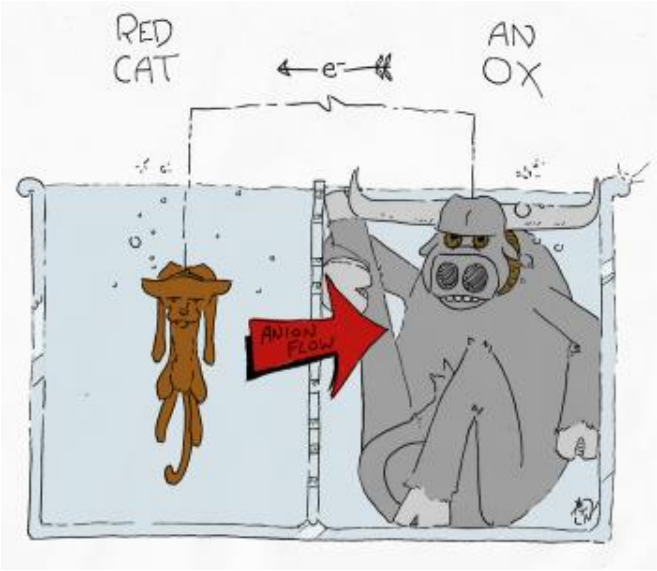
Unit 13: Electrochemistry



Oxidation Number Review

Oxidation numbers are very important in this chapter "Redox Reactions." Without the complete understanding of how to assign these numbers, we cannot move ahead with this chapter. They are much like ionic charges, except that every element will be assigned a number.

Assign oxidation numbers to each element in the following: **Remember when there are more than two elements in a compound, assign oxidation numbers to the outside elements first, then determine the oxidation number of the middle element that makes the overall charge of the compound zero.**

1. NaCl Na___ Cl___
2. H_2S H___ S___
3. H_2O H___ O ___
4. CO_2 C ___ O___
5. H_2SO_4 H ___ S___ O___
6. $FeCO_3$ Fe___ C___ O___
7. AgI Ag___ I___
8. H_2 H___
9. $PbCl_2$ Pb___ Cl___
10. $BaCO_3$ Ba___ C ___ O___
11. Fe_2O_3 Fe___ O___
12. I_2 I____
13. BeO Be____ O____
14. CaF_2 Ca____ F ____
15. $FeCl_3$ Fe____ Cl____
16. PF_5 P____ F____
17. H_3PO_4 H____ P____ O___
18. KCl K ____ Cl____
19. K_2O K ____ O____
20. O_3 O ____
21. LiH Li ____ H____
22. HBr H ____ Br____
23. Li^+ Li____
24. PO_4^{3-} P____ O___
25. Cr_2O_3 Cr___ O___
26. Na_2SO_4 Na___ S___ O___

REDOX Reactions Review

Indicate which element is being oxidized, and which is being reduced.

1. $Cu_2O \rightarrow Cu + O_2$
2. $Cl_2 + KBr \rightarrow KCl + Br_2$
3. $CH_4 + O_2 \rightarrow CO_2 + H_2O$

Redox reactions are usually synthesis reactions, decomposition, combustion or single replacement reactions. Double replacement and neutralization reactions are NOT redox reactions. Usually they are easy to spot because if an element goes from being "free" (with an oxidation number of 0) to being in a compound (with a new oxidation number) it shows there was an exchange of electrons.

In the following examples, identify what type of reaction they are and then state if they are redox reactions.

1. $N_2 + O_2 \rightarrow 2NO$ _____ _____
2. $Cl_2 + 2NaBr \rightarrow NaCl + Br_2$ _____ _____
3. $2NaOH + HCl \rightarrow H_2O + NaCl$ _____ _____

A half reaction shows either the oxidation or reduction portion of a redox equation including if the electrons are gained or lost. A reduction half reaction shows an atom or ion gaining one of more e^-:

$Fe^{3+} + 3e^- \rightarrow Fe$ Notice that the e^- is on the left.

An oxidation half reaction shows an atom or ion losing one or more e-:

$Mg \rightarrow Mg^{2+} + 2\ e^-$ Notice that the e^- is on the right.

For the following examples, determine if they represent oxidation or reduction.

1. $e^- + Cr^{+3} \rightarrow Cr^{+2}$
2. $2e^- + Mn^{+7} \rightarrow Mn^{+5}$
3. $Mg^{+2} + 2e^- \rightarrow Mg$
4. $K \rightarrow e^- + K^{+1}$

For the following examples, add in the e- to balance the charge.

5. $Cr^{+5} \rightarrow Cr^{+2}$
6. $Mn^{+4} \rightarrow Mn^{+7}$
7. $Cu^{+1} \rightarrow Cu^{+2}$
8. $B^{+3} \rightarrow B$

For the following examples, balance the elements first, then add in the e- to balance the charge.

9. $Cl^- \rightarrow Cl_2$
10. $Br_2 \rightarrow Br^{-1}$
11. $I_2 \rightarrow I^-$
12. $N^{+3} \rightarrow N_2$
13. $S_8 \rightarrow S^{-2}$
14. $O^{-2} \rightarrow O_2$

Use Table J to help you with the following questions.

1. Write the oxidation and reduction half reaction for:
   $Ca + Cu^{2+} \rightarrow Ca^{2+} + Cu$

2. According to Table J, the element higher on the list will oxidize. Which element is oxidizing here and does that mean that this reaction is spontaneous?

3. Write the oxidation and reduction half reaction for
   $Mg + Ca^{2+} \rightarrow Mg^{2+} + Ca$

REGENTS CHECKPOINT

Assess your understanding of this lesson. If you are still having difficulty you should see me for extra help and/or re-watch the lesson video assignment

1. Which half-reaction correctly represents oxidation?
   (1) $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$
   (2) $Fe^{2+}(aq) \rightarrow Fe(s) + 2e^-$
   (3) $Fe(s) + 2e^- \rightarrow Fe^{2+}(aq)$
   (4) $Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$

2. In a redox reaction, there is a conservation of
   (1) mass, only
   (2) both mass and charge
   (3) neither mass nor charge

3. What occurs during the reaction below?

   $$4\ HCl + MnO_2 \rightarrow MnCl_2 + 2\ H_2O + Cl_2$$

   (1) The manganese is reduced and its oxidation number changes from +4 to +2.
   (2) The manganese is oxidized and its oxidation number changes from +4 to +2.
   (3) The manganese is reduced and its oxidation number changes from +2 to +4.
   (4) The manganese is oxidized and its oxidation number changes from +2 to +4.

4. Given the redox reaction:
   $2\ Fe^{3+} + 3\ Zn \rightarrow 2\ Fe + 3\ Zn^{2+}$
   As the reaction takes place, there is a transfer of electrons
   (1) from Fe^{3+} to Zn
   (2) from Zn to Fe^{3+}
   (3) from Zn^{2+} to Fe
   (4) from Fe to Zn^{2+}

Lesson 13.3 Balancing Redox Reactions

Practice: *Balance the following redox reactions. Remember that you do not include the spectator ions in your half reactions. The first one is done for you.*

1. $PbO + CO \rightarrow Pb + CO_2$

2. $MgCl_2 + Cr \rightarrow Mg + CrCl_3$

3. $Pb + AgNO_2 \rightarrow Pb(NO_2)_2 + Ag$

4. $CsF + Na \rightarrow NaF + Cs$

5. $NaCl + Br_2 \rightarrow NaBr + Cl_2$

6. $Fe^{+2} + Cu^{+} \rightarrow Fe^{+3} + Cu$

7. $Cr + CuBr_2 \rightarrow CrBr_3 + Cu$

8. $Zn + CuO \rightarrow ZnO + Cu$

REGENTS CHECKPOINT

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1. Given the unbalanced ionic equation:

When this equation is balanced, both Fe^{3+} and Fe have a coefficient of

A) 1, because a total of 6 electrons is transferred
B) 2, because a total of 6 electrons is transferred
C) 1, because a total of 3 electrons is transferred
D) 2, because a total of 3 electrons is transferred

2. Which expression correctly represents a balanced reduction half-reaction?

A) $Na^+ + e^- \rightarrow Na$ B) $Na \rightarrow Na^+ + e^-$
C) $Cl_2 + 2e^- \rightarrow Cl^-$ D) $2\ Cl^- \rightarrow Cl_2 + 2e^-$

3. Which equation shows conservation of charge?

A) $Fe \rightarrow Fe^{2+} + e^-$ B) $Fe + 2e^- \rightarrow Fe^{2+}$
C) $Fe \rightarrow Fe^{2+} + 2e^-$ D) $Fe + 2e^- \rightarrow Fe^{3+}$

4. Which half-reaction shows both the conservation of mass and the conservation of charge?

A) $Cl_2 + 2e^- \rightarrow 2\ Cl$ B) $Cl_2 \rightarrow Cl^- + 2e^-$
C) $2\ Br^- + 2e^- \rightarrow Br2$ D) $Br^- \rightarrow Br2 + 2e^-$

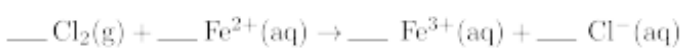
5. Given the balanced equation:

$$3\ Fe^{3+}(aq) + Al(s) \rightarrow 3\ Fe^{2+}(aq) + Al^{3+}(aq)$$

What is the total number of moles of electrons lost by 2 moles of Al(s)?

A) 1 mole B) 6 moles
C) 3 moles D) 9 moles

6. Given the reaction:



When the equation is correctly balanced using *smallest* whole numbers, the coefficient of $Cl^-(aq)$ will be

A) 1 B) 2 C) 6 D) 7

20. A flashlight can be powered by a rechargeable nickel-cadmium battery. The unbalanced equation below represents the reaction that occurs as the battery produces electricity. When a nickel-cadmium battery is recharged, the reverse reaction occurs.

$$\_\_\_\_\_\ Cd(s) + \_\_\_\_\_\ NiO_2(s) + \_\_\_\_\_\ H_2O(\ell) \rightarrow \_\_\_\_\_\ Cd(OH)_2(s) + \_\_\_\_\_\ Ni(OH)_2(s)$$

(a) Balance the equation above using the smallest whole-number coefficients.

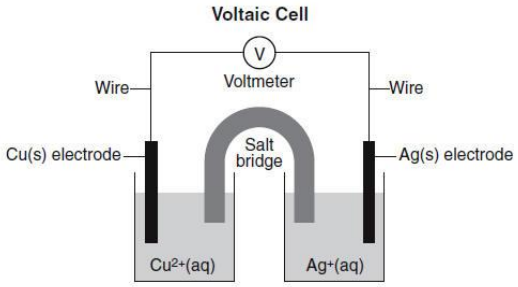
(b) Determine the change in oxidation number for Cd.

(c) Explain why Cd would be above Ni if placed on Table *J*.

Voltaic Cells

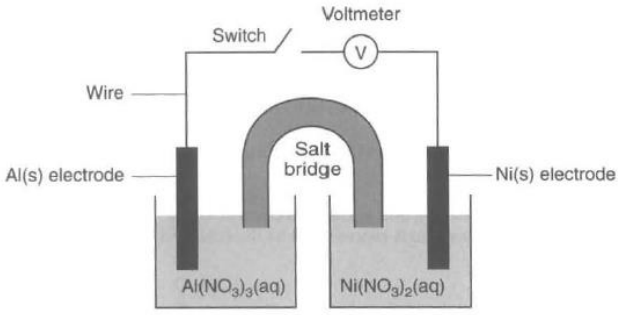
Directions: In each of the following, determine which element oxidized easier on table J. Then label the anode, cathode, direction of e- flow, and the half reactions. Then find the voltage.

1.



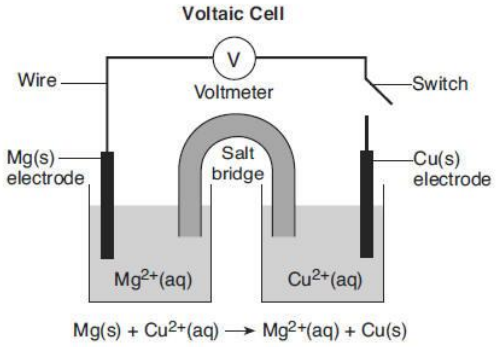
$Cu(s) + 2Ag^+(aq) \longrightarrow Cu^{2+}(aq) + 2Ag(s)$

2.



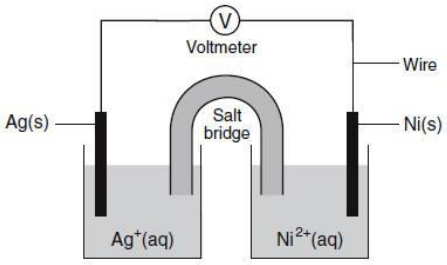
$2Al(s) + 3Ni^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Ni(s)$

3.



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

4.



Additional Questions:

5. On diagram 1, which way will anions travel through the salt bridge? _____
6. On diagram 2, towards which electrode will cations travel through the salt bridge? _____
7. On all diagrams, at which electrode does oxidation occur? _____
8. On all diagrams, at which electrode does reduction occur? _____
9. On all diagrams, from which electrode will electrons travel? _____
10. What is the purpose of the salt bridge? _____
11. Describe the change in energy that occurs in voltaic cells in terms of electric and chemical energies:

REGENTS CHECKPOINT

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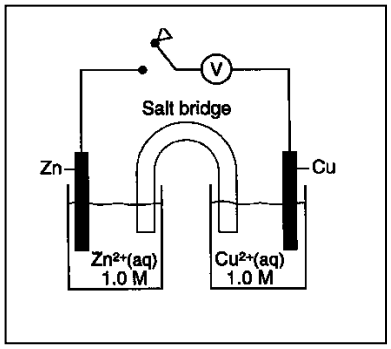
Answer questions 1 and 2 using the diagram below, which represents an electrochemical cell.



1. When the switch is closed, in which half-cell does oxidation occur?

2. What occurs when the switch is closed?
(1) Zn is reduced.
(2) Cu is oxidized.
(3) Electrons flow from Cu to Zn.
(4) Electrons flow from Zn to Cu.

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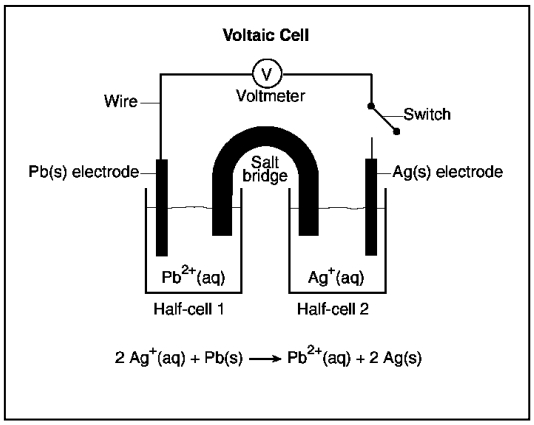
3. Base your answers to the following questions on the diagram of the voltaic cell below.



(a) Identify the anode and the cathode.

(b) Write the oxidation and reduction half-reactions for this voltaic cell.

(c) What is the total number of moles of electrons needed to completely reduce 6 moles of Ag^{+}(aq) ions?

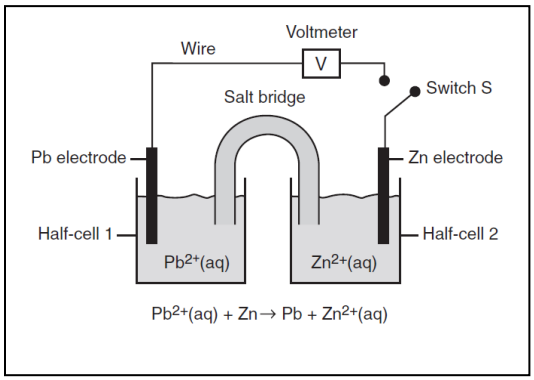
(d) Describe the direction of electron flow between the electrodes.

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

(f) State the electrode to which positive ions migrate when the switch is closed.

(g) As this voltaic cell operates, the mass of the Ag(s) electrode increases. Explain, in terms of silver ions *and* silver atoms, why this increase in mass occurs.

4. Base your answers to the following questions on the diagram below, which represents a voltaic cell at 298 K and 1 atm.



(a) In which half-cell will oxidation occur when switch *S* is closed?

(b) Write the balanced half-reaction equation that will occur in half-cell 1 when switch *S* is closed.

(c) Describe the direction of electron flow between the electrodes when switch *S* is closed.

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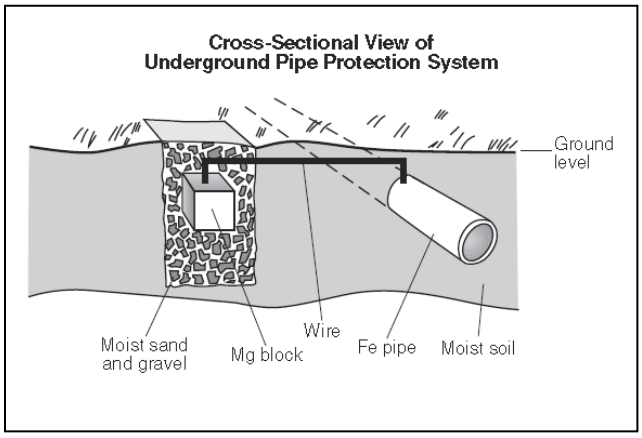
5. Base your answers to the following questions on the information below.

Underground iron pipes in contact with moist soil are likely to corrode. This corrosion can be prevented by applying the principles of electrochemistry. Connecting an iron pipe to a magnesium block with a wire creates an electrochemical cell. The magnesium block acts as the anode and the iron pipe acts as the cathode. A diagram of this system is shown below.

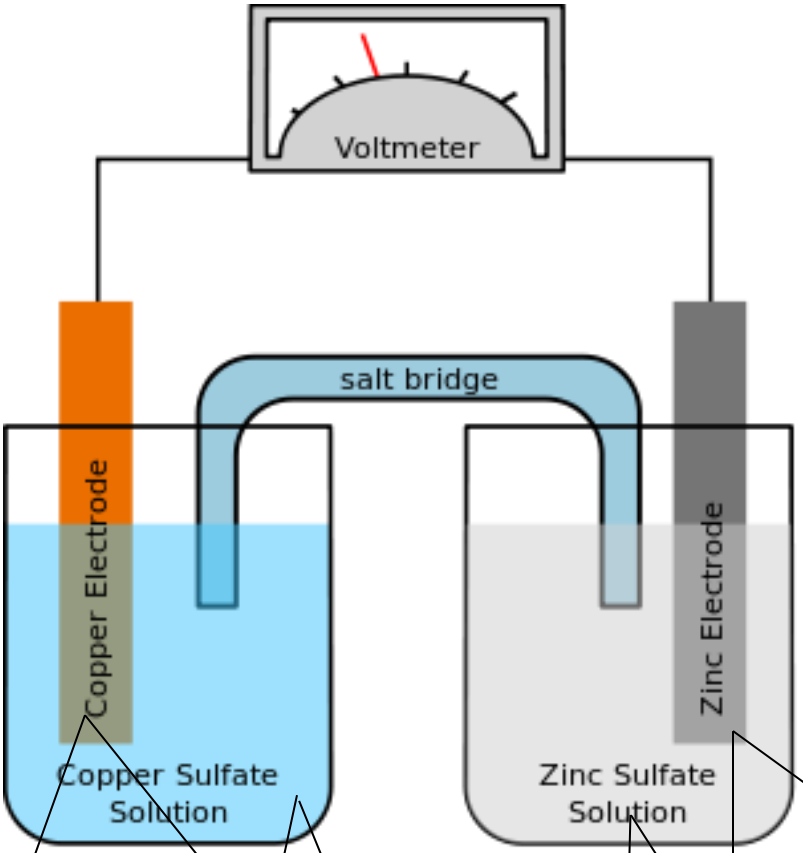


(a) State the direction of the flow of electrons between the electrodes in this cell.

(b) Explain, in terms of reactivity, why magnesium is preferred over zinc to protect underground iron pipes. Your response must include *both* magnesium and zinc.

Voltaic Cell Modeling

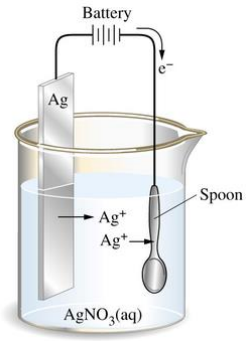
Directions: Using table J and your knowledge of atoms, ions, and redox, draw and explain how electrons are transferred and mass changes in the following cells. Draw Bohr diagrams in the zoomed in circles to show charge and mass transfers in more detail.



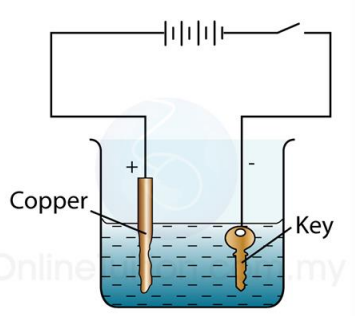
Explain your diagram. Label the anode, cathode, charges, and direction of electron flow. A key for your drawings may be useful.

Electrolytic Cells

1. In an electrolytic cell, _____ energy is converted into _____ energy.
2. Identify the cathode in the cell.
3. What is the purpose of the battery?



Base your answers to the following questions on the diagram below.



4. Label the anode and cathode.
5. Label the direction of electron flow through the wire.
6. Write the half reaction for the Cu reducing on the key.

7. Why will the mass of the key increase?

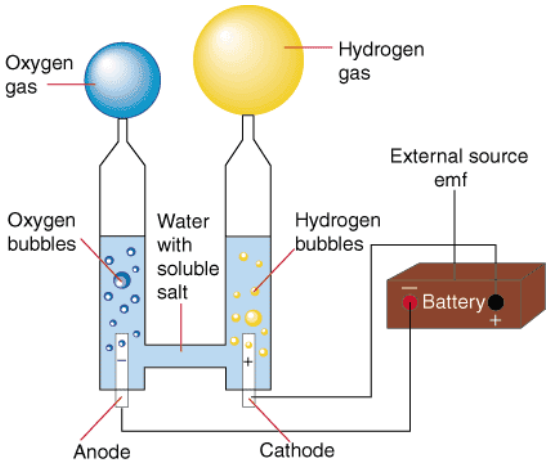
8. Why will the mass of the copper decrease?

9. Is this type of cell a spontaneous or nonspontaneous reaction?

10. State the difference between voltaic and electrolytic cells in terms of energy being released or absorbed?

Base your answers to the following questions on the diagram below:

11. Water is being decomposed using a battery in the diagram. Write the equation for the decomposition of water.



12. Which element is being oxidized?

13. How many electrons are being lost?

14. Is this reaction spontaneous?

REGENTS CHECKPOINT

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1. In a voltaic cell, chemical energy is converted to
   (1) electrical energy, spontaneously
   (2) electrical energy, nonspontaneously
   (3) nuclear energy, spontaneously
   (4) nuclear energy, nonspontaneously

2. 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

3. A voltaic cell differs from an electrolytic cell in that in a voltaic cell
   (1) energy is produced when the reaction occurs
   (2) energy is required for the reaction to occur
   (3) both oxidation and reduction occur
   (4) neither oxidation nor reduction occurs

4. Which half-reaction can occur at the anode in a voltaic cell?
   (1) $Ni^{2+} + 2e^- \rightarrow Ni$
   (2) $Sn + 2e^- \rightarrow Sn^{2+}$
   (3) $Zn \rightarrow Zn^{2+} + 2e^-$
   (4) $Fe^{3+} \rightarrow Fe^{2+} + e^-$

5. Which process requires an external power source?
   (1) neutralization
   (2) synthesis
   (3) fermentation
   (4) electrolysis

6. Which energy transformation occurs when an electrolytic cell is in operation?
   (1) chemical energy → electrical energy
   (2) electrical energy → chemical energy
   (3) light energy → heat energy
   (4) light energy → chemical energy

7. What is the purpose of the salt bridge in a voltaic cell?

(1) It blocks the flow of electrons.
(2) It blocks the flow of positive and negative ions.
(3) It is a path for the flow of electrons.
(4) It is a path for the flow of positive and negative ions.

8. 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.

9. Given the balanced equation representing a reaction occurring in an electrolytic cell:

$2NaCl_{(l)} \rightarrow 2Na_{(l)} + Cl_{2(g)}$

Where is Na(l) produced in the cell?

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

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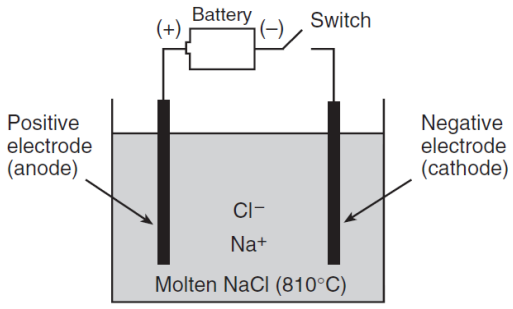
6. Base your answers to the following questions on the diagram and balanced equation below, which represent the electrolysis of molten NaCl.

(a) When the switch is closed, which electrode will attract the sodium ions?

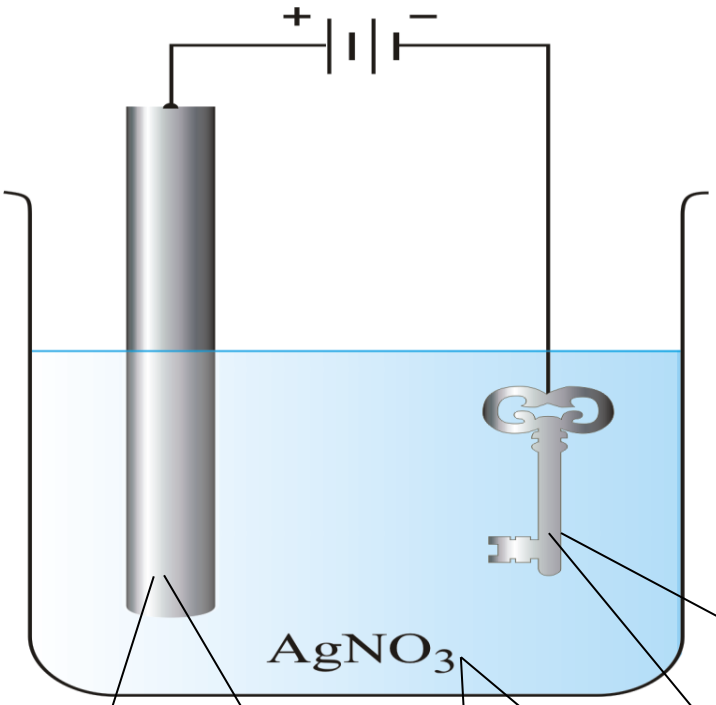
(b) What is the purpose of the battery in this electrolytic cell?

(c) Write the balanced half-reaction for the reduction that occurs in this electrolytic cell.



$2NaCl \longrightarrow Cl_2 + 2Na$

Electrolytic Cells Modeling Activity



Explain your diagram. Label the anode, electrode, charges, and direction of electron flow. A key for your drawings may be useful.