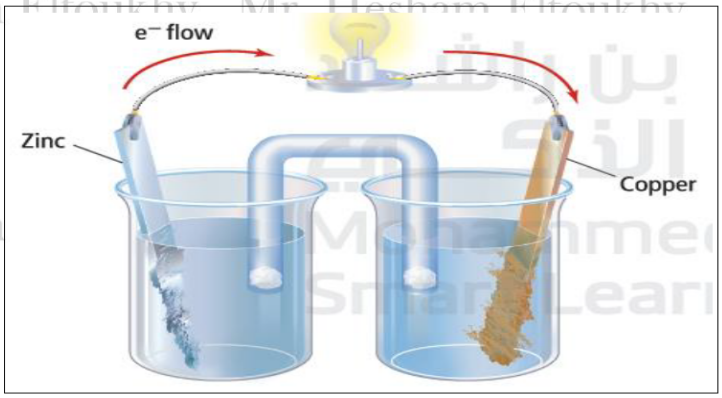
Answer Key	36	d

Sec. (3) Electrolysis

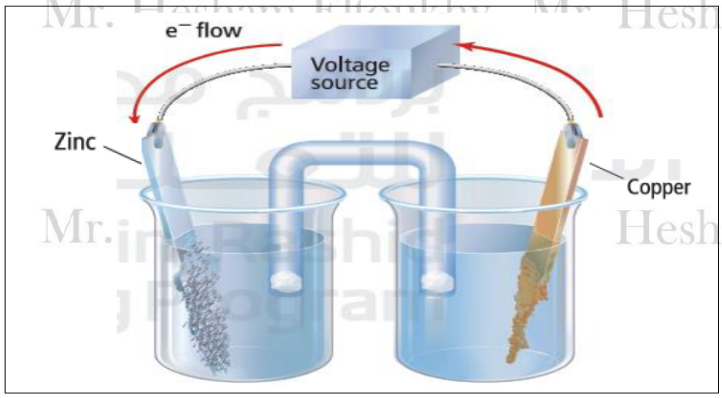
What is produced by the Redox reaction in a voltaic cell?

Electrons flow through the external circuit from the anode electrode to the cathode electrode.

When does the reaction stop in the voltaic cell shown in the corresponding figure?



When the zinc electrode is consumed.



How can the cell be renewed?

When a current is applied in the opposite direction using an external (voltage) power supply.

When the voltage source is left long enough, the cell will return to nearly its original power.

voltaic cell

spontaneous

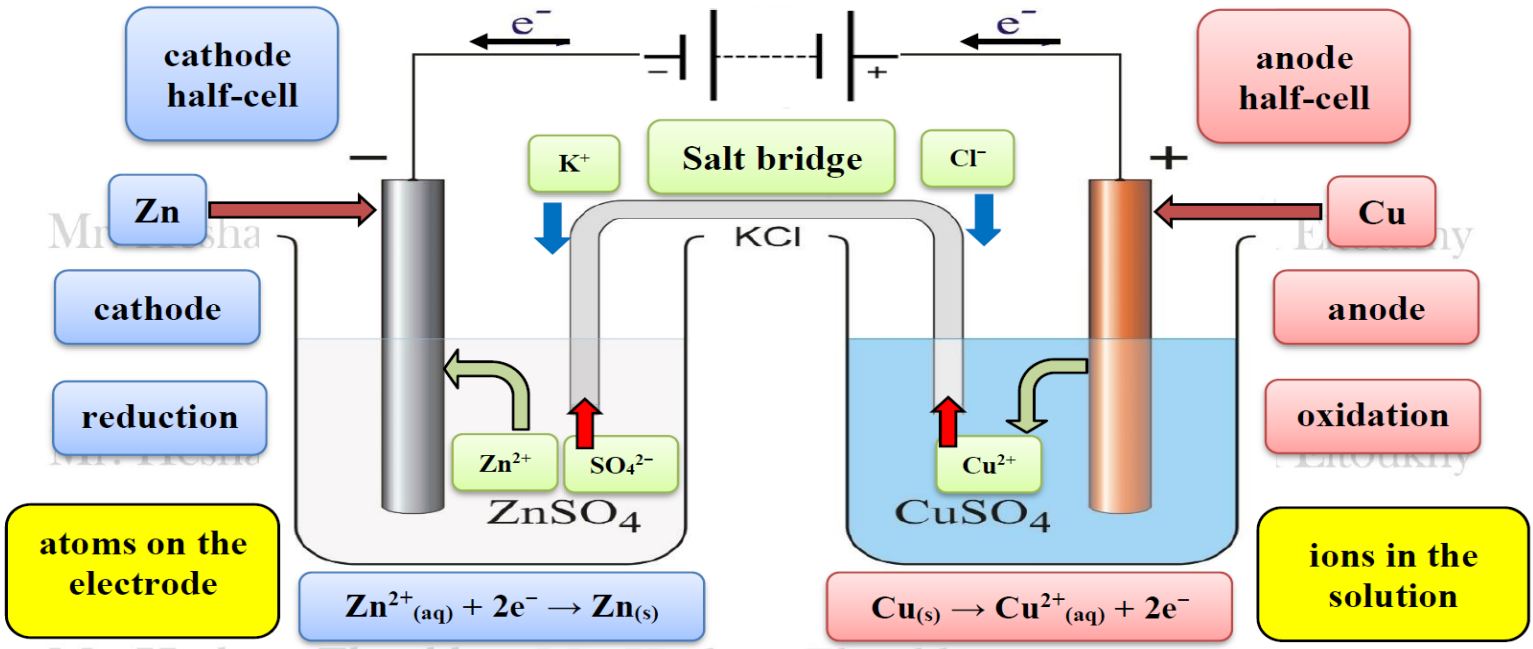
$$Zn + Cu^{2+} \rightleftarrows Zn^{2+} + Cu$$

non-spontaneous

electrolytic cell

Electrolysis: Use of electrical energy to bring out a chemical reaction.

Electrolytic Cell: The electrochemical cell in which electrolysis occurs.



The external energy source in the electrolytic cell reverses the electrodes reactions.

Comparison	voltaic cell	electrolytic cell
energy changes	from chemical to electrical	from electrical to chemical
external energy source	no	yes
spontaneity	spontaneous	non-spontaneous
cell potential sign	positive	negative
anode reaction	oxidation	
cathode reaction	reduction	
electrons movement	from anode to cathode	

37) Which of the following describes electrolytic cells?

a. a spontaneous cell

b. energy is converted from chemical to electrical

c. has a positive potential cell

d. the oxidation process occurs at the anode electrode

38) The hydrolysis cell has the following reaction: $2H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)}$

The fuel cell has the reaction: $2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)}$ $E^\circ_{cell} = +1.229$ V

What is the value of E°_{cell} of the hydrolysis cell (V)?

a. +1.229 b. –1.229 c. 2.458 d. –2.458

39) Which of the following statements describes electrolytic cells?

a. the reduction process occurs at the anode

b. corrosion occurs to the cathode electrode

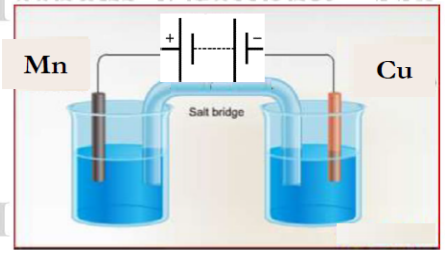
c. the battery reverses the redox reactions

d. the electrons move from the cathode to the anode through the wire

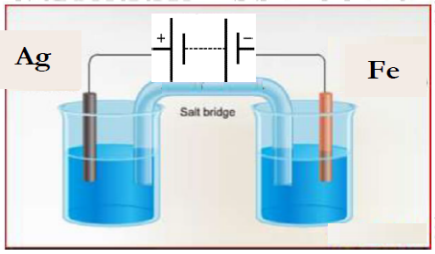
40) Depending on the values of the reduction potentials in the table, which of the following cells represent an electrolytic cell?

Electrode	Ag^+/Ag	Cu^{2+}/Cu	Fe^{2+}/Fe	Mn^{2+}/Mn
E° (V)	+0.799	+0.342	–0.447	–1.185

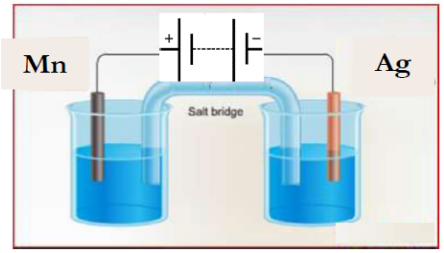
a.



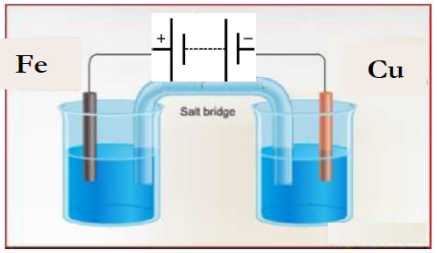
b.



c.



d.



Electrolysis of molten $NaCl_{(l)}$

Molten sodium chloride can be decomposed into sodium metal and chlorine gas in a cell called Down's cell.

Anode	material: carbon	reaction: $2Cl^-_{(l)} \rightarrow Cl_{2(g)} + 2e^-$
Cathode	material: iron	reaction: $Na^+_{(l)} + e^- \rightarrow Na_{(l)}$

overall reaction: $2Na^+_{(l)} + 2Cl^-_{(l)} \rightarrow 2Na_{(l)} + Cl_{2(g)}$

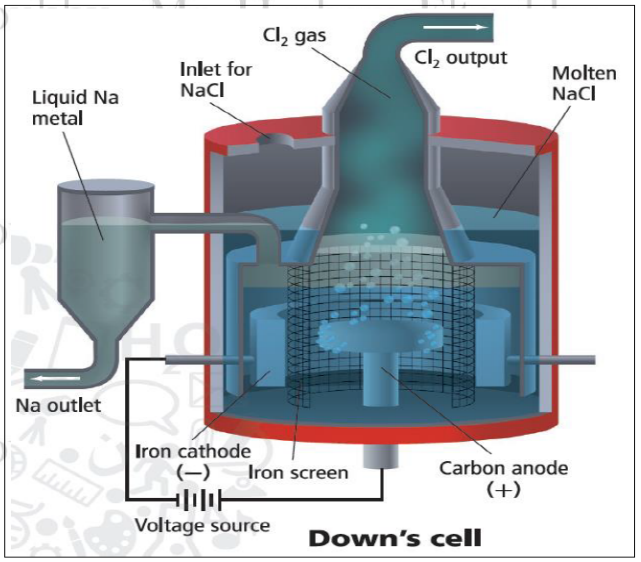
Electrolyte	molten NaCl

The electrical source provides the electrons which are used to reduce the sodium ions at the cathode.

When electrons are lost from the anode, and the chloride ions at the anode oxidized to form chlorine gas.

Why is NaCl used as molten in Down's cell?

Because ionic compounds conduct current when they are in solution or molten form where the ions can move.



uses of chlorine

- produce of paper, plastics, pesticides, textiles, dyes and paints
- produce of household detergents such as household bleach
- purified water for drinking and swimming

uses of sodium

- produce many salts used in foods in its ionic compounds
- produce of outdoor sodium vapor lamps
- coolant in nuclear reactions in its pure form

not required to memorize

Electrolysis of brine $NaCl_{(aq)}$

Decomposition of brine (sodium chloride solution) is a typical electrolytic cell.

Anode	reaction: $2Cl^-_{(l)} \rightarrow Cl_{2(g)} + 2e^-$
Cathode	reaction: $2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$

overall reaction: $2H_2O_{(l)} + 2NaCl_{(aq)} \rightarrow H_{2(g)} + Cl_{2(g)} + 2NaOH_{(aq)}$

Which of the two reactions takes place at the anode? why?

$2Cl^-_{(aq)} \rightarrow Cl_{2(g)} + 2e^-$

$2H_2O_{(l)} \rightarrow O_{2(g)} + 4H^+_{(aq)} + 4e^-$

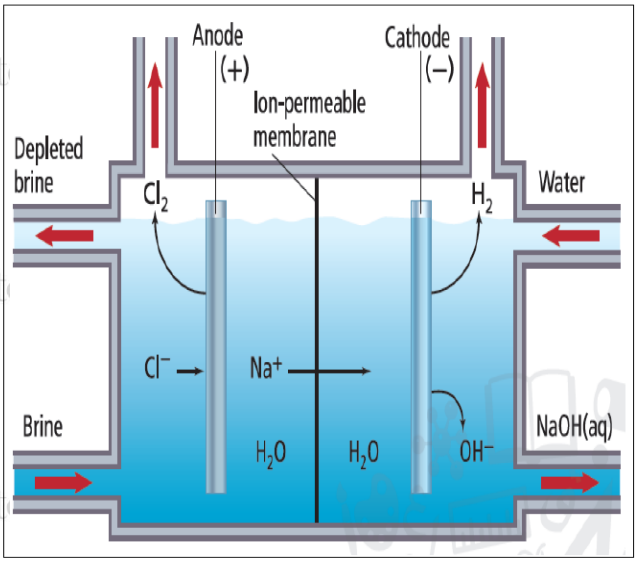
$2Cl^-_{(aq)} \rightarrow Cl_{2(g)} + 2e^-$
because the desired product is chlorine gas, Cl_2, the concentration of chloride ions, Cl^-, is kept high.

Which of the two reactions takes place at the cathode? why?

$Na^+_{(aq)} + e^- \rightarrow Na_{(s)}$

$2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$

$2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$
because water is easier to reduce.



The materials resulting from the total reaction (H_2 gas, Cl_2 gas, and NaOH solution) are important commercial substances.

Chlorine gas is used in the manufacture of PVC products such as water pipes.

41) What is the anode reaction in a Down's cell?

a. $2Cl^-_{(l)} \rightarrow Cl_{2(g)} + 2e^-$

b. $Cl_{2(g)} + 2e^- \rightarrow 2Cl^-_{(l)}$

c. $Na_{(l)} \rightarrow Na^+_{(l)} + e^-$

d. $Na^+_{(l)} + e^- \rightarrow Na_{(l)}$

42) What is the reaction of the cathode in a NaCl solution electrolytic cell?

a. $Cl_{2(g)} + 2e^- \rightarrow 2Cl^-_{(aq)}$

b. $O_{2(g)} + 4H^+_{(aq)} + 4e^- \rightarrow 2H_2O_{(l)}$

c. $Na^+_{(aq)} + e^- \rightarrow Na_{(s)}$

d. $2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$

43) Which of the following substances does not result from the overall reaction of the electrolysis of a NaCl solution?

a. $H_{2(g)}$

b. $Cl_{2(g)}$

c. $Na_{(s)}$

d. $NaOH_{(aq)}$

44) Why is NaCl used as molten or solution in electrolytic cells?

①	②	③
ionic compounds in the solid-state conduct electricity	molten NaCl contains free moving ions	NaCl solution in which the Na^+ and Cl^- ions move freely

a. ① and ② only

b. ② and ③ only

c. ①, ② and ③

d. ① and ③ only

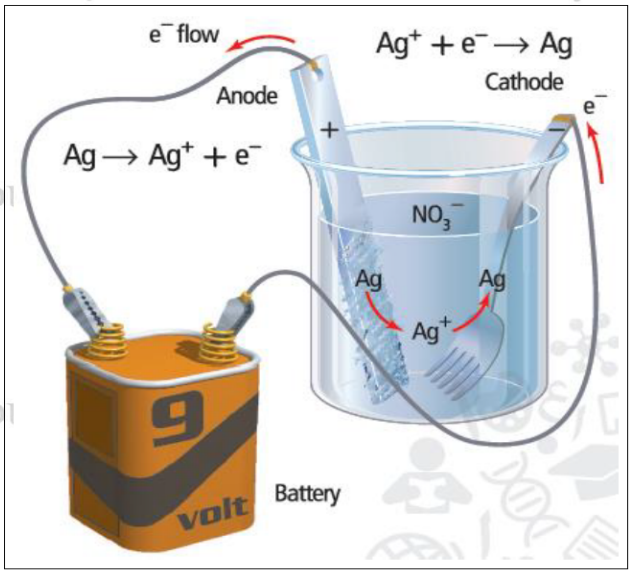
Electroplating

Objects are electroplated by applying a thin and uniform layer of metal.

Anode	**material to be plated with**	**connect to the positive of the battery.**
Cathode	**material to be plated**	**connect to the negative of the battery.**
Electrolyte	**solution of the material to be plated with**	

Electroplating of an item with silver

Anode material	**silver**
Anode reaction	$Ag \rightarrow Ag^+ + e^-$
Cathode material	**item to be plated**
Cathode reaction	$Ag^+ + e^- \rightarrow Ag$
Electrolyte	$AgNO_{3(aq)}$

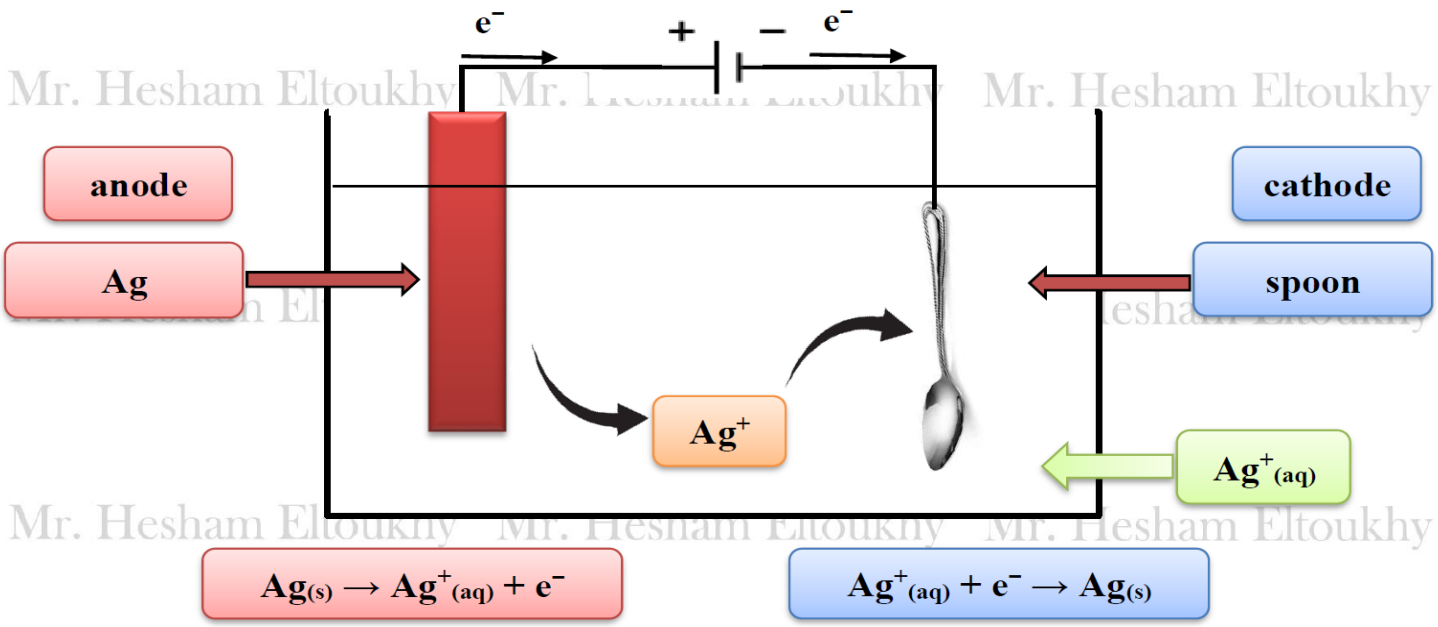


Silver atoms are transferred from the anode to the cathode, the silver electrode is eroded, and the body is coated with a layer of silver.

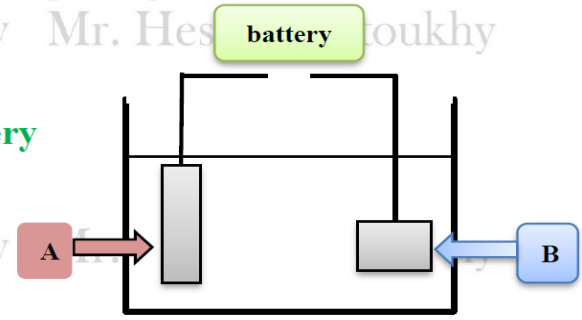
The current passing through the cell must be carefully controlled to obtain a smooth and even layer of metal in the coating.

Some cars are electroplated with nickel and then chromium to make them more rust-resistant.

Electroplating of metallic spoon with silver



45) Which of the following statements describes the electroplating process of object B with metal A?



a. B is connected to the positive electrode of the battery

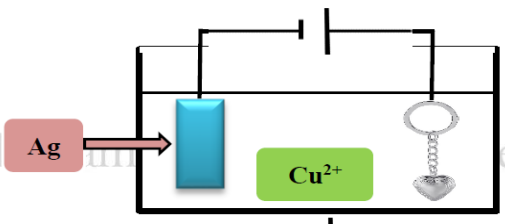
b. cathode reaction: $A \rightarrow A^{2+} + 2e^-$

c. the solution used as the electrolyte contains B ions

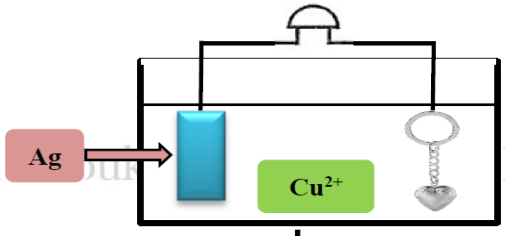
d. mass of A decreases when the plating process is completed

46) Which of the following cells represents an electrolytic cell in which a metal medal is electroplated with silver metal?

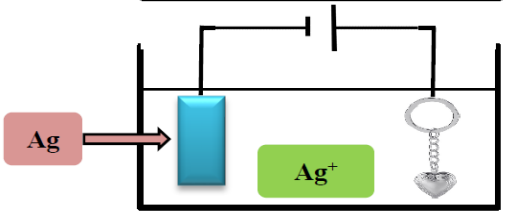
a.



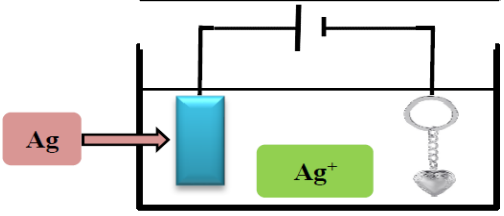
b.



c.



d.



Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy
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Mr. Hesham Eltoukhy

Part Two (Questions with answers)

Additional questions on each section with answer key at the end of each section.

Mr. Hesham Eltoukhy
Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy
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Section (1) Practices

Glossary	
Electrochemistry	Study of oxidation and reduction processes, during which chemical energy is converted into electrical energy and vice versa.
Electrochemical cell	A device that uses a redox reaction to produce electrical energy or uses electrical energy to cause a chemical reaction.
Voltaic cell	A type of electrochemical cell that converts chemical energy into electrical energy through a spontaneous redox reaction.
Half-cell reaction	The reaction that occurs in each half-cell.
Electrode	An electrically conductive material.
Anode	The electrode at which the oxidation reaction occurs.
Cathode	The electrode at which the reduction reaction occurs.
Salt bridge	A path to maintain the neutrality of a solution by allowing ions to pass from one side to the other.
Reduction potential	The tendency (ability) of a substance to gain electrons.

Essay Questions		
1	Under what conditions does a redox reaction produce an electric current flowing through a wire?	An electrochemical cell in which an oxidation half-reaction and a reduction half-reaction occur and are connected to a salt bridge results in the flow of electrons (electrical current) through the conducting wire.
2	What are the components of a voltaic cell, and what is the role of each component in the cell's operation?	It consists of an anode (at which oxidation occurs), a cathode (at which reduction occurs), a salt bridge (which allows the movement of ions through solutions), and a conducting wire (which allows electrons to pass from the anode to the cathode).
3	What property of a redox reaction allows it to be used to generate an electric current?	The exchange of electrons between the reactants in the equation.
4	Why do electrons move from one electrode to another in a voltaic cell?	Because ions in solution at the cathode gain electrons more willingly than ions in solution at the anode.

5	What information do you need to determine the standard potential of a voltaic cell?	Standard reduction potentials for each half equation.
6	The half-cell potential varies depending on the concentration of reactants and products, which is why standard potential are measured at a concentration of 1M. Maintaining the pressure at 1 atm is important in half cells that contain gases, whether reactants or products. Suggest a reason why gas pressure in these cells is important.	Pressure is an indication of concentration, so pressure is a concentration factor in half-cells containing gases.

Multiple choice questions

1) Under what conditions are standard reduction potentials measured?

a. 1°C, 25 atm

b. 1°C, 1 atm

c. 25°C, 25 atm

d. 25°C, 1 atm

2) Which of the following is not a function of a salt bridge?

a. Allows ions to pass from one side to another

b. Allows electrons to move in the cell

c. Maintains the balance of the solution

d. Do not allow the two solutions to mix

3) How does charge transfer occur across the external wires in a voltaic cell?

a. Ionization **b. Ions movement**

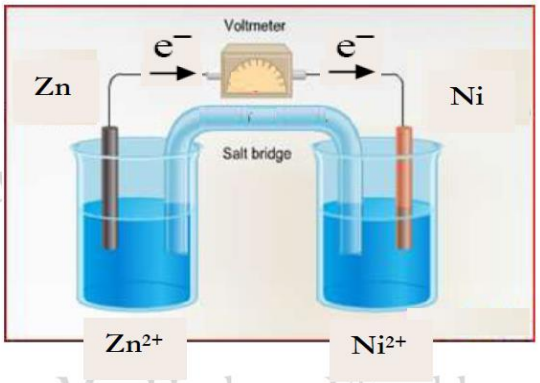
c. Electrons movement **d. Protons movement**

4) How does charge transfer occur across the salt bridge in a voltaic cell?

a. Ionization **b. Ions movement**

c. Electrons movement **d. Protons movement**

5) **Based on the corresponding figure, which of the following statements is correct?**



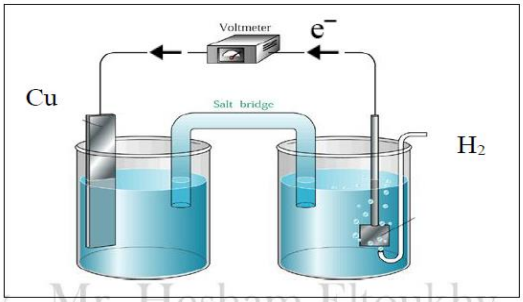
a. The mass of the Zn electrode increases

b. The mass of the Ni electrode decreases

c. Zn^{2+} ions move through the salt bridge towards the Ni half-cell

d. Ni^{2+} ions move through the salt bridge towards the Zn half-cell

6) **Based on the corresponding figure, which of the following statements is correct?**



a. Cathode reaction: $H_2 \rightarrow 2H^+ + 2e^-$

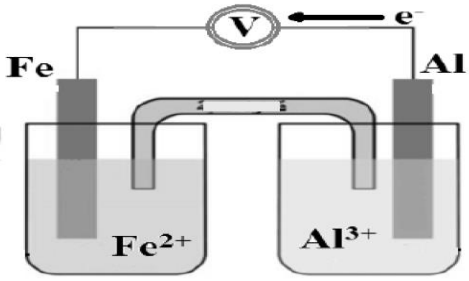
b. Anode reaction: $Cu^{2+} + 2e^- \rightarrow Cu$

c. The mass of the copper electrode decreases

d. Cell notation: $H_2 \mid 2H^+ \parallel Cu^{2+} \mid Zn$

7) **Depending on the table and the corresponding drawing representing a voltaic cell. Which of the following statements is correct?**

electrode القطب	Fe^{2+}	Al^{3+}
potential الجهد	–0.41 V	–1.66 V



a. cell potential = –1.25 V

b. Aluminum represents the anode electrode

c. cathode reaction: $Fe^{2+} + 2e^- \rightarrow Fe$

d. anode reaction: $Al^{3+} + 3e^- \rightarrow Al$

8) **What is the balanced chemical equation for a standard cell that has cell notation?**

$Zn \mid Zn^{2+} \parallel Cd^{2+} \mid Cd$

a. $Zn + Cd^{2+} \rightarrow Zn^{2+} + Cd$

b. $Zn^{2+} + Cd \rightarrow Zn + Cd^{2+}$

c. $Zn + Cd \rightarrow Zn^{2+} + Cd^{2+}$

d. $Zn^{2+} + Cd^{2+} \rightarrow Zn + Cd$

9) **Based on the standard reduction potentials mentioned in the following table if the silver electrode is connected to the chromium electrode in a voltaic cell. Which electrode is oxidized, and which electrode is reduced?**

a. oxidation of Cr, reduction of Ag^+

b. oxidation of Ag, reduction of Cr^{3+}

c. oxidation of Cr^{3+}, reduction of Ag

d. oxidation of Ag^+, reduction of Cr

Standard Reduction Potentials at 25°C, 1 atm, and 1*M* Solution	
$Ag^+ + e^- \rightarrow Ag$	0.7996
$Cr^{3+} + 3e^- \rightarrow Cr$	−0.744

10) **Which statement describes a voltaic cell made up of the following electrodes?**

electrode القطب	Cu	Cd
potential الجهد	+0.34 V	–0.40 V

a. Reduction of cadmium

b. Oxidation of copper

c. Positive ions move from the copper half-cell to the cadmium half cell

d. Electrons move from the cadmium half-cell to the copper half cell

11) **What is the anode electrode and cathode electrode and the direction of electron flow for the two-electrode cell?**

electrode القطب	Ag	Cr
potential الجهد	+0.799 V	–0.744 V

choice	anode electrode	cathode electrode	electron flow direction
a.	Silver	Chromium	From silver to chromium
b.	Silver	Chromium	From chromium to silver
c.	Chromium	Silver	From silver to chromium
d.	Chromium	Silver	From chromium to silver

12) What is the cell notation when the next half of the cell is connected to a standard hydrogen electrode? $(E^{\circ}_{H_2} = 0.0\ V)$

$Cu^{2+} \mid Cu$	$E^{\circ}_{Cu^{2+}\mid Cu} = +0.3419\ V$

a. $Cu \mid Cu^{2+} \parallel 2H^{+} \mid H_2$

b. $Cu^{2+} \mid Cu \parallel H_2 \mid 2H^{+}$

c. $H_2 \mid 2H^{+} \parallel Cu^{2+} \mid Cu$

d. $2H^{+} \mid H_2 \parallel Cu \mid Cu^{2+}$

13) What is the cell notation when the next half of the cell is connected to a standard hydrogen electrode? $(E^{\circ}_{H_2} = 0.0\ V)$

$Zn^{2+} \mid Zn$	$E^{\circ}_{Zn^{2+}\mid Zn} = -0.7618\ V$

a. $Zn \mid Zn^{2+} \parallel 2H^{+} \mid H_2$

b. $2H^{+} \mid H_2 \parallel Zn \mid Zn^{2+}$

c. $Zn^{2+} \mid Zn \parallel H_2 \mid 2H^{+}$

d. $H_2 \mid 2H^{+} \parallel Zn^{2+} \mid Zn$

14) What is the cell notation when the next half of the cell is connected to a standard hydrogen electrode? $(E^{\circ}_{H_2} = 0.0\ V)$

$Al^{3+} \mid Al$	$E^{\circ}_{Al^{3+}\mid Al} = -1.662\ V$

a. $Al \mid Al^{3+} \parallel 2H^{+} \mid H_2$

b. $Al^{3+} \mid Al \parallel H_2 \mid 2H^{+}$

c. $H_2 \mid 2H^{+} \parallel Al^{3+} \mid Al$

d. $2H^{+} \mid H_2 \parallel Al \mid Al^{3+}$

15) What is the oxidation half-reaction and reduction half-reaction of a silver-chromium voltaic cell?

electrode القطب	Ag	Cr
potential الجهد	+0.799 V	–0.744 V

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choice	oxidation half-reaction	reduction half-reaction
a.	$Cr^{3+} + 3e^- \rightarrow Cr$	$Ag \rightarrow Ag^+ + e^-$
b.	$Ag \rightarrow Ag^+ + e^-$	$Cr^{3+} + 3e^- \rightarrow Cr$
c.	$Ag^+ + e^- \rightarrow Ag$	$Cr \rightarrow Cr^{3+} + 3e^-$
d.	$Cr \rightarrow Cr^{3+} + 3e^-$	$Ag^+ + e^- \rightarrow Ag$

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16) What is the cell potential (V) of the voltaic cell made up of the following two halves of the cell?

half-reaction نصف التفاعل	$Sn^{2+} + 2e^- \rightarrow Sn$	$Cr^{3+} + 3e^- \rightarrow Cr$
potential الجهد	–0.137 V	–0.744 V

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a. +0.881

b. –0.881

c. +0.607

d. –0.607

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17) Based on the following spontaneous cell reaction, which notation correctly represents a voltaic cell?

$$Mg + Pb^{2+} \rightarrow Pb + Mg^{2+} \qquad E^\circ_{cell} = +2.246\ V$$

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a. $Mg^{2+} \mid Mg \parallel Pb \mid Pb^{2+}$

b. $Mg \mid Mg^{2+} \parallel Pb^{2+} \mid Pb$

c. $Pb^{2+} \mid Pb \parallel Mg \mid Mg^{2+}$

d. $Pb \mid Pb^{2+} \parallel Mg^{2+} \mid Mg$

18) What is the balanced equation for the spontaneous cell reaction that occurs in the cell along with the following reduction half-reactions?

half-reaction نصف التفاعل	$Sn^{2+}_{(aq)} + 2e^- \rightarrow Sn_{(s)}$	$Fe^{3+}_{(aq)} + 3e^- \rightarrow Fe_{(s)}$
potential الجهد	–0.137 V	–0.037 V

a. $2Fe_{(s)} + 3Sn^{2+}_{(aq)} \rightarrow 2Fe^{3+}_{(aq)} + 3Sn_{(s)}$

b. $2Fe^{3+}_{(aq)} + 3Sn_{(s)} \rightarrow 2Fe_{(s)} + 3Sn^{2+}_{(aq)}$

c. $2Fe_{(s)} + 3Sn_{(s)} \rightarrow 2Fe^{3+}_{(aq)} + 3Sn^{2+}_{(aq)}$

d. $2Fe^{3+}_{(aq)} + 3Sn^{2+}_{(aq)} \rightarrow 2Fe_{(s)} + 3Sn_{(s)}$

19) What is the balanced equation for the spontaneous cell reaction that occurs in the cell along with the following reduction half-reactions?

half-reaction نصف التفاعل	$Pb^{2+}_{(aq)} + 2e^- \rightarrow Pb_{(s)}$	$Pt^{2+}_{(aq)} + 2e^- \rightarrow Pt_{(s)}$
potential الجهد	–0.365 V	+1.18 V

a. $Pt^{2+}_{(aq)} + Pb_{(s)} \rightarrow Pt_{(s)} + Pb^{2+}_{(aq)}$

b. $Pt_{(s)} + Pb^{2+}_{(aq)} \rightarrow Pt^{2+}_{(aq)} + Pb_{(s)}$

c. $Pt^{2+}_{(aq)} + Pb^{2+}_{(aq)} \rightarrow Pt_{(s)} + Pb_{(s)}$

d. $Pt_{(s)} + Pb_{(s)} \rightarrow Pt^{2+}_{(aq)} + Pb^{2+}_{(aq)}$

20) What is the balanced equation for the spontaneous cell reaction that occurs in the cell along with the following reduction half-reactions?

half-reaction نصف التفاعل	$Ag^{+}_{(aq)} + e^- \rightarrow Ag_{(s)}$	$Ni^{2+}_{(aq)} + 2e^- \rightarrow Ni_{(s)}$
potential الجهد	+0.799 V	–0.257 V

a. $Ni + 2Ag^{+} \rightarrow Ni^{2+} + 2Ag$

b. $Ni^{2+} + 2Ag \rightarrow Ni + 2Ag^{+}$

c. $Ni^{+} + 2Ag^{2+} \rightarrow Ni + 2Ag$

d. $Ni + 2Ag \rightarrow Ni^{2+} + 2Ag^{+}$

21) What is the cell potential (V) at which the following reaction occurs?

cell reaction تفاعل الخلية	$Mn_{(s)} + Ni^{2+}_{(aq)} \rightarrow Mn^{2+}_{(aq)} + Ni_{(s)}$	
reduction potential جهد الاختزال	$E^{\circ}_{Mn} = -1.185$ V	$E^{\circ}_{Ni} = -0.257$ V

a. –0.928

b. +0.928

c. –1.442

d. +1.442

22) What is the cell potential (V) at which the following reaction occurs?

cell reaction تفاعل الخلية	$Be^{2+}_{(aq)} + Ag_{(s)} \rightarrow Be_{(s)} + Ag^{+}_{(aq)}$	
reduction potential جهد الاختزال	$E^{\circ}_{Ag} = +0.79$ V	$E^{\circ}_{Be} = -1.85$ V

a. –1.06

b. +1.06

c. –2.64

d. +2.64

23) What is the cell potential (V) at which the following reaction occurs?

cell reaction تفاعل الخلية	$I_{2(aq)} + Sn_{(s)} \rightarrow 2I^{-}_{(aq)} + Sn^{2+}_{(aq)}$	
reduction potential جهد الاختزال	$E^{\circ}_{I_2} = +0.535$ V	$E^{\circ}_{Sn} = -0.137$ V

a. +0.672

b. –0.672

c. +0.398

d. –0.398

24) What is the standard potential of the following electrochemical cell, and is the reaction spontaneous or non-spontaneous?

cell reaction تفاعل الخلية	$Cd_{(s)} + 2NO_3^-{}_{(aq)} + 4H^+{}_{(aq)} \rightarrow Cd^{2+}{}_{(aq)} + 2NO_{2(g)} + 2H_2O_{(l)}$	
reduction potential جهد الاختزال	$E^\circ_{Cd} = -0.403$ V	$E^\circ_{NO_3^-} = +0.775$ V

choice	E°_{cell} (V)	Reaction spontaneity
a.	+1.178	spontaneous
b.	+1.178	non-spontaneous
c.	–0.372	spontaneous
d.	–0.372	non-spontaneous

25) What is the standard potential of the following electrochemical cell, and is the reaction spontaneous or non-spontaneous?

cell reaction تفاعل الخلية	$2Mn^{2+}{}_{(aq)} + 8H_2O_{(l)} + 10Hg^{2+}{}_{(aq)} \rightarrow 2MnO_4^-{}_{(aq)} + 16H^+{}_{(aq)} + 5Hg_2^{2+}{}_{(aq)}$	
جهد الاختزال reduction potential	$E^\circ_{Mn} = +1.507$ V	$E^\circ_{Hg} = +0.920$ V

choice	E°_{cell} (V)	Reaction spontaneity
a.	+0.587	non-spontaneous
b.	+0.587	spontaneous
c.	–0.587	non-spontaneous
d.	–0.587	spontaneous

26) Which of the following does not represent a correct electrochemical cell notation?

a. $Zn \mid Zn^{2+} \parallel Cu^{2+} \mid Cu$

b. $Al \mid Al^{3+} \parallel Zn^{2+} \mid Zn$

c. $Ag^{+} \mid Ag \parallel Cu \mid Cu^{2+}$

d. $Mg \mid Mg^{2+} \parallel Zn^{2+} \mid Zn$

27) What is the cell potential for the following balanced redox reaction, and is the reaction spontaneous or not?

cell reaction تفاعل الخلية	$2Al^{3+}_{(aq)} + 3Cu_{(s)} \rightarrow 3Cu^{2+}_{(aq)} + 2Al_{(s)}$	
reduction potential جهد الاختزال	$E^{\circ}_{Al} = -1.662$ V	$E^{\circ}_{Cu} = +0.341$ V

choice	E°_{cell} (V)	Reaction spontaneity
a.	–1.321	spontaneous
b.	+1.321	non-spontaneous
c.	–2.003	non-spontaneous
d.	+2.003	spontaneous

28) What is the cell potential for the following balanced redox reaction, and is the reaction spontaneous or not?

cell reaction تفاعل الخلية	$Hg^{2+}_{(aq)} + 2Cu^{+}_{(aq)} \rightarrow 2Cu^{2+}_{(aq)} + Hg_{(l)}$	
reduction potential جهد الاختزال	$E^{\circ}_{Hg} = +0.851$ V	$E^{\circ}_{Cu} = +0.153$ V

choice	E°_{cell} (V)	Reaction spontaneity
a.	–0.698	non-spontaneous
b.	+0.698	spontaneous
c.	+1.004	spontaneous
d.	–1.004	non-spontaneous

29) What is the cell potential (V) at which the following reaction occurs?

cell notation ترميز الخلية	$H_2 \mid 2H^+ \parallel 2I^- \mid I_2$	
reduction potential جهد الاختزال	$E^\circ_{H_2} = 0.0$ V	$E^\circ_{I_2} = +0.53$ V

a. –1.06

b. +1.06

c. –0.53

d. +0.53

30) Based on the data in the table below for the reduction half reactions of the voltaic cell. Which of the following statements is correct?

half-reaction نصف التفاعل	$Pt^{2+}_{(aq)} + 2e^- \rightarrow Pt_{(s)}$	$Sn^{2+}_{(aq)} + 2e^- \rightarrow Sn_{(s)}$
potential الجهد	+1.18 V	–0.1375 V

a. Standard cell potential = –1.3175 V

b. Overall cell reaction: $Pt + Sn^{2+} \rightarrow Pt^{2+} + Sn$

c. Cell notation: $Sn \mid Sn^{2+} \parallel Pt^{2+} \mid Pt$

d. Anode reaction: $Sn^{2+}_{(aq)} + 2e^- \rightarrow Sn_{(s)}$

31) Based on the data in the table below for the reduction half reactions of the voltaic cell. Which of the following statements is correct?

half-reaction نصف التفاعل	$Hg^{2+}_{(aq)} + 2e^- \rightarrow Hg_{(l)}$	$Cr^{2+}_{(aq)} + 2e^- \rightarrow Cr_{(s)}$
potential الجهد	+0.851 V	–0.913 V

a. Cell notation: $Cr^{2+} \mid Cr \parallel Hg \mid Hg^{2+}$

b. Electrons move from the Hg electrode to the Cr electrode

c. Cr represents the cathode electrode

d. Overall cell reaction: $Cr + Hg^{2+} \rightarrow Cr^{2+} + Hg$

32) Based on the data in the table below for the reduction half reactions of the voltaic cell. Which of the following statements is correct?

نصف التفاعل half-reaction	$NO_3^-{}_{(aq)} + 4H^+{}_{(aq)} + 3e^- \rightarrow NO_{(g)} + 2H_2O_{(l)}$	$O_{2(g)} + 2H_2O_{(l)} + 4e^- \rightarrow 4OH^-{}_{(aq)}$
potential الجهد	+0.957 V	+0.401 V

a. Cell notation: $NO \mid NO_3^- \parallel O_2 \mid OH^-$

b. Standard cell potential = +0.556 V

c. Overall cell reaction: $4NO_3^- + 3O_2 + 12OH^- \rightarrow 16H^+ + 14H_2O + 4NO$

d. Cathode reaction: $O_{2(g)} + 2H_2O_{(l)} + 4e^- \rightarrow 4OH^-{}_{(aq)}$

33) What is the balanced chemical equation for a standard cell that has the following notation?

$I^- \mid I_2 \parallel Fe^{3+} \mid Fe^{2+}$

a. $I_2 + 2Fe^{2+} \rightarrow 2I^- + 2Fe^{3+}$

b. $2I^- + 2Fe^{3+} \rightarrow I_2 + 2Fe^{2+}$

c. $I_2 + 2Fe^{3+} \rightarrow 2I^- + 2Fe^{2+}$

d. $2I^- + 2Fe^{2+} \rightarrow I_2 + 2Fe^{3+}$

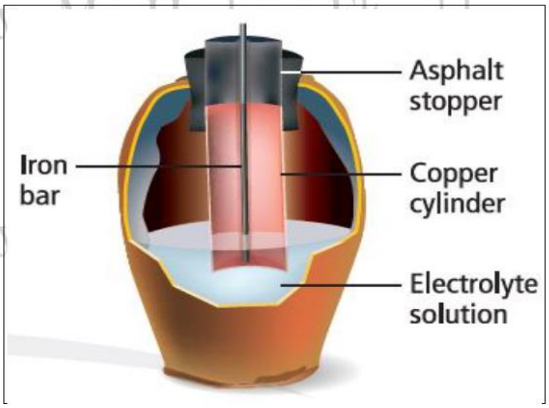
34) Assume that scientists have chosen $Cu^{2+} \mid Cu$ half-cell instead of $H^+ \mid H_2$ as a standard cell, what would the potential of the hydrogen electrode be if the copper electrode was the standard electrode? How will the relationships between standard reduction potential change?

$E^\circ_{Cu} = +0.34$ V

choice	$E^\circ_{H_2}$ (V)	reduction potentials values	Relationships between standard reduction potentials
a.	–0.34 V	change	do not change
b.	–0.34 V	do not change	change
c.	+0.34 V	change	do not change
d.	+0.34 V	do not change	change

35) A ceramic vessel was discovered in 1938 near Baghdad. This ancient vessel had an iron rod surrounded by a copper cylinder as shown in the figure. When the container was filled with an electrolyte solution such as vinegar. This vessel worked as a battery. Based on the reduction potential values in the table below. Which of the following statements is correct?

electrode القطب	Cu^{2+}	Fe^{2+}
potential الجهد	+0.34 V	–0.447



a. Cathode reaction: $Cu^{2+} + 2e^- \rightarrow Cu$

b. Zn represents the cathode electrode

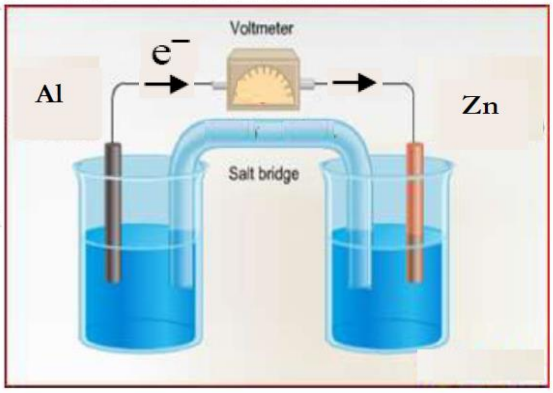
c. The mass of the copper electrode decreases

d. Standard cell potential = +0.107 V

36) Depending on the table and the corresponding figure representing a voltaic cell. Which of the following statements is correct?

E°_{cell} = +0. 9 V

electrode القطب	Zn^{2+}	Al^{3+}
potential الجهد	–0.76 V	??



a. Cathode reaction: $Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e^-$

b. The mass of the Zn electrode decreases

c. Anode reaction: $Al^{3+}_{(aq)} + 3e^- \rightarrow Al_{(s)}$

d. Reduction potential of Al^{3+} = –1.66 V

37) A voltaic cell consisting of Zn^{2+} and Al^{3+} electrodes. What happens when the aluminum plate is replaced with a silver plate? Use the reduction potential table below.

electrode القطب	Al^{3+}	Zn^{2+}	Ag^{+}
potential الجهد	–1.66 V	–0.76 V	+0.79 V

a. Electrons move from the Ag electrode to the Zn electrode

b. Zinc represents the cathode

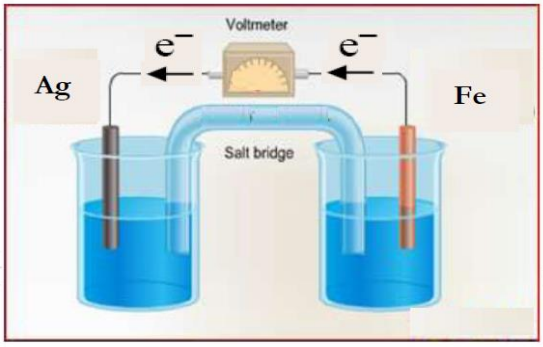
c. The cell potential increases to +1.55 V

d. Silver represents the anode electrode

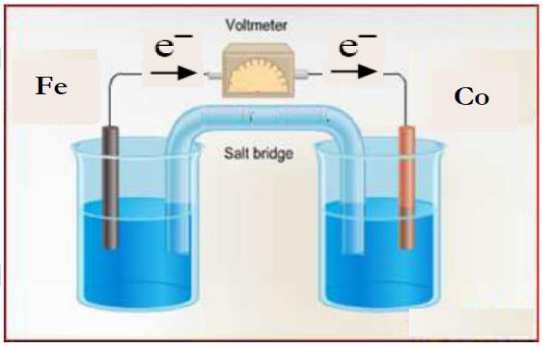
38) Based on the values of the following standard reduction potentials, which of the following cells does not represent a voltaic cell?

electrode	Co^{3+}/Co^{2+}	Ag^{+}/Ag	Cu^{2+}/Cu	Fe^{2+}/Fe	Mn^{2+}/Mn	Li^{+}/Li
potential (V)	+1.92	+0.799	+0.342	–0.447	–1.185	–3.040

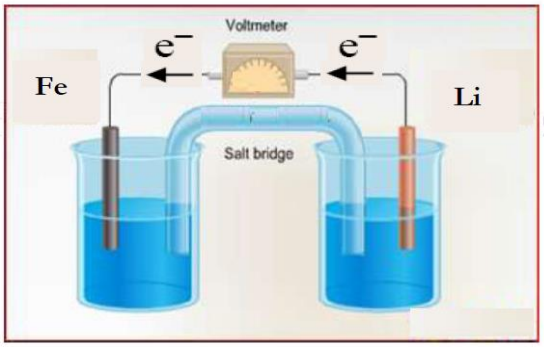
a.



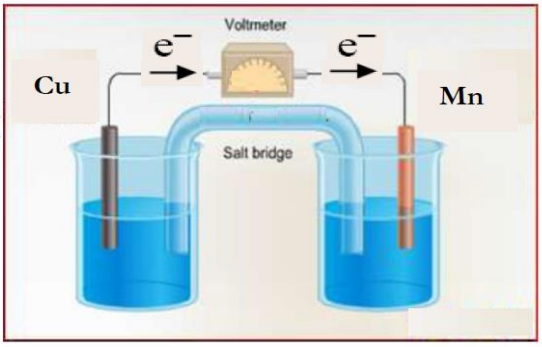
b.



c.



d.



39) What is the correct order of the following ions according to the relative strength of the oxidizing agent given the standard reduction potentials?

electrode القطب	Ag^+	Mg^{2+}	Cu^{2+}	Pb^{2+}
potential الجهد	+0.80	–2.37	+0.34	–0.13

a. least: $Ag^+ \rightarrow Cu^{2+} \rightarrow Pb^{2+} \rightarrow Mg^{2+}$:greatest

b. least: $Pb^{2+} \rightarrow Mg^{2+} \rightarrow Ag^+ \rightarrow Cu^{2+}$:greatest

c. least: $Cu^{2+} \rightarrow Ag^+ \rightarrow Mg^{2+} \rightarrow Pb^{2+}$:greatest

d. least: $Mg^{2+} \rightarrow Pb^{2+} \rightarrow Cu^{2+} \rightarrow Ag^+$:greatest

40) What is the correct order of the following ions according to the relative strength of the oxidizing agent given the standard reduction potentials?

electrode القطب	Fe	Ca	Ag	H_2
potential الجهد	–0.41	–2.76	+0.80	0.00

a. least: silver → hydrogen → iron → calcium :greatest

b. least: calcium → iron → hydrogen → silver :greatest

c. least: hydrogen → calcium → silver → iron :greatest

d. least: iron → silver → calcium → hydrogen :greatest

41) Depending on the cell potential of the following notation, which of the following statements is correct?

$Zn \mid Zn^{2+} \parallel Cu^{2+} \mid Cu$

a. Zn^{2+} ions move towards the anode electrode through the wire

b. Zn^{2+} ions move towards the cathode electrode through the salt bridge

c. Cu^{2+} ions move towards the anode electrode through the salt bridge

d. Electrons move from the Zn electrode to the Cu electrode through the wire

42) Suppose you have a voltaic cell, half of which consists of a tin strip immersed in a solution of tin II ions, and electrons flow from the zinc electrode. How can you determine whether the tin strip is the anode or cathode of this cell by measuring the potential?

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a. If the cell voltage is negative, the tin is reduced and becomes the anode

b. If the cell voltage is positive, the tin is oxidized and becomes the anode

c. If the cell voltage is positive, the tin is reduced and becomes the cathode

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d. If the cell voltage is negative, the tin is oxidized and becomes the cathode

43) Suppose you have a voltaic cell, half of which consists of a tin strip immersed in a solution of tin II ions, and electrons flow from the zinc electrode. How can you determine whether the tin strip is the anode or the cathode in this cell just by simple observation?

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a. The increase in the mass of the tin electrode

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b. The decrease in the mass of the cathode

c. The decrease in the mass of the tin electrode

d. The mass of the tin electrode does not change

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44) Which of the following represents a half-reaction of a cell made up of magnesium and copper?

electrode القطب	Cu	Mg
potential الجهد	+0.34 V	–2.37 V

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a. $Mg^{2+} + 2e^- \rightarrow Mg$

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b. $Cu \rightarrow Cu^{2+} + 2e^-$

c. $Cu \rightarrow Cu^{+} + e^-$

d. $Mg \rightarrow Mg^{2+} + 2e^-$

45) Given the values of the reduction potentials, what is the correct order of the following cells according to the value of the cell potential?

	Cell notation
①	$Al_{(s)} \mid Al^{3+}_{(aq)} \parallel Zn^{2+}_{(aq)} \mid Zn_{(s)}$
②	$Al_{(s)} \mid Al^{3+}_{(aq)} \parallel H^{+}_{(aq)} \mid H_{2(g)}$
③	$H_{2(g)} \mid H^{+}_{(aq)} \parallel Ag^{+}_{(aq)} \mid Ag_{(s)}$
④	$Zn_{(s)} \mid Zn^{2+}_{(aq)} \parallel Ag^{+}_{(aq)} \mid Ag_{(s)}$

Standard reduction potential (V)			
Al^{3+}	Ag^{+}	Cu^{2+}	Zn^{2+}
–1.66	+0.80	+0.34	–0.76

a. least: ③ → ① → ④ → ② :greatest

b. least: ① → ③ → ② → ④ :greatest

c. least: ② → ④ → ① → ③ :greatest

d. least: ④ → ② → ③ → ① :greatest

46) Given the values of the reduction potentials, what is the correct order of the following cells according to the value of the cell potential?

	Cell notation
①	$H_{2(g)} + 2Ag^{+}_{(aq)} \rightarrow 2H^{+}_{(aq)} + 2Ag_{(s)}$
②	$Cu_{(s)} + 2Ag^{+}_{(aq)} \rightarrow Cu^{2+}_{(aq)} + 2Ag_{(s)}$
③	$Fe_{(s)} + Cu^{2+}_{(aq)} \rightarrow Fe^{2+}_{(aq)} + Cu_{(s)}$
④	$H_{2(g)} + Cu^{2+}_{(aq)} \rightarrow 2H^{+}_{(aq)} + Cu_{(s)}$

Standard reduction potential (V)			
Cu^{2+}	Ag^{+}	Fe^{2+}	H_2
+0.34	+0.80	–0.41	0.00

a. least: ③ → ① → ④ → ② :greatest

b. least: ① → ③ → ② → ④ :greatest

c. least: ② → ④ → ① → ③ :greatest

d. least: ④ → ② → ③ → ① :greatest

47) Based on the following table of reduction potentials, which of the following statements is correct?

Electrode	reduction potentials (V)
Ag^+	+0.79
H^+	0.0
Ni^{2+}	–0.25
Zn^{2+}	–0.76

a. The cell consisting of Ag^+ and Zn^{2+} electrodes have the largest value for the cell potential

b. The cell consisting of H^+ and Ni^{2+} electrodes have the largest value for the cell potential

c. Electrons move from the Ag^+ electrode to the Zn^{2+} electrode in the voltaic cell

d. Electrons move from the H^+ electrode to the Ni^{2+} electrode in the voltaic cell

48) A voltaic cell consists of two halves as in the table below. Which of the following statements is correct?

half-cell نصف الخلية	Cu^{2+} | Cu	Co^{2+} | Co
potential الجهد	+0.34 V	–0.28 V

a. Oxidation of Co

b. Anode reaction: $Cu \rightarrow Cu^{2+} + 2e^-$

c. Standard cell potential = +0.06 V

d. Cell notation: Cu| Cu^{2+} || Co^{2+} | Co

49) Based on the following table of reduction potentials, which of the following statements is correct?

half-cell نصف الخلية	$2H^+$ | H_2	Al^{3+} | Al	Ag^+ | Ag	Cr^{3+} | Cr	Fe^{2+} | Fe
potential الجهد	0.0 V	–1.66 V	+0.80 V	–0.74 V	–0.41 V

a. H_2 represents the anode in a voltaic cell with Fe

b. Cell notation of chromium, hydrogen: H_2 | $2H^+$ || Cr^{3+} | Cr

c. The cell consisting of Cr and Fe electrodes have the largest value for the cell potential

d. The Ag^+ ion has the greatest ability to gain electrons

50) Depending on the following data. Which of the following statements is correct?

$Al \mid Al^{3+} \parallel Zn^{2+} \mid Zn$	$E^{\circ}_{\text{الخلية}} = +0.9\ V$

electrode القطب	Zn^{2+}	Al^{3+}
potential الجهد	??	–1.66 V

a. Al represents the cathode electrode

b. Zn represents the anode electrode

c. Zinc reduction voltage = –0.76 V

d. Electrons move from the Zn electrode to the Al electrode in the voltaic cell

51) Use the table below to determine which of the following statements is correct?

Selected Standard Reduction Potentials at 25°C, 1 atm, and 1*M* Ion Concentration	
Half-Reaction	E^0 (V)
$Mg^{2+} + 2e^- \rightarrow Mg$	−2.372
$Al^{3+} + 3e^- \rightarrow Al$	−1.662
$Pb^{2+} + 2e^- \rightarrow Pb$	−0.1262
$Ag^+ + e^- \rightarrow Ag$	0.7996
$Hg^{2+} + 2e^- \rightarrow Hg$	0.851

a. Electrons move from the Hg electrode to the Pb electrode in the voltaic cell

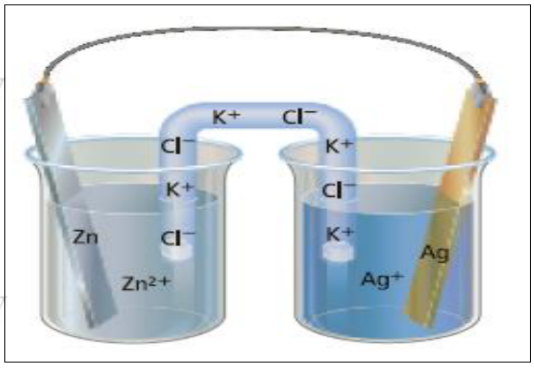
b. Standard cell potential of Mg, Ag cell = +1.572 V

c. Cell notation: $Ag \mid Ag^+ \parallel Al^{3+} \mid Al$

d. The Hg^{2+} ion is the most easily reduced electrode

52) The figure opposite shows a voltaic cell consisting of a strip of zinc in a 0.1 M zinc nitrate solution and a strip of silver in a 0.1 M silver nitrate solution. Which of the following statements describes what happens in the cell?

electrode القطب	Ag^+	Zn^{2+}
potential الجهد	+0.80 V	–0.76 V



a. Anode reaction: $Zn^{2+}_{(aq)} + 2e^- \rightarrow Zn$

b. The electrons move through the salt bridge towards the silver electrode

c. The ions move through the wire from the silver plate to the zinc plate

d. Ag^+ ions accumulate on the silver plate

53) Based on the table of standard reduction potentials for half-cells in the table, which of the following redox reactions is non-spontaneous?

a. $Br_{2(l)} + Mn_{(s)} \rightarrow Mn^{2+}_{(aq)} + 2Br^-_{(aq)}$

b. $2Fe^{3+}_{(aq)} + Sn_{(s)} \rightarrow 2Fe^{2+}_{(aq)} + Sn^{2+}_{(aq)}$

c. $Ni^{2+}_{(aq)} + Mg_{(s)} \rightarrow Mg^{2+}_{(aq)} + Ni_{(s)}$

d. $Pb^{2+}_{(aq)} + 2Cu^+_{(aq)} \rightarrow 2Cu^{2+}_{(aq)} + Pb_{(s)}$

Half-cell	reduction potentials (V)
Mn^{2+} | Mn	–1.185
Br_2 | Br^-	+1.066
Fe^{3+} | Fe^{2+}	+0.771
Sn^{2+} | Sn	–0.137
Ni^{2+} | Ni	–0.257
Mg^{2+} | Mg	–2.372
Pb^{2+} | Pb	–0.126
Cu^{2+} | Cu^+	+0.153

54) Remember that the reducing agent is the substance being oxidized and the oxidizing agent is the substance being reduced.

Given the values of the reduction potentials, which of the following electrodes can convert Au to Au^{3+} but will not convert Co^{2+} to Co^{3+}?

a. Hg^{2+}

b. Pt^{2+}

c. Au^{+}

d. F_2

electrode	reduction potential (V)
$Hg^{2+} + 2e^- \rightarrow Hg$	+0.92
$Pt^{2+} + 2e^- \rightarrow Pt$	+1.18
$Au^{3+} + 3e^- \rightarrow Au$	+1.498
$Au^{+} + e^- \rightarrow Au$	+1.692
$Co^{3+} + 3e^- \rightarrow Co^{2+}$	+1.92
$F_2 + 2e^- \rightarrow 2F^-$	+2.866

Answer Key

1	d	2	b	3	c	4	b	5	c
6	d	7	c	8	a	9	a	10	d
11	d	12	c	13	a	14	a	15	d
16	c	17	b	18	b	19	a	20	a
21	b	22	c	23	a	24	a	25	c
26	c	27	c	28	b	29	d	30	c
31	d	32	b	33	b	34	a	35	a
36	d	37	c	38	d	39	d	40	a
41	b	42	c	43	a	44	d	45	a
46	d	47	a	48	a	49	d	50	c
51	d	52	d	53	d	54	c		

Section (3) Practices

Glossary	
electrolysis	Use of electrical energy to bring out a chemical reaction.
Electrolysis cell	The electrochemical cell in which electrolysis occurs.
Down cell	A cell used to decompose molten sodium chloride into sodium metal and chlorine gas.

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Essay Questions		
1	How can the spontaneous redox reaction of a voltaic cell be reversed?	By passing an electric current through the voltaic cell in the opposite direction.
2	Where does the oxidation process occur in electrolysis?	At the anode.
3	Explain the difference in the electrolysis products of sodium chloride (salt) solution and molten sodium chloride?	Brine electrolysis contains an aqueous solution (water), which affects the products.
4	Use standard reduction potential values to calculate the down's cell potential. Will the cell potential be positive or negative? ($E^{\circ}_{Cl} = -2.71$ V, $E^{\circ}_{Na} = +1.36$ V)	Down's cell is a non-spontaneous reaction, so the cell potential is negative. $E^{\circ}_{Cell} = -4.07$ V
5	Explain why brine electrolysis is widely used in many locations around the world?	Because the products of electrolysis are hydrogen gas, chlorine gas, and sodium hydroxide, which are important commercial products.

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Multiple choice questions

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1) What results when passing an electric current through an electrochemical cell that has a negative cell potential?

a. Redox reaction **b. Electrical energy**

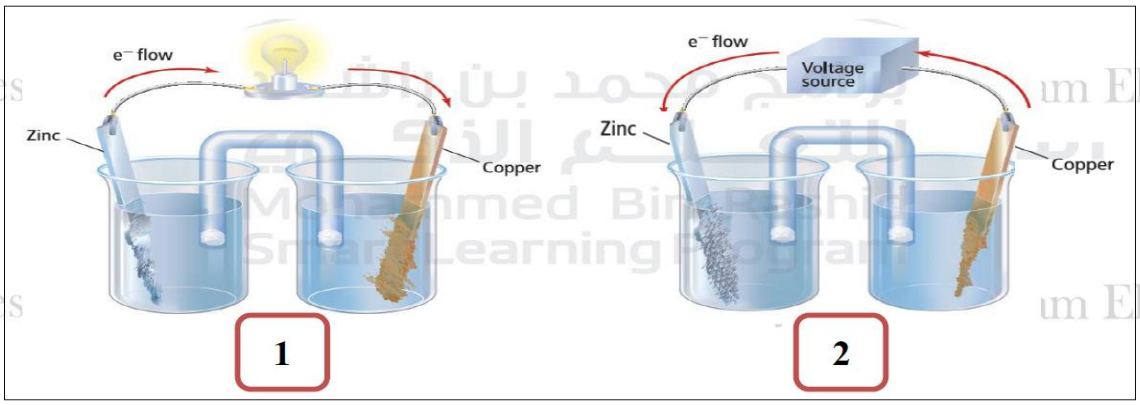
c. Spontaneous reaction **d. Reduction at anode electrode**

2) What is electrolysis and how is it related to the spontaneity of redox reactions?

choice	Electrolysis	Spontaneity
a.	Use of electrical energy to bring out a chemical reaction	Spontaneous
b.	Use of electrical energy to bring out a chemical reaction	Non-spontaneous
c.	Converting chemical energy into electrical energy	Spontaneous
d.	Converting chemical energy into electrical energy	Non-spontaneous

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3) Which of the following is correct regarding the two cells in the figure below?



a. Electrical energy converted to chemical energy in cell (1)

b. A spontaneous redox reaction occurs in cell (1)

c. Chemical energy converted to electrical energy in cell (2)

d. A spontaneous redox reaction occurs in cell (2)

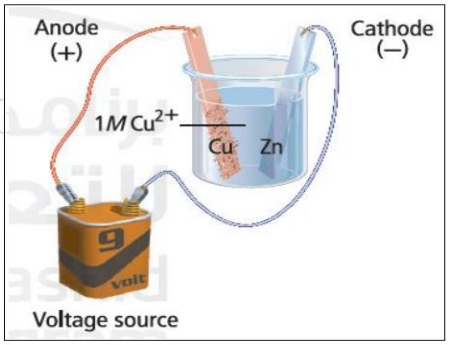
4) Based on the corresponding figure, which of the following statements is correct?

a. The mass of the copper electrode increases

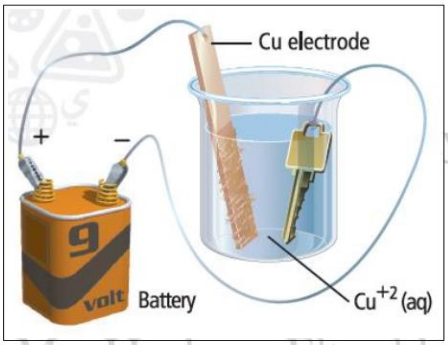
b. Anode reaction: $Cu \rightarrow Cu^{2+} + 2e^-$

c. Oxidation of Zn atoms

d. The zinc ions move to the copper electrode and cover it



5) **The corresponding figure shows the electrolysis process of a copper key in an electrolytic cell. Which of the following statements is correct?**



a. The anode is the key

b. The key mass decreases

c. The mass of the copper plate (Cu) increases

d. Copper is oxidized to Cu^{2+} ions at the anode

6) **What reaction occurs at the anode in a molten sodium chloride electrolysis cell?**

A	$Na^+_{(l)} + e^- \rightarrow Na_{(l)}$
B	$2Cl^-_{(l)} \rightarrow Cl_{2(g)} + 2e^-$
C	$Cl_{2(g)} + 2e^- \rightarrow 2Cl^-_{(l)}$
D	$Na_{(l)} \rightarrow Na^+_{(l)} + e^-$

a. D

b. A

c. B

d. C

7) **What reaction occurs at the cathode in a molten sodium chloride electrolysis cell?**

A	$2Cl^-_{(l)} \rightarrow Cl_{2(g)} + 2e^-$
B	$Na_{(l)} \rightarrow Na^+_{(l)} + e^-$
C	$Na^+_{(l)} + e^- \rightarrow Na_{(l)}$
D	$Cl_{2(g)} + 2e^- \rightarrow 2Cl^-_{(l)}$

a. C

b. A

c. B

d. D

8) What reaction occurs at the anode in a brine electrolysis cell?

A	$Na^+_{(aq)} + e^- \rightarrow Na_{(s)}$
B	$2Cl^-_{(aq)} \rightarrow Cl_{2(g)} + 2e^-$
C	$2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$
D	$2H_2O_{(l)} \rightarrow O_{2(g)} + 4H^+_{(aq)} + 4e^-$

a. A

b. B

c. D

d. C

9) What reaction occurs at the cathode in a brine electrolysis cell?

A	$Na^+_{(aq)} + e^- \rightarrow Na_{(s)}$
B	$2Cl^-_{(aq)} \rightarrow Cl_{2(g)} + 2e^-$
C	$2H_2O_{(l)} \rightarrow O_{2(g)} + 4H^+_{(aq)} + 4e^-$
D	$2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$

a. B

b. A

c. D

d. C

10) Which of the following statements does not describe what happens at electrolysis of $KI_{(aq)}$?

a. The reaction is non-spontaneous

b. The cell potential is negative

c. Anode reaction: $2I^-_{(aq)} \rightarrow I_{2(g)} + 2e^-$

d. Cathode reaction: $K^+_{(aq)} + e^- \rightarrow K_{(s)}$

11) An electrolytic cell releases bromine vapor and hydrogen gas during the electrolysis process. After electrolysis, we found that the cell contained a concentrated potassium hydroxide solution. What is the content of the cell before the electrolysis process begins?

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a. Potassium bromide and water

b. Molten sodium chloride

c. Molten potassium bromide

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d. Sodium chloride and water

12) Which of the following statements is incorrect for the electrolysis of molten NaCl?

a. Sodium ions are reduced at the cathode

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b. Chloride ions and sodium ions move freely in molten NaCl

c. Anode reaction: $2Cl^-_{(l)} \rightarrow Cl_{2(g)} + 2e^-$

d. The energy resulting from redox reaction is converted to electrical energy

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13) Which of the following statements is correct for the electrolysis of brine?

a. Oxidation of chloride ions at the cathode

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b. Reduction of sodium ions at the cathode

c. Reduction of water at the cathode

d. Oxidation of hydrogen ions at the anode

14) In the cell used in the process of plating an object with gold, what happens to the gold metal?

a. Oxidized at the anode

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b. Reduced at the anode

c. Oxidized at the cathode

d. Deposited at the anode

15) Describe the anode and cathode in an electrolysis cell in which a medallion is plated with gold?

choice	Anode	Cathode
a.	The medallion is connected to the negative electrode	The gold alloy is connected to the positive electrode
b.	The medallion is connected to the positive electrode	The gold alloy is connected to the negative electrode
c.	The gold alloy is connected to the negative electrode	The medallion is connected to the positive electrode
d.	The gold alloy is connected to the positive electrode	The medallion is connected to the negative electrode

16) Which of the following electrolytes is used in the process of electroplating an iron ring with a layer of silver?

a. $FeSO_{4(aq)}$

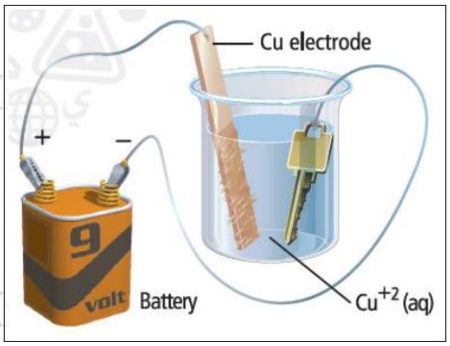
b. $Fe(NO_3)_{2(aq)}$

c. $AgNO_{3(aq)}$

d. $HNO_{3(aq)}$

17) The figure opposite shows an image of a switch being electroplated with copper in an electrolytic cell. Which of the following statements is correct?

①	Oxidation of copper atoms
②	Energy is transformed from chemical to electrical
③	Copper atoms are deposited on the key



a. ②, ③ only

b. ①, ② only

c. ①, ③ only

d. ①, ②, ③

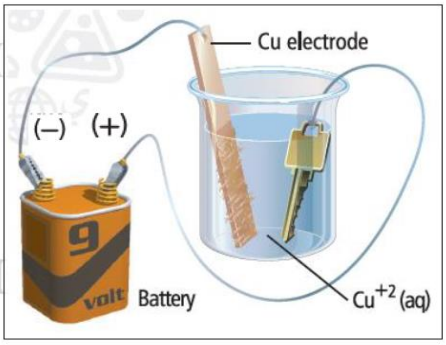
18) What results when a copper electrode is connected to the negative terminal of a battery, and a key is connected to the positive terminal of the battery in electroplating cell of a key with copper shown in the corresponding figure?

a. The key will not be electroplated

b. Oxidation of the copper electrode

c. Electroplating the key with copper

d. Reduction of the key



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Answer Key

1	a	2	b	3	b	4	b	5	d
6	c	7	a	8	b	9	c	10	d
11	a	12	d	13	c	14	a	15	d
16	c	17	c	18	a				

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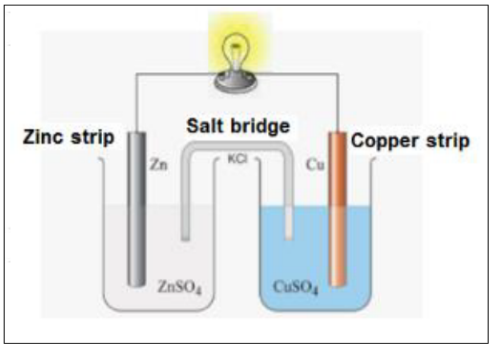
Part Three (Exams of last years)

Last year's exam questions with answer key at the end of each exam.

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Exam 2021-2022 (12 Advanced)

1) In the cell shown in the figure below, which of the following statements is correct?



a. uses electrical energy to cause a chemical reaction

b. positive zinc ions build up around the zinc electrode

c. electrons move through the salt bridge to the copper side

d. the wire can serve as a pathway for electrons to flow from the zinc strip to the copper strip

2) The following reduction half-reactions represent the half-cells of a voltaic cell, which of the following is correct?

$Co^{2+}_{(aq)} + 2e^- \rightarrow Co$ $\quad E^\circ\ (V) = -0.28$

$Pt^{2+}_{(aq)} + 2e^- \rightarrow Pt$ $\quad E^\circ\ (V) = +1.18$

	anode	cathode	Electrochemical cell potential (E°)	Reaction type
A	Pt	Co	+0.9 V	spontaneous
B	Co	Pt	+1.46 V	spontaneous
C	Pt	Co	–0.9 V	nonspontaneous
D	Co	Pt	–1.46 V	nonspontaneous

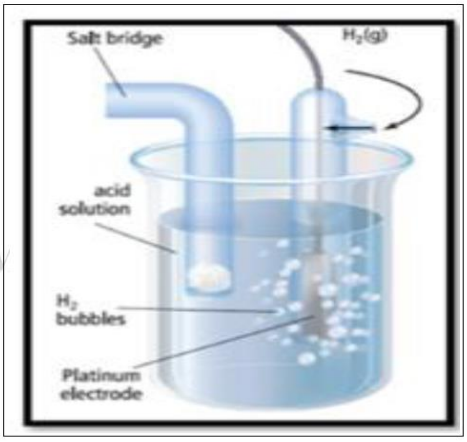
a. B

b. D

c. C

d. A

3) Which of the following is correct of the standard hydrogen electrode shown in the figure below?



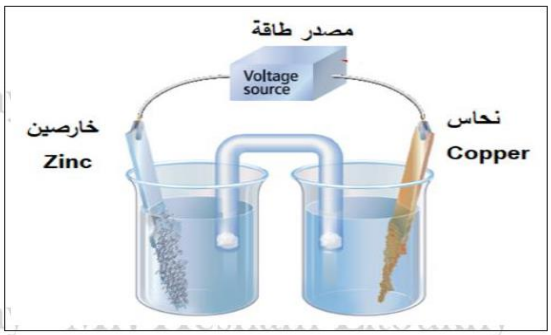
a. The reduction potential of this electrode is 0.000 V at all conditions

b. It is the anode in all the voltaic cells in which it is connected

c. It is the cathode in all the voltaic cells in which it is connected

d. The reduction potential of this electrode is 0.000 V when the concentration of the acid solution is 1 M and hydrogen gas is pumped under a pressure of 1 atm and the temperature is maintained at 25 °C

4) Which of the following is correct of the electrochemical cell in the figure below?



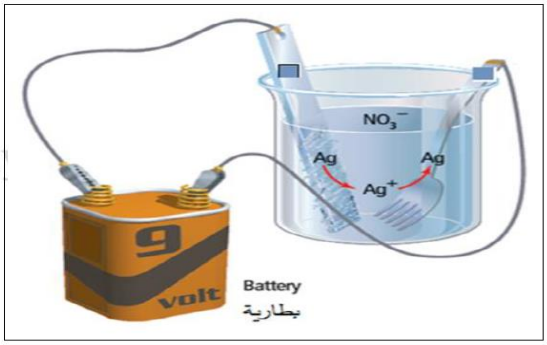
a. Converts chemical energy to electrical energy

b. Non-spontaneous oxidation and reduction reactions occur

c. Spontaneous oxidation and reduction reactions occur

d. The reaction continues until the zinc strip is used up, then the reaction stops

5) Objects are electroplated when a uniform coating is deposited as a protective or decorative layer, as shown in the figure below. Which of the following is correct?



a. The metal used for coating is the cathode

b. Silver is oxidized to silver ions at the cathode

c. Silver is oxidized to silver ions at the anode

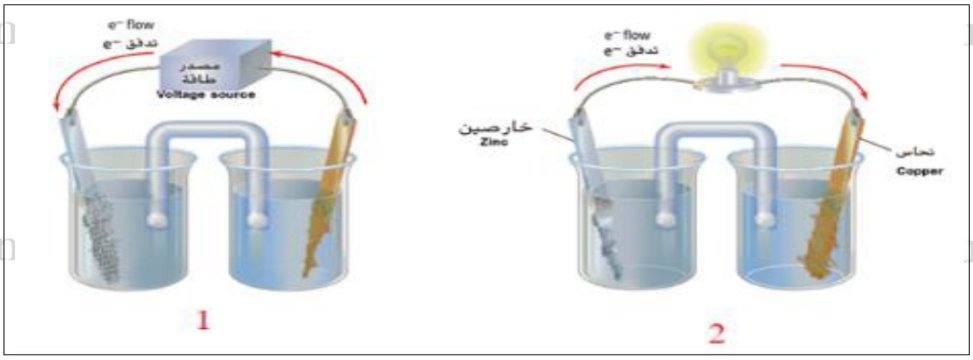
d. The object to be plated is the anode

Answer Key

1	d	2	a	3	d	4	b	5	c

Exam 2022-2023 (12 Advanced)

1) Regarding the two cells in the figure below. Which of the following is correct?



a. Cell 1 is voltaic and converts chemical energy to electrical energy

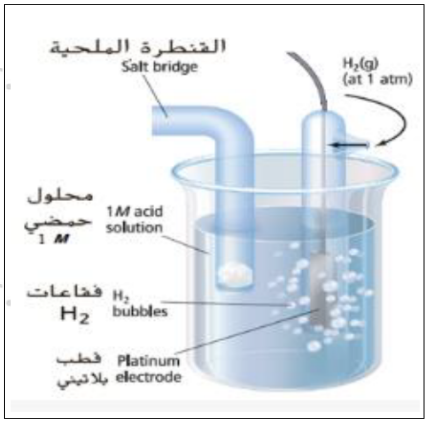
b. Cell 2 is electrolytic and converts chemical energy to electrical energy

c. The reaction in cell 1 is spontaneous

d. The reaction continues in cell 2 until the zinc strip is used up and then the reaction stops

2) Regarding the standard hydrogen electrode in the figure below. Which of the following is correct?

$Cu^{2+} + 2e^- \rightleftarrows Cu$	$E^\circ(V) = +0.3419$
$Zn^{2+} + 2e^- \rightleftarrows Zn$	$E^\circ(V) = -0.7618$



a. It will be cathode when connected to Cu | Cu^{2+} electrode

b. It will be anode when connected to Zn | Zn^{2+} electrode

c. The standard reduction potential (E°) of a standard hydrogen electrode is defined as 0.000 V

d. The standard reduction potential (E°) of a standard hydrogen electrode is defined as 1.104 V

3) **In the figure below, what do the two half-cells need so that you can convert chemical energy into electrical energy?**



a. Only connecting the zinc and copper strips with a metal wire to serve as a pathway for electrons to flow

b. Only a salt bridge to serve as a pathway for ions to flow

c. A salt bridge to serve as a pathway for electrons to flow and a metal wire to serve as a pathway for ions to flow

d. A salt bridge and a metal wire to provide an unbroken pathway for electrical charge to flow

4) **The voltaic half-cell expressed by the following reaction has been connected with one of the half-cells shown in the table below, and the standard cell potential found to be (+3.89 V). What is the half-cell connected?**

$Pt^{2+} + 2e^- \rightleftarrows Pt$ $\quad E^\circ(V) = +1.18$

a. $Na^+ + e^- \rightleftarrows Na$

b. $Mn^{2+} + 2e^- \rightleftarrows Mn$

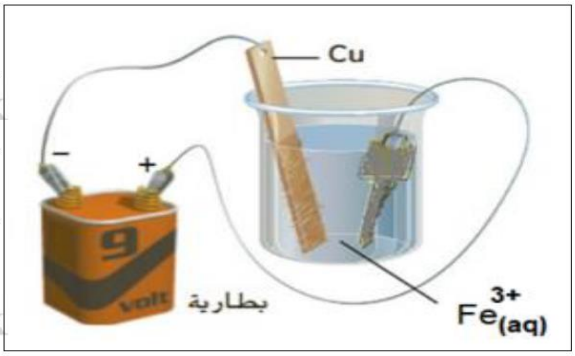
c. $Cr^{3+} + 3e^- \rightleftarrows Cr$

d. $Fe^{2+} + 2e^- \rightleftarrows Fe$

Half reaction نصف التفاعل	$E^\circ(V)$
$Na^+ + e^- \rightleftarrows Na$	−2.71
$Mn^{2+} + 2e^- \rightleftarrows Mn$	−1.185
$Cr^{3+} + 3e^- \rightleftarrows Cr$	−0.744
$Fe^{2+} + 2e^- \rightleftarrows Fe$	−0.447

5) **Khalifa tried to electroplate an iron key with a layer of copper. He designed the electroplating cell shown in the figure below. What is the error(s) in the cell?**

1	Connect the battery poles
2	The electrolyte used does not contain Cu^{2+} ions
3	The key was not connected to a light bulb



a. 1 only

b. 3 only

c. Both 1 and 2

d. Both 1 and 3

Answer Key

1	d	2	c	3	d	4	a	5	c

Exam 2021-2022 (12 General)

1) **Which of the following statements is not correct concerning electrochemistry?**

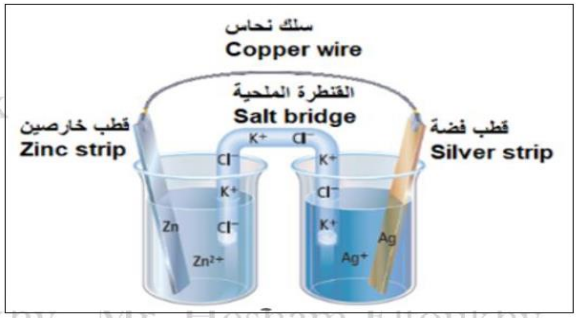
a. The study of the redox process

b. Useful in industry and critically important for biological functioning

c. Mechanical energy is converted to electrical energy and vice versa

d. Chemical energy is converted to electrical energy and vice versa

2) **In the voltaic cell shown below, where are the ions move from one side to another?**



a. Through the zinc strip

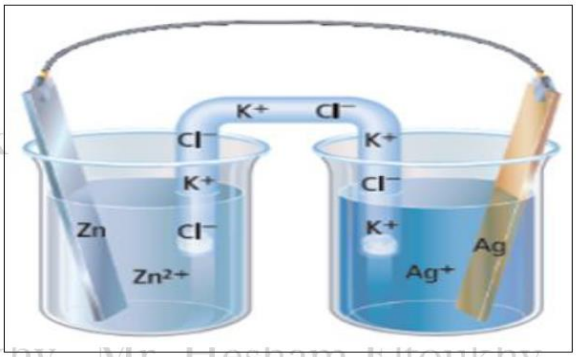
b. Through the salt bridge

c. Through the silver strip

d. Through the copper wire

3) **In the voltaic cell shown below, where are electrons gained?**

التفاعل النصفي Half-Reaction	E°(V)
$Zn^{2+} + 2e^- \rightarrow Zn$	-0.7618
$Ag^+ + e^- \rightarrow Ag$	+ 0.7996



a. At both strips

b. At silver strip

c. At zinc strip

d. At salt bridge

4) **The following reaction takes place in a voltaic cell, which of the following takes place at the anode?**

$$Zn_{(s)} + Cu^{2+}_{(aq)} \rightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$$

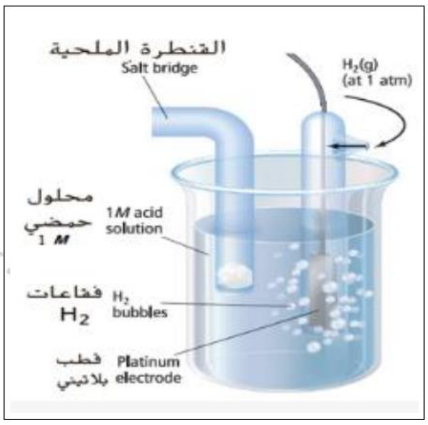
a. Oxidation of Cu

b. Reduction of Cu^{2+}

c. Reduction of Zn^{2+}

d. Oxidation of Zn

5) **In the figure shown below, what is the value of reduction potential E° for this electrode at a pressure of 1 atm and a temperature of 25°C?**



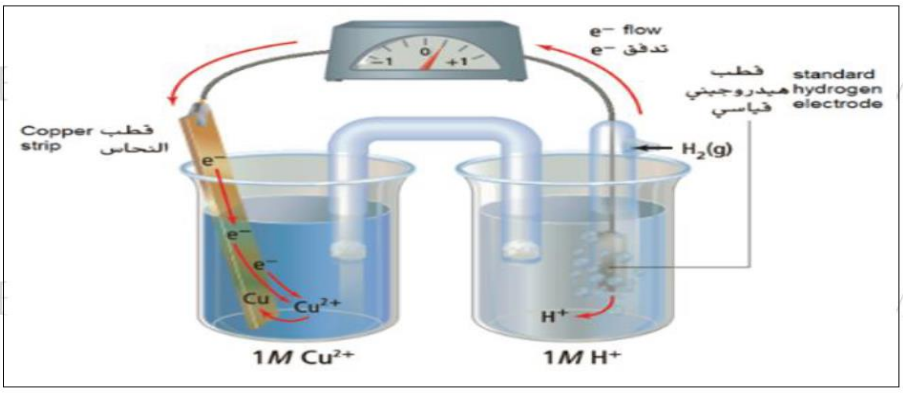
a. 0.500 V

b. 1.500 V

c. 0.000 V

d. 1.000 V

6) **What does the positive value of the voltaic cell shown in the figure below indicates?**



(Cu^{2+} = +0.342 V)

a. H^+ ions accept electrons more readily than Cu^{2+} ions

b. Oxidation takes place at the copper electrode, and reduction takes place at the hydrogen electrode

c. Cu^{2+} ions accept electrons more readily than H^+ ions

d. Electrons flow from the copper electrode to the hydrogen electrode

7) **Using the data in the table below, which half-reaction is most likely to be a reduction half-reaction?**

a. $Ag^+ + e^- \rightleftarrows Ag$

b. $Hg^{2+} + 2e^- \rightleftarrows Hg$

c. $Mg^{2+} + 2e^- \rightleftarrows Mg$

d. $Al^{3+} + 3e^- \rightleftarrows Al$

التفاعل النصفي Half-Reaction	E°(V)
$Mg^{2+} + 2e^- \rightleftarrows Mg$	- 2.372
$Ag^+ + e^- \rightleftarrows Ag$	+ 0.7996
$Al^{3+} + 3e^- \rightleftarrows Al$	- 1.662
$Hg^{2+} + 2e^- \rightleftarrows Hg$	+ 0.851

8) Which of the following represents the cell notation for the voltaic cell consisting of nickel and calcium electrodes?

a. $Ca \mid Ca^{2+} \parallel Ni^{2+} \mid Ni$

b. $Ni \mid Ni^{2+} \parallel Ca^{2+} \mid Ca$

c. $Ca^{2+} \mid Ca \parallel Ni \mid Ni^{2+}$

d. $Ni^{2+} \mid Ni \parallel Ca^{2+} \mid Ca$

التفاعل النصفي Half-Reaction	E°(V)
$Ni^{2+} + 2e^- \rightarrow Ni$	- 0.257
$Ca^{2+} + 2e^- \rightarrow Ca$	-2.868

9) What is the standard cell potential (E°_{cell}) for the spontaneous redox reaction that occurs between magnesium and silver?

a. +1.573 V

b. +3.172 V

c. +0.773 V

d. +2.971 V

التفاعل النصفي Half-Reaction	E°(V)
$Mg^{2+} + 2e^- \rightarrow Mg$	- 2.372
$Ag^{+} + e^- \rightarrow Ag$	+ 0.7996

10) Which of the reactions represented in the table below is non-spontaneous under standard conditions?

a. $Ni + Fe^{2+} \rightarrow Ni^{2+} + Fe$

b. $2Au^{3+} + 3Cu \rightarrow 3Cu^{2+} + 2Au$

c. $Fe + 2Cu^{+} \rightarrow Fe^{2+} + 2Cu$

d. $2Au^{3+} + 3Cu \rightarrow 3Cu^{2+} + 2Au$

التفاعل Reaction	E°(V)
$2Au^{3+} + 3Cu \rightarrow 3Cu^{2+} + 2Au$	+ 1.16
$2Fe^{3+} + 3Mn \rightarrow 3Mn^{2+} + 2Fe$	+ 1.148
$Fe + 2Cu^{+} \rightarrow Fe^{2+} + 2Cu$	+ 0.96
$Ni + Fe^{2+} \rightarrow Ni^{2+} + Fe$	- 0.218

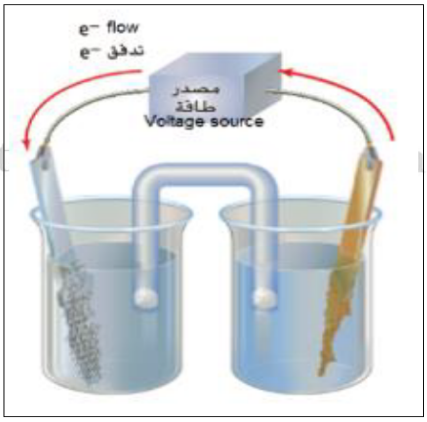
11) What does the figure below represent?

a. The salt bridge

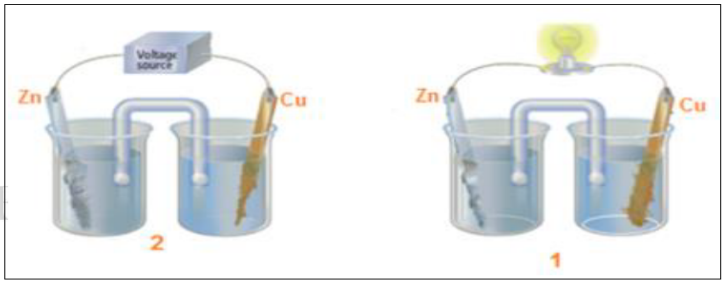
b. The standard hydrogen electrode

c. An electrolytic cell

d. A voltaic cell



12) **What is the similarity between the two cells below?**



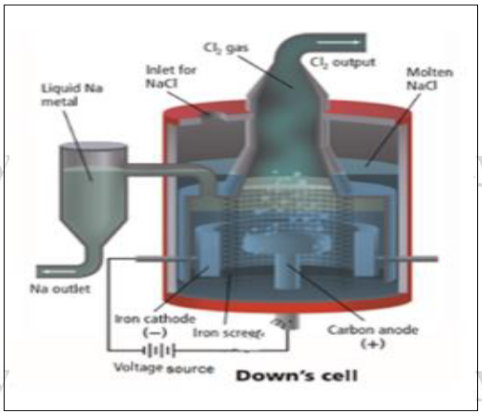
a. A non-spontaneous reaction occurs

b. An oxidation-reduction reaction occurs

c. A spontaneous reaction occurs

d. A neutralization reaction occurs

13) **During electrolysis process of molten sodium chloride (NaCl) in a Down's cell shown below. What happens to the sodium ions?**



a. Reduced at the anode

b. Reduced at the cathode

c. Oxidized at the cathode

d. Oxidized at the anode

14) **The figure below shows the electroplating of an iron fork with silver in an electrolytic cell. What is the cathode in the cell?**



a. The battery

b. An electrolyte solution

c. The silver plate

d. The iron fork

Answer Key

1	c	2	b	3	b	4	d	5	c
6	c	7	b	8	a	9	b	10	a
11	c	12	b	13	b	14	d		

Exam 2022-2023 (12 General)

1) **Under what conditions are standard reduction potentials measured?**

   a. 25°C, 1 atm and 1M ion solution

   b. 100°C, 100 atm and 0.1M ion solution

   c. 0°C, 0.5 atm and 0.5M ion solution

   d. 1°C, 1 atm and 1M ion solution

2) **Using the data in the table below, which metal ion is most easily reduced?**

   a. Mg^{2+}

   b. Ag^{+}

   c. Al^{3+}

   d. Hg^{2+}

التفاعل النصفي Half-Reaction	E°(V)
$Mg^{2+} + 2e^- \rightleftarrows Mg$	- 2.372
$Ag^{+} + e^- \rightleftarrows Ag$	+ 0.7996
$Al^{3+} + 3e^- \rightleftarrows Al$	- 1.662
$Hg^{2+} + 2e^- \rightleftarrows Hg$	+ 0.851

3) **The following reaction takes place in a voltaic cell, which of the following takes place at the anode?**

$$3Mn_{(s)} + 2Fe^{2+}_{(aq)} \rightarrow 3Mn^{2+}_{(aq)} + 2Fe_{(s)}$$

   a. Oxidation of iron atoms

   b. Reduction of manganese ions

   c. Reduction of iron ions

   d. Oxidation of manganese atoms

4) **The study of the redox processes by which chemical energy is converted to electrical energy and vice versa is called .....?**

   a. Nuclear chemistry

   b. Organic chemistry

   c. Electrochemistry

   d. Physical Chemistry

5) Which of the reactions represented in the table below is non-spontaneous under standard conditions?

a. $2Au^{3+} + 3Cu \rightarrow 3Cu^{2+} + 2Au$

b. $2Fe^{3+} + 3Mn \rightarrow 3Mn^{2+} + 2Fe$

c. $Fe + 2Cu^{+} \rightarrow Fe^{2+} + 2Cu$

d. $Ni + Fe^{2+} \rightarrow Ni^{2+} + Fe$

Reaction التفاعل	E°(V)
$2Au^{3+} + 3Cu \rightarrow 3Cu^{2+} + 2Au$	+ 1.16
$2Fe^{3+} + 3Mn \rightarrow 3Mn^{2+} + 2Fe$	+ 1.148
$Fe + 2Cu^{+} \rightarrow Fe^{2+} + 2Cu$	+ 0.96
$Ni + Fe^{2+} \rightarrow Ni^{2+} + Fe$	- 0.218

6) Which of the following represents the cell notation for the voltaic cell consisting of nickel and calcium electrodes?

a. $Ca \mid Ca^{2+} \parallel Ni^{2+} \mid Ni$

b. $Ni \mid Ni^{2+} \parallel Ca^{2+} \mid Ca$

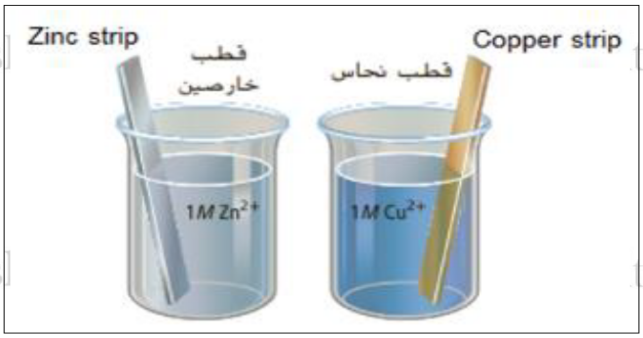
c. $Ni^{2+} \mid Ni \parallel Ca^{2+} \mid Ca$

d. $Ca^{2+} \mid Ca \parallel Ni \mid Ni^{2+}$

التفاعل النصفي Half-Reaction	E°(V)
$Ni^{2+} + 2e^{-} \rightarrow Ni$	- 0.257
$Ca^{2+} + 2e^{-} \rightarrow Ca$	-2.868

7) What parts are missing in the figure below for the voltaic cell to be complete?

Metal wire سلك فلزي	1
Salt bridge قنطرة ملحية	2
Voltage source مصدر طاقة	3



a. 1 and 3

b. 1 and 2

c. 2 and 3

d. 1,2 and 3

8) The figure below shows the electroplating of an iron fork with silver in an electrolytic cell. Which of the following statements is correct?



a. The fork is a cathode

b. The fork is a positive electrode

c. The silver electrode is the cathode

d. The solution is a non-electrolyte solution

9) **What is the standard cell potential (E°_{cell}) for the reaction that occurs when these half-cells are connected?**

Half-Reaction التفاعل النصفي	E°(V)
$Mg^{2+} + 2e^- \rightarrow Mg$	- 2.372
$Ag^+ + e^- \rightarrow Ag$	+ 0.7996

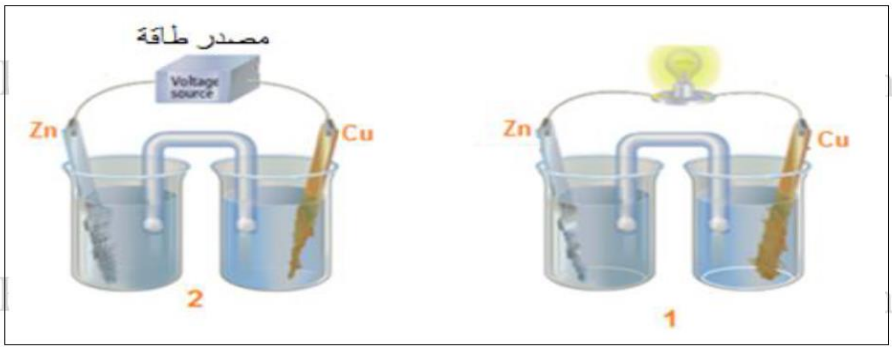
a. +1.5724 V

b. +0.7728 V

c. +3.9712 V

d. +3.1716 V

10) **Which of the following is correct for the two cells below?**



a. The cell number (1) represents electrolytic cell

b. The cell number (2) represents voltaic cell

c. The electrons flow in the cell number (1) from the Cu side

d. The electrons flow in the cell number (2) from the Cu side

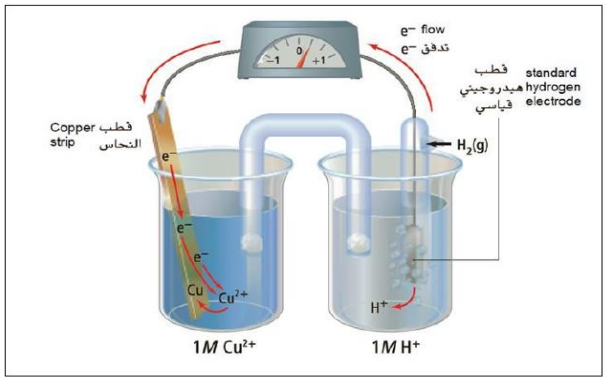
11) **What is the half-reduction reaction takes place in the cell shown in the figure below?**

a. $Cu^{2+} + 2e^- \rightarrow Cu$

b. $Cu \rightarrow Cu^{2+} + 2e^-$

c. $H_2 + 2e^- \rightarrow 2H^+$

d. $2H^+ \rightarrow H_2 + 2e^-$



12) Which of the following correctly describes the parts of an electrochemical cell?

جزأين حيث يحدث كل من تفاعلات الأكسدة والاختزال كل على حدة Two parts where the separate oxidation and reduction reactions take place	نصفا الخلية Half –cells	1
الإلكترود (القطب) حيث يحدث تفاعل الأكسدة The electrode where oxidation reaction take place	الأنود Anode	2
الإلكترود (القطب) حيث يحدث تفاعل الاختزال The electrode where reduction reaction take place	الكاثود Cathode	3

a. 1 and 3

b. 1 and 2

c. 2 and 3

d. 1,2 and 3

Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy

Answer Key

1	a	2	d	3	d	4	c	5	d
6	a	7	b	8	a	9	d	10	d
11	a	12	d						

Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy Mr. Hesham Eltoukhy