Predicting the Products of Chemical Reactions

Unit: Chemical Reactions

MA Curriculum Frameworks (2016): HS-PS1-2

Mastery Objective(s): (Students will be able to…)

- Accurately predict the products of single replacement, double replacement, and combustion reactions.

Success Criteria:

- Cation & anion are correct for single and double replacement reactions.
- Products that are ionic compounds have correctly balanced charges.

Tier 2 Vocabulary: product, replacement

Language Objectives:

- Explain how you can tell from the reactants what the reaction is likely to be.

Notes:

Recognizing Reaction Types from the Reactants

If you are familiar with the different types of chemical reactions, you can often tell the reaction type by looking only at the reactants. Once you know the reaction type, it is relatively straightforward to predict what the products should be.

Combustion Reactions

In a combustion reaction, the reactants are always a hydrocarbon (with some unknown number of atoms C, H, and O) and oxygen (O_2). The products are always CO_2 and H_2O.

If you were asked to write a combustion reaction for C_5H_{12}, you would write:

$$C_5H_{12} + O_2 \rightarrow CO_2 + H_2O$$

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Single Replacement Reactions

Single and double replacement reactions usually involve ionic compounds (and sometimes water, which we treat as the ionic compound H^+OH^-).

In a single replacement reaction, atoms of an element react with a compound, replacing the atom of the same type. Metals replace metals; non-metals replace non-metals. For example:

$Na + MgI_2 \rightarrow NaI + Mg$ (Na replaces Mg.)

$KBr + Cl_2 \rightarrow KCl + Br_2$ (Cl replaces Br.)

If an element reacts with a compound, you can predict the products, because the element simply replaces the other element of the same type.

For example, if you were given the problem:

$$Ca + NaCl \rightarrow ?$$

Calcium is a metal, so it will replace sodium. This means calcium will end up with chloride ($CaCl_2$), and sodium will end up by itself (Na). The reaction is therefore:

$$Ca + NaCl \rightarrow CaCl_2 + Na$$

Remember that *we have to balance the charges <u>every</u> <u>time</u> we put two new ions together*. This is the most common mistake beginning students make—forgetting to balance the charges in the new compounds. You can think of breaking apart the reactants as "unbalancing" the charges, which means you need to "re-balance" them when you put them back together in a new arrangement.

In the example above, the Na ion (which has a +1 charge) needed only one Cl^- ion for the charges to balance, but the Ca ion (which has a +2 charge) needs two.

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Double Replacement Reactions

In a double replacement reaction, the two ions of the same type switch places, as in:

$$KCl + MgO \rightarrow MgCl_2 + K_2O$$

(K and Mg are trading places;
in the products, K is now with O and Mg is now with Cl.)

Notice again that we had to balance the charges. We needed only one K^+ ion with Cl^-, but we need 2 K^+ ions with O^{2-}. Similarly, Mg^{2+} needed only one O^{2-} ion, but it needs two Cl^- ions.

If we had the problem:

$$NH_4OH + Ca_3(PO_4)_2 \rightarrow ?$$

we would swap NH_4^+ with Ca^{2+}. When we balance the charges, NH_4^+ would go with PO_4^{3-} to form $(NH_4)_3PO_4$, and Ca^{2+} would go with OH^- to form $Ca(OH)_2$. This gives the equation:

$$NH_4OH + Ca_3(PO_4)_2 \rightarrow (NH_4)_3PO_4 + Ca(OH)_2$$

Acid-base reactions are a type of double replacement reaction in which H^+ and OH^- ions combine to form "HOH", which is really H_2O. For example:

$$HCl + Ca(OH)_2 \rightarrow CaCl_2 + H_2O$$

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Homework Problems

Predict the products for each of the following single replacement, double replacement and combustion reactions. (*Don't forget to balance the charges!*)

1. $Ca + AlCl_3 \rightarrow$
2. $BaCl_2 + O_2 \rightarrow$
3. $KCl + Mg(OH)_2 \rightarrow$
4. $Na_3PO_4 + MgSO_4 \rightarrow$
5. $Na + HCl \rightarrow$
6. $Al + CoCl_2 \rightarrow$
7. $Pb(NO_3)_2 + NaI \rightarrow$
8. $SiO_2 + Ca \rightarrow$
9. $Al + FeO \rightarrow$
10. $Zn + HCl \rightarrow$

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11. $Mg + NaNO_3 \rightarrow$

12. $NaOH + HNO_3 \rightarrow$

13. $Mg + CrCl_3 \rightarrow$

14. $Fe(OH)_3 + H_2SO_4 \rightarrow$

15. $H_2S + AuCl_3 \rightarrow$

16. $Cr_2(SO_4)_3 + KOH \rightarrow$

17. $PbCl_2 + Na_2SO_4 \rightarrow$

18. $AgNO_3 + CuCl_2 \rightarrow$

19. $BaCl_2 + Al_2(SO_4)_3 \rightarrow$

20. $TiO_2 + HCl \rightarrow$

21. $Zn + AgNO_3 \rightarrow$

22. $Al + Fe_3O_4 \rightarrow$

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