Single Replacements

"One moves in, one moves out…"

Single Replacements

- General form: A free element reacts with a compound to produce a different free element and a different compound.
- $A + BC \rightarrow B + AC$

- The products formed depend on the reactants started with.
    - **Reactant element → ion**
    - **Reactant ion → element**
- The equation must balance in mass and charge
- In general:
    - *Metals replace metals*
    - *Nonmetals replace nonmetals*

More detail:

- *“free”* ***metal elements*** *replace* ***metal ions*** *(or H) that start in the compound*

- *“free”* ***nonmetal elements*** *replace* ***nonmetal ions***

- *Remember: free elements are <u>NEUTRAL</u>*

Examples…

- $Zn^0 + Cu^{2+}Cl_2 \rightarrow Zn^{2+}Cl_2 + Cu^0$

- $Mg^0 + 2\ H^+Cl \rightarrow Mg^{2+}Cl_2 + H_2{}^0$

- $2\ NaCl + F_2 \rightarrow 2\ NaF + Cl_2$

When?

- *Do all free elements react with all compounds?*

Well,…no.

- Metals will only replace metals that are *less active* than themselves.

When?

- We use an activity series (reduction potentials sheet) to determine which metals can replace which metals
- Metals listed as products are **more active** the **lower** they are on the reduction potentials sheet

$Sn^{4+} + 2e^-$	→	Sn^{2+}	0.15
$S(s) + 2H^+ + 2e^-$	→	$H_2S(g)$	0.14
$2H^+ + 2e^-$	→	$H_2(g)$	0.00
$Pb^{2+} + 2e^-$	→	$Pb(s)$	−0.13
$Sn^{2+} + 2e^-$	→	$Sn(s)$	−0.14
$Ni^{2+} + 2e^-$	→	$Ni(s)$	−0.25
$Co^{2+} + 2e^-$	→	$Co(s)$	−0.28
$Cd^{2+} + 2e^-$	→	$Cd(s)$	−0.40
$Cr^{3+} + e^-$	→	Cr^{2+}	−0.41
$Fe^{2+} + 2e^-$	→	$Fe(s)$	−0.44
$Cr^{3+} + 3e^-$	→	$Cr(s)$	−0.74
$Zn^{2+} + 2e^-$	→	$Zn(s)$	−0.76
$2H_2O(l) + 2e^-$	→	$H_2(g) + 2OH^-$	−0.83
$Mn^{2+} + 2e^-$	→	$Mn(s)$	−1.18
$Al^{3+} + 3e^-$	→	$Al(s)$	−1.66
$Be^{2+} + 2e^-$	→	$Be(s)$	−1.70
$Mg^{2+} + 2e^-$	→	$Mg(s)$	−2.37
$Na^+ + e^-$	→	$Na(s)$	−2.71
$Ca^{2+} + 2e^-$	→	$Ca(s)$	−2.87
$Sr^{2+} + 2e^-$	→	$Sr(s)$	−2.89
$Ba^{2+} + 2e^-$	→	$Ba(s)$	−2.90
$Rb^+ + e^-$	→	$Rb(s)$	−2.92
$K^+ + e^-$	→	$K(s)$	−2.92
$Cs^+ + e^-$	→	$Cs(s)$	−2.92
$Li^+ + e^-$	→	$Li(s)$	−3.05

Less active metals

Most active metals

- Can replace the metals above them from compounds

$Sn^{4+} + 2\,e^-$	$\rightarrow$	Sn^{2+}	0.15
$S(s) + 2\,H^+ + 2\,e^-$	$\rightarrow$	$H_2S(g)$	0.14
$2\,H^+ + 2\,e^-$	$\rightarrow$	$H_2(g)$	0.00
$Pb^{2+} + 2\,e^-$	$\rightarrow$	$Pb(s)$	−0.13
$Sn^{2+} + 2\,e^-$	$\rightarrow$	$Sn(s)$	−0.14
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$Zn^{2+} + 2\,e^-$	$\rightarrow$	$Zn(s)$	−0.76
$2\,H_2O(l) + 2\,e^-$	$\rightarrow$	$H_2(g) + 2\,OH^-$	−0.83
$Mn^{2+} + 2\,e^-$	$\rightarrow$	$Mn(s)$	−1.18
$Al^{3+} + 3\,e^-$	$\rightarrow$	$Al(s)$	−1.66
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$Ca^{2+} + 2\,e^-$	$\rightarrow$	$Ca(s)$	−2.87
$Sr^{2+} + 2\,e^-$	$\rightarrow$	$Sr(s)$	−2.89
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$Rb^+ + e^-$	$\rightarrow$	$Rb(s)$	−2.92
$K^+ + e^-$	$\rightarrow$	$K(s)$	−2.92
$Cs^+ + e^-$	$\rightarrow$	$Cs(s)$	−2.92
$Li^+ + e^-$	$\rightarrow$	$Li(s)$	−3.05

Metals from here to the bottom of the page react with acids (replace the H+)

Most active metals
- From here down

Can replace the H from water!

When?

Zinc metal, for example, is more active than copper…

So the zinc metal replaces the copper ions from the aqueous compound…

And the copper becomes neutral atoms.

How?

How does this actually happen?

If one metal is losing electrons…

…and another is gaining electrons…

…it is an **oxidation-reduction** process

Oxidation = losing electrons

Reduction = gaining electrons

- The Zinc metal appears to dissolve…

…it is becoming zinc ions and dissolving into the water…

$$Zn^0 \rightarrow Zn^{2+} + 2e^-$$ **oxidation**

- As the copper ions leave solution, the distinctive blue color of an aqueous copper solution fades away

$$Cu^{2+} + 2e^- \rightarrow Cu^0$$ **reduction**