Knowledge/Understanding

True/False

In your notebook, indicate whether each statement is true or false. If a statement is false, rewrite it to make it true.

1. The molecular formula of a compound is the same as its empirical formula.

2. A 2.02 g sample of hydrogen, H_2, contains the same number of molecules as 32.0 g of oxygen, O_2.

3. The average atomic mass of an element is equal to the mass of its most abundant isotope.

4. The numerical value of the molar mass of a compound (expressed in atomic mass units) is the same as its molar mass (expressed in grams).

5. The fundamental unit for chemical quantity is the gram.

6. The mass of 1.00 mol of any chemical compound is always the same.

7. 1.00 mol of any chemical compound or element contains 6.02×10^{23} particles.

8. The value of the Avogadro constant depends on temperature.

9. The empirical formula of an unknown compound must be determined by experiment.

10. The actual yield of most chemical reactions is less than 100%.

11. The theoretical yield of a chemical reaction must be determined by experiment.

12. Stoichiometric calculations are used to determine the products of a chemical reaction.

Multiple Choice

In your notebook, write the letter for the best answer to each question.

13. The number of molecules in 2.0 mol of nitrogen gas, $N_{2(g)}$, is
    (a) 1.8×10^{24}
    (b) 2.4×10^{23}
    (c) 1.2×10^{24}
    (d) 1.2×10^{23}
    (e) 4.0×10^{23}

14. The molar mass of a compound with the empirical formula CH_2O has a mass of approximately 121 g. What is the molecular formula of the compound?
    (a) $C_4H_8O_4$
    (b) $C_2H_6O_2$
    (c) $C_3H_3O_6$
    (d) $C_3H_6O_3$
    (e) CH_6O

15. Read the following statements about balancing chemical equations. Which of these statements is true?
    (a) To be balanced, an equation must have the same number of moles on the left side and the right side.
    (b) A chemical formula may be altered in order to balance a chemical equation.
    (c) To be balanced, a chemical equation must have the same number of each type of atom on both sides.
    (d) It is unacceptable to use fractional coefficients when balancing a chemical equation.
    (e) A skeleton equation contains all the spectator ions.

16. What is the molar mass of ammonium dichromate, $(NH_4)_2Cr_2O_7$?
    (a) 248 g/mol
    (b) 234 g/mol
    (c) 200 g/mol
    (d) 252 g/mol
    (e) 200 g/mol

17. A sample of benzene, C_6H_6, contains 3.0×10^{23} molecules of benzene. How many atoms are in the sample?
    (a) 36×10^{24}
    (b) 1.8×10^{23}
    (c) 3.6×10^{24}
    (d) 2.5×10^{22}
    (e) 3.0×10^{23}

18. What is the molar mass of zinc sulfate heptahydrate, $ZnSO_4 \cdot 7H_2O$?
    (a) 161 g/mol
    (b) 288 g/mol
   (c) 182 g/mol
    (d) 240 g/mol
    (e) 312 g/mol

19. The molecular formula of citric acid monohydrate is $C_6H_8O_7 \cdot H_2O$. Its molecular mass is as follows:
(a) 192 g/mol
(b) 210 g/mol
(c) 188 g/mol
(d) 206 g/mol
(e) 120 g/mol

20. The relative mass of one isotope of sulfur is 31.9721 u. Its abundance is 95.02%. Naturally occurring elemental sulfur has a relative atomic mass of 32.066. The mass number of the one other isotope of sulfur is
(a) 31
(b) 32
(c) 33
(d) 34
(e) 35

21. A sample of ethane, C_2H_6, has a mass of 9.3 g. It contains the same number of atoms as
(a) 23.0 g of sodium, Na
(b) 32.0 g of oxygen, O_2
(c) 48.0 g of ozone, O_3
(d) 30.0 g of formaldehyde, CH_2O
(e) 14.0 g of nitrogen gas, N_2

22. A sample of ozone, O_3, has a mass of 48.0 g. It contains the same number of atoms as
(a) 58.7 g of nickel
(b) 27.0 g of aluminum
(c) 38.0 g of fluorine
(d) 3.02 g of hydrogen
(e) 32.0 g of oxygen

23. Which substance contains 9.03×10^{23} atoms?
(a) 16.0 g of oxygen, O_2
(b) 4.00 g of helium, He
(c) 28.0 g of nitrogen, N_2
(d) 22.0 g of carbon dioxide, CO_2
(e) 8.0 g of methane, CH_4

24. Examine the following formulas. Which formula is an empirical formula?
(a) C_2H_4
(b) C_6H_6
(c) C_2H_2
(d) H_2O_2
(e) $Na_2Cr_2O_7$

25. A sample of sulfur trioxide, SO_3, has a mass of 20 g. How many moles are in the sample?
(a) 0.20
(b) 0.25
(c) 0.50
(d) 0.75
(e) 0.80

26. How many molecules are in 1.00 mg of glucose, $C_6H_{12}O_6$?
(a) 2.18×10^{18}
(b) 3.34×10^{18}
(c) 2.18×10^{21}
(d) 3.34×10^{21}
(e) 3.34×10^{20}

27. A sample that contains carbon, hydrogen, and oxygen is analyzed in a carbon-hydrogen combustion analyzer. All the oxygen in the sample is
(a) converted to the oxygen in carbon dioxide
(b) converted to oxygen in water
(c) mixed with the excess oxygen used to combust the sample
(d) converted to oxygen in carbon dioxide and/or water
(e) both (c) and (d)

28. A compound that contains carbon, hydrogen, and oxygen is going to be analyzed in a carbon-hydrogen combustion analyzer. Before beginning the analysis, which of the following steps must be carried out?
  I. Find the mass of the unknown sample.
 II. Add the precise amount of oxygen that is needed for combustion.
III. Find the mass of the carbon dioxide and water absorbers.
(a) I only
(b) I and II only
(c) I, II, and III
(d) I and III only
(e) none of the above

Short Answer

29. Answer the following questions, related to the concept of the mole.
  (a) How many N_2 molecules are in a 1.00 mol sample of N_2? How many N atoms are in this sample?
  (b) How many PO_4^{3-} ions are in 2.5 mol of $Ca_3(PO_4)_2$?
  (c) How many O atoms are in 0.47 mol of $Ca_3(PO_4)_2$?

30. Explain how a balanced chemical equation follows the law of conservation of mass. Use an example to illustrate your explanation.

31. List all the information that can be obtained from a balanced chemical equation.

32. Answer the following questions, related to the limiting reactant.
  (a) Explain the concept of the limiting reactant. Use a real-life analogy that is not used in this textbook.
  (b) What is the opposite of a limiting reactant?
  (c) Explain why, in many chemical reactions, the reactants are not present in stoichiometric amounts.

33. Consider a 7.35 g sample of propane, C_3H_8.
  (a) How many moles of propane are in this sample?
  (b) How many molecules of propane are in this sample?
  (c) How many atoms of carbon are in this sample?

34. How many atoms are in 10.0 g of white phosphorus, P_4?

35. A 2.00 g sample of the mineral troegerite, $(UO_2)_3(AsO_4)_2 \cdot 12H_2O$, has 1.38×10^{21} uranium atoms. How many oxygen atoms are present in 2.00 g of troegerite?

36. Fuels that contain hydrogen can be classified according to their mass percent of hydrogen. Which of the following compounds has the greatest mass percent of hydrogen: ethanol, C_2H_5OH, or cetyl palmitate, $C_{32}H_{64}O_2$? Explain your answer.

37. Methyl tertiary butyl ether, or MTBE, is currently used as an octane booster in gasoline. It has replaced the environmentally unsound tetraethyl lead. MTBE has the formula $C_5H_{12}O$. What is the percentage composition of each element in MTBE?

38. Ammonia can be produced in the laboratory by heating ammonium chloride with calcium hydroxide.

$2NH_4Cl_{(s)} + Ca(OH)_{2(s)}$
$$\rightarrow CaCl_{2(s)} + 2NH_{3(g)} + 2H_2O_{(g)}$$
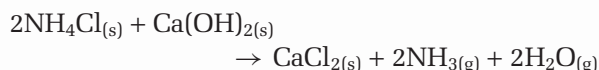
8.93 g of ammonium chloride is heated with 7.48 g of calcium hydroxide. What mass of ammonia, NH_3, can be expected? Assume that the reaction has 100% yield.

Inquiry

39. Design an experiment to determine the value of x in sodium thiosulfate, $Na_2S_2O_3 \cdot xH_2O$. Include an outline of your procedure. Describe the data that you need to collect. What assumptions do you need to make?

40. Design an experiment to determine the mole-to-mole ratio of lead(II) nitrate, $Pb(NO_3)_2$, to potassium iodide, KI, in the reaction:
$Pb(NO_3)_{2(aq)} + KI_{(aq)} \rightarrow PbI_{2(s)} + KNO_{3(aq)}$
Assume that you have solutions of lead(II) nitrate and potassium iodide. Both of these solutions contain 0.0010 mol of solute per 10 mL of solution.

41. The following reaction can be used to obtain lead(II) chloride, $PbCl_2$. Lead(II) chloride is moderately soluble in warm water.
$Pb(NO_3)_{2(aq)} + 2NaCl_{(aq)} \rightarrow PbCl_{2(s)} + 2NaNO_{3(aq)}$
Explain why carrying out this reaction in a warm aqueous solution is unlikely to produce a 100% yield of lead(II) chloride.

42. Imagine that you are given a sheet of aluminum foil that measures 10.0 cm × 10.0 cm. It has a mass of 0.40 g.
  (a) The density of aluminum is 2.70 g/cm^3. Determine the thickness of the aluminum foil, in millimeters.
  (b) Using any of the above information, determine the radius of an aluminum atom, in nanometers. Assume that each aluminum atom is cube-shaped.
  (c) How will your answer to part (b) change if you assume that each aluminum atom is spherical?

(d) What question(s) do your answers to parts (b) and (c) raise?

43. Consider the double displacement reaction below.

$$CaCl_{2(aq)} + Na_2SO_{4(aq)} \rightarrow CaCO_{3(s)} + 2NaCl_{(aq)}$$
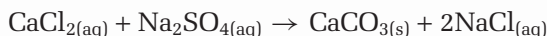
(a) Design an experiment to determine the percentage yield of this reaction. Clearly indicate the measurements that need to be taken, along with suggested amounts.

(b) How could the skills of a chemist influence the outcome of this experiment?

Communication

44. It is impossible for a single atom of neon, with a mass of exactly 20.18 u, to exist. Explain why.

45. The molecular mass of a compound is measured in atomic mass units but its molar mass is measured in grams. Explain why this is true.

46. Explain the relationship between an empirical formula and a molecular formula. Use sodium tartrate, $Na_2C_4H_4O_6$, and cyanocolabamin, $C_{63}H_{88}C \cdot N_{14}O_{14}P$ (vitamin B_{12}), to illustrate your answer.

47. Explain why an empirical formula can represent many different molecules.

48. Chemists need to know the percentage yield of a reaction. Why is this true, particularly for industrial reactions?

49. Examine the following reaction. List the steps needed to calculate the number of grams of C that can be expected when a given mass of A reacts with a given mass of B. Include proper units for each step. Express the answer in terms of A, B, C, and/or D as necessary.
$$2A + 3B \rightarrow 4C + D$$
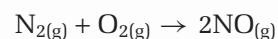
Making Connections

50. Reread the Unit 2 opener.
    (a) Suppose that you ate a dessert containing poppy seeds. As a result, you tested positive for opiates when you applied for a summer job. What can you do?
    (b) Now suppose that you are a policy-writer for a manufacturing company that uses large, dangerous machines. What do you need to

consider when you write a policy that deals with employee drug testing? What factors influence whether drug testing is warranted, how often it is warranted, and what substances should be tested for? How will you decide on levels that are acceptable? Do the federal and provincial Human Rights Commissions have anything to say about these issues?

51. The combustion of gasoline in an automobile engine can be represented by the equation
$$2C_8H_{18(g)} + 25O_{2(g)} \rightarrow 16CO_{2(g)} + 18H_2O_{(g)}$$
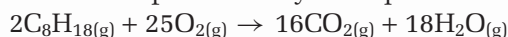
    (a) In a properly tuned engine with a full tank of gas, what reactant do you think is limiting? Explain your reasoning.

    (b) A car that is set to run properly at sea level will run poorly at higher altitudes, where the air is less dense. Explain why.

    (c) The reaction of atmospheric oxygen with atmospheric nitrogen to form nitrogen monoxide, NO, occurs along with the combustion of fuel.
    $$N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$$
    What adjustments need to be made to a vehicle's carburetor or fuel injectors (which control the amount of fuel and air that are mixed) to compensate for this reaction? Explain your answer.

COURSE CHALLENGE

Planet Unknown

Consider the following as you continue to plan for your Chemistry Course Challenge:

- In a reaction that produces a precipitate that you want to recover, what techniques would you use to maximize your percentage yield?

- When you have a given amount of one reactant and you decide the amount of a second reactant, which reactant should be the limiting reactant if you want to maximize your percentage yield?

- Write a balanced chemical equation for the reaction between sodium phosphate and calcium nitrate. Recall that ionic compounds containing sodium are soluble.