Single Replacement Reactions

In single replacement reactions, one element reacts with a compound by replacing one of the elements within the compound.

REPLACING A CATION

A metal can replace a metal ion in a salt, or a hydrogen ion in an acid:

$$A + BC \rightarrow AC + B$$

1) Element A must be more reactive than B to displace B from the compound BC. If B were more reactive than A, no displacement would occur.

2) It is possible to arrange the metals in a series called the **electromotive series** or **activity series.** An activity series is provided on the right. Elements that are higher on the activity series have a greater tendency to lose electrons than those below it. Thus, an element will displace any element below it in the activity series from a compound.

In general, within a family of representative metals, the larger metals tend to be more reactive. They have lower ionization energies; therefore they tend to lose electrons more easily than smaller metals. Truthfully, if you compare the activity series to the positions these elements hold on the periodic table, you'll see that it's quite hard to predict which element is higher on the activity series from the table. This is why we use the activity series and not the periodic table when answering this sort of question.

lithium	Li
potassium	K
barium	Ba
calcium	Ca
sodium	Na
magnesium	Mg
aluminum	Aℓ
manganese	Mn
zinc	Zn
chromium	Cr
iron	Fe
cadmium	Cd
nickel	Ni
tin	Sn
lead	Pb
hydrogen	H
antimony	Sb
bismuth	Bi
copper	Cu
mercury	Hg
silver	Ag
gold	Au

Example 1: Complete and balance the following single replacement reactions, if they would occur:

1) $Na + Cr(C\ell O_3)_3 \rightarrow$
2) $Sn + A\ell(C\ell O_3)_3 \rightarrow$

Solution: First we look on the activity table to decide whether the reactions would occur at all.

(1) Sodium is higher than chromium so it would replace chromium in a single replacement. Since the sodium ion is Na^+, the products will be Cr and $NaC\ell O_3$. We balance the resulting equations:

$$3\ Na + Cr(C\ell O_3)_3 \rightarrow Cr + 3\ NaC\ell O_3$$

(2) Tin is lower than aluminum, so it does not replace it. There is no reaction.

$$Sn + A\ell(C\ell O_3)_3 \rightarrow \text{no reaction}$$

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REPLACING AN ANION *(OPTIONAL)*

A nonmetal can replace a nonmetal ion in a salt or acid:

$$DE + F \rightarrow DF + E$$

1) Again, element F must be more reactive than E in order to displace E from the compound DE. If E were more reactive than F, no displacement would have occurred.

2) A similar activity series can be prepared for the halogen nonmetals. It appears at the right.

fluorine	F_2
chlorine	Cl_2
bromine	Br_2
iodine	I_2

lithium	Li
potassium	K
barium	Ba
calcium	Ca
sodium	Na
magnesium	Mg
aluminum	Al
manganese	Mn
zinc	Zn
chromium	Cr
iron	Fe
cadmium	Cd
nickel	Ni
tin	Sn
lead	Pb
hydrogen	H
antimony	Sb
bismuth	Bi
copper	Cu
mercury	Hg
silver	Ag
gold	Au

EXERCISES

A. Complete and balance the following single replacement reactions, if they would occur:

1) $Al + CuSO_4 \rightarrow$

2) $Ag + Cu(NO_3)_2 \rightarrow$

3) $K + Ca(NO_3)_2 \rightarrow$

4) $Fe + SbCl_3 \rightarrow$
[*Hint: Fe^{2+} is more common than Fe^{3+}.*]

5) $Na + ZnCrO_4 \rightarrow$

6) $Bi + HBr \rightarrow$

B. Complete and balance the following single replacement reactions, if they would occur (optional):

1) $Cl_2 + NaI \rightarrow$

2) $I_2 + NaBr \rightarrow$

SOLUTIONS

A. (1) $2\ Al + 3\ CuSO_4 \rightarrow 3\ Cu + Al_2(SO_4)_3$ (2) no reaction
(3) $2\ K + Ca(NO_3)_2 \rightarrow Ca + 2\ KNO_3$ (4) $3\ Fe + 2\ SbCl_3 \rightarrow 2\ Sb + 3\ FeCl_2$
(5) $2\ Na + ZnCrO_4 \rightarrow Zn + Na_2CrO_4$ (6) no reaction

B. (1) $Cl_2 + 2\ NaI \rightarrow I_2 + 2\ NaCl$ (2) no reaction