a place of mind

FACULTY OF EDUCATION

Department of
Curriculum and Pedagogy

Chemistry
Chemical Reactions: Types of Reactions

Science and Mathematics Education Research Group

Supported by UBC Teaching and Learning Enhancement Fund 2012-2013

Predicting Products

$$? \rightarrow Na_2SO_4 + HCl$$

Best Practices I

Example 1 – What is the missing product in the reaction below?

$$K_3PO_4 + MgCl_2 \rightarrow \_\_\_\_\_ + KCl$$

1. Determine what type of a reaction is occurring. *This is a double replacement reaction because each reactant has a cation and an anion that can "switch places".*

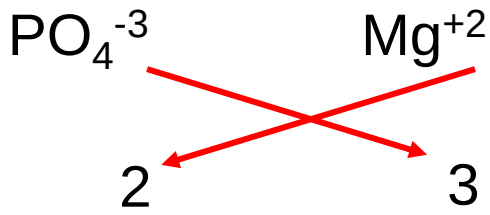
2. Switch the cations in the reactants. The missing product would thus be a combination of a Mg cation and a PO_4 anion.

Best Practices II

Example 1 – What is the missing product in the reaction below?

$K_3PO_4 + MgCl_2 \rightarrow$ _____ + KCl

3. Reconcile the charges in the predicted compound. *The Mg ion has a charge of +2 and the PO_4 ion has a charge of -3. Thus, to make a neutral molecule you need 3 of the Mg ions and 2 of the PO_4 ions.*



The missing product would thus be $Mg_3(PO_4)_2$.

Best Practices III

Example 1 – What is the missing product in the reaction below?

$$K_3PO_4 + MgCl_2 \rightarrow \_\_\_\_\_ + KCl$$

The complete (and balanced) chemical reaction is thus:

$$2K_3PO_4 + 3MgCl_2 \rightarrow Mg_3(PO_4)_2 + 6KCl$$

The subscripts tell you how many of each ion is needed to balance the charges in the molecule. When a chemical reaction occurs, this information needs to change to reflect the new substances produced. The subscripts must be modified each time a chemical reaction occurs.

$$K_3(PO_4)_1 + Mg_1Cl_2 \rightarrow Mg_3(PO_4)_2 + KCl$$

If you just used the same subscripts as the reactants, you would obtain a product of $MgPO_4$ which would be incorrect because the charges of the cation and anion do not balance.

Predicting Products I

What kind of reaction would occur if you react C_2H_4 with oxygen?

A. Single replacement

B. Combustion

C. Synthesis

D. Double replacement

E. Neutralization

Solution

Answer: B

Justification: If a reaction occurs with oxygen then it is most likely a combustion reaction.

However, there are some synthesis reactions with oxygen. Thus to verify that it is a combustion reaction, you need to predict the products.

Since, the reactant has both carbon and hydrogen in it, when it reacts with oxygen it will form CO_2 and H_2O. This verifies that the reaction is a combustion reaction.

The complete balanced equation is shown below:

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$

Predicting Products II

What kind of reaction would occur if you obtained $BaSO_4$ and AgCl?

A. Single replacement

B. Decomposition

C. Synthesis

D. Double replacement

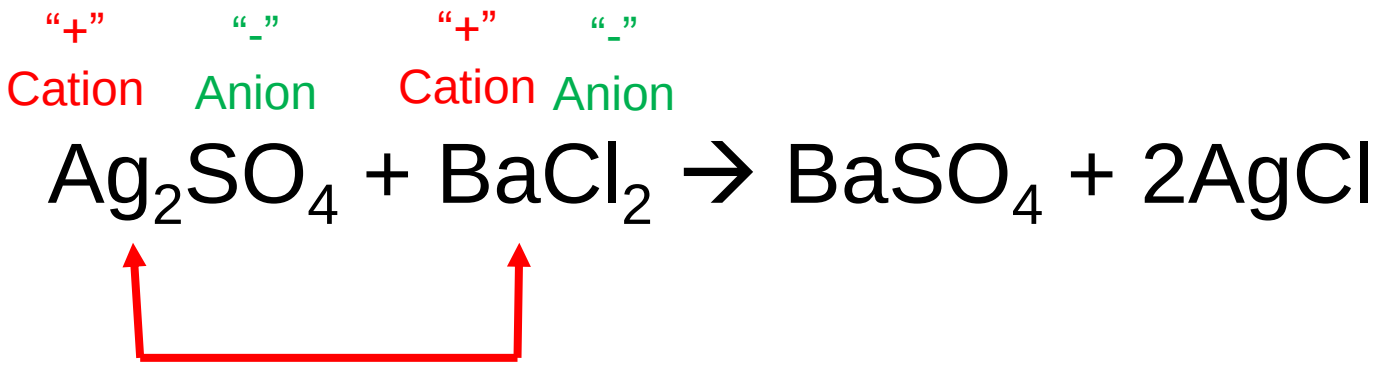
E. Neutralization

Solution

Answer: D

Justification: This is a double replacement reaction since both the products have a cation and an anion. A reaction would have occurred by one of the cations in one of the reactants switching places with the other cation in the second reactant.

The balanced chemical equation is shown below:



Predicting Products III

What is a product of the following reaction?

$Mg + O_2 \rightarrow$?

A. CO_2

B. H_2O

C. MgO_2

D. More than one of the above

E. None of the above

Solution

Answer: E

Justification: This is a synthesis reaction, not a combustion reaction. We know this because carbon and hydrogen do not exist in the reactants, thus CO_2 and H_2O could not be produced.

The product that would be produced is MgO. It would not be MgO_2 because the charges would not be balanced. The charges of each ion are shown below:

$$Mg^{+2} \quad O^{-2}$$

Thus to form a neutral molecule, only 1 Mg atom and 1 O atom would bond together.

Remember that when predicting products, you can't use the same subscripts that the reactant had.

Predicting Products IV

What is a product of the following reaction?

$Mg + HCl \rightarrow$?

A. Mg_2Cl

B. MgHCl

C. MgCl

D. $MgCl_2$

E. None of the above

Solution

Answer: D

Justification: This is a single replacement reaction, not a synthesis reaction. Therefore the answer is not B. The HCl has both a cation and an anion, which allows the Mg to take the place of the H cation. Also, MgHCl is not a molecule that makes sense because it has 2 cations and only 1 anion.

The answer is not C or A because the charges are not balanced correctly. The charges for each ion are: Mg^{+2} and Cl^{-1}
Thus, to form a neutral molecule, 2 Cl^{-} anions would bond with 1 Mg^{+2} cation.

Remember that when predicting products, you can't use the same subscripts that the reactant had.

Predicting Products V

What are the reactants in the chemical equation below?

A. $Na_2S + O_2 + HCl$

B. $Na_2Cl + HSO_4$

C. $NaCl + H_2SO_4$

D. $Na + SO_4 + H_2 + Cl_2$

E. More than one of the above

Solution

Answer: C

Justification: The correct equation is shown below:

$$NaCl + H_2SO_4 \rightarrow Na_2SO_4 + HCl$$

The answer is not B, because the charges in Na_2Cl and HSO_4 do not balance.

When predicting the reactants, you can't just break the products apart into smaller pieces and call those the reactants. You need to show a double replacement by switching the cations and reconciling the charges to predict the full compounds. Thus, A and D are incorrect.

Predicting Products VI

For the chemical reaction shown below, what type of reaction is it and what are the products?

$$H_2CO_3 + Fe(OH)_3 \rightarrow \quad ?$$

A. Neutralization / $Fe_2(CO_3)_3 + H_2O$

B. Double Replacement / $Fe(CO_3) + H_2(OH)_3$

C. Neutralization / $Fe_2(CO_3) + H_2O$

D. Double Replacement / $Fe_2(CO_3)_3 + HOH$

E. None of the above

Solution

Answer: A

Justification: The reaction appears to be a double replacement reaction because both reactants have a cation and an anion. However, when you predict what the products are going to be, water is one of them. Thus, this reaction is a neutralization reaction.

The answer is not B or C since the wrong products were predicted.

D would be the second best answer since neutralization is a type of double replacement reaction and the products have been predicted correctly. Notice that HOH is the same molecule as H_2O.

Predicting Products VII

What is the missing product in the chemical reaction below? What type of chemical reaction is this?

$$NH_4Cl + NaOH \rightarrow NaCl + \_\_\_\_\_ + H_2O$$

A. NH_4 / Neutralization

B. NH_3 / Double replacement

C. NH_3 / Decomposition

D. NH_4 / Synthesis

E. More than one of the above

Solution

Answer: E

Justification: This is a double replacement reaction (as shown in the first chemical equation below), except one of the products decomposes into two other product (as shown in the second chemical equation below). Thus the answer would be both B and C. These two reactions can be written as a single reaction (as shown in the third equation below).

Reaction 1: $NH_4Cl + NaOH \rightarrow NaCl + NH_4OH$

Reaction 2: $NH_4OH \rightarrow NH_3 + H_2O$

Combined Reaction: $NH_4Cl + NaOH \rightarrow NaCl + NH_3 + H_2O$

Predicting Products VIII

For the following reaction, predict the missing product and balance the chemical equation.

$$KI + Pb(NO_3)_2 \rightarrow \_\_\_\_\_ + KNO_3$$

What mass of the missing product would you get if you used 2.5 g of KI?

A. 6.9 g

B. 3.5 g

C. 5.0 g

D. 2.5 g

E. None of the above

Solution

Answer: B

Justification: The correctly predicted and balanced chemical equation is shown below:

$$2KI + Pb(NO_3)_2 \rightarrow PbI_2 + 2KNO_3$$

The stoichiometry conversions that are needed are:

g KI ⟶ mol KI ⟶ mol PbI_2 ⟶ g PbI_2

$$2.5\ g\ KI \times \frac{1\ mol\ KI}{166.0\ g} \times \frac{1\ mol\ PbI_2}{2\ mol\ KI} \times \frac{461.0\ g}{1\ mol\ PbI_2} = 3.5\ g\ PbI_2$$

Continued on next slide...

Solution

Answer: B

Justification: Often, errors in stoichiometry calculation derive from errors early on in the predicting products and balancing stages of the calculation.

If you predicted the incorrect product to be PbI, then the molar mass and the mole ratio (from balancing the equation) would most likely be incorrect. This mistake would have lead to the answer C.

If you predicted the correct product, but did not balance the equation, you would have gotten A.

The answer is not D because you can't presume that the amount of product that you obtain will be the same as the amount of reactant that you started with.