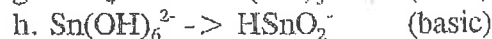
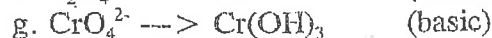
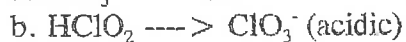
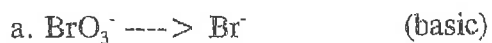
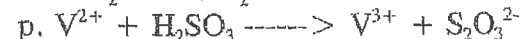
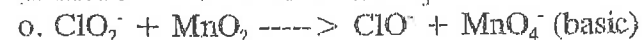
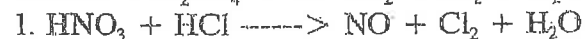
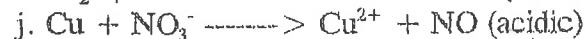
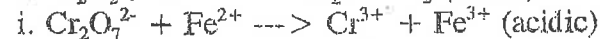
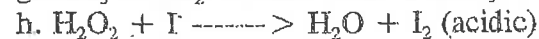
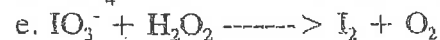
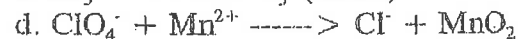
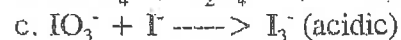
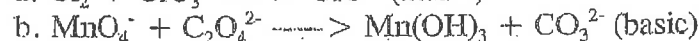


Chemistry 12 Electrochemistry Worksheet No. 1

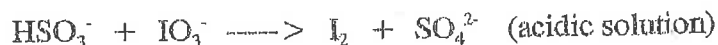
1. Balance the following half reactions and state whether oxidation or reduction is taking place.



2. Use half reactions to balance the following redox reactions and underline the oxidizing agent.



3. Iodine is recovered from iodates in Chilean saltpeter (NaIO_3) by the reaction described in this unbalanced equation:



What mass of iodine is produced when a 20 kg sample of NaIO_3 reacts with excess HSO_3^- ?

Chemistry 12 Electrochemistry Worksheet No. 2

1. Determine the oxidation number of phosphorus in each of the following:

- phosphorus pentoxide, P_2O_5
- phosphorus trioxide, P_2O_3
- hypophosphoric acid, $H_4P_2O_6$
- hydrogen diphosphide, P_2H_4
- hypophosphorus acid, H_3PO_2
- phosphine, PH_3
- phosphite, PO_3^{3-}
- phosphorus acid, H_3PO_3
- metaphosphoric acid, HPO_3
- white phosphorus, P_4

2. Indicate the change in oxidation number for each of the following conversions:

- gallium III, Ga^{3+} is converted to $H_2GaO_3^-$
- americium III, Am^{3+} is converted to AmO_2^{2+}
- selenate, SeO_4^{2-} is converted to selenous acid, H_2SeO_3
- thiosulphate, $S_2O_3^{2-}$ is converted to tetrathionate, $S_4O_6^{2-}$
- magnetite, Fe_3O_4 is converted to iron, Fe

3. For each of the following compounds find the oxidation number of the indicated atom:

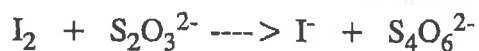
- | | | |
|---------------------------|------------|--------------|
| a. potassium | K | K |
| b. potassium oxide | K_2O | K
O |
| c. chlorine | Cl_2 | Cl |
| d. magnesium chloride | $MgCl_2$ | Mg
Cl |
| e. hydrogen peroxide | H_2O_2 | H
O |
| f. sodium sulphate | Na_2SO_4 | Na
S
O |
| g. ammonia | NH_3 | N
H |
| h. potassium permanganate | $KMnO_4$ | K
Mn
O |

4. Balance the following reactions using either half reactions or the oxidation number method:

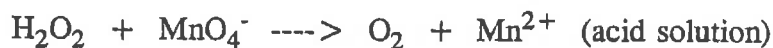
- $Cr_2O_7^{2-} + HNO_2 \longrightarrow Cr^{3+} + NO_3^-$ (acidic)
- $IO_3^- + N_2O \longrightarrow I_2 + NO$ (acidic)
- $MnO_4^- + Te \longrightarrow MnO_2 + TeO_3^{2-}$ (basic)
- $P_4 + NO_2^- \longrightarrow H_2PO_2^- + N_2O$ (basic)
- $HPO_2^- \longrightarrow PO_4^{3-} + P_4$ (basic)
- $N_2O \longrightarrow N_2H_4 + NO_3^-$ (basic)

Electrochemistry #3

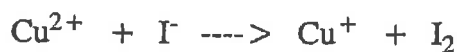
1. 20.0 mL of 0.20 M $\text{Na}_2\text{S}_2\text{O}_3$ are used to react with 35.0 mL of I_2 solution. Calculate the initial $[\text{I}_2]$ in the solution .



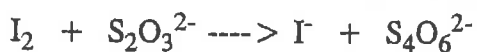
2. Calculate the moles of H_2O_2 present in a sample if 50.0 mL of 0.25 M KMnO_4 solution are required to completely react with the sample.



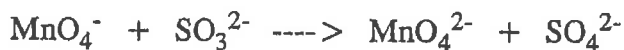
3. 25.0 mL of $\text{Cu}(\text{NO}_3)_2$ is reacted with excess KI solution according to:



and the mixture is titrated with 0.20 M $\text{Na}_2\text{S}_2\text{O}_3$ solution. If 35.0 mL of $\text{Na}_2\text{S}_2\text{O}_3$ are required, what is the concentration of the $\text{Cu}(\text{NO}_3)_2$ solution?



4. 25.0 mL of sulfurous acid (H_2SO_3) are titrated with 35.0 mL of 0.020 M KMnO_4 solution. What is the concentration of the H_2SO_3 solution?



Electrochemistry #4

Use the following unbalanced equation to answer questions 1 - 9.



1. What is the highest oxidation number of chromium in the equation?
2. What is the highest oxidation number of chlorine in the equation?
3. Write the balanced reduction half reaction in an acid solution.
4. Write the balanced oxidation half reaction in an acid solution.
5. Write the balanced full reaction in an acid solution.
6. Write the formula for the oxidizing agent.
7. Write the formula of the species that is getting reduced.
8. What effect would the addition of $\text{NaOH}_{(\text{SOLID})}$ have on the equilibrium?
9. What effect would the addition of $\text{NaOH}_{(\text{SOLID})}$ have on the cell potential?

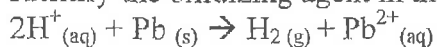
Chemistry 12: Electrochemistry 1
Review Worksheet

Name _____
Date _____ Block _____

1. When a substance is reduced, it

- loses electrons.
- causes oxidation.
- undergoes oxidation.
- increases in oxidation number.

2. Identify the oxidizing agent in the following equation:



- $\text{H}_{2(\text{g})}$
- $\text{H}^+_{(\text{aq})}$
- $\text{Pb}_{(\text{s})}$
- $\text{Pb}^{2+}_{(\text{aq})}$

3. An example of reduction is

- $\text{Mn}_{(\text{s})} \rightarrow \text{Mn}^{2+}_{(\text{aq})}$
- $\text{H}^+_{(\text{aq})} + \text{MnO}_4^-_{(\text{aq})} + \text{K}^+_{(\text{aq})} + \text{OH}^-_{(\text{aq})} \rightarrow \text{K}^+_{(\text{aq})} + \text{MnO}_4^-_{(\text{aq})} + \text{H}_2\text{O}_{(\text{l})}$
- $\text{Mn}^{2+}_{(\text{aq})} + \text{S}^{2-}_{(\text{aq})} \rightarrow \text{MnS}_{(\text{s})}$
- $\text{MnO}_{2(\text{s})} + 4\text{H}^+_{(\text{aq})} + 2\text{e}^- \rightarrow \text{Mn}^{2+}_{(\text{aq})} + 2\text{H}_2\text{O}_{(\text{l})}$

4. A strip of Zn metal is placed into 0.1M $\text{Ga}(\text{NO}_3)_3$ and its surface darkens. From this observation it may be concluded that Ga^{3+} is a

- weaker reducing agent than Zn^{2+}
- weaker oxidizing agent than Zn^{2+}
- stronger reducing agent than Zn^{2+}
- stronger oxidizing agent than Zn^{2+}

5. Which of the following oxidizing agents will react spontaneously with Br^- at standard conditions?

- H^+
- Li^+
- NO_3^- in acid
- $\text{Cr}_2\text{O}_7^{2-}$ in acid

6. Which of the following most readily loses electrons?

- Ag
- Cl^-
- Sr
- Mg^{2+}

7. Which of the following could be a product of a reaction in which SO_3^{2-} acts as a reducing agent?
- SO_4^{2-}
 - SO_2
 - S_2O
 - $\text{S}_2\text{O}_5^{2-}$
8. Given the half-cell reaction $\text{S}_2\text{O}_8^{2-} + 2\text{H}^+ \rightarrow 2\text{HSO}_4^-$, which of the following will balance electric charges?
- Add $2e^-$ to the left side
 - Add $2e^-$ to the right side
 - Add $3e^-$ to the left side
 - Add $3e^-$ to the right side

Use the following information to answer question 9.

Cl_2 is pale yellow in CCl_4

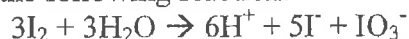
Cl^- is colorless in water

Br_2 is red in CCl_4

Br^- is colorless in water

9. Aqueous Cl_2 and aqueous KBr are shaken with CCl_4 in a test tube. The CCl_4 layer is red and the water layer is colorless. What is the best conclusion?
- Br^- is oxidized
 - No reaction occurred.
 - Cl_2 was oxidized
 - CCl_4 was oxidized
10. What is the oxidation number of Cr in CrO_4^{2-} ?
- 2
 - +6
 - +8
 - +10
11. The oxidation number for a sulphur atom in $\text{Na}_2\text{S}_2\text{O}_5$ is
- 2
 - +1
 - +4
 - +8
12. In which of the following compounds does carbon have an oxidation number of -2?
- CO
 - CO_2
 - CH_2O
 - CH_3OH

13. Consider the following reaction:



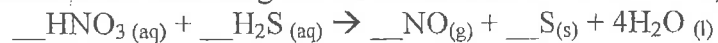
In this reaction atoms in I_2 undergo

- oxidation only
 - reduction only
 - neither oxidation nor reduction
 - both oxidation and reduction
14. Which one of the following half-reactions is balanced?
- $\text{IO}_3^- (\text{aq}) + 6\text{H}^+ (\text{aq}) + 5\text{e}^- \rightarrow \text{I}_2 (\text{s}) + 2\text{H}_2\text{O} (\text{l})$
 - $\text{ClO}^- (\text{aq}) + \text{H}_2\text{O} (\text{l}) + 2\text{e}^- \rightarrow \text{Cl}^- (\text{aq}) + 2\text{OH}^- (\text{aq})$
 - $\text{SO}_4^{2-} (\text{aq}) + 8\text{H}^+ (\text{aq}) + 6\text{e}^- \rightarrow \text{H}_2\text{S} (\text{g}) + 4\text{H}_2\text{O} (\text{l})$
 - $\text{NO}_2^- (\text{aq}) + \text{H}_2\text{O} (\text{l}) + 2\text{e}^- \rightarrow 2\text{H}^+ (\text{aq}) + \text{NO}_3^- (\text{aq})$
15. Of the following metals, which would be the best one to use to make a container in which to store an aqueous copper(II) sulfate solution?
- Ag (s)
 - Fe (s)
 - Ni (s)
 - Pb (s)
16. The correctly balanced half-reaction for $\text{ClO}^- (\text{aq}) \rightarrow \text{Cl}^- (\text{aq})$ in a basic solution is
- $2\text{H}^+ (\text{aq}) + \text{ClO}^- (\text{aq}) + 2\text{e}^- \rightarrow \text{Cl}^- (\text{aq}) + \text{H}_2\text{O} (\text{l})$
 - $\text{H}_2\text{O} (\text{l}) + \text{ClO}^- (\text{aq}) \rightarrow \text{Cl}^- (\text{aq}) + 2\text{OH}^- (\text{aq}) + 2\text{e}^-$
 - $\text{H}_2\text{O} (\text{l}) + \text{ClO}^- (\text{aq}) + 2\text{e}^- \rightarrow \text{Cl}^- (\text{aq}) + 2\text{OH}^- (\text{aq})$
 - $2\text{H}^+ (\text{aq}) + \text{ClO}^- (\text{aq}) \rightarrow \text{Cl}^- (\text{aq}) + \text{H}_2\text{O} (\text{l}) + 2\text{e}^-$
17. Experiments were performed with three metal strips, X, Y, and Z, and their corresponding 1.0M nitrate solutions, $\text{X}(\text{NO}_3)_2$, $\text{Y}(\text{NO}_3)_2$ and $\text{Z}(\text{NO}_3)_3$.
- metal Y reacted with X^{2+} but not with Z^{3+} .
 - metal X did not react with any of the solutions

Which of the following gives the metals in order of decreasing strength as reducing agent (strongest reducing agent first)?

- Z, Y, X
- X, Y, Z
- Y, Z, X
- X, Z, Y

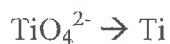
18. Which of the following sets of coefficients balances the equation



- a. 4, 2, 4, 1
 - b. 4, 1, 4, 1
 - c. 2, 3, 2, 3
 - d. 2, 1, 2, 1
19. Which of the following agents would reduce $\text{Sn}^{4+}(\text{aq})$ to $\text{Sn}^{2+}(\text{aq})$?
- a. $\text{Fe}(\text{s})$
 - b. $\text{I}^{-}(\text{aq})$
 - c. $\text{Fe}^{2+}(\text{aq})$
 - d. $\text{Ag}(\text{s})$
20. In a particular redox reaction, the oxidation number of phosphorus changed from -3 to 0 . From this it may be concluded that phosphorus
- a. lost 3 electrons and was reduced.
 - b. lost 3 electrons and was oxidized.
 - c. gain 3 electrons and was reduced.
 - d. gain 3 electrons and was oxidized.

SHORT ANSWER QUESTIONS

21. Balance the following half-reaction occurring in acid solution.



Electrochemistry #5

1. Calculate the electrochemical cell potential for the following reactions and indicate whether the reaction is spontaneous as written.
 - (a) $\text{Co} + \text{Fe}^{3+} \rightarrow \text{Co}^{2+} + \text{Fe}^{2+}$
 - (b) $\text{H}_2 + \text{Cl}_2 \rightarrow 2\text{H}^+ + 2\text{Cl}^-$
 - (c) $\text{I}^- + \text{MnO}_4^- \rightarrow \text{I}_2 + \text{Mn}^{2+}$
2. Write a red-ox reaction for Ag metal in Cl_2 gas and determine whether the reaction is spontaneous by calculating the cell potential.
3. Will anything happen if an aluminum spoon is used to stir an iron III nitrate solution? Explain, using cell potentials.
4. Will anything happen if an iron spoon is used to stir an aluminum chloride solution? Explain, using cell potentials.
5. A common test for silver purity is to add a drop of nitric acid. Explain what this test does, using cell potentials.
6. Would the nitric acid test for silver purity work for gold? Explain, using cell potentials.
7. Good stainless steel is mostly nickel metal. Can copper II sulphate solution be stored in a stainless steel container? Explain, using cell potentials.
8. Will anything happen to the copper plumbing in a house if acidified dichromate solution is poured down the drain? Explain, using cell potentials.

If the cell voltage for the sum of two half-reactions is positive, the net redox reaction will proceed spontaneously. Use a table of standard reduction potentials to predict whether the reactions below are spontaneous. In each case, show the addition of half-reactions and E° values.



In an electrochemical cell, an oxidation-reduction reaction produces electrical energy. Identify the labeled parts of the cell that is shown in the figure by writing the corresponding letters into the blanks below. The reaction that is taking place is:



Voltmeter

Solution of copper(II)

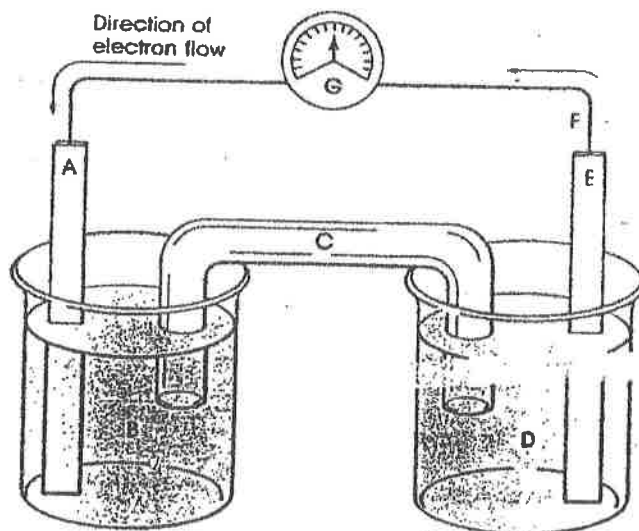
Salt bridge

Solution of zinc(II)

Anode

External wire

Cathode



Electrochemistry #6

1. Balance the equation and indicate the
 - (a) oxidizing agent.
 - (b) reducing agent.
 - (c) the element being reduced.
 - (d) the element being oxidized.



2. Balance the equation and indicate the
 - (a) oxidizing agent.
 - (b) reducing agent.
 - (c) the element being reduced.
 - (d) the element being oxidized.



3. Write the net ionic electrochemical equation for:

Oxygen + hydrogen sulfide (ACID)

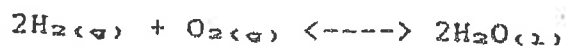
4. Balance the following electrochemical reaction and determine the cell E° value.



5. An iron-nickel electrochemical cell uses a salt bridge to join a half-cell containing a strip of iron in a 1.0 M solution of Fe^{2+} to a half-cell which contains a strip of nickel in a 1.0 M Ni^{2+} solution. A voltmeter connects the two metal strips.

- (a) In which cell does reduction occur?
- (b) Write the two half-cell reactions involved.
- (c) Which metal is the anode?
- (d) In which direction are electrons passing through the voltmeter?
- (e) What is the expected initial voltmeter reading?
- (f) What would be the effect on the voltmeter reading if the Fe^{2+} concentration only were increased to 2.0 M?
- (g) What would be the effect if only the $[\text{Ni}^{2+}]$ were decreased to 0.50 M?
- (h) What is the voltmeter reading when the cell reaches equilibrium?

6. A fuel cell converts about 75% of the available chemical energy into usable electric energy. One type of fuel cell is based on the combustion of hydrogen forming water:



- (a) Write the anode reaction occurring in basic solution.
- (b) Write the cathode reaction also occurring in basic solution.
- (c) Would a low or high gas pressure give the better E° value? Explain.
7. Corrosion of iron involves the oxidation of iron into Fe^{2+} when impurities such as copper serve as the cathode half cell where the reduction of oxygen occurs.
- $$\text{Fe}(\text{s}) + \frac{1}{2}\text{O}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{Fe}(\text{OH})_2(\text{s})$$
- Further oxidation of $\text{Fe}(\text{OH})_2$ by oxygen yields $\text{Fe}(\text{OH})_3$.
- (a) What two factors are involved in corrosion of iron?
- (b) Write the anode reaction.
- (c) Write the cathode reaction.
8. (a) Draw a diagram for an experimental setup that demonstrates how a copper-plated spoon could be plated with silver.
- (b) Identify the cathode and anode materials and the electrolytic solution.
9. Predict the principal product discharged at each electrode during the electrolysis of these 1 M solutions. Assume platinum electrodes are used.
- (a) KI
- (b) H_2SO_4
- (c) HCl
10. Explain why chromium, aluminum or magnesium metal does not corrode as rapidly as a less active metal such as iron.