

5.E: Introduction to Chemical Reactions (Exercises)

5.1: The Law of Conservation of Matter

1. What is the law of conservation of matter?
2. How does the law of conservation of matter apply to chemistry?

ANSWERS

1. The law of conservation of matter states that in any given system that is closed to the transfer of matter, the amount of matter in the system stays constant
2. The law of conservation of matter says that in chemical reactions, the total mass of the products must equal the total mass of the reactants.

Exercises

1. Express the law of conservation of matter in your own words.
2. Explain why the concept of conservation of matter is considered a scientific law.
3. Potassium hydroxide (KOH) readily reacts with carbon dioxide (CO_2) to produce potassium carbonate (K_2CO_3) and water (H_2O). How many grams of potassium carbonate is produced if 224.4 g of KOH reacted with 88.0 g of CO_2 . The reaction also produced 36.0 g of water.

Answers

1. Matter may not be created or destroyed.
2. The concept is a scientific law because it is based on experimentation.
3. 276.4 g

5.2: Chemical Equations

Concept Review Exercises

- a. What are the parts of a chemical equation?
- b. Explain why chemical equations need to be balanced.

Answers

- a. reactants and products
- b. Chemical equations need to be balanced to satisfy the law of conservation of matter.

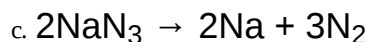
Exercises

1. Write a chemical equation to express the fact that hydrogen gas and solid iodine react to make gaseous hydrogen iodide. Make sure the equation satisfies the law of conservation of matter.
2. Write a chemical equation to express the fact that sodium metal and chlorine gas react to make solid sodium chloride. Make sure the equation satisfies the law of conservation of matter.
3. Write an equation expressing the fact that hydrogen gas and fluorine gas react to make gaseous hydrogen fluoride. Make sure the equation satisfies the law of conservation of matter.
4. Write an equation expressing the fact that solid potassium and fluorine gas react to make solid potassium fluoride. Make sure the equation satisfies the law of conservation of matter.
5. Mercury reacts with oxygen to make mercury(II) oxide. Write a balanced chemical equation that summarizes this reaction.
6. Octane (C_8H_{18}) reacts with oxygen to make carbon dioxide and water. Write a balanced chemical equation that summarizes this reaction.

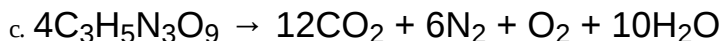
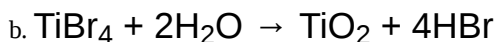
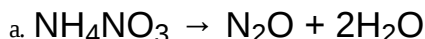
7. Propyl alcohol ($\text{C}_3\text{H}_7\text{OH}$) reacts with oxygen to make carbon dioxide and water. Write a balanced chemical equation that summarizes this reaction.
8. Sulfuric acid (H_2SO_4) reacts with iron metal to make iron(III) sulfate and hydrogen gas. Write a balanced chemical equation that summarizes this reaction.
9. Balance each equation.
 - a. $\text{MgCl}_2 + \text{K} \rightarrow \text{KCl} + \text{Mg}$
 - b. $\text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$
 - c. $\text{NaN}_3 \rightarrow \text{Na} + \text{N}_2$ (This is the reaction used to inflate airbags in cars.)
10. Balance each equation.
 - a. $\text{NH}_4\text{NO}_3 \rightarrow \text{N}_2\text{O} + \text{H}_2\text{O}$
 - b. $\text{TiBr}_4 + \text{H}_2\text{O} \rightarrow \text{TiO}_2 + \text{HBr}$
 - c. $\text{C}_3\text{H}_5\text{N}_3\text{O}_9 \rightarrow \text{CO}_2 + \text{N}_2 + \text{O}_2 + \text{H}_2\text{O}$ (This reaction represents the decomposition of nitroglycerine.)
11. Balance each equation.
 - a. $\text{NH}_3 + \text{O}_2 \rightarrow \text{NO} + \text{H}_2\text{O}$
 - b. $\text{Li} + \text{N}_2 \rightarrow \text{Li}_3\text{N}$
 - c. $\text{AuCl} \rightarrow \text{Au} + \text{AuCl}_3$
12. Balance each equation.
 - a. $\text{NaOH} + \text{H}_3\text{PO}_4 \rightarrow \text{Na}_3\text{PO}_4 + \text{H}_2\text{O}$
 - b. $\text{N}_2\text{H}_4 + \text{Cl}_2 \rightarrow \text{N}_2 + \text{HCl}$
 - c. $\text{Na}_2\text{S} + \text{H}_2\text{S} \rightarrow \text{NaSH}$
13. Chromium(III) oxide reacts with carbon tetrachloride to make chromium(III) chloride and phosgene (COCl_2). Write the balanced chemical equation for this reaction.
14. The reaction that occurs when an Alka-Seltzer tablet is dropped into a glass of water has sodium bicarbonate reacting with citric acid ($\text{H}_3\text{C}_6\text{H}_5\text{O}_7$) to make carbon dioxide, water, and sodium citrate ($\text{Na}_3\text{C}_6\text{H}_5\text{O}_7$). Write the balanced chemical equation for this reaction.
15. When sodium hydrogen carbonate is used to extinguish a kitchen fire, it decomposes into sodium carbonate, carbon dioxide and water. Write a balanced chemical equation for this reaction.
16. Elemental bromine gas can be generated by reacting sodium bromide with elemental chlorine. The other product is sodium chloride. Write a balanced chemical equation for this reaction.

Answers

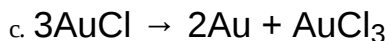
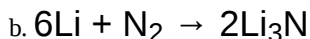
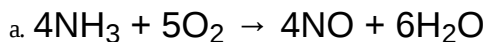
1. $\text{H}_2(\text{g}) + \text{I}_2(\text{s}) \rightarrow 2\text{HI}(\text{g})$
2. $2\text{Na}(\text{s}) + \text{Cl}_2(\text{g}) \rightarrow 2\text{NaCl}(\text{s})$
3. $\text{H}_2(\text{g}) + \text{F}_2(\text{g}) \rightarrow 2\text{HF}(\text{g})$
4. $2\text{K}(\text{s}) + \text{F}_2(\text{g}) \rightarrow 2\text{KF}(\text{s})$
5. $2\text{Hg} + \text{O}_2 \rightarrow 2\text{HgO}$
6. $2\text{C}_8\text{H}_{18} + 25\text{O}_2 \rightarrow 16\text{CO}_2 + 18\text{H}_2\text{O}$
7. $2\text{C}_3\text{H}_7\text{OH} + 9\text{O}_2 \rightarrow 6\text{CO}_2 + 8\text{H}_2\text{O}$
8. $3\text{H}_2\text{SO}_4 + 2\text{Fe} \rightarrow \text{Fe}_2(\text{SO}_4)_3 + 3\text{H}_2$
9. a. $\text{MgCl}_2 + 2\text{K} \rightarrow 2\text{KCl} + \text{Mg}$
 b. $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$



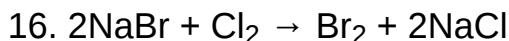
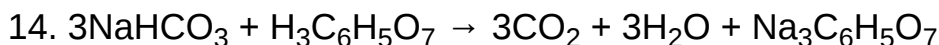
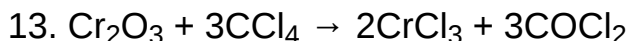
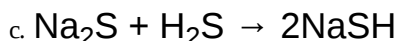
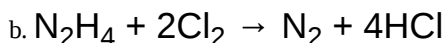
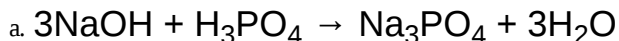
10.



11.



12.



5.3: Quantitative Relationships Based on Chemical Equations

Concept Review Exercises

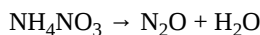
1. Explain how stoichiometric ratios are constructed from a chemical equation.
2. Why is it necessary for a chemical equation to be balanced before it can be used to construct conversion factors?

Answers

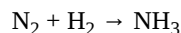
1. Stoichiometric ratios are made using the coefficients of the substances in the balanced chemical equation.
2. A balanced chemical equation is necessary so one can construct the proper stoichiometric ratios.

Exercises

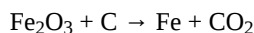
1. Balance this equation and write every stoichiometric ratio you can from it.



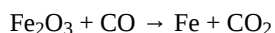
2. Balance this equation.



3. Balance this equation and write every stoichiometric ratio you can from it.



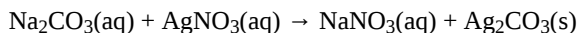
4. Balance this equation.



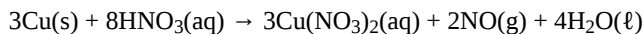
5. Balance this equation and determine how many molecules of CO_2 are formed if 15 molecules of C_6H_6 are reacted.



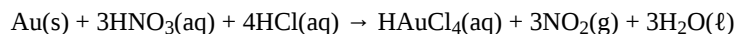
6. Balance this equation and determine how many formula units of $\text{Ag}_2\text{CO}_3(\text{s})$ are produced if 20 formula units of Na_2CO_3 are reacted.



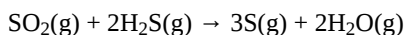
7. Copper metal reacts with nitric acid according to this equation:



- Verify that this equation is balanced.
 - How many Cu atoms will react if 488 molecules of aqueous HNO_3 are reacted?
8. Gold metal reacts with a combination of nitric acid and hydrochloric acid according to this equation:



- Verify that this equation is balanced.
 - How many Au atoms react with 639 molecules of aqueous HNO_3 ?
9. Sulfur can be formed by reacting sulfur dioxide with hydrogen sulfide at high temperatures according to this equation:



- Verify that this equation is balanced.
 - How many S atoms will be formed from by reacting 1,078 molecules of H_2S ?
10. Nitric acid is made by reacting nitrogen dioxide with water:
- $$3\text{NO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow 2\text{HNO}_3(\text{aq}) + \text{NO}(\text{g})$$
- Verify that this equation is balanced.
 - How many molecules of NO will be formed by reacting 2,268 molecules of NO_2 ?

Answers

- $\text{NH}_4\text{NO}_3 \rightarrow \text{N}_2\text{O} + 2\text{H}_2\text{O}$; the stoichiometric ratios are $\frac{1\text{NH}_4\text{NO}_3}{1\text{N}_2\text{O}}$, $\frac{1\text{NH}_4\text{NO}_3}{2\text{H}_2\text{O}}$, $\frac{1\text{N}_2\text{O}}{2\text{H}_2\text{O}}$, and their reciprocals.
- $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$
- $2\text{Fe}_2\text{O}_3 + 3\text{C} \rightarrow 4\text{Fe} + 3\text{CO}_2$; the stoichiometric ratios are $\frac{2\text{Fe}_2\text{O}_3}{3\text{C}}$, $\frac{2\text{Fe}_2\text{O}_3}{4\text{Fe}}$, $\frac{2\text{Fe}_2\text{O}_3}{3\text{CO}_2}$, $\frac{3\text{C}}{4\text{Fe}}$, $\frac{3\text{C}}{3\text{CO}_2}$, $\frac{4\text{Fe}}{3\text{CO}_2}$, and their reciprocals.
- $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$
- $2\text{C}_6\text{H}_6 + 15\text{O}_2 \rightarrow 12\text{CO}_2 + 6\text{H}_2\text{O}$; 90 molecules
- $\text{Na}_2\text{CO}_3(\text{aq}) + 2\text{AgNO}_3(\text{aq}) \rightarrow 2\text{NaNO}_3(\text{aq}) + \text{Ag}_2\text{CO}_3(\text{s})$; 20 formula units
- It is balanced.
 - 183 atoms
- It is balanced.
 - 213 atoms

- 9.
- It is balanced.
 - 1,617 atoms
- 10.
- It is balanced.
 - 756 molecules

5.4: Some Types of Chemical Reactions

Concept Review Exercises

- What is the difference between a combination reaction and a combustion reaction?
- Give the distinguishing characteristic(s) of a decomposition reaction.
- How do we recognize a combustion reaction?

Answers

- A combination reaction produces a certain substance; a combustion reaction is a vigorous reaction, usually a combination with oxygen, that is accompanied by the production of light and/or heat.
- In a decomposition reaction, a single substance reacts to make multiple substances as products.
- A combustion reaction is typically a vigorous reaction accompanied by light and/or heat, usually because of reaction with oxygen.

Exercises

- Identify each type of reaction.
 - $\text{C}_6\text{H}_5\text{CH}_3 + 9\text{O}_2 \rightarrow 7\text{CO}_2 + 4\text{H}_2\text{O}$
 - $2\text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}_2$
 - $\text{C} + 2\text{H}_2 \rightarrow \text{CH}_4$
- Identify each type of reaction.
 - $\text{P}_4\text{O}_{10} + 6\text{H}_2\text{O} \rightarrow 4\text{H}_3\text{PO}_4$
 - $\text{FeO} + \text{SO}_3 \rightarrow \text{FeSO}_4$
 - $\text{CaCO}_3(\text{s}) \rightarrow \text{CO}_2(\text{g}) + \text{CaO}(\text{s})$
- Identify each type of reaction.
 - $2\text{NH}_4\text{NO}_3(\text{s}) \rightarrow 2\text{N}_2(\text{g}) + 4\text{H}_2\text{O}(\text{g}) + \text{O}_2(\text{g})$
 - $\text{Hg}(\ell) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{HgO}(\text{s})$
 - $\text{CH}_2\text{CH}_2(\text{g}) + \text{Br}_2(\ell) \rightarrow \text{CH}_2\text{BrCH}_2\text{Br}$
- Identify each type of reaction.
 - $\text{Ti}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{TiO}_2(\text{s})$
 - $\text{H}_2\text{SO}_3(\text{aq}) \rightarrow \text{H}_2\text{O}(\ell) + \text{SO}_2(\text{g})$
 - $3\text{O}_2(\text{g}) \rightarrow 2\text{O}_3(\text{g})$

Answers

- combustion
 - decomposition
 - combination
-

- a. combination
- b. combination
- c. decomposition

3.

- a. decomposition
- b. combustion (also combination)
- c. combination

4.

- a. combination
- b. decomposition
- c. combination

5.5: Oxidation-Reduction (Redox) Reactions

Concept Review Exercises

1. Give two different definitions for oxidation and reduction.
2. Give an example of each definition of oxidation and reduction.

Answers

1. Oxidation is the loss of electrons or the addition of oxygen; reduction is the gain of electrons or the addition of hydrogen.
2. $\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^-$ (oxidation); $\text{C}_2\text{H}_4 + \text{H}_2 \rightarrow \text{C}_2\text{H}_6$ (reduction) (answers will vary)

Exercises

1. Which reactions are redox reactions? For those that are redox reactions, identify the oxidizing and reducing agents.
 - a. $\text{NaOH} + \text{HCl} \rightarrow \text{H}_2\text{O} + \text{NaCl}$
 - b. $3\text{Mg} + 2\text{AlCl}_3 \rightarrow 2\text{Al} + 3\text{MgCl}_2$
 - c. $\text{H}_2\text{O}_2 + \text{H}_2 \rightarrow 2\text{H}_2\text{O}$
 - d. $\text{KCl} + \text{AgNO}_3 \rightarrow \text{AgCl} + \text{KNO}_3$
2. Which reactions are redox reactions? For those that are redox reactions, identify the oxidizing and reducing agents.
 - a. $3\text{Cu} + 8\text{HNO}_3 \rightarrow 3\text{Cu}(\text{NO}_3)_2 + 2\text{NO} + 4\text{H}_2\text{O}$
 - b. $2\text{C}_2\text{H}_6 + 7\text{O}_2 \rightarrow 4\text{CO}_2 + 6\text{H}_2\text{O}$
 - c. $2\text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{CO}_2 + \text{H}_2\text{O}$
 - d. $2\text{K} + 2\text{H}_2\text{O} \rightarrow 2\text{KOH} + \text{H}_2$
3. Balance each redox reaction by writing appropriate half reactions and combining them to cancel the electrons.
 - a. $\text{Ca(s)} + \text{H}^+(\text{aq}) \rightarrow \text{Ca}^{2+}(\text{aq}) + \text{H}_2(\text{g})$
 - b. $\text{I}^-(\text{aq}) + \text{Br}_2(\ell) \rightarrow \text{Br}^-(\text{aq}) + \text{I}_2(\text{s})$
4. Balance each redox reaction by writing appropriate half reactions and combining them to cancel the electrons.
 - a. $\text{Fe(s)} + \text{Sn}^{4+}(\text{aq}) \rightarrow \text{Fe}^{3+}(\text{aq}) + \text{Sn}^{2+}(\text{aq})$
 - b. $\text{Pb(s)} + \text{Pb}^{4+}(\text{aq}) \rightarrow \text{Pb}^{2+}(\text{aq})$ (Hint: both half reactions will yield the same product.)

Answers

1.

- a. no
 - b. yes; oxidizing agent: AlCl_3 ; reducing agent: Mg
 - c. yes; oxidizing agent: H_2O_2 ; reducing agent: H_2
 - d. no
- 2.
- a. yes; oxidizing agent: HNO_3 ; reducing agent: Cu
 - b. yes; oxidizing agent: O_2 ; reducing agent: C_2H_6
 - c. no
 - d. yes; oxidizing agent: H_2O ; reducing agent: K
- 3.
- a. Combined: $\text{Ca} + 2\text{H}^+ \rightarrow \text{Ca}^{2+} + \text{H}_2$
 - b. Combined: $\text{Br}_2 + 2\text{I}^- \rightarrow 2\text{Br}^- + \text{I}_2$
- 4.
- a. $(\text{Fe} \rightarrow \text{Fe}^{3+} + 3\text{e}^-) \times 2$
 $(\text{Sn}^{4+} + 2\text{e}^- \rightarrow \text{Sn}^{2+}) \times 3$
 Combined: $2\text{Fe} + 3\text{Sn}^{4+} \rightarrow 2\text{Fe}^{3+} + 3\text{Sn}^{2+}$
 - b. $\text{Pb} \rightarrow \text{Pb}^{2+} + 2\text{e}^-$
 $\text{Pb}^{4+} + 2\text{e}^- \rightarrow \text{Pb}^{2+}$
 Combined: $\text{Pb} + \text{Pb}^{4+} \rightarrow 2\text{Pb}^{2+}$

5.6: Redox Reactions in Organic Chemistry and Biochemistry

Concept Review Exercise

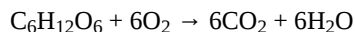
1. Give some biochemical examples of oxidation and reduction reactions.

Answer

1. photosynthesis and antioxidants in foods (answers will vary)

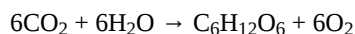
Exercises

1. A typical respiratory reaction discussed in the text is the oxidation of glucose ($\text{C}_6\text{H}_{12}\text{O}_6$):



Is this a redox reaction? If so, what are the oxidizing and reducing agents?

2. The major net reaction in photosynthesis is as follows:



Is this a redox reaction? If so, what are the oxidizing and reducing agents?

3. What would be the ultimate organic product if $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ were to react with a solution of $\text{K}_2\text{Cr}_2\text{O}_7$?
4. What would be the ultimate organic product if $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ were to react with a solution of $\text{K}_2\text{Cr}_2\text{O}_7$?

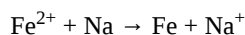
- What would be the final organic product if $\text{CH}_3\text{CH}_2\text{CHOHCH}_3$ were to react with a solution of $\text{K}_2\text{Cr}_2\text{O}_7$?
- What would be the major organic product if $\text{CH}_3\text{CH}_2\text{CHOHCH}_2\text{CH}_3$ were to react with a solution of $\text{K}_2\text{Cr}_2\text{O}_7$?
- What alcohol is produced in the reduction of acetone $[(\text{CH}_3)_2\text{CO}]$?
- What alcohol is produced in the reduction of propanal ($\text{CH}_3\text{CH}_2\text{CHO}$)?

Answers

- yes; oxidizing agent: O_2 ; reducing agent: $\text{C}_6\text{H}_{12}\text{O}_6$
- yes; oxidizing agent: CO_2 ; reducing agent: H_2O
- $\text{CH}_3\text{CH}_2\text{COOH}$
- $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$
- $\text{CH}_3\text{CH}_2\text{C}(\text{O})\text{CH}_3$, where the carbon is double bonded to the oxygen
- $\text{CH}_3\text{CH}_2\text{C}(\text{O})\text{CH}_2\text{CH}_3$, carbon #3 is double bonded to the oxygen
- $\text{CH}_3\text{CHOHCH}_3$, or isopropyl alcohol
- $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
-

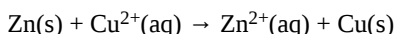
Additional Exercises

- Isooctane (C_8H_{18}) is used as a standard for comparing gasoline performance. Write a balanced chemical equation for the combustion of isooctane.
- Heptane (C_7H_{16}), like isooctane (see Exercise 1), is also used as a standard for determining gasoline performance. Write a balanced chemical equation for the combustion of heptane.
- What is the difference between a combination reaction and a redox reaction? Are all combination reactions also redox reactions? Are all redox reactions also combination reactions?
- Are combustion reactions always redox reactions as well? Explain.
- A friend argues that the equation



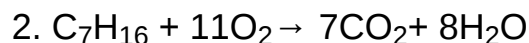
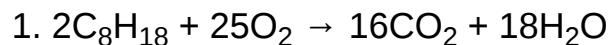
is balanced because each side has one iron atom and one sodium atom. Explain why your friend is incorrect.

- Some antacids contain aluminum hydroxide $[\text{Al}(\text{OH})_3]$. This compound reacts with excess hydrochloric acid (HCl) in the stomach to neutralize it. If the products of this reaction are water and aluminum chloride, what is the balanced chemical equation for this reaction? What is the stoichiometric ratio between the number of HCl molecules made to the number of H_2O molecules made?
- Sulfuric acid is made in a three-step process: (1) the combustion of elemental sulfur to produce sulfur dioxide, (2) the continued reaction of sulfur dioxide with oxygen to produce sulfur trioxide, and (3) the reaction of sulfur trioxide with water to make sulfuric acid (H_2SO_4). Write balanced chemical equations for all three reactions.
- If the products of glucose metabolism are carbon dioxide and water, what is the balanced chemical equation for the overall process? What is the stoichiometric ratio between the number of CO_2 molecules made to the number of H_2O molecules made?
- Historically, the first true battery was the Leclanché cell, named after its discoverer, Georges Leclanché. It was based on the following reaction:



Identify what is being oxidized, what is being reduced, and the respective reducing and oxidizing agents.

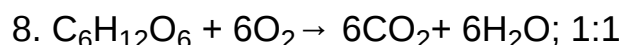
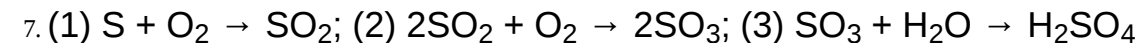
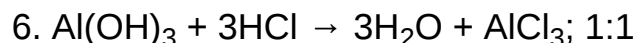
Answers



3. A combination reaction makes a new substance from more than one reactant; a redox reaction rearranges electrons. Most (not all) combination reactions are redox reactions. Not all redox reactions are combination reactions.

4. All combustion reactions are redox reactions. In combustion a chemical is combining with oxygen and that chemical is being oxidized. Oxygen, on the other hand, is being reduced.

5. Your friend is incorrect because the number of electrons transferring is not balanced. A balanced equation must not only have the same number of atoms of each element on each side of the equation but must also have the same charge on both sides.



9. oxidized and reducing agent: Zn; reduced and oxidizing agent: Cu^{2+}

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