Equilibria Between Metals and Metal Ions

Introduction

In this lab you will observe some possible oxidation-reduction reactions involving several metal and metallic ions. The results can be used to estimate the ease of reduction of the metallic ions relative to each other.

Prelab Assignment

1. A, B and C are three different metals. When they are allowed to react with aqueous solutions of their ions, the following results are observed:

$$A_{(s)} + B^{+1}_{(aq)} \text{ -----> No reaction}$$
$$B_{(s)} + C^{+1}_{(aq)} \text{ -----> } B^{+1}_{(aq)} + C_{(s)}$$
$$C_{(s)} + A^{+1}_{(aq)} \text{ -----> No reaction}$$
$$A_{(s)} + C^{+1}_{(aq)} \text{ -----> } A^{+1}_{(aq)} + C_{(s)}$$
$$B_{(s)} + A^{+1}_{(aq)} \text{ -----> } A_{(s)} + B^{+1}_{(s)}$$

   a) List the metal ions in order of decreasing reactivity.
   b) List the metals in order of decreasing reactivity.
   c) Which metal is the best reducing agent?
   d) Which metal is the best oxidizing agent?

2. Calcium metal and $HCl_{(aq)}$ when combined, undergo a displacement reaction such as those found in #1 above.
   a) Write the net ionic equation for this reaction.
   b) Identify which reactant is oxidized and which is reduced.

3. Silverware tarnishes as a result of the reaction of metallic silver with small amounts of hydrogen sulphide in the air:

$$Ag_{(s)} + H_2S_{(g)} + O_{2(g)} \text{ -----> } Ag_2S_{(s)} + H_2O_{(l)}$$

Identify the following...
   a) the substance being oxidized,
   b) the oxidizing agent,
   c) the substance being reduced,
   d) the reducing agent.

Purpose

To determine which metal ions are better competitors for electrons (ie. which are stronger oxidizing agents).

Materials

Test tubes, Emery paper
Small strips of Zn, Cu, Mg, Fe, Pb, small pieces of each of these metals
0.1 mol L^{-1} solutions of: $Zn(NO_3)_2$, $Cu(NO_3)_2$, $Mg(NO_3)_2$, $FeSO_4$, Pb $(NO_3)_2$, 3M $HCl_{(aq)}$

Safety

1. The metal nitrate solutions used in this experiment are poisonous. Avoid direct contact with them.
2. Silver nitrate is corrosive as well as poisonous and a strong oxidizing agent. If spilled on your skin, it will leave brown stains. If this occurs wash with sodium thiosulphate solution and rinse with plenty of water.

Procedure

1. Clean the strips of metal with emery paper. Avoid cross-contamination by using different pieces of emery paper, one for each metal.
2. Dip a piece of each metal into solutions of salts of each of the other metals. Leave for ~ 2 min.
3. Examine each test-tube and record your observations in a suitable table.
4. Place ~ 2 cm^3 of $HCl_{(aq)}$ in five test tubes, add a small piece of each of the metal, and note the rate of reactivity (order of 1 - 5, where 1 represents very reactive, and 5 no observable r reaction)

Developing the Idea

1. Write the net ionic equations for all the reactions that you have observed.
2. In each case, state which of the reactants has been oxidised and which has been reduced. Show any changes in oxidation number.
3. a) Which ion was the best oxidizing agent?
   b) Which ion was the poorest oxidizing agent?
   c) Rank the ions in order from strongest to weakest oxidizing agent.
   d) Which metal was the best reducing agent?
   e) Which metal was the poorest reducing agent?
4. Which of the metals has acted as both reducing agent and oxidising agent?

Conclusion

Summarise your results in a suitable table to provide a suitable conclusion to the lab.

Applying the Idea

1. Some nuclear power plants have used sea water as a coolant. Choosing the correct type of piping to carry the sea water throughout the plant is very important because sea water contains trace amounts of gold and silver ions. Are copper pipes suitable for nuclear power plants that use sea water? Explain your answer.
2. Lead poisoning may have contributed to the decline of the Roman Empire. The wine makers of ancient Rome used lead pots to boil down a grape syrup that was used to sweeten and preserve wine. As the syrup was being boiled, lead was oxidized by the acidity of the grape juice, releasing ions into the grape syrup.
   a) Write the net ionic equation for the chemical reaction that poisoned the Romans and caused the collapse of the Roman Empire.
   b) Compare the oxidizing ability of the lead ions to the other metal ions used in this lab.
3. Blocks of zinc or magnesium are attached to steel boat hulls, underground steel tanks, and steel pipelines to prevent the corrosion of the iron in the steel. Why does this anti-corrosion tactic work so well?
4. Use the list constructed in question 3(c) in Developing the Idea above, to answer the following questions...
   a) Would it be feasible to store a solution of copper sulphate in a container made of metallic zinc? Explain.
   b) Would it be feasible to store a solution, $CuSO_{4(aq)}$, in a container made of metallic silver? Explain.