P3: Activity Series of Metals

The **reactivity series** is a series of metals, in order of reactivity from highest to lowest. It is used to determine the products of single displacement reactions, whereby metal A will replace another metal B in a solution if A is higher in the series. Activity series of some of the more common metals, listed in descending order of reactivity.

Metals	Metal Ion	Reactivity
K	K^+	reacts with water
Na	Na^+	reacts with water
Li	Li^+	reacts with water
Ba	Ba^{2+}	reacts with water
Sr	Sr^{2+}	reacts with water
Ca	Ca^{2+}	reacts with water
Mg	Mg^{2+}	reacts with acids
Al	Al^{3+}	reacts with acids
Mn	Mn^{2+}	reacts with acids
Zn	Zn^{2+}	reacts with acids
Cr	Cr^{2+}	reacts with acids
Fe	Fe^{2+}	reacts with acids
Cd	Cd^{2+}	reacts with acids
Co	Co^{2+}	reacts with acids
Ni	Ni^{2+}	reacts with acids
Sn	Sn^{2+}	reacts with acids
Pb	Pb^{2+}	reacts with acids
H_2	H^+	included for comparison
Sb	Sb^{2+}	highly unreactive
Bi	Bi^{2+}	highly unreactive
Cu	Cu^{2+}	highly unreactive
Hg	Hg^{2+}	highly unreactive
Ag	Ag^+	highly unreactive
Au	Au^{3+}	highly unreactive
Pt	Pt^+	highly unreactive

When a metal in elemental form is placed in a solution of another metal salt it may be more energetically feasible for this "elemental metal" to exist as an ion and the "ionic metal" to exist as the element. Therefore the elemental metal will "displace" the ionic metal and the two swap places.

Only a metal higher in the reactivity series will displace another.

A metal can displace metal ions listed **below** it in the activity series, but not above. For example, zinc is more active than copper and is able to displace copper ions from solution

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s) \tag{P3.1}$$

However, silver **cannot** displace copper ions from solution. It is important to distinguish between the displacement of hydrogen from an acid and hydrogen from water. Sodium is highly active and is able to displace hydrogen from water:

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g) \tag{P3.2}$$

Less active metals like iron or zinc cannot displace hydrogen from water but do readily react with acids:

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g) \tag{P3.3}$$

Those metals that can displace H^+ ions from acids are easily recognized by their position above H in the activity series. The boundary between the metals that react with water and those that don't is harder to spot. For example, calcium is quite reactive with water, whereas magnesium does not react with cold water but does displace hydrogen from steam. A more sophisticated calculation involving electrode potentials is required to make accurate predictions in this area.

Origin

The reactivity of metals is due to the difference in stability of their electron configurations as atoms and as ions. As they are all metals they will form positive ions when they react.

Potassium has a single outer shell electron to lose to obtain a stable "Noble gas" electron configuration; the precious metals which exist in the d-block cannot form structures which are much more stable than their elemental state with the loss of just a few electrons. Metals that require the loss of only one electron to form stable ions are more reactive than similar metals which require the loss of more than one electron. Group 1A metals are the most reactive for that reason.

Metals with a greater total number of electrons tend to be more reactive as their outermost electrons (the ones which will be lost) exist further from the positive nucleus and therefore they are held less strongly.