Name:

Skill Sheet 21 Predicting Chemical Equations

Chemical reactions are the mechanism of chemical change. Elements and compounds enter into a reaction, and new substances are formed as a result. Often, we know the types of substances that entered the reaction and, with chemical analysis, determine what types of substance(s) were formed. Sometimes, though, it might be helpful if we could predict the products of the chemical reaction—know in advance what would be formed and how much of it would be produced. For certain chemical reactions, this is possible, using our knowledge of oxidation numbers, mechanics of chemical reactions, and balancing equations. In this skill sheet, you will practice writing a complete balanced equation for chemical reactions when only the identities of the reactants are known.

1. Chemical equations

Recall that chemical equations document, in shorthand form, the process of a chemical change or chemical reaction. The equation reads from left to right with the reactants, substances entering the reaction, separated from the products, substances formed from the reaction, by an arrow that indicates "yields" or "produces."

In the chemical equation:

$$2Li + BaCl_2 \rightarrow 2LiCl + Ba$$

two atoms of lithium combine with one molecule of barium chloride to yield or produce two molecules of lithium chloride and one atom of barium. The equation fully describes the nature of the chemical change that we are generating with the reaction.

For reactions such as the one above, a single-displacement reaction, and double-displacement reactions, we are generally capable of predicting the nature of the products in advance and write a completely balanced equation for the chemical change. To do this we must:

1. Predict the products for the reaction.
2. Determine the chemical formulas for the products of the reaction.
3. Balance the equation.

2. Predicting the products of single- and double-displacement reactions

In displacement reactions, one member of a compound is replaced by some other substance, usually an element or polyatomic ion. The pattern for this replacement is easily predictable: if the substance doing the replacing forms a positive ion, it replaces the member of the compound that also forms a positive ion. If the substance doing the replacing forms a negative ion, it replaces the member of the compound that also forms a negative ion. The balance of negative and positive charges must be maintained in the new compound that will be formed. For the reaction described above:

$$2Li + BaCl_2 \rightarrow 2LiCl + Ba$$

we could predict that the lithium would replace the barium in the compound barium chloride since both lithium and barium have positive oxidation numbers. The resulting product would pair lithium (1+) and chlorine (1-): the positive/negative combination required for ionic compounds.

For double-replacement reactions, the substance with the positive oxidation number of one compound replaces the substance with the positive oxidation number of the second compound, with the same holding true for the negative members:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

$$H^{1+}Cl^{1-} + Na^{1+}OH^{1-} \rightarrow Na^{1+}Cl^{1-} + H_2^{1+}O^{2-}$$

3. Predicting replacements

1. If calcium were to combine with the compound barium nitrate, which member of barium nitrate would calcium replace?

2. If LiCl and $MgBr_2$ were to enter into a chemical reaction, which member of $MgBr_2$ will chlorine replace?

3. If Fe^{2+} were to combine with K_2Br, what component of K_2Br would be replaced by the Fe^{2+}?

4. Predicting chemical formulas for reaction products

In 19.2, you examined the method by which we can predict the chemical formula for ionic compounds. Using oxidation numbers and the fact that the sum of the oxidation numbers for an ionic compound must equal zero, we were able to determine the chemical formula for compounds formed from ionic bonding.

You will follow this same procedure when writing the chemical formula for the products of single- and double-replacement reactions. Once you have determined which elements or ions will be swapped to form the new compounds, the products of the reaction, use the oxidation numbers of the elements/ions to be combined to generate the chemical formulas for the new compounds.

Example

If beryllium (Be) combines with potassium iodide (KI) in a chemical reaction, what will be the identities of the products?

First, we decide which member of KI will be replaced by the beryllium. Since beryllium has an oxidation number of 2+, it replaces the element in KI that also has a positive oxidation number—the potassium (K^{1+}). It will therefore combine with the iodine to form a new compound.

Because beryllium has an oxidation number of 2+ and iodine's oxidation number is 1-, it is necessary for two atoms of iodine to combine with one atom of beryllium to form an electrically neutral compound:

$$(2+) + 2(1-) = 0$$

The resulting chemical formula for beryllium iodide is BeI_2.

In single-replacement reactions, the component of the compound that has been replaced by the uncombined reactant now stands alone and uncombined. The resulting products of this chemical reaction, therefore, are BeI_2 and K.

For polyatomic ions, the process is identical to that used when replacing monoatomic ions. Find the oxidation number of the polyatomic ion from a reference table and use that value in your calculations.

5. Predicting product formulas for single- and double-replacement reactions

For the following combinations of reactants, predict the chemical symbols or formulas of the products:

Reactants	Products
$Li + AlCl_3$	
$BeO + Na_2SO_4$	
$CaCO_3 + KF$	
$K + CaO$	
$AlPO_4 + NH_4Cl$	
$KBr + Cs_2O$	

6. Predicting chemical equations for single- and double-replacement reactions

Once you have determined the nature and formulas/symbols of the products for a chemical reaction, the final step is to write a balanced equation for the reaction. Using the skills you practiced in 20.2, write complete balanced equations for the following combinations of reactants.

1. NaCl and $Mg(OH)_2$

2. Ca and K_2S

3. LiF and BI_3

4. $BeCrO_4$ and KNO_3

5. Mg and Fe_2O_3