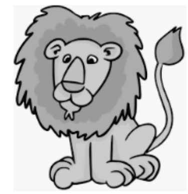
Redox Chemistry

Objective # 1: Defining Oxidation and Reduction

A **Redox Reaction** is a type of reaction in which there is a _____________________of electrons between species to generate an __________________________________. Redox reactions have two parts (half reactions): Oxidation and Reduction.



a) Oxidation: the ________________of electrons by a species in a chemical reaction

- the element becomes more positively charged

b) Reduction: the ________________of electrons by a species in a chemical reaction

- the element becomes more negatively charged

Objective #2: Determining Oxidation Numbers

Oxidation numbers (aka _________________________) are a number assigned to keep track of electron loss or gain in redox reactions

Rules to know:

1) A lone element (including diatomic) has an oxidation number of _______________ because it has not yet lost or gained any electrons ($\#e^- = \#p^+$)
2) When there are more than two elements in a compound, you must choose the oxidation number(s) in such that the overall charge of the compound equals _________________.
3) If an element has more than one "selected oxidation numbers" listed, use the other element oxidation numbers to figure out which oxidation number to use.

Species	**Oxidation Numbers**		
Li	Li =		
Br_2	Br_2 =		
BaO	Ba =	O =	
$NiCl_2$	Ni =	Cl =	
Mn_2O_7	Mn =	O =	
$CuSO_4$	Cu =	S =	O =
H_2CO_3	H =	C =	O =
$Ca_3(PO_4)_2$	Ca =	P =	O =
$Fe(NO_3)_2$	Fe =	N =	O =

Determining Oxidation Numbers

1. What is the oxidation state of nitrogen in the compound NH_4Br?
   1) –1 2) +2 3) –3 4) +5

2. What is the oxidation number of sulfur in $Na_2S_2O_3$?
   1) -1 2) +2 3) +6 4) +4

3. What is the oxidation number of manganese in $KMnO_4$?
   1) +7 2) +2 3) +3 4) +4

4. What is the oxidation number of chromium in $K_2Cr_2O_7$?
   1) +12 2) +2 3) +3 4) +6

5. In which substance is the oxidation number of Cl equal to +1?
   1) Cl_2 2) Cl_2O 3) $AlCl_3$ 4) $HClO_2$

Objective #3: Writing Balanced Half Reactions

A half reaction is an equation to show either the loss or gain of electrons by a species in a chemical reaction

- The loss of electrons must occur before the gain of electrons can occur. This means the oxidation half reaction will be written before the reduction half reaction.

Oxidation and Reduction Half Reactions (LEO the lion says GER)

A. Oxidation: **L**oss **o**f **E**lectrons

- electrons are placed on the _______________________ side to indicate "loss" → **e-**

B. Reduction: **G**ain **o**f **E**lectrons

- electrons are placed on the _______________________ side to indicate "gain" **e-** →

C. Balanced Redox Reactions

The number of electrons lost ___________________________ the number of electrons gained

*** Law of Conservation of Charge*** : the total overall charge on the reactant side must equal the total overall charge on the product side

Example 1: $Co(s) + PbCl_2 (aq) \rightarrow Pb (s) + CoCl_2 (aq)$

Oxidation: ____

Reduction: ____

Balanced Redox Reaction**:** ____

Example 2: $Al\ (s) + Cu^{+2}\ (aq) \rightarrow Cu\ (s) + Al^{+3}\ (aq)$

Oxidation: ____

Reduction: ____

Balanced Redox Reaction: ____

Example 3: $2\ Na\ (s) + FeO\ (aq) \rightarrow Fe\ (s) + Na_2O\ (aq)$

Oxidation: ____

Reduction: ____

Balanced Redox Reaction: ____

Writing Half Reactions

1. Given the reaction: $Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$ Which half-cell reaction represents the reduction that occurs?

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

2. Given the reaction: $Ca(s) + Cu^{2+}(aq) \rightarrow Ca^{2+}(aq) + Cu(s)$ What is the correct reduction half-reaction?

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

3. In the reaction $Mg + Cl_2 \rightarrow MgCl_2$, the correct half-reaction for the oxidation that occurs is

1) $Mg + 2e^- \rightarrow Mg^{2+}$ 2) $Cl_2 + 2e^- \rightarrow 2Cl^{-1}$ 3) $Mg \rightarrow Mg^{2+} + 2e^-$ 4) $Cl_2 \rightarrow 2Cl^{-1} + 2e^-$

4. Given the reaction: $Zn(s) + 2\ HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$ Which equation represents the correct oxidation half-reaction?

1) $Zn(s) \rightarrow Zn^{2+} + 2e^-$
2) $2\ H + 2e^- \rightarrow H_2(g)$
3) $Zn^{2+} + 2e \rightarrow Zn(s)$
4) $2\ Cl^{-1} \rightarrow Cl_2(g) + 2e^-$

5. Given the reaction: $3\ Sn^{4+}(aq) + 2\ Cr(s) \rightarrow 3\ Sn^{2+}(aq) + 2\ Cr^{3+}(aq)$ Which half-reaction correctly represents the reduction that occurs?

1) $Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$
2) $Sn^{2+}(aq) \rightarrow Sn^{4+}(aq) + 2e^-$
3) $Cr(s) \rightarrow Cr^{3+}(aq) + 3e^-$
4) $Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$

When determining total voltage power as a result of the oxidation and reduction reactions, you must use the Standard Reduction Potentials table to determine voltages

* The table only lists Reduction Half Reactions, so you will need to reverse the direction of each equation on the table to find the oxidation reaction
* The voltage sign will then also need to be reversed for the oxidation voltage

Ex) Reduction potential: $Pb^{+2} + 2e^- \rightarrow Pb^0$ = ___________________V

Oxidation potential: $Pb^{+2} + 2e^- \leftarrow Pb^0$ = ____________________V

*To determine the total voltage (E^0_{total}) by adding the two voltages

** If overall voltage total is positive = reaction is* ________________________________

** If overall voltage total is negative = reaction is* ________________________________

Example 1: $Sr\ (s) + Ni^{+2}\ (aq) \rightarrow Sr^{+2}\ (aq) + Ni\ (s)$

Oxidation: ____ E° (V)__________

Reduction: ____ E° (V)__________

Balanced
Redox Reaction: ____ $E°_{total}$ (V)__________

Example 2: $Ag^{+1}\ (aq) + Sn^{+2}\ (aq) \rightarrow Ag\ (s) + Sn^{+4}\ (aq)$

Oxidation: ____ E° (V)__________

Reduction: ____ E° (V)__________

Balanced
Redox Reaction: ____ $E°_{total}$ (V)__________

Example 3: $Co\ (s) + Li^{+1}\ (aq) \rightarrow Co^{+2}\ (aq) + Li\ (s)$

Oxidation: ____ E° (V)__________

Reduction: ____ E° (V)__________

Balanced
Redox Reaction: ____ E°_{total} (V)__________

Voltage and Redox Reactions

1. Which reduction half-reaction has a standard electrode potential (E^0) of 1.50 volts?
   1) $Au^{3+} + 3e^- \rightarrow Au(s)$
   2) $Al^{3+} + 3e^- \rightarrow Al(s)$
   3) $Co^{2+} + 2e^- \rightarrow Co(s)$
   4) $Ca^{2+} + 2e^- \rightarrow Ca(s)$

2. Given the reaction: $Mg + Fe^{2+} \rightarrow Mg^{2+} + Fe$ What is the net cell potential (Eº) for the overall reaction?
   1) 0.45 V 2) 1.93 V 3) 2.37 V 4) 2.82 V

3. Given the reaction: $3\ Zn(s) + 2\ Au^{3+}\ (aq) \rightarrow 3\ Zn^{2+}\ (aq) + 2\ Au(s)$ What is the maximum cell voltage (E^0) for the overall reaction?
   1) +1.50 V 2) +2.26 V 3) +5.28 V 4) +0.74 V

4. Given the reaction: $2\ Cr(s) + 3\ Pb^{2+}\ (aq) \rightarrow 2\ Cr^{3+}\ (aq) + 3\ Pb(s)$ The cell voltage (E^0) for the overall reaction is
   1) 0.61 volts 2) 0.87 volts 3) 1.09 volts 4) 1.87 volts

5. Given the chemical cell reaction: $2\ Ag^{+1} + Zn^0 \rightarrow 2\ Ag^0 + Zn^{2+}$ What is the net potential (E^0) for the cell?
   1) 1.56 V 2) 2.36 V 3) 0.84 V 4) 0.04 V

Objective #5: Knowing and labeling Voltaic Cells

Voltaic Cells: ____________________________________ redox reactions in which ____________________ energy is used and converted to _______________________ energy

- The transfer of electrons from the species undergoing oxidation to the species undergoing reduction produces a __________________ voltage reading
- This type of cell is commonly called ___________________________!!

Parts of a voltaic cell

a) Half Cell: container(s) where the oxidation and reduction reactions occur
There are two half cells to make up the total cell

b) Electrodes: metal samples used that are capable of conducting an electric current

Anode: ____

Cathode: ____

** MUST USE REFERENCE TABLE J ACTIVITY SERIES to determine which electrode is the anode (metal with _______________ activity) and which electrode is the cathode (metal with _______________ activity)

c) Wire : ____

- Electrons will always flow from the ________________ to the ________________

d) Salt bridge: ____

e) Electrolyte(s): ____
* ions in solution should be the same as the metal electrode
Example: Cu metal in a solution with Cu^{+2} ions
Fe metal in a solution with Fe^{+2} or Fe^{+3} ions

f) Voltmeter: ____

Voltaic Cell Diagram

Example problem: $Zn(s) + Cu^{+2}(aq) \rightarrow Zn^{+2}(aq) + Cu(s)$

Oxidation: ____ E° (V)__________

Reduction: ____ E° (V)__________

Balanced
Redox Reaction**:** ____ E°_{total} (V)__________

Example problem: $Mg\ (s) + Al^{+3}\ (aq) \rightarrow Al\ (s) + Mg^{+2}\ (aq)$

Oxidation: ____ E° (V)__________

Reduction: ____ E° (V)__________

Balanced
Redox Reaction**:** ____ E°_{total} (V)__________

Voltaic Cells

____ 1) A voltaic cell spontaneously converts

1) electrical energy to chemical energy
2) chemical energy to electrical energy
3) electrical energy to nuclear energy
4) nuclear energy to electrical energy

____ 2) Given the redox reaction in an electrochemical cell:

$$Ni(s) + Pb^{2+}(aq) \leftrightarrow Ni^{2+}(aq) + Pb(s)$$

A salt bridge is used to connect

1) Ni(s) and Pb(s)
2) Pb^{2+}(aq) and Ni^{2+}(aq)
3) Ni(s) and Ni^{2+}(aq)
4) Pb^{2+}(aq) and Pb(s)

____ 3) Which statement is true for any electrochemical cell?

1) Oxidation occurs at the anode, only.
2) Reduction occurs at the anode, only.
3) Oxidation occurs at both the anode and the cathode.
4) Reduction occurs at both the anode and the cathode.

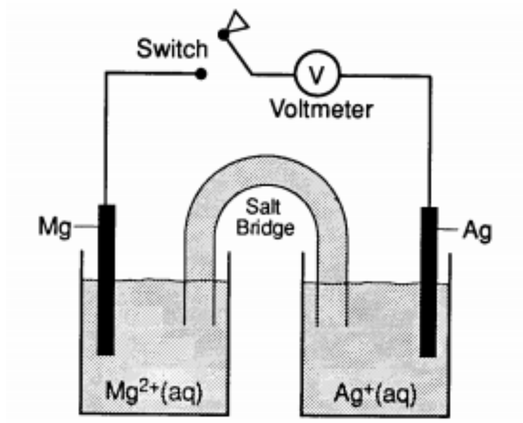
____ 4) In an oxidation-reduction reaction, the number of electrons lost is

1) equal to the number of electrons gained
2) equal to the number of protons gained
3) less than the number of electrons gained
4) less than the number of protons gained

____ 5) The redox reaction in a battery during discharge can best be described as

1) non-spontaneous and occurring in a chemical
cell
2) spontaneous and occurring in a chemical cell
3) non-spontaneous and occurring in an electrolytic cell
4) spontaneous and occurring in an electrolytic
cell

____ 6) Base your answer to the following question on the equation and diagram below represent an electrochemical cell at 298 K and 1 atmosphere.



$$Mg(s) + 2Ag^{+}(aq) \longrightarrow Mg^{2+}(aq) + 2Ag(s)$$

Which species is oxidized when the switch is closed?

1) Mg(s)
2) Mg^{2+} (aq)
3) Ag(s)
4) Ag^{+}(aq)

____ 7) Given the overall cell reaction:

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

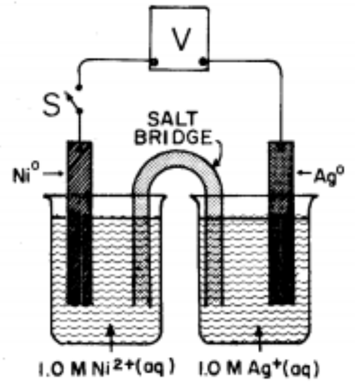
Which will occur as the cell operates?

1) The amount of Zn(s) will increase.
2) The amount of Ag(s) will decrease.
3) The concentration of Zn^{+2}(aq) will increase.
4) The concentration of Ag^{+}(aq) will increase.

____ 8) Which component of an electrochemical cell is correctly paired with its function?

1) external conductor – allows the solutions to mix
2) external conductor – permits the migration of ions
3) salt bridge – allows the solutions to mix
4) salt bridge – permits the migration of ions

____ 9) Base your answer to the following question on the diagram of the chemical cell at 298 K and on the equation below.

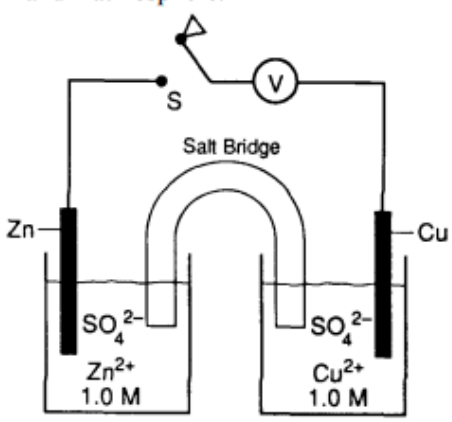


$$Ni^{0}(s) + 2Ag^{+}(aq) \rightarrow Ni^{2+}(aq) + 2Ag^{0}(s)$$

In the given reaction, the Ag^{+} ions

1) gain electrons
2) lose electrons
3) gain protons
4) lose protons

Base your answers to questions **10** and **11** on the diagram below which represents a chemical cell at 298 K and 1 atmosphere.



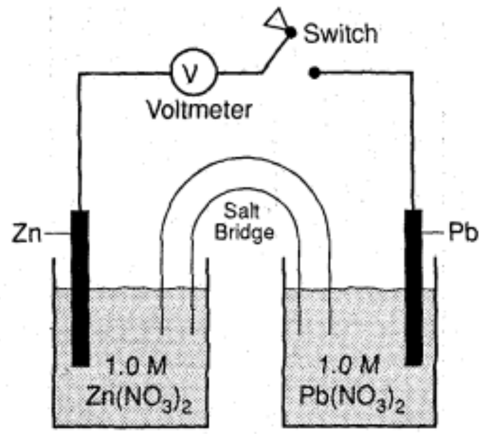
____ 10) Which species represents the cathode?

1) Zn 2) Zn^{2+} 3) Cu 4) Cu^{2+}

____ 11) When switch S is closed, electrons in the external circuit will flow from

1) Zn to Zn^{2+}
2) Zn to Cu
3) Cu to Zn^{2+}
4) Cu to Zn

____ 12) Base your answer to the following question on the diagram of the chemical cell shown below. The reaction occurs at 1 atmosphere and 298 K.



$$Zn^{0}(s) + Pb^{2+}(aq) \longrightarrow Zn^{2+}(aq) + Pb^{0}(s)$$

When the switch is closed, what occurs?

1) Pb is oxidized and electrons flow to the Zn electrode.
2) Pb is reduced and electrons flow to the Zn electrode.
3) Zn is oxidized and electrons flow to the Pb electrode.
4) Zn is reduced and electrons flow to the Pb electrode.

____ 13) A student collects the materials and equipment below to construct a voltaic cell:

- two 250-mL beakers
- wire and a switch
- one strip of magnesium
- one strip of copper
- 125 mL of 0.20 M $Mg(NO_3)_2(aq)$
- 125 mL of 0.20 M $Cu(NO_3)_2(aq)$

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

1) an anode
2) a battery
3) a cathode
4) a salt bridge

____ 14) Which ionic equation is balanced?

1) $Fe^{3+} + Al \rightarrow Fe^{2+} + Al^{3+}$
2) $Fe^{3+} + 3Al \rightarrow Fe^{2+} + 3Al^{3+}$
3) $3Fe^{3+} + Al \rightarrow 3Fe^{2+} + Al^{3+}$
4) $3Fe^{3+} + Al \rightarrow Fe^{2+} + 3Al^{3+}$

Objective #6: Knowing and labeling Electrolytic Cells

Electrolytic Cells: ______________________________ reactions in which a battery (voltaic cell) is used to force a chemical reaction to occur

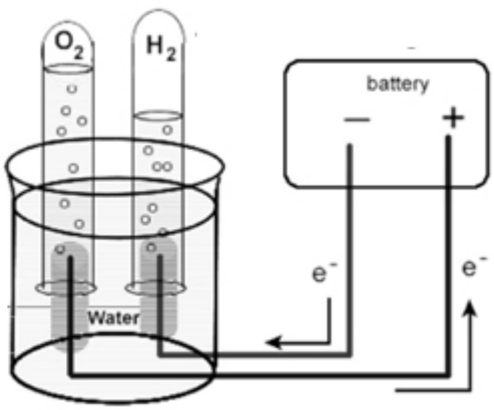
- ________________________ energy from the battery causes _______________________ energy, which drives a chemical reaction that otherwise normally would not occur

There are two types of electrolytic cells to know: Electrolysis and Electroplating

1. Electrolysis

Hydrogen and oxygen are very plentiful on earth, but they are both so reactive that they are only found in compounds. We commonly use the electricity in electrolysis to separate and collect the two gases.

$$2\ H_2O(l) \rightarrow 2\ H_2(g) + O_2(g)$$



Electrolysis

____ 1) The reaction $2\ H_2O\ (\ell) \rightarrow 2\ H_2(g) + O_2(g)$ is forced to occur by use of an externally applied electric current. This procedure is called

1) neutralization 2) esterification 3) electrolysis 4) hydrolysis

____ 2) An electrolytic cell differs from a voltaic cell because an electrolytic cell

1) generates its own energy from a spontaneous physical reaction
2) generates its own energy from a nonspontaneous physical reaction
3) requires an outside energy source for a spontaneous chemical reaction to occur
4) requires an outside energy source for a nonspontaneous chemical reaction to occur

____ 3) Where do reduction and oxidation occur in an electrolytic cell?

1) Both occur at the anode.
2) Both occur at the cathode.
3) Reduction occurs at the anode, and oxidation occurs at the cathode.
4) Reduction occurs at the cathode, and oxidation occurs at the anode.

____ 4) Which energy conversion occurs in an operating electrolytic cell?

1) chemical energy to electrical energy 3) nuclear energy to thermal energy
2) electrical energy to chemical energy 4) thermal energy to nuclear energy

____ 5) In an electrolytic cell, the positive electrode is the

1) anode, where oxidation occurs 3) cathode, where oxidation occurs
2) anode, where reduction occurs 4) cathode, where reduction occurs

____ 6) In an electrolytic cell, a negative ion will migrate to and undergo oxidation at the

1) anode, which is negatively charged
2) anode, which is positively charged
3) cathode, which is negatively charged
4) cathode, which is positively charged

____ 7) In an electrolytic cell, the negative electrode is called the

1) anode, at which oxidation occurs
2) anode, at which reduction occurs
3) cathode, at which oxidation occurs
4) cathode, at which reduction occurs

____ 8) Given the reaction:

$2\ H_2O + \text{electricity} \rightarrow 2\ H_2 + O_2$

In which type of cell would this reaction most likely occur?

1) a voltaic cell, because it is releases energy
2) an electrolytic cell, because it releases energy
3) a voltaic cell, because it requires energy
4) an electrolytic cell, because it requires energy

2. Electroplating

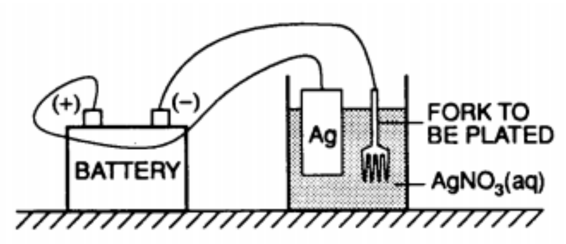
Electroplating is the process of coating an object with a chosen metal, such as plating a ring with gold or a spoon with silver. The electricity from a battery is used to power the process; this energy forces a metal to plate (or coat) another object capable of conducting electricity. Gold, Silver, Copper and Palladium are just some of the common metals used in electroplating.

Electroplating

____ 1) A metal object is to be electroplated with silver. Which set of electrodes should be used?

1) a silver anode and a metal object as the cathode
2) a platinum anode and a metal object as the cathode
3) a silver cathode and a metal object as the anode
4) a platinum cathode and a metal object as the anode

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



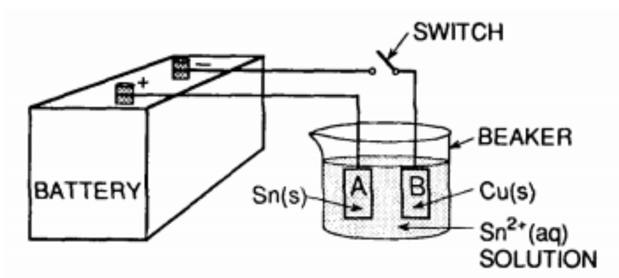
____ 2) Which equation represents the half-reaction that takes place at the fork?

1) $Ag^+ + NO_3^- \rightarrow AgNO_3$
2) $AgNO_3 \rightarrow Ag^+ + NO_3^-$
3) $Ag^+ + e^- \rightarrow Ag(s)$
4) $Ag(s) \rightarrow Ag^+ + e^-$

____ 3) Which part of the electroplating system is provided by the fork?

1) the anode, which is the negative electrode
2) the cathode, which is the negative electrode
3) the anode, which is the positive electrode
4) the cathode, which is the positive electrode

Base your answers to questions **4** and **5** on the diagram below of an electrolytic cell in which the electrodes are tin and copper.



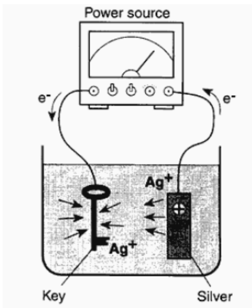
____ 4) In this electrolytic cell, electrode *A* is designated as the

1) anode and is positive
2) anode and is negative
3) cathode and is positive
4) cathode and is negative

____ 5) When the switch is closed, what will happen to the two electrodes?

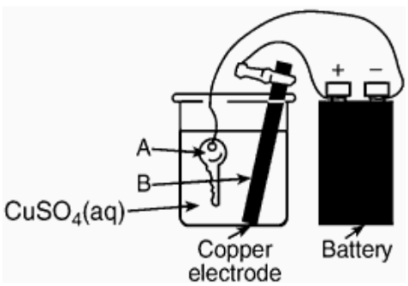
1) *B* will dissolve and *A* will become coated with tin.
2) *A* will dissolve and *B* will become coated with tin.
3) *B* will dissolve and *A* will become coated with copper.
4) *A* will dissolve and *B* will become coated with copper.

____ 6) Which statement best describes the key?



1) It acts as the cathode and is negative.
2) It acts as the cathode and is positive.
3) It acts as the anode and is negative.
4) It acts as the anode and is positive.

____ 7) The diagram below shows a key being plated with copper in an electrolytic cell



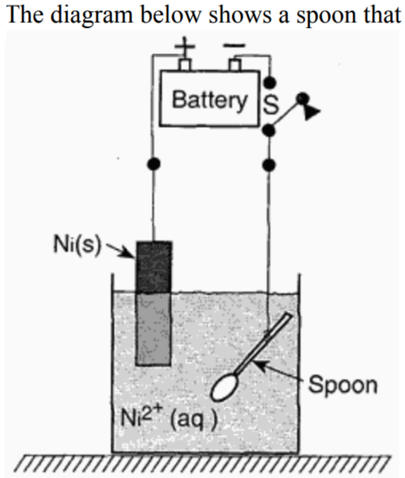
Given the reduction reaction for this cell:

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

This reduction occurs at

1) *A*, which is the anode
2) *A*, which is the cathode
3) *B*, which is the anode
4) *B*, which is the cathode

___ 8) The diagram below shows a spoon that will be electroplated with nickel metal.



What will occur when switch S is closed?

1) The spoon will lose mass, and the Ni(s) will be reduced.
2) The spoon will lose mass, and the Ni(s) will be oxidized.
3) The spoon will gain mass, and the Ni(s) will be reduced.
4) The spoon will gain mass, and the Ni(s) will be oxidized.