Double Replacement Reactions

A double replacement reaction has the form:

$$AB + CD \rightarrow AD + CB$$

There are four different possible outcomes to a reaction such as this:

[1] **Formation of a gas.** There are certain compounds which are unstable and decompose to water and a gas. Three common ones are H_2CO_3, H_2SO_3 and NH_4OH. They decompose like this:

$$H_2CO_3 \rightarrow H_2O_{\,(l)} + CO_{2\,(g)}$$
$$H_2SO_3 \rightarrow H_2O_{\,(l)} + SO_{2\,(g)}$$
$$NH_4OH \rightarrow H_2O_{\,(l)} + NH_{3\,(g)}$$

When any of these three compounds appears as a product, write the decomposed form instead.

[2] **Formation of a slightly ionized compound.** Look for compounds like H_2O, $HC_2H_3O_2$ (acetic acid), $H_2C_2O_4$ (oxalic acid) or H_3PO_4 as products. Heat release is the evidence of the formation of these compounds. Any of these compounds should be marked as "$_{(l)}$".

[3] **Formation of a precipitate.** Consult the solubility table on page 61–62 in the Chem 061/071 Lab Manual or the User-Friendly Solubility Table from the Learning Centre. "Low solubility" means that very little of the substance dissolves in water, so most of it forms as a precipitate, and should be marked "$_{(s)}$". "Soluble" means that the ions will stay in solution.

[4] **There is no reaction.** None of the above happens, probably because the ions all stay in solution.

Example 1: Complete and balance the following equation, if a reaction occurs:
$Na_2CO_{3\,(aq)} + HC\ell_{\,(aq)} \rightarrow ?$

Solution: [1] **Determine what ions are formed.** Consult a list of ions if necessary. The ions in this case are Na^+ (*not* Na_2^+), CO_3^{2-}, H^+, and $C\ell^-$.

[2] **Form the hypothetical products.** Take into account the valences of the ions involved. The products here would be $NaC\ell$ and H_2CO_3.

[3] **Look for precipitates, slightly ionized compounds and unstable compounds on the product side.** We want to make sure that a reaction will actually occur before we do too much work! In this case, $NaC\ell$ is soluble and so is H_2CO_3, but H_2CO_3 is unstable, so there will be a reaction.

[4] **Write the double replacement equation, if there is a reaction.**

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The equation is $Na_2CO_{3\,(aq)} + HC\ell_{(aq)} \rightarrow NaC\ell + H_2CO_3$.

[5] **Balance the equation, then adjust it for unstable compounds and gases.** It's easier to do it this way than to break down the gases and balance it afterwards.

$Na_2CO_3 + 2\ HC\ell \rightarrow 2\ NaC\ell + H_2CO_3$ which becomes:
$Na_2CO_3 + 2\ HC\ell \rightarrow 2\ NaC\ell_{(aq)} + H_2O_{(l)} + CO_{2\,(g)}$

Example 2: Complete and balance the following equation, if a reaction occurs:
$NaOH + HC\ell \rightarrow ?$

Solution: We'll use the same steps as in Example 1.
[1] **Determine what ions are formed.**
Na^+, OH^-, H^+, $C\ell^-$.

[2] **Form the hypothetical products.**
$NaC\ell$ and H_2O.

[3] **Look for precipitates, slightly ionized compounds and unstable compounds on the product side.**
$NaC\ell$ is soluble. H_2O is a slightly ionized compound, so a reaction will occur.

[4] **Write the double replacement equation, if there is a reaction.**
$NaOH + HC\ell \rightarrow NaC\ell_{(aq)} + H_2O_{(l)}$

[5] **Balance the equation, then adjust it for unstable compounds and gases.**
It's balanced as it stands, so we're done.

Example 3: Complete and balance the following equation, if a reaction occurs:
$NaC\ell + AgNO_3 \rightarrow ?$

Solution: [1] **Determine what ions are formed.**
Na^+, $C\ell^-$, Ag^+, NO_3^-.

[2] **Form the hypothetical products.**
$NaNO_3$ and $AgC\ell$.

[3] **Look for precipitates, slightly ionized compounds and unstable compounds on the product side.**
$NaNO_3$ is soluble, but $AgC\ell$ has low solubility, so a reaction will occur.

[4] **Write the double replacement equation, if there is a reaction.**
$NaC\ell + AgNO_3 \rightarrow NaNO_{3\,(aq)} + AgC\ell_{(s)}$

[5] **Balance the equation, then adjust it for unstable compounds and gases.**
It's balanced as it stands, so we're done.

Example 4: Complete and balance the following equation, if a reaction occurs:
$NaC\ell + KNO_3 \rightarrow$?

Solution: [1] **Determine what ions are formed.**
Na^+, $C\ell^-$, K^+, NO_3^-.

[2] **Form the hypothetical products.**
$NaNO_3$ and $KC\ell$.

[3] **Look for precipitates, slightly ionized compounds and unstable compounds on the product side.**
$NaNO_3$ and $KC\ell$ are both soluble, so no reaction will occur. We can stop at this step, since these ions will stay in solution.

EXERCISES

Complete and balance the following equations, if a reaction occurs:

1) $BaC\ell_{2\,(aq)} + \quad H_2SO_{4\,(aq)} \rightarrow$

2) $Na_2CO_{3\,(aq)} + \quad HC\ell_{(aq)} \rightarrow$

3) $NaC_2H_3O_{2\,(aq)} + \quad HC\ell_{(aq)} \rightarrow$

4) $K_2CrO_{4\,(aq)} + \quad Pb(NO_3)_{2\,(aq)} \rightarrow$

5) $BiC\ell_{3\,(aq)} + \quad H_2S_{(aq)} \rightarrow$

6) $SrS_{(aq)} + \quad FrC\ell O_{3\,(aq)} \rightarrow$

7) $K_2C_2O_{4\,(aq)} + \quad HC\ell_{(aq)} \rightarrow$

8) $H_3PO_{4\,(aq)} + \quad Ca(OH)_{2\,(aq)} \rightarrow$

9) $(NH_4)_2CO_{3\,(aq)} + \quad HNO_{3\,(aq)} \rightarrow$

10) $(NH_4)_2CO_3$ (aq) + $CaCl_2$ (aq) →

11) MgI_2 (aq) + $Ca(C_2H_3O_2)_2$ (aq) →

12) KOH (aq) + H_3PO_4 (aq) →

13) $Na_2C_2O_4$ (aq) + $CaCl_2$ (aq) →

14) $(NH_4)_2SO_4$ (aq) + KOH (aq) →

SOLUTIONS

(1) $BaCl_2$ (aq) + H_2SO_4 (aq) → $BaSO_4$ (s) + 2 HCl (aq)
(2) Na_2CO_3 (aq) + 2 HCl (aq) → 2 $NaCl$ (aq) + H_2O (l) + CO_2 (g)
(3) $NaC_2H_3O_2$ (aq) + HCl (aq) → $NaCl$ (aq) + $HC_2H_3O_2$ (l)
(4) K_2CrO_4 (aq) + $Pb(NO_3)_2$ (aq) → 2 KNO_3 (aq) + $PbCrO_4$ (s)
(5) 2 $BiCl_3$ (aq) + 3 H_2S (aq) → Bi_2S_3 (s) + 6 HCl (aq)
(6) no reaction
(7) $K_2C_2O_4$ (aq) + 2 HCl (aq) → 2 KCl (aq) + $H_2C_2O_4$ (l)
(8) 2 H_3PO_4 (aq) + 3 $Ca(OH)_2$ (aq) → 6 H_2O (l) + $Ca_3(PO_4)_2$ (s)
(9) $(NH_4)_2CO_3$ (aq) + 2 HNO_3 (aq) → 2 NH_4NO_3 (aq) + H_2O (l) + CO_2 (g)
(10) $(NH_4)_2CO_3$ (aq) + $CaCl_2$ (aq) → 2 NH_4Cl (aq) + $CaCO_3$ (s)
(11) no reaction
(12) 3 KOH (aq) + H_3PO_4 (aq) → K_3PO_4 (aq) + 3 H_2O (l)
(13) $Na_2C_2O_4$ (aq) + $CaCl_2$ (aq) → 2 $NaCl$ (aq) + CaC_2O_4 (s)
(14) $(NH_4)_2SO_4$ (aq) + 2 KOH (aq) → 2 NH_3 (g) + 2 H_2O (l) + K_2SO_4 (aq)