CHAPTER 12 Study Guide

Study Tip

Prioritize Schedule your time realistically. Stick to your deadlines.

Interactive Textbook

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CHAPTER 12 Study Guide

Key Concepts

12.1 The Arithmetic of Equations

- A balanced chemical equation provides the same kind of quantitative information that a recipe does.
- Chemists use balanced chemical equations as a basis to calculate how much reactant is needed or product is formed in a reaction.
- A balanced chemical equation can be interpreted in terms of different quantities, including numbers of atoms, molecules, or moles; mass; and volume.
- Mass and atoms are conserved in every chemical reaction.

12.2 Chemical Calculations

- In chemical calculations, mole ratios are used to convert between moles of reactant and moles of product, between moles of reactants, or between moles of products.
- In a typical stoichiometric problem, the given quantity is first converted to moles. Then the mole ratio from the balanced equation is used to calculate the moles of the wanted substance. Finally, the moles are converted to any other unit of measurement related to the unit mole.

12.3 Limiting Reagent and Percent Yield

- In a chemical reaction, an insufficient quantity of any of the reactants will limit the amount of product that forms.
- The percent yield is a measure of the efficiency of a reaction performed in the laboratory.

Vocabulary

- actual yield (p. 372)
- excess reagent (p. 369)
- limiting reagent (p. 369)
- mole ratio (p. 359)
- percent yield (p. 372)
- stoichiometry (p. 354)
- theoretical yield (p. 372)

Key Equations

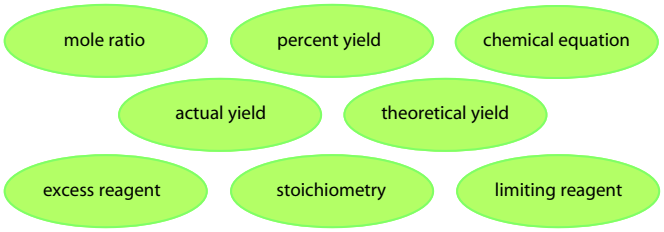
- mole-mole relationship for $aG \longrightarrow bW$:

$$x \text{ mol } G \times \frac{b \text{ mol } W}{a \text{ mol } G} = \frac{xb}{a} \text{ mol } W$$

- percent yield $= \dfrac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$

Organizing Information

Use these terms to construct a concept map that organizes the major ideas of this chapter.



Interactive Textbook

Concept Map 12 Create your Concept Map using the computer.

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Chapter Resources

Print

- **Core Teaching Resources,** Chapter 12, *Practice Problems*, *Vocabulary Review*, *Quiz*, *Chapter Test A*, *Chapter Test B*

Technology

- **Computer Test Bank,** Chapter 12 Test
- **Interactive Textbook with ChemASAP,** Chapter 12
- **Virtual Chem Labs,** Lab 14

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CHAPTER 12

Assessment

Reviewing Content

12.1 The Arithmetic of Equations

36. Interpret each chemical equation in terms of interacting particles.

a. $2KClO_3(s) \longrightarrow 2KCl(s) + 3O_2(g)$

b. $4NH_3(g) + 6NO(g) \longrightarrow 5N_2(g) + 6H_2O(g)$

c. $4K(s) + O_2(g) \longrightarrow 2K_2O(s)$

37. Interpret each equation in Problem 36 in terms of interacting numbers of moles of reactants and products.

38. Calculate and compare the mass of the reactants with the mass of the products for each equation in Problem 36. Show that each balanced equation obeys the law of conservation of mass.

12.2 Chemical Calculations

39. Explain the term *mole ratio* in your own words. When would you use this term?

40. Carbon disulfide is an important industrial solvent. It is prepared by the reaction of coke with sulfur dioxide.

$$5C(s) + 2SO_2(g) \longrightarrow CS_2(l) + 4CO(g)$$

a. How many moles of CS_2 form when 2.7 mol C reacts?

b. How many moles of carbon are needed to react with 5.44 mol SO_2?

c. How many moles of carbon monoxide form at the same time that 0.246 mol CS_2 forms?

d. How many mol SO_2 are required to make 118 mol CS_2?

41. Methanol (CH_3OH) is used in the production of many chemicals. Methanol is made by reacting carbon monoxide and hydrogen at high temperature and pressure.

$$CO(g) + 2H_2(g) \longrightarrow CH_3OH(g)$$

a. How many moles of each reactant are needed to produce 3.60×10^2 g CH_3OH?

b. Calculate the number of grams of each reactant needed to produce 4.00 mol CH_3OH.

c. How many grams of hydrogen are necessary to react with 2.85 mol CO?

42. The reaction of fluorine with ammonia produces dinitrogen tetrafluoride and hydrogen fluoride.

$$5F_2(g) + 2NH_3(g) \longrightarrow N_2F_4(g) + 6HF(g)$$

a. If you have 66.6 g NH_3, how many grams of F_2 are required for complete reaction?

b. How many grams of NH_3 are required to produce 4.65 g HF?

c. How many grams of N_2F_4 can be produced from 225 g F_2?

43. What information about a chemical reaction is derived from the coefficients in a balanced equation?

44. Lithium nitride reacts with water to form ammonia and aqueous lithium hydroxide.

$$Li_3N(s) + 3H_2O(l) \longrightarrow NH_3(g) + 3LiOH(aq)$$

a. What mass of water is needed to react with 32.9 g Li_3N?

b. When the above reaction takes place, how many molecules of NH_3 are produced?

c. Calculate the number of grams of Li_3N that must be added to an excess of water to produce 15.0 L NH_3 (at STP).

12.3 Limiting Reagent and Percent Yield

45. What is the significance of the limiting reagent in a reaction? What happens to the amount of any reagent that is present in an excess?

46. How would you identify a limiting reagent in a chemical reaction?

47. In a reaction chamber, 3.0 mol of aluminum is mixed with 5.3 mol Cl_2 and reacts. The reaction is described by the following balanced chemical equation.

$$2Al + 3Cl_2 \longrightarrow 2AlCl_3$$

a. Identify the limiting reagent for the reaction.

b. Calculate the number of moles of product formed.

c. Calculate the number of moles of excess reagent remaining after the reaction.

48. Heating an ore of antimony (Sb_2S_3) in the presence of iron gives the element antimony and iron(II) sulfide.

$$Sb_2S_3(s) + 3Fe(s) \longrightarrow 2Sb(s) + 3FeS(s)$$

When 15.0 g Sb2S3 reacts with an excess of Fe, 9.84 g Sb is produced. What is the percent yield of this reaction?

CHAPTER 12 Assessment

Reviewing Content

36. a. Two formula units $KClO_3$ decompose to form two formula units KCl and three molecules O_2.
b. Four molecules NH_3 react with six molecules NO to form five molecules N_2 and six molecules H_2O.
c. Four atoms K react with one molecule O_2 to form two formula units K_2O.

37. a. Two mol $KClO_3$ decompose to form two mol KCl and three mol O_2.
b. Four mol NH_3 react with six mol NO to form five mol N_2 and six mol H_2O.
c. Four mol K react with one mol O_2 to form two mol K_2O.

38. a. 245.2 g **b.** 248.0 g
c. 188.4 g
All obey the law of conservation of mass.

39. Acceptable answers include the idea of writing a ratio using the coefficients of two substances from a balanced equation as the number of moles of each substance reacting or being formed.

40. a. 0.54 mol **b.** 13.6 mol
c. 0.984 mol **d.** 236 mol

41. a. 11.3 mol CO, 22.5 mol H_2
b. 112 g CO, 16.0 g H_2
c. 11.4 g H_2

42. a. 372 g F_2
b. 1.32 g NH_3
c. 123 g N_2F_4

43. The coefficients indicate the relative number of moles (or particles) of reactants and products.

44. a. 51.2 g H_2O
b. 5.71×10^{23} molecules NH_3
c. 23.2 g Li_3N

45. The amount of the limiting reagent determines the maximum amount of product that can be formed. The excess reagent is only partially consumed in the reaction.

46. To identify the limiting reagent, express quantities of reactants as moles; compare to the mole ratios from the balanced equation.

47. a. Al
b. 3.0 mol $AlCl_3$
c. 0.8 mol Cl_2

48. 91.5%

Understanding Concepts

49. a. 2.36 g H_3PO_4
b. 1.89 g CO_2

50. a. 5.70×10^{21} atoms Zn
b. 95.2 g Zn

51. a. 7.0×10^2 L N_2
b. no reagent in excess

52. a. 96.4%
b. 45.0 g

53. 10.7 kg $CaSO_4$

54. 224 L gas

55. a. Initially, the amount of NaCl formed increases as the amount of Na used increases. For this part of the curve, sodium is the limiting reagent. Beyond a mass of about 2.5 g of Na, the amount of product formed remains constant because chlorine is now the limiting reagent.
b. Chlorine becomes the limiting reagent when the mass of sodium exceeds 2.5 g. This corresponds to a mass of about 3.9 g chlorine.

56. 50.0% yield; 0.500 mol; 0.0500 mol; 20.0% yield

Understanding Concepts

49. Calcium carbonate reacts with phosphoric acid to produce calcium phosphate, carbon dioxide, and water.

$$3CaCO_3(s) + 2H_3PO_4(aq) \longrightarrow Ca_3(PO_4)_2(aq) + 3CO_2(g) + 3H_2O(l)$$

a. How many grams of phosphoric acid react with excess calcium carbonate to produce 3.74 g $Ca_3(PO_4)_2$?
b. Calculate the number of grams of CO_2 formed when 0.773 g H_2O is produced.

50. Nitric acid and zinc react to form zinc nitrate, ammonium nitrate, and water.

$$4Zn(s) + 10HNO_3(aq) \longrightarrow 4Zn(NO_3)_2(aq) + NH_4NO_3(aq) + 3H_2O(l)$$

a. How many atoms of zinc react with 1.49 g HNO_3?
b. Calculate the number of grams of zinc that must react with an excess of HNO_3 to form 29.1 g NH_4NO_3.

51. Hydrazine (N_2H_4) is used as rocket fuel. It reacts with oxygen to form nitrogen and water.

$$N_2H_4(l) + O_2(g) \longrightarrow N_2(g) + 2H_2O(g)$$

a. How many liters of N_2 (at STP) form when 1.0 kg N_2H_4 reacts with 1.0 kg O_2?
b. How many grams of the excess reagent remain after the reaction?

52. When 50.0 g of silicon dioxide is heated with an excess of carbon, 32.2 g of silicon carbide is produced.

$$SiO_2(s) + 3C(s) \longrightarrow SiC(s) + 2CO(g)$$

a. What is the percent yield of this reaction?
b. How many grams of CO gas are made?

53. If the reaction below proceeds with a 96.8% yield, how many kilograms of $CaSO_4$ are formed when 5.24 kg SO_2 reacts with an excess of $CaCO_3$ and O_2?

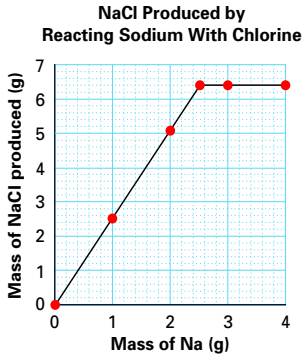
$$2CaCO_3(s) + 2SO_2(g) + O_2(g) \longrightarrow 2CaSO_4(s) + 2CO_2(g)$$

54. Ammonium nitrate will decompose explosively at high temperatures to form nitrogen, oxygen, and water vapor.

$$2NH_4NO_3(s) \longrightarrow 2N_2(g) + 4H_2O(g) + O_2(g)$$

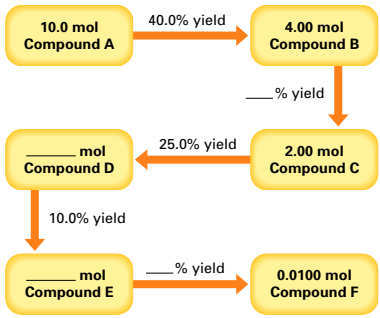
What is the total number of liters of gas formed when 228 g NH_4NO_3 is decomposed? (Assume STP.)

55. In an experiment, varying masses of sodium metal are reacted with a fixed initial mass of chlorine gas. The amounts of sodium used and the amounts of sodium chloride formed are shown on the following graph.



a. Explain the general shape of the graph.
b. Estimate the amount of chlorine gas used in this experiment at the point where the curve becomes horizontal.

56. The manufacture of compound F requires five separate chemical reactions. The initial reactant, compound A, is converted to compound B, compound B is converted to compound C, and so forth. The diagram below summarizes the stepwise manufacture of compound F, including the percent yield for each step. Provide the missing quantities or missing percent yields. Assume that the reactant and product in each step react in a one-to-one mole ratio.



Critical Thinking

57. Given a certain quantity of reactant, you calculate that a particular reaction should produce 55 g of a product. When you perform the reaction, you find that you have produced 63 g of product. What is your percent yield? What could have caused a percent yield greater than 100%?

58. Would the law of conservation of mass hold in a net ionic equation? Explain.

59. A bicycle-built-for-three has a frame, two wheels, six pedals, and three seats. The balanced equation for this bicycle is

$$F + 2W + 6P + 3S \longrightarrow FW_2P_6S_3$$

How many of each part are needed to make 29 bicycles-built-for-three?

a. frames **b.** wheels
c. pedals **d.** seats

60. A car gets 9.2 kilometers to a liter of gasoline. Assuming that gasoline is 100% octane (C_8H_{18}), which has a specific gravity of 0.69, how many liters of air (21% oxygen by volume at STP) will be required to burn the gasoline for a 1250-km trip? Assume complete combustion.

61. Ethyl alcohol (C_2H_5OH) can be produced by the fermentation of glucose ($C_6H_{12}O_6$). If it takes 5.0 h to produce 8.0 kg of alcohol, how many days will it take to consume 1.0×10^3 kg of glucose? (An enzyme is used.)

$$C_6H_{12}O_6 \xrightarrow{\text{enzyme}} 2C_2H_5OH + 2CO_2$$

Concept Challenge

62. A 1004.0-g sample of $CaCO_3$ that is 95.0% pure gives 225 L CO_2 at STP when reacted with an excess of hydrochloric acid.

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + CO_2 + H_2O$$

What is the density (in g/L) of the CO_2?

63. The white limestone cliffs of Dover, England, contain a large percentage of calcium carbonate ($CaCO_3$). A sample of limestone weighing 84.4 g reacts with an excess of hydrochloric acid to form calcium chloride.

$$CaCO_3 + 2HCl \longrightarrow CaCO_3 + CaCl_2 + H_2O + CO_2$$

The mass of calcium chloride formed is 81.8 g. What is the percentage of calcium carbonate in the limestone?

64. For the reaction below there is a 100.0 g of each reactant available. Which reagent is the limiting reagent?

$$2MnO_2 + 4KOH + O_2 + Cl_2 \longrightarrow 2KMnO_4 + 2KCl + 2H_2O$$

65. The equation for one of the reactions in the process of reducing iron ore to the metal is

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

a. What is the maximum mass of iron, in grams, that can be obtained from 454 g (1.00 lb) of iron(III) oxide?
b. What mass of CO is required to reduce the iron(III) oxide to iron metal?

66. SO_3 can be produced in the following two-step process:

$$FeS_2 + O_2 \longrightarrow Fe_2O_3 + SO_2$$
$$SO_2 + O_2 \longrightarrow SO_3$$

Assuming that all the FeS_2 reacts, how many grams of SO_3 are produced when 20.0 g of the FeS_2 reacts with 16.0 g of O_2?

Critical Thinking

57. The percent yield is 115%; such a yield could be attributed to experimenter error, or to unreacted starting material, or to outside materials contaminating the product.
58. Yes, a net ionic equation is balanced and thus obeys the law of conservation of mass.
59. **a.** 29 frames
b. 58 wheels
c. 174 pedals
d. 87 seats
60. 1.1×10^6 L air
61. 13 days

Concept Challenge

62. 1.86 g/L
63. 87.4% $CaCO_3$
64. KOH is the limiting reagent.
65. **a.** 347 g Fe
b. 239 g CO
66. 6.51 g SO_3

CHAPTER 12

Assessment *continued*

Cumulative Review

67. a. 22, 22, 25
b. 50, 50,70
c. 8, 8,10
d. 12,12,14

68. a. ultraviolet
b. ultraviolet
c. ultraviolet

69. a. sodium
b. arsenic
c. cesium

70. a. Cs·

b. :$\ddot{\underset{\cdot\cdot}{\text{Br}}}$·

c. ·Ca·

d. $\cdot\ddot{\underset{\cdot}{\text{P}}}\cdot$

71. c and d

72. single bond, one pair shared electrons; double bond, two pairs of shared electrons; triple bond, three pairs of shared electrons

73. Yes, an ionic compound with at least one polyatomic ion has covalent bonds.

74. A cation has a positive charge, and an anion has a negative charge.

75. a. phosphate ion
b. aluminum ion
c. selenide ion
d. ammonium ion

76. a. silicon dioxide
b. potassium sulfate
c. carbonic acid
d. magnesium sulfide

77. a. $Al_2(CO_3)_3$
b. NO_2
c. K_2S
d. $MnCrO_4$
e. NaBr

78. 1.30×10^{-22} g

79. 7.38 g Be

80. $C_2H_2O_4$

81. a. 0.473 mol KNO_3
b. 9.91×10^{-2} mol SO_2
c. 3.74×10^{-2} mol PCl_3

82. a. $2Pb(NO_3)_2 \rightarrow 2PbO + 4NO_2 + O_2$
b. $2C_3H_7OH + 9O_2 \rightarrow 6CO_2 + 8H_2O$
c. $2Al + 3FeO \rightarrow 3Fe + Al_2O_3$

83. a. 1, 1, 1, 2
b. 1, 3, 3, 1
c. 1, 1, 1, 2

Cumulative Review

67. How many electrons, protons, and neutrons are in an atom of each isotope? *(Chapter 4)*
a. titanium-47
b. tin-120
c. oxygen-18
d. magnesium-26

68. When comparing ultraviolet and visible electromagnetic radiation, which has *(Chapter 5)*
a. a higher frequency
b. a higher energy
c. a shorter wavelength

69. Identify the larger atom of each pair. *(Chapter 6)*
a. sodium and chlorine
b. arsenic and nitrogen
c. fluorine and cesium

70. Write electron dot formulas for the following atoms. *(Chapter 7)*
a. Cs
b. Br
c. Ca
d. P

71. Which of these elements form ions with a 2+ charge? *(Chapter 7)*
a. potassium
b. sulfur
c. barium
d. magnesium

72. Distinguish among single, double, and triple covalent bonds. *(Chapter 8)*

73. Can a compound have both ionic and covalent bonds? Explain your answer. *(Chapter 8)*

74. How do you distinguish between a cation and an anion? *(Chapter 9)*

75. Name these ions. *(Chapter 9)*
a. PO_4^{3-}
b. Al^{3+}
c. Se^{2-}
d. NH_4^+

76. Name each substance. *(Chapter 9)*
a. SiO_2
b. K_2SO_4
c. H_2CO_3
d. MgS

77. Write the formula for each compound. *(Chapter 9)*
a. aluminum carbonate
b. nitrogen dioxide
c. potassium sulfide
d. manganese(II) chromate
e. sodium bromide

78. What is the mass, in grams, of a molecule of benzene (C_6H_6)? *(Chapter 10)*

79. How many grams of beryllium are in 147 g of the mineral beryl ($Be_3Al_2Si_6O_{18}$)? *(Chapter 10)*

80. What is the molecular formula of oxalic acid, molar mass 90 g/mol? Its percent composition is 26.7% C, 2.2% H, and 71.1% O. *(Chapter 10)*

81. How many moles is each of the following? *(Chapter 10)*
a. 47.8 g KNO_3
b. 2.22 L SO_2 (at STP)
c. 2.25×10^{22} molecules PCl_3

82. Write a balanced chemical equation for each reaction. (*Chapter 11*)
a. When heated, lead(II) nitrate decomposes to form lead(II) oxide, nitrogen dioxide, and molecular oxygen.
b. The complete combustion of isopropyl alcohol (C_3H_7OH) produces carbon dioxide and water vapor.
c. When a mixture of aluminum and iron(II) oxide is heated, metallic iron and aluminum oxide are produced.

83. Balance each equation. *(Chapter 11)*
a. $Ba(NO_3)_2(aq) + Na_2SO_4(aq) \longrightarrow BaSO_4(s) + NaNO_3(aq)$
b. $AlCl_3(aq) + AgNO_3(aq) \longrightarrow AgCl(s) + Al(NO_3)_3(aq)$
c. $H_2SO_4(aq) + Mg(OH)_2(aq) \longrightarrow MgSO_4(aq) + H_2O(l)$

84. Write a net ionic equation for each reaction in Problem 83. *(Chapter 11)*

85. Identify the spectator ions in each reaction in Problem 83. *(Chapter 11)*

86. Write a balanced chemical equation for the complete combustion of ribose, $C_5H_{10}O_5$. *(Chapter 11)*

84. a. $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$
b. $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
c. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

85. a. sodium ion and nitrate ion
b. aluminum ion and nitrate ion
c. magnesium ion and sulfate ion

86. $C_5H_{10}O_5 + 5O_2 \rightarrow 5CO_2 + 5H_2O$

Standardized Test Prep

Test-Taking Tip

Anticipate the answer. Use what you know to guess what you think the answer should be. Then look to see if your answer, or one much like it, is given as an option.

Select the choice that best answers each question or completes each statement.

1. Nitric acid is formed by the reaction of nitrogen dioxide with water.

$$3NO_2(g) + H_2O(l) \longrightarrow NO(g) + 2HNO_3(aq)$$

How many moles of water are needed to react with 8.4 mol NO_2?

a. 2.8 mol
b. 3.0 mol
c. 8.4 mol
d. 25 mol

2. Phosphorus trifluoride is formed from its elements.

$$P_4(s) + 6F_2(g) \longrightarrow 4PF_3(g)$$

How many grams of fluorine are needed to react with 6.20 g of phosphorus?

a. 2.85 g
b. 5.70 g
c. 11.4 g
d. 37.2 g

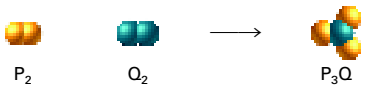
3. Magnesium nitride is formed in the reaction of magnesium metal with nitrogen gas.

$$3Mg(s) + N_2(g) \longrightarrow Mg_3N_2(s)$$

The reaction of 4.0 mol of nitrogen with 6.0 mol of magnesium produces

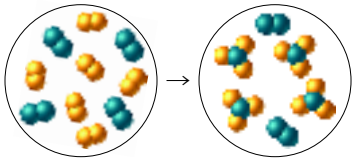
a. 2.0 mol of Mg_3N_2 and 2.0 mol of excess N_2.
b. 4.0 mol of Mg_3N_2 and 1.0 mol of excess Mg.
c. 6.0 mol of Mg_3N_2 and 3.0 mol of excess N_2.
d. no product because the reactants are not in the correct mole ratio.

Questions 4 and 5 involve the reaction between diatomic element P and diatomic element Q to form the compound P_3Q.



4. Write a balanced equation for the reaction between element P and element Q.

5. Based on the atomic windows below, identify the limiting reagent.



For each question there are two statements. Decide whether each statement is true or false. Then decide whether Statement II is a correct explanation for Statement I.

	Statement I		Statement II
6.	Every stoichiometry calculation uses a balanced equation.	BECAUSE	Every chemical reaction obeys the law of conservation of mass.
7.	A percent yield is always greater than 0% and less than 100%.	BECAUSE	The actual yield in a reaction is never more than the theoretical yield.
8.	The amount of the limiting reagent left after a reaction is zero.	BECAUSE	The limiting reagent is completely used up in a reaction.
9.	The coefficients in a balanced equation represent the relative masses of the reactants and products.	BECAUSE	The mass of the reactants must equal the mass of the products in a chemical reaction.
10.	A mole ratio is always written with the larger number in the numerator.	BECAUSE	A mole ratio will always be greater than 1.

Standardized Test Prep

1. a
2. c
3. a
4. $3P_2 + Q_2 \rightarrow 2P_3Q$
5. P_2 is the limiting reagent.
6. True, True, correct explanation
7. False, True
8. True, True, correct explanation
9. False, True
10. False, False