1. Most metals have high thermal and electrical conductivities, high luster, malleability, and ductility, whereas nonmetals usually have low thermal and electrical conductivities, low luster, low malleability, and low ductility. In addition, relative to nonmetals, metals have low ionization potentials and low electron affinities.
2. Ionization energy is the energy required to remove an electron from an atom in the gaseous state.
3. Electron affinity is the energy produced when an electron is added to a species in the gas phase and is the inverse of the ionization energy in a physical sense, but the values are not just of opposite sign because you are considering slightly different processes; in each case, they differ by one electron.
4. An oxidation must always be accompanied by a reduction because the species being oxidized must transfer an electron to some other species that is reduced. The electron cannot just be given up to free space.
5. By systematically observing the displacement reactions among metals and their cations, it is possible to determine the relative oxidation potentials of the metals. The metal with the lower reduction potential will reduce a cation of a metal with a higher reduction potential.
6. $2Mg + O_2 \longrightarrow 2MgO$; $Zn + 2HCl \longrightarrow ZnCl_2 + H_2$; $Zn + Cu^{2+} \longrightarrow Zn^{2+} + Cu$.

7. Oxidized: I^-, H_2, Ca, Al

Reduced: Cl_2, W^{4+}, H, O_2

8. Li, Cr, Cd

Name _____ Desk _____

Date _____ Laboratory Instructor _____

REPORT SHEET | EXPERIMENT

Activity Series | 15

A. Reactions of Metals with Acid

Metal	Reaction with HCl	Observation	Equations
Ca	Yes	Ca all dissolved with very vigorous evolution of H_2 gas; colorless solution	$Ca(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2(g)$ $Ca(s) + 2H^+(aq) \longrightarrow Ca^{2+}(aq) + H_2(g)$
Cu	No	No reaction	_____
Mg	Yes	Mg dissolved, but more slowly than Ca, to produce a colorless solution with H_2 gas evolution	$Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$ $Mg(s) + 2H^+(aq) \longrightarrow Mg^{2+}(aq) + H_2(g)$
Fe	Yes	Very, very slow reaction with evolution of some H_2 gas	$Fe(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2(g)$ $Fe(s) + 2H^+(aq) \longrightarrow Fe^{2+}(aq) + H_2(g)$
Sn	Yes	Extremely slow evolution of H_2	$Sn(s) + 2HCl(aq) \longrightarrow SnCl_2(aq) + H_2(g)$ $Sn(s) + 2H^+(aq) \longrightarrow Sn^{2+}(aq) + H_2(g)$
Zn	Yes	Zn dissolved to produce colorless solution with H_2 gas evolution	$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$ $Zn(s) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + H_2(g)$
Example: Co	Yes, slowly	Gas evolved; solution turned blue	$Co(s) + 2HCl(aq) \longrightarrow CoCl_2(aq) + H_2(g)$ $Co(s) + 2H^+(aq) \longrightarrow Co^{2+}(aq) + H_2(g)$

Example:

$$2Al(s) + 3Zn(NO_3)_2(aq) \longrightarrow 2Al(NO_3)_3(aq) + 3Zn(s)$$

$$2Al(s) + 3Zn^{2+}(aq) \longrightarrow 2Al^{3+}(aq) + 3Zn(s)$$

Complete equation	*Net ionic equation*
$Ca(s) + Mg(NO_3)_2(aq) \longrightarrow Ca(NO_3)_2(aq) + Mg(s)$	$Ca + Mg^{2+} \longrightarrow Ca^{2+} + Mg$
$Ca(s) + Zn(NO_3)_2(aq) \longrightarrow Ca(NO_3)_2(aq) + Zn(s)$	$Ca + Zn^{2+} \longrightarrow Ca^{2+} + Zn$
$Ca(s) + Fe(NO_3)_2(aq) \longrightarrow Ca(NO_3)_2(aq) + Fe(s)$	$Ca + Fe^{2+} \longrightarrow Ca^{2+} + Fe$
$3Ca(s) + 2Fe(NO_3)_3(aq) \longrightarrow 3Ca(NO_3)_2(aq) + 2Fe(s)$	$3Ca + 2Fe^{3+} \longrightarrow 3Ca^{2+} + 2Fe$
$2Ca(s) + SnCl_4(aq) \longrightarrow 2CaCl_2(aq) + Sn(s)$	$2Ca + Sn^{4+} \longrightarrow 2Ca^{2+} + Sn$
$Ca(s) + CuSO_4(aq) \longrightarrow CaSO_4(aq) + Cu(s)$	$Ca + Cu^{2+} \longrightarrow Ca^{2+} + Cu$
$Mg(s) + Zn(NO_3)_2(aq) \longrightarrow Mg(NO_3)_2(aq) + Zn(s)$	$Mg + Zn^{2+} \longrightarrow Mg^{2+} + Zn$
$Mg(s) + Fe(NO_3)_2(aq) \longrightarrow Mg(NO_3)_2(aq) + Fe(s)$	$Mg + Fe^{2+} \longrightarrow Mg^{2+} + Fe$
$3Mg(s) + 2Fe(NO_3)_2(aq) \longrightarrow 3Mg(NO_3)_2(aq) + 2Fe(s)$	$3Mg + 2Fe^{3+} \longrightarrow 3Mg^{2+} + 2Fe$
$2Mg(s) + SnCl_4(aq) \longrightarrow 2MgCl_2(aq) + Sn(s)$	$2Mg + Sn^{4+} \longrightarrow 2Mg^{2+} + Sn$
$Mg(s) + CuSO_4(aq) \longrightarrow MgSO_4(aq) + Cu(s)$	$Mg + Cu^{2+} \longrightarrow Mg^{2+} + Cu$
$Zn(s) + Fe(NO_3)_2(aq) \longrightarrow Zn(NO_3)_2(aq) + Fe(s)$	$Zn + Fe^{2+} \longrightarrow Zn^{2+} + Fe$
$3Zn(s) + 2Fe(NO_3)_3(aq) \longrightarrow 3Zn(NO_3)_2(aq) + 2Fe(s)$	$3Zn + 2Fe^{3+} \longrightarrow 3Zn^{2+} + 2Fe$
$2Zn(s) + SnCl_4(aq) \longrightarrow 2ZnCl_2(aq) + Sn(s)$	$2Zn + Sn^{4+} \longrightarrow 2Zn^{2+} + Sn$
$Zn(s) + CuSO_4(aq) \longrightarrow ZnSO_4(aq) + Cu(s)$	$Zn + Cu^{2+} \longrightarrow Zn^{2+} + Cu$
$2Fe(s) + SnCl_4(aq) \longrightarrow 2FeCl_2(aq) + Sn(s)$	$2Fe + Sn^{4+} \longrightarrow 2Fe^{2+} + Sn$
$Fe(s) + CuSO_4(aq) \longrightarrow FeSO_4(aq) + Cu(s)$	$Fe + Cu^{2+} \longrightarrow Fe^{2+} + Cu$
$Sn(s) + CuSO_4(aq) \longrightarrow SnSO_4(aq) + Cu(s)$	$Sn + Cu^{2+} \longrightarrow Sn^{2+} + Cu$

C. Relative-Activity Series

Most reactive — Least reactive

1. Ca 2. Mg 3. Zn 4. Fe 5. Sn 6. Cu

QUESTIONS

1. Which of these six metals should be the most reactive toward oxygen? Ca
2. Which of the oxides would be expected to be thermally unstable and decompose according to the equation?

   $2MO \xrightarrow{\Delta} 2M + O_2$ Sn

3. Sodium is slightly less reactive than calcium. Predict the outcome of the following reactions:

   $Na + H_2O \longrightarrow$ $2Na + 2H_2O \longrightarrow 2NaOH + H_2$
   $Na + O_2 \longrightarrow$ $4Na + O_2 \longrightarrow 2Na_2O$ (actually $2Na + O_2 \longrightarrow Na_2O_2$ occurs)
   $Na + HCl \longrightarrow$ $2Na + 2HCl \longrightarrow 2NaCl + H_2$
   $Na + Ca^{2+} \longrightarrow$ No reaction

4. Which is more reactive, Fe^{2+} or Fe^{3+}, and why?

   Fe^{3+} has more chemical potential than Fe^{2+}, and it reacted faster and to a greater extent with Zn. The emf for the half reaction $Fe^{3+} + 3e^- \longrightarrow Fe$ is greater than the emf for the half reaction $Fe^{2+} + 2e^- \longrightarrow Fe$. Therefore, Fe^{3+} is a stronger oxidizing agent than Fe^{2+}.

5. From the data in Table B, rank the activity of aluminum.

   Because aluminum does not replace magnesium ion, it is less reactive than magnesium. It does replace zinc ion and is therefore more reactive than zinc. Hence, the order of reactivity is Mg > Al > Zn.

6. For each of the following reactions, indicate which substance is oxidized and which is reduced. Which substance is the oxidizing agent and which is the reducing agent?

	Substance oxidized	*Substance reduced*	*Oxidizing agent*	*Reducing agent*
$2Al(s) + 3Cl_2(g) \longrightarrow 2AlCl_3(s)$	Al	Cl_2	Cl_2	Al
$8H^+(aq) + MnO_4^-(aq) + 5Fe^{2+}(aq) \longrightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$	Fe^{2+}	MnO_4^-	MnO_4^-	Fe^{2+}
$FeS(s) + 3NO_3^-(aq) + 4H^+(aq) \longrightarrow 3NO(g) + SO_4^{2-}(aq) + Fe^{3+}(aq) + 2H_2O(l)$	FeS	NO_3^-	NO_3^-	FeS