7.E: Stoichiometry and the Mole (Exercises)

Exercises (Stoichiometry)

1. Think back to the pound cake recipe. What possible conversion factors can you construct relating the components of the recipe?

2. Think back to the pancake recipe. What possible conversion factors can you construct relating the components of the recipe?

3. What are all the conversion factors that can be constructed from the balanced chemical reaction: *[Math Processing Error]*

4. What are all the conversion factors that can be constructed from the balanced chemical reaction $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$?

5. Given the chemical equation : $Na(s) + H_2O(\ell) \rightarrow NaOH(aq) + H_2(g)$
   a. Balance the equation.
   b. How many molecules of H_2 are produced when 332 atoms of Na react?

6. Given the chemical equation: $S(s) + O_2(g) \rightarrow SO_3(g)$
   a. Balance the equation.
   b. How many molecules of O_2 are needed when 38 atoms of S react?

7. For the balanced chemical equation:

   $6H^+(aq) + 2MnO_4^-(aq) + 5H_2O_2(\ell) \rightarrow 2Mn^{2+}(aq) + 5O_2(g) + 8H_2O(\ell)$

   how many molecules of H_2O are produced when 75 molecules of H_2O_2 react?

8. For the balanced chemical reaction

   $2C_6H_6(\ell) + 15O_2(g) \rightarrow 12CO_2(g) + 6H_2O(\ell)$

   how many molecules of CO_2 are produced when 56 molecules of C_6H_6 react?

9. Given the balanced chemical equation

   $Fe_2O_3(s) + 3SO_3(g) \rightarrow Fe_2(SO_4)_3$

   how many molecules of $Fe_2(SO_4)_3$ are produced if 321 atoms of S are reacted?

10. For the balanced chemical equation

    $CuO(s) + H_2S(g) \rightarrow CuS + H_2O(\ell)$

    how many molecules of CuS are formed if 9,044 atoms of H react?

11. For the balanced chemical equation

    $Fe_2O_3(s) + 3SO_3(g) \rightarrow Fe_2(SO_4)_3$

    suppose we need to make 145,000 molecules of $Fe_2(SO_4)_3$. How many molecules of SO_3 do we need?

12. One way to make sulfur hexafluoride is to react thioformaldehyde, CH_2S, with elemental fluorine:

    $CH_2S + 6F_2 \rightarrow CF_4 + 2HF + SF_6$

    If 45,750 molecules of SF_6 are needed, how many molecules of F_2 are required?

13. Construct the three independent conversion factors possible for these two reactions:
    a. $2H_2 + O_2 \rightarrow 2H_2O$
    b. $H_2 + O_2 \rightarrow H_2O_2$

Why are the ratios between H_2 and O_2 different?

The conversion factors are different because the stoichiometries of the balanced chemical reactions are different.

 tions:

a. $2Na + Cl_2 \rightarrow 2NaCl$
b. $4Na + 2Cl_2 \rightarrow 4NaCl$

What similarities, if any, exist in the conversion factors from these two reactions?

Answers

1. *[Math Processing Error]* or *[Math Processing Error]* are two conversion factors that can be constructed from the pound cake recipe. Other conversion factors are also possible.

3. *[Math Processing Error]* , *[Math Processing Error]* , *[Math Processing Error]* and their reciprocals are the conversion factors that can be constructed.

5.

a. $2Na(s) + 2H_2O(\ell) \rightarrow 2NaOH(aq) + H_2(g)$
b. 166 molecules

7. 120 molecules

9. 107 molecules

11. 435,000 molecules

13.

a. *[Math Processing Error]*
b. *[Math Processing Error]*

Excercises (The Mole)

1. How many atoms are present in 4.55 mol of Fe?

2. How many atoms are present in 0.0665 mol of K?

3. How many molecules are present in 2.509 mol of H_2S?

4. How many molecules are present in 0.336 mol of acetylene (C_2H_2)?

5. How many moles are present in 3.55×10^{24} Pb atoms?

6. How many moles are present in 2.09×10^{22} Ti atoms?

7. How many moles are present in 1.00×10^{23} PF_3 molecules?

8. How many moles are present in 5.52×10^{25} penicillin molecules?

9. Determine the molar mass of each substance.
   a. Si
   b. SiH_4
   c. K_2O

10. Determine the molar mass of each substance.
   a. Cl_2
   b. $SeCl_2$
   c. $Ca(C_2H_3O_2)_2$

a. Al
b. Al_2O_3
c. $CoCl_3$

12. Determine the molar mass of each substance.
    a. O_3
    b. NaI
    c. $C_{12}H_{22}O_{11}$

13. What is the mass of 4.44 mol of Rb?

14. What is the mass of 0.311 mol of Xe?

15. What is the mass of 12.34 mol of $Al_2(SO_4)_3$?

16. What is the mass of 0.0656 mol of $PbCl_2$?

17. How many moles are present in 45.6 g of CO?

18. How many moles are present in 0.00339 g of LiF?

19. How many moles are present in 1.223 g of SF_6?

20. How many moles are present in 48.8 g of $BaCO_3$?

21. How many moles are present in 54.8 mL of mercury if the density of mercury is 13.6 g/mL?

22. How many moles are present in 56.83 mL of O_2 if the density of O_2 is 0.00133 g/mL?

Answers

1. 2.74×10^{24} atoms

3. 1.511×10^{24} molecules

5. 5.90 mol

7. 0.166 mol

9.
    a. 28.086 g
    b. 32.118 g
    c. 94.195 g

11.
    a. 26.981 g
    b. 101.959 g
    c. 165.292 g

13. 379 g

15. 4,222 g

17. 1.63 mol

19. 0.008374 mol

21. 3.72 mol

Exercises (The Mole in Chemical Reactions)

1. Express in mole terms what this chemical equation means: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
2. Express in mole terms what this chemical equation means.

   $Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$
3. How many molecules of each substance are involved in the equation in Exercise 1 if it is interpreted in terms of moles?
4. How many molecules of each substance are involved in the equation in Exercise 2 if it is interpreted in terms of moles?
5. For the chemical equation

   $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$

   what equivalents can you write in terms of moles? Use the ⇔ sign.
6. For the chemical equation

   $2Al + 3Cl_2 \rightarrow 2AlCl_3$

   what equivalents can you write in terms of moles? Use the ⇔ sign.
7. Write the balanced chemical reaction for the combustion of C_5H_{12} (the products are CO_2 and H_2O) and determine how many moles of H_2O are formed when 5.8 mol of O_2 are reacted.
8. Write the balanced chemical reaction for the formation of $Fe_2(SO_4)_3$ from Fe_2O_3 and SO_3 and determine how many moles of $Fe_2(SO_4)_3$ are formed when 12.7 mol of SO_3 are reacted.
9. For the balanced chemical equation

   $3Cu(s) + 2NO_3^-(aq) + 8H^+(aq) \rightarrow 3Cu^{2+}(aq) + 4H_2O(\ell) + 2NO(g)$

   how many moles of Cu^{2+} are formed when 55.7 mol of H^+ are reacted?
10. For the balanced chemical equation

    $Al(s) + 3Ag^+(aq) \rightarrow Al^{3+}(aq) + 3Ag(s)$

    how many moles of Ag are produced when 0.661 mol of Al are reacted?
11. For the balanced chemical reaction

    $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(\ell)$

    how many moles of H_2O are produced when 0.669 mol of NH_3 react?
12. For the balanced chemical reaction

    $4NaOH(aq) + 2S(s) + 3O_2(g) \rightarrow 2Na_2SO_4(aq) + 2H_2O(\ell)$

    how many moles of Na_2SO_4 are formed when 1.22 mol of O_2 react?
13. For the balanced chemical reaction

    $4KO_2(s) + 2CO_2(g) \rightarrow 2K_2CO_3(s) + 3O_2(g)$

    determine the number of moles of both products formed when 6.88 mol of KO_2 react.
14. For the balanced chemical reaction

    $2AlCl_3 + 3H_2O(\ell) \rightarrow Al_2O_3 + 6HCl(g)$

    determine the number of moles of both products formed when 0.0552 mol of $AlCl_3$ react.

Answers

H_2O.

3. 6.022×10^{23} molecules of CH_4, 1.2044×10^{24} molecules of O_2, 6.022×10^{23} molecules of CO_2, and 1.2044×10^{24} molecules of H_2O

5. 2 mol of C_2H_6 ⇔ 7 mol of O_2 ⇔ 4 mol of CO_2 ⇔ 6 mol of H_2O

7. $C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$; 4.4 mol

9. 20.9 mol

11. 1.00 mol

13. 3.44 mol of K_2CO_3; 5.16 mol of O_2

Exercises (Mole-Mass and Mass-Mass Calculations)

1. What mass of CO_2 is produced by the combustion of 1.00 mol of CH_4?

   $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell)$

2. What mass of H_2O is produced by the combustion of 1.00 mol of CH_4?

   $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell)$

3. What mass of HgO is required to produce 0.692 mol of O_2?

   $2HgO(s) \rightarrow 2Hg(\ell) + O_2(g)$

4. What mass of $NaHCO_3$ is needed to produce 2.659 mol of CO_2?

   $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(\ell) + CO_2(g)$

5. How many moles of Al can be produced from 10.87 g of Ag?

   $Al(NO_3)\ _3(s) + 3Ag \rightarrow Al + 3AgNO_3$

6. How many moles of HCl can be produced from 0.226 g of $SOCl_2$?

   $SOCl_2(\ell) + H_2O(\ell) \rightarrow SO_2(g) + 2HCl(g)$

7. How many moles of O_2 are needed to prepare 1.00 g of $Ca(NO_3)_2$?

   $Ca(s) + N_2(g) + 3O_2(g) \rightarrow Ca(NO_3)\ _2(s)$

8. How many moles of C_2H_5OH are needed to generate 106.7 g of H_2O?

   $C_2H_5OH(\ell) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(\ell)$

9. What mass of O_2 can be generated by the decomposition of 100.0 g of $NaClO_3$?

   $2NaClO_3 \rightarrow 2NaCl(s) + 3O_2(g)$

10. What mass of Li_2O is needed to react with 1,060 g of CO_2?

    $Li_2O(aq) + CO_2(g) \rightarrow Li_2CO_3(aq)$

11. What mass of Fe_2O_3 must be reacted to generate 324 g of Al_2O_3?

    $Fe_2O_3(s) + 2Al(s) \rightarrow 2Fe(s) + Al_2O_3(s)$

12. What mass of Fe is generated when 100.0 g of Al are reacted?

    $Fe_2O_3(s) + 2Al(s) \rightarrow 2Fe(s) + Al_2O_3(s)$

13. What mass of MnO_2 is produced when 445 g of H_2O are reacted?

    $H_2O(\ell) + 2MnO_4^-(aq) + Br^-(aq) \rightarrow BrO_3^-(aq) + 2MnO_2(s) + 2OH^-(aq)$

14. What mass of $PbSO_4$ is produced when 29.6 g of H_2SO_4 are reacted?

    $Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \rightarrow 2PbSO_4(s) + 2H_2O(\ell)$

$Zn(s) + 2MnO_2(s) \rightarrow ZnO(s) + Mn_2O_3(s)$

16. If 14.7 g of NO_2 are reacted, what mass of H_2O is reacted with it?

$3NO_2(g) + H_2O(\ell) \rightarrow 2HNO_3(aq) + NO(g)$

17. If 88.4 g of CH_2S are reacted, what mass of HF is produced?

$CH_2S + 6F_2 \rightarrow CF_4 + 2HF + SF_6$

18. If 100.0 g of Cl_2 are needed, what mass of NaOCl must be reacted?

$NaOCl + HCl \rightarrow NaOH + Cl_2$

Answers

1. 44.0 g
3. 3.00×10^2 g
5. . 0.0336 mol
7. 0.0183 mol
9. 45.1 g
11. 507 g
13. 4.30×10^3 g
15. 163 g
17. 76.7 g

Exercises (Yields)

1. What is the difference between the theoretical yield and the actual yield?
2. What is the difference between the actual yield and the percent yield?
3. A worker isolates 2.675 g of SiF_4 after reacting 2.339 g of SiO_2 with HF. What are the theoretical yield and the actual yield?

   $SiO_2(s) + 4HF(g) \rightarrow SiF_4(g) + 2H_2O(\ell)$
4. A worker synthesizes aspirin, $C_9H_8O_4$, according to this chemical equation. If 12.66 g of $C_7H_6O_3$ are reacted and 12.03 g of aspirin are isolated, what are the theoretical yield and the actual yield?

   $C_7H_6O_3 + C_4H_6O_3 \rightarrow C_9H_8O_4 + HC_2H_3O_2$
5. A chemist decomposes 1.006 g of $NaHCO_3$ and obtains 0.0334 g of Na_2CO_3. What are the theoretical yield and the actual yield?

   $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(\ell) + CO_2(g)$
6. A chemist combusts a 3.009 g sample of C_5H_{12} and obtains 3.774 g of H_2O. What are the theoretical yield and the actual yield?

   $C_5H_{12}(\ell) + 8O_2(g) \rightarrow 5CO_2 + 6H_2O(\ell)$
7. What is the percent yield in Exercise 3?
8. What is the percent yield in Exercise 4?
9. What is the percent yield in Exercise 5?
10. What is the percent yield in Exercise 6?

Answers

1. Theoretical yield is what you expect stoichiometrically from a chemical reaction; actual yield is what you actually get from a chemical reaction.

3. theoretical yield = 4.052 g; actual yield = 2.675 g

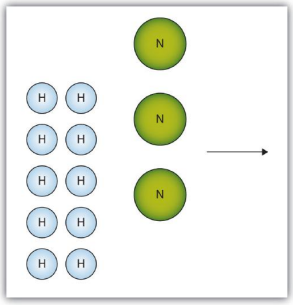
5. theoretical yield = 0.635 g; actual yield = 0.0334 g

7. 66.02%

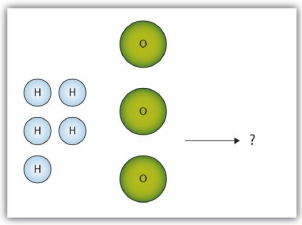
9. 5.26%

Exercises (Limiting Reagents)

1. The box below shows a group of nitrogen and hydrogen molecules that will react to produce ammonia, NH_3. What is the limiting reagent?



2. The box below shows a group of hydrogen and oxygen molecules that will react to produce water, H_2O. What is the limiting reagent?



3. Given the statement “20.0 g of methane is burned in excess oxygen,” is it obvious which reactant is the limiting reagent?
4. Given the statement “the metal is heated in the presence of excess hydrogen,” is it obvious which substance is the limiting reagent despite not specifying any quantity of reactant?
5. Acetylene (C_2H_2) is formed by reacting 7.08 g of C and 4.92 g of H_2.

   $2C(s) + H_2(g) \rightarrow C_2H_2(g)$

   What is the limiting reagent? How much of the other reactant is in excess?
6. Ethane (C_2H_6) is formed by reacting 7.08 g of C and 4.92 g of H_2.

   $2C(s) + 3H_2(g) \rightarrow C_2H_6(g)$

   What is the limiting reagent? How much of the other reactant is in excess?
7. Given the initial amounts listed, what is the limiting reagent, and how much of the other reactant is in excess?

   [Math Processing Error]
8. Given the initial amounts listed, what is the limiting reagent, and how much of the other reactant is in excess?

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9. To form the precipitate $PbCl_2$, 2.88 g of NaCl and 7.21 g of $Pb(NO_3)_2$ are mixed in solution. How much precipitate is formed? How much of which reactant is in excess?
10. In a neutralization reaction, 18.06 g of KOH are reacted with 13.43 g of HNO_3. What mass of H_2O is produced, and what mass of which reactant is in excess?

Answers

1. Nitrogen is the limiting reagent.

3. Yes; methane is the limiting reagent.

5. C is the limiting reagent; 4.33 g of H_2 are left over.

7. H_2O is the limiting reagent; 25.9 g of P_4O_6 are left over.

9. 6.06 g of $PbCl_2$ are formed; 0.33 g of NaCl is left over.

Additional Exercises

1. How many molecules of O_2 will react with 6.022×10^{23} molecules of H_2 to make water? The reaction is $2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell)$.
2. How many molecules of H_2 will react with 6.022×10^{23} molecules of N_2 to make ammonia? The reaction is $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$.
3. How many moles are present in 6.411 kg of CO_2? How many molecules is this?
4. How many moles are present in 2.998 mg of SCl_4? How many molecules is this?
5. What is the mass in milligrams of 7.22×10^{20} molecules of CO_2?
6. What is the mass in kilograms of 3.408×10^{25} molecules of SiS_2?
7. What is the mass in grams of 1 molecule of H_2O?
8. What is the mass in grams of 1 atom of Al?
9. What is the volume of 3.44 mol of Ga if the density of Ga is 6.08 g/mL?
10. What is the volume of 0.662 mol of He if the density of He is 0.1785 g/L?
11. For the chemical reaction

    $2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(\ell)$

    assume that 13.4 g of C_4H_{10} reacts completely to products. The density of CO_2 is 1.96 g/L. What volume in liters of CO_2 is produced?
12. For the chemical reaction

    $2GaCl_3(s) + 3H_2(g) \rightarrow 2Ga(\ell) + 6HCl(g)$

    if 223 g of $GaCl_3$ reacts completely to products and the density of Ga is 6.08 g/mL, what volume in milliliters of Ga is produced?
13. Calculate the mass of each product when 100.0 g of CuCl react according to the reaction

    $2CuCl(aq) \rightarrow CuCl_2(aq) + Cu(s)$

    What do you notice about the sum of the masses of the products? What concept is being illustrated here?
14. Calculate the mass of each product when 500.0 g of $SnCl_2$ react according to the reaction

    $2SnCl_2(aq) \rightarrow SnCl_4(aq) + Sn(s)$

    What do you notice about the sum of the masses of the products? What concept is being illustrated here?
15. What mass of CO_2 is produced from the combustion of 1 gal of gasoline? The chemical formula of gasoline can be approximated as C_8H_{18}. Assume that there are 2,801 g of gasoline per gallon.
16. What mass of H_2O is produced from the combustion of 1 gal of gasoline? The chemical formula of gasoline can be approximated as C_8H_{18}. Assume that there are 2,801 g of gasoline per gallon.
17. A chemical reaction has a theoretical yield of 19.98 g and a percent yield of 88.40%. What is the actual yield?
18. A chemical reaction has an actual yield of 19.98 g and a percent yield of 88.40%. What is the theoretical yield?

19. Given the initial amounts listed, what is the limiting reagent, and how much of the other reactants are in excess?

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20. Given the initial amounts listed, what is the limiting reagent, and how much of the other reactants are in excess?

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21. Verify that it does not matter which product you use to predict the limiting reagent by using both products in this combustion reaction to determine the limiting reagent and the amount of the reactant in excess. Initial amounts of each reactant are given.

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22. Just in case you suspect Exercise 21 is rigged, do it for another chemical reaction and verify that it does not matter which product you use to predict the limiting reagent by using both products in this combustion reaction to determine the limiting reagent and the amount of the reactant in excess. Initial amounts of each reactant are given.

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Answers

1. 1.2044×10^{24} molecules

3. 145.7 mol; 8.77×10^{25} molecules

5. 52.8 mg

7. 2.99×10^{-23} g

9. 39.4 mL

11. 20.7 L

13. 67.91 g of $CuCl_2$; 32.09 g of Cu. The two masses add to 100.0 g, the initial amount of starting material, demonstrating the law of conservation of matter.

15. 8,632 g

17. 17.66 g

19. The limiting reagent is NaOH; 21.9 g of P_4 and 3.61 g of H_2O are left over.

21. Both products predict that O_2 is the limiting reagent; 20.3 g of C_3H_8 are left over.