CHEMISTRY

STOICHIOMETRY

Stoichiometry -

Balanced Chemical Equations and the Molar Relationship

The reason why chemical equations are balanced are so they adhere to the Law of Conservation of Mass. After a chemical equation is balanced it will tell us the molar relationship between reactants and products.

Ex: Na + Cl_2 → NaCl

Now that the equation is balanced, one can see that …

2 mol Na + 1 mol Cl_2 creates **2 mol NaCl**

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2 Na + **1** Cl_2 → **2** NaCl

This is the molar relationship for the production of salt. In order to produce any quantity of NaCl, this relationship (or recipe) must be followed.

For example, what if you wanted 4 mol of NaCl, how many moles of sodium and chlorine would you need?

__ Na + ___ Cl_2 → **4** NaCl

What if you wanted 9 mol of NaCl, how many moles of sodium and chlorine would you need?

__ Na + ___ Cl_2 → **9** NaCl

Based on the molar ratio, you can determine how varying molar amounts will relate to each other within a chemical equation.

Ex: If you have 3.6 mol of sodium, how many moles of chlorine do you need?

2 Na + **1** Cl_2 → **2** NaCl

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These molar ratios can then be used to calculate the mass-mole relationships.

Ex: *Nitrogen gas and hydrogen gas combine to create ammonia. How many grams of ammonia are created from 10 grams of nitrogen gas?*

Ex: *Carbon dioxide reacts with lithium hydroxide to produce lithium carbonate and water. What mass of lithium hydroxide do you need to react with 1000 g of carbon dioxide?*

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Summary:

Steps for Solving Stoichiometric Problems …

1.

2.

3.

4.

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Practice Problems

11. What amount in moles of silver chromate, $Ag_2CrO_4(s)$, is produced from 0.50 mol of silver nitrate, $AgNO_3(aq)$?

$$2AgNO_3(aq) + Na_2CrO_4(aq) \rightarrow Ag_2CrO_4(s) + 2NaNO_3(aq)$$

12. What amount in moles of water forms when 6.00 mol of carbon dioxide is consumed in the following reaction?

$$2NH_3(g) + CO_2(g) \rightarrow NH_2CONH_2(s) + H_2O(g)$$

13. Calculate the amount in moles of ammonia, $NH_3(g)$, that is needed to prepare 22 500 mol of the fertilizer ammonium sulfate, $(NH_4)_2SO_4(s)$.

$$2NH_3(g) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(s)$$

14. Calculate the amount in moles of oxygen that is needed to react with 2.4 mol of ammonia to produce poisonous hydrogen cyanide, HCN(g).

$$2NH_3(g) + 3O_2(g) + 2CH_4(g) \rightarrow 2HCN(g) + 6H_2O(g)$$

15. What amount in moles of fluorine, $F_2(g)$, yields 2.35 mol of xenon tetrafluoride, $XeF_4(s)$?

$$Xe(g) + 2F_2(g) \rightarrow XeFe_4(s)$$

16. These equations show two possible reactions:

$$2N_2(g) + O_2(g) \rightarrow 2N_2O(g)$$
$$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$$

a. What amount in moles of oxygen reacts with 93.5 mol of nitrogen to form dinitrogen monoxide, $N_2O(g)$?

b. What amount in moles of nitrogen dioxide, $NO_2(g)$ forms in the other reaction?

17. What amount in moles of oxygen reacts with 11.3 mol of propane gas, $C_3H_8(g)$, during the combustion of propane?

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

18. What amount in moles of phosphorus produces 6.45 mol of tetraphosphorus hexoxide, $P_4O_6(s)$?

$$P_4(s) + 3O_2(g) \rightarrow P_4O_6(s)$$

19. Silver tarnishes when it is exposed to small amounts of hydrogen sulfide, $H_2S(g)$, in the air.

$$4Ag(s) + 2H_2S(g) + O_2(g) \rightarrow 2Ag_2S(s) + 2H_2O(\ell)$$

How many molecules of hydrogen sulfide react with 1.7 mol of silver?

20. When heated, magnesium hydrogen carbonate, $Mg(HCO_3)_2(s)$, decomposes and forms magnesium carbonate, $MgCO_3(s)$, carbon dioxide and water, vapour. What amount in moles of water is produced from 7.24×10^5 mol of magnesium hydrogen carbonate?

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21. The production of acetic acid, $CH_3COOH(\ell)$, is represented by the following chemical equation:

$$CH_3OH(\ell) + CO(g) \rightarrow CH_3COOH(\ell)$$

Calculate the mass of acetic acid that is produced by the reaction of 6.0×10^4 g of carbon monoxide with sufficient methanol, $CH_3OH(\ell)$.

22. Calculate the mass of silver nitrate, $AgNO_3(aq)$, that must react with solid copper to provide 475 kg of of copper nitrate, $Cu(NO_3)_2(aq)$.

$$Cu(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Cu(NO_3)_2(aq)$$

23. What mass of oxygen is produced if 22.7 mol of carbon dioxide is consumed in a controlled photosynthesis reaction?

$$6CO_2(g) + 6H_2O(\ell) \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$$

24. Sodium phosphate, $Na_3PO_4(aq)$, is an all-purpose cleaner that can be used to clean walls before painting. It is often referred to as trisodium phosphate, or TSP, and it must be handled with care because it is corrosive. It is prepared by the following reaction:

$$3NaOH(aq) + H_3PO_4(aq) \rightarrow Na_3PO_4(aq) + 3H_2O(\ell)$$

What amount in moles of TSP is produced if 14.7 g of sodium hydroxide reacts with phosphoric acid, $H_3PO_4(aq)$?

25. What mass of hydrogen is produced when 3.75 g of aluminum reacts with sulfuric acid, $H_2SO_4(aq)$?

$$2Al(s) + 3H_2SO_4(aq) \rightarrow 3H_2(g) + Al_2(SO_4)_3(aq)$$

26. Nitrogen monoxide, NO(g), reacts with oxygen gas to form nitrogen dioxide, $NO_2(g)$. What mass of nitrogen dioxide is produced from 2.84 g of nitrogen monoxide?

27. Iron(III) oxide, $Fe_2O_3(s)$, reacts with carbon monoxide to form solid iron and carbon dioxide in the following reaction:

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$$

What mass (in grams) of carbon dioxide is produced from 12.4 g of iron(III) oxide?

28. Methane, $CH_4(g)$, reacts with sulfur, $S_8(s)$, to produce carbon disulfide, $CS_2(\ell)$, and hydrogen sulfide, $H_2S(g)$. Carbon disulfide is often used in the production of cellophane.

$$2CH_4(g) + S_8(s) \rightarrow 2CS_2(\ell) + 4H_2S(g)$$

What mass of methane is required if 4.09 g of hydrogen sulfide is produced?

29. The addition of concentrated hydrochloric acid to manganese(IV) oxide, $MnO_2(s)$, produces chlorine gas, $Cl_2(g)$.

$$4HCl(aq) + MnO_2(s) \rightarrow MnCl_2(aq) + Cl_2(g) + 2H_2O(\ell)$$

What mass of manganese(IV) oxide is needed to react with 8.65×10^{-2} g of hydrochloric acid?

30. Aluminum carbide, $Al_4C_3(s)$, is a yellow powder that reacts with water, $H_2O(\ell)$, to produce aluminum hydroxide, $Al(OH)_3(s)$, and methane, $CH_4(g)$. Write a balanced chemical equation for the reaction and determine the mass of water required to react with 14.0 g of aluminum carbide.

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Answers

11. 0.25 mol
12. 6.00 mol
13. 4.50×10^4 mol
14. 3.6 mol $O_2(g)$
15. 4.70 mol
16. **a.** 46.8 mol
b. 187 mol
17. 56.5 mol $O_2(g)$
18. 6.45 mol of $P_4(s)$
19. 5.1×10^{23}
20. 7.24×10^5 mol of $H_2O(g)$
21. 1.3×10^5 g
22. 860 kg
23. 726 g
24. 0.123 mol
25. 0.421 g
26. 4.35 g
27. 10.3 g
28. 0.963 g
29. 5.16×10^{-2} g
30. 21.0 g

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Ex: Iron (III) oxide is made by combining iron metal with oxygen. Calculate how much oxygen is needed to react with 5.0 g of iron.

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Ex: 5g of potassium iodide will react with lead(II)nitrate in a double displacement reaction to produce a precipitate.

a) How many grams of lead nitrate does one need to complete this reaction?

b) How many grams of precipitate are produced?

c) If the precipitate was removed, how many grams of the other product would remain after distillation?

d) Do your calculations adhere to the law of conservation of mass?

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Ex: A 20kg BBQ tank of propane is accidentally left on and allowed to completely combust.

a) How many kilograms of carbon dioxide and water would this produce?

b) How many kilograms of oxygen would this reaction consume? How would the reaction change if this amount of oxygen was unavailable?

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$$CH_3OH(\ell) + CO(g) \rightarrow CH_3COOH(\ell)$$

Calculate the mass of acetic acid that is produced by the reaction of 6.0×10^4 g of carbon monoxide with sufficient methanol, $CH_3OH(\ell)$.

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25. What mass of hydrogen is produced when 3.75 g of aluminum reacts with sulfuric acid, $H_2SO_4(aq)$?

$$2Al(s) + 3H_2SO_4(aq) \rightarrow 3H_2(g) + Al_2(SO_4)_3(aq)$$

Pg. 305 #1 - 10

26. Nitrogen monoxide, NO(g), reacts with oxygen gas to form nitrogen dioxide, $NO_2(g)$. What mass of nitrogen dioxide is produced from 2.84 g of nitrogen monoxide?

27. Iron(III) oxide, $Fe_2O_3(s)$, reacts with carbon monoxide to form solid iron and carbon dioxide in the following reaction:

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$$

What mass (in grams) of carbon dioxide is produced from 12.4 g of iron(III) oxide?

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$$2CH_4(g) + S_8(s) \rightarrow 2CS_2(\ell) + 4H_2S(g)$$

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Pg. 305 #1 - 10

Review Questions

1. K/U What important chemical information about the reactants and products in a reaction is obtained from the coefficients of a balanced chemical equation?
2. K/U Why is a balanced chemical equation needed for stoichiometric calculations?
3. K/U Determine all the possible mole ratios for each balanced chemical equation.
   a. $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$
   b. $3Fe(s) + 4H_2O(\ell) \rightarrow Fe_3O_4(s) + 4H_2(g)$
   c. $2HgO(s) \rightarrow 2Hg(\ell) + O_2(g)$
   d. $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$
   e. $CaO(s) + H_2O(\ell) \rightarrow Ca(OH)_2(s)$
4. T/I The oxidation of aluminum is represented by the following chemical equation:
   $$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(aq)$$
   What mass of oxygen is required to oxidize 25 mol of aluminum?
5. T/I The reaction of nitrogen gas with hydrogen gas is represented by the following chemical equation:
   $$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$
   What mass (in grams) of nitrogen reacts with 6.0 g of hydrogen?
6. T/I A student says that 1.0 g of magnesium reacts with 1.0 g of chlorine, $Cl_2(g)$, according to this equation:
   $$Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$$
   Using mathematical calculations, explain why the student's reasoning is incorrect.
7. A Iron ore, $Fe_2O_3(s)$, is treated with carbon monoxide, CO(g), to extract and purify the iron. This reaction is represented by the following unbalanced equation:
   $\_\_\_Fe_2O_3(s) + \_\_\_CO(g) \rightarrow \_\_\_Fe(s) + \_\_\_CO_2(g)$
   a. Balance the chemical equation.
   b. Calculate the minimum mass of carbon monoxide that must be ordered by a refining company for every metric tonne of iron ore that is processed.
8. C Complete a flowchart to show how you would use mole ratios to determine the unknown amount of a substance that reacts with a known amount of another substance.
9. T/I The neutralization reaction of hydrobromic acid, HBr(aq), and calcium hydroxide, $Ca(OH)_2(aq)$, is represented by the following balanced chemical equation:
   $$2HBr(aq) + Ca(OH)_2(aq) \rightarrow CaBr_2(aq) + 2H_2O(\ell)$$
   Copy and complete this table to show all the quantity ratios that are implied by the balanced chemical equation.

Neutralization Reaction

	$2HBr(aq)$	$Ca(OH)_2(aq)$	$CaBr_2(aq)$	$2H_2O(\ell)$
Amount (mol)				
Number of Units				
Mass (g)				

10. T/I When heated, the orange crystals of ammonium dichromate, $(NH_4)_2Cr_2O_7(s)$, slowly decompose to form green chromium(III) oxide, $Cr_2O_3(s)$. Colourless nitrogen gas and water vapour are given off.
    $(NH_4)_2Cr_2O_7(s) \rightarrow Cr_2O_3(s) + N_2(g) + 4H_2O(g)$
    a. How many formula units of chromium(III) oxide are produced from the decomposition of 7.0 g of ammonium dichromate?
    b. How many formula units of ammonium dichromate are needed to produce 2.75 g of water vapour?

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Answers

Answers to Section 7.1 Review Questions

4. 6.0×10^2 g

5. 28 g

7. a. $Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$

b. 526.2 kg or about ½ tonne

9. 2, 1, 1, 2; 1.20×10^{24}, 6.02×10^{23}, 6.02×10^{23}, 1.20×10^{24}; 162 g, 74.0 g, 200 g, 36.0 g

10. a. 1.7×10^{22}

b. 2.30×10^{22} formula units

21. 1.3×10^5 g

22. 860 kg

23. 726 g

24. 0.123 mol

25. 0.421 g

26. 4.35 g

27. 10.3 g

28. 0.963 g

29. 5.16×10^{-2} g

30. 21.0 g