## Chapter 9: Review Questions

*Solutions to odd numbered questions at the end of this document*

### Basic Questions

**9.1 Chemical Equations**

1. What is the purpose of coefficients in a chemical equation?

2. How many oxygen atoms are indicated on the right side of this balanced chemical equation:

$$4\ Cr(s) + 3\ O_2(g) \rightarrow 2\ Cr_2O_3(g)$$

3. Why is it important that a chemical equation be balanced?

4. Why is it important never to change a subscript in a chemical formula when balancing a chemical equation?

**9.2 Measuring Molecules**

5. Why don't equal masses of golf balls and Ping-Pong balls contain the same number of balls?

6. Why don't equal masses of carbon atoms and oxygen molecules contain the same number of particles?

7. What is the formula mass of nitrogen monoxide, NO, in atomic mass units?

**9.3 Grams to Moles**

8. If you had 1 mole of marbles, how many marbles would you have? How about 2 moles?

9. How many moles of water are there in 18 grams of water?

10. How many molecules of water are there in 18 grams of water?

11. Why is saying you have 1 mole of water molecules the same as saying you have $6.02 \times 10^{23}$ water molecules?

12. What is the mass of an oxygen atom in atomic mass units?

**9.4 Exothermic or Endothermic**

13. If it takes 436 kilojoules to break a bond, how many kilojoules are released when the same bond is formed?

14. What is released by an exothermic reaction?

15. What is absorbed by an endothermic reaction?

**9.5 Entropy and Chemical Reactions**

16. As energy disperses, where does it go?

17. What is always increasing?

18. Why are exothermic reactions self-sustaining?

**9.6 Chemical Kinetics**

19. Why don't all collisions between reactant molecules lead to product formation?

20. What generally happens to the rate of a chemical reaction with increasing temperature?

21. Which reactant molecules are the first to pass over the energy barrier?

22. What term is used to describe the minimum amount of energy required in order for a reaction to proceed?

**9.7 Chemical Catalysts**

23. What catalyst is effective in the destruction of atmospheric ozone, $O_3$?

24. What does a catalyst do to the energy of activation for a reaction?

25. What net effect does a chemical reaction have on a catalyst?

26. Why are catalysts so important to our economy?

**9.8 Chemical Equilibrium**

27. What is true about a chemical reaction in equilibrium?

28. How can the chemical equilibrium of a reaction be changed?

29. Which molecule is deeper brown in color: nitrogen dioxide, $NO_2$, or dinitrogen tetroxide, $N_2O_4$?

## Quantitative Questions

30. Show that there are $1.0 \times 10^{22}$ carbon atoms in a one carat pure diamond, which has a mass of 0.20 grams.

31. How many gold atoms are there in a 5.00 gram sample of pure gold, Au (197 amu)?

32. Show that one mole of $KClO_3$ contains 122.55 grams.

33. Small samples of oxygen gas needed in the laboratory can be generated by a number of simple chemical reactions, such as

$$2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$$

According to this balanced chemical equation, how many moles of oxygen gas are produced from the reaction of two moles of $KClO_3$ solid?

34. Small samples of oxygen gas needed in the laboratory can be generated by a number of simple chemical reactions, such as

$$2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$$

What mass of oxygen (in grams) is produced when 122.55 grams of $KClO_3$ (formula mass 122.55 atomic mass units) takes part in this reaction?

35. Show that the formula mass of 2-propanol, $C_3H_8O$, is 60 amu, and that the formula mass of propene, $C_3H_6$, is 42 amu, and also that the formula mass of water, $H_2O$, is 18 amu.

36. How many grams of water, $H_2O$, and propene, $C_3H_6$, can be formed from the reaction of 6.0 grams of 2-propanol, $C_3H_8O$?

$$C_3H_8O \rightarrow C_3H_6 + H_2O$$

37. A 16 g sample of methane, $CH_4$, is combined with a 16 g sample of molecular oxygen, $O_2$, in a sealed container. Upon ignition, what is the maximum amount of carbon dioxide, $CO_2$, that can be formed?

$$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$$

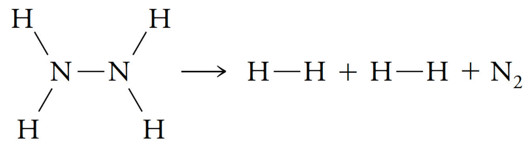
38. Use the bond energies in Table 9.1 and the accounting format shown in Section 9.6 to determine whether these reactions are exothermic or endothermic:

$$H_2 + Cl_2 \rightarrow 2\ HCl$$

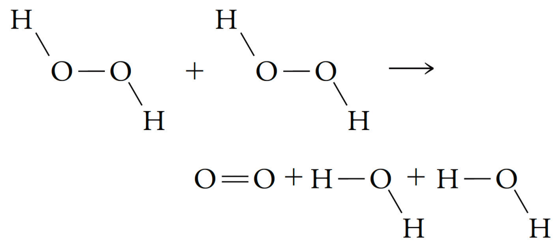
$$2\ HC^{o}CH + 5\ O_2 \rightarrow 4\ CO_2 + 2\ H_2O$$

39. Use the bond energies in Table 9.1 to determine whether these reactions are exothermic or endothermic:

(a)



(b)



40. Show that the equilibrium constant for the following reaction is 56

$$H_2\,(g) \;+\; I_2\,(g). \leftrightarrows \; HI\,(g) \;+\; HI\,(g)$$

Equilibrium concentrations:

$H_2$ (g) = 0.0037 moles per liter

$I_2$ (g) = 0.0037 moles per liter

HI (g) = 0.0276 moles per liter

41. The equilibrium constant for the following equation is $3.5 \times 10^8$:

$$N_2\,(g) \;+\; 3\,H_2\,(g) \leftrightarrows \; 2\,NH_3\,(g)$$

Calculate the equilibrium constant for the reverse reaction:

$$2\,NH_3\,(g) \rightarrow \; N_2\,(g) \;+\; 3\,H_2\,(g)$$

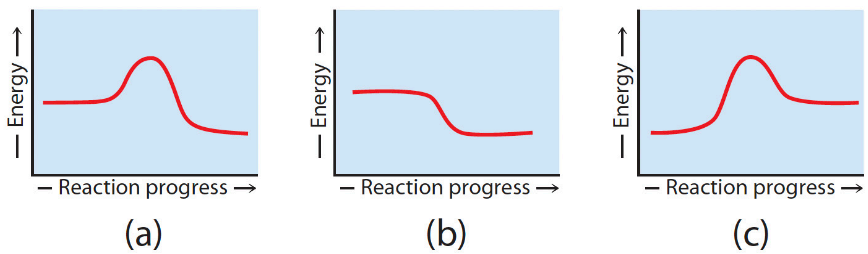
42. Rank the following in order of increasing number of atoms:

A. 52 g of Vanadium, V;

B. 52 g of Chromium, Cr

C. 52 g of Manganese, Mn

43. Rank the following reaction profiles in order of increasing reaction speed.




44. Rank the following covalent bonds in order of increasing bond strength.

| | | |
|---|---|---|
| C ≡ C | C=C | C—C |
| A. | B. | C. |

45. Rank the following in order of increasing entropy. A deck of playing cards

A. at 45°C, new and unshuffled sitting in a room at 25°C.

B. at 233°C, new and unshuffled sitting in a room at 25°C.

C. at 25°C, used and shuffled sitting in a room at 25°C.

## Challenging Questions

### 9.1 Chemical Equations

46. Balance these equations:

a) _____ Fe (s) + _____ $O_2$ (g) → _____ $Fe_2O_3$ (s)

b) _____ $H_2$ (g) + _____ $N_2$ (g) → _____ $NH_3$ (g)

c) _____ $Cl_2$ (g) + _____ KBr (aq) → _____ $Br_2$ (l) + _____ KCl (aq)

d) _____ $CH_4$ (g) + _____ $O_2$ (g) → _____ $CO_2$ (g) + _____ $H_2O$ (l)

47. Balance these equations:

a) _____ Fe (s) + _____ S (s) → _____ $Fe_2S_3$ (s)

b) _____ $P_4$ (s) + _____ $H_2$ (g) → _____ $PH_3$ (g)

c) _____ NO (g) + _____ $Cl_2$ (g) → _____ NOCl (g)

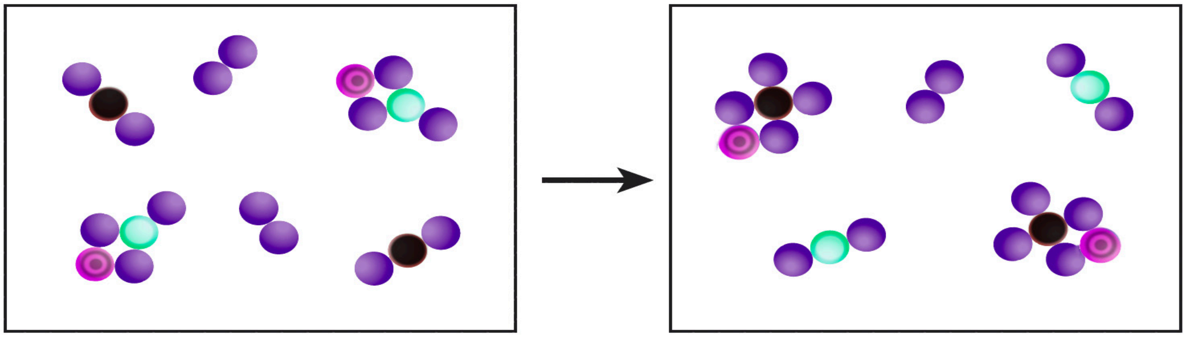
d) _____ $SiCl_4$ (l) + _____ Mg (s) → _____ Si (s) + _____ $MgCl_2$ (s)

48. Which of the following two chemical equations is balanced?

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

$4\ C_6H_7N_5O_{16}$(s) + $19\ O_2$(g) → $24\ CO_2$(g) + $20\ NO_2$(g) + $14\ H_2O$(g)

*Use the following illustration to answer exercises 49 – 51.*



49. Assume the illustrations above are two frames of a movie—one from before the reaction and the other from after the reaction. How many diatomic molecules are represented in this movie?

50. There is an excess of at least one of the reactant molecules. Which one?

51. Which equation best describes this reaction?

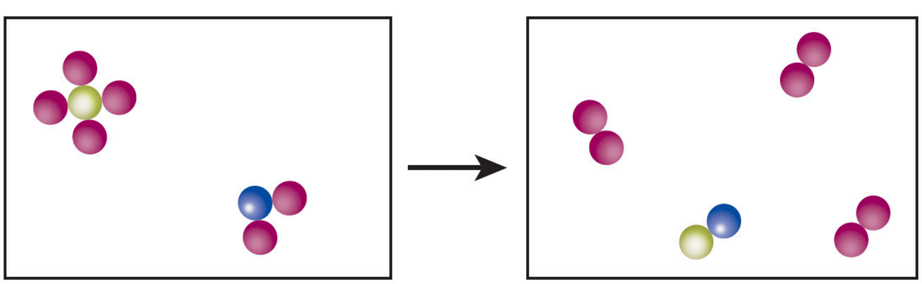
a) $2\,WX_2 + 2\,ZYX_3 + X_2 \rightarrow 2\,ZXW_4 + 2\,YW_2$

b) $2\,WX_2 + 2\,YZW_3 + X_2 \rightarrow 2\,Y_2W_4 + 2\,ZXW$

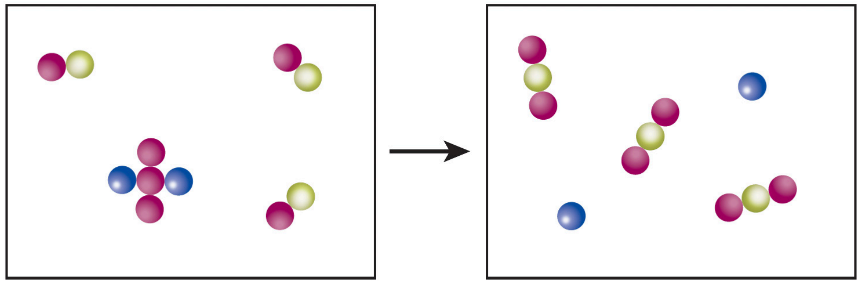
c) $2\,WX_2 + 2\,YZW_3 + W_2 \rightarrow 2\,ZXW_4 + 2\,YW_2$

d) $2\,XW_2 + 2\,ZYW_3 + W_2 \rightarrow 2\,ZXW_4 + 2\,YW_2$

52. The reactants shown schematically on the left represent methane, $CH_4$, and water, $H_2O$. Write out the full balanced chemical equation that is depicted.



53. The reactants shown schematically on the left represent iron oxide, $Fe_2O_3$ and carbon monoxide, CO. Write out the full balanced chemical equation that is depicted.



54. The following is a tough equation to balance. Hint: Treat the $PO_4$ polyatomic ion as a single entity.

$Mg(OH)_2 + H_3PO_4 \rightarrow Mg_3(PO_4)_2 + H_2O$

55. The following is a tough equation to balance. Hint: temporarily use a fraction for a coefficient.

$FeS_2 + O_2 \rightarrow Fe_2O_3 + SO_2$

**9.2 Measuring Molecules**

56. Which has more atoms: 17.031 grams of ammonia, $NH_3$, or 72.922 grams of hydrogen chloride, HCl?

57. How many moles of molecules are there in:

a. 28 grams of nitrogen, $N_2$

b. 32 grams of oxygen, $O_2$

c. 32 grams of methane, $CH_4$

d. 38 grams of fluorine, $F_2$

58. How many moles of atoms are there in:

a. 28 grams of nitrogen, $N_2$

b. 32 grams of oxygen, $O_2$

c. 16 grams of methane, $CH_4$

d. 38 grams of fluorine, $F_2$

59. What is the mass of a water molecule in atomic mass units?

60. What is the mass of a water molecule in grams?

61. Is it possible to have a sample of oxygen that has a mass of 14 atomic mass units? Explain.

62. Which has the greater mass, $1.204 \times 10^{24}$ molecules of molecular hydrogen or $1.204 \times 10^{24}$ molecules of water?

**9.3 Grams to Moles**

63. How many grams of gallium are there in a 145 gram sample of gallium arenside, GaAs?

64. How many atoms of arsenic are there in a 145 gram sample of gallium arsenide, GaAs?

65. How is it possible for a jet airplane carrying 110 tons of jet fuel to emit 340 tons of carbon dioxide?

**9.4 Exothermic or Endothermic**

66. During a chemical reaction, bonds break and then reform. Why isn't the energy required to break these bonds equal to the energy released when the bonds are reformed?

67. Are the chemical reactions that take place in a disposable battery exothermic or endothermic? What evidence supports your answer?

68. Is the reaction going on in a rechargeable battery while it is recharging exothermic or endothermic?

69. Exothermic reactions are favored because they release heat to the environment. Would an exothermic reaction be more favored or less favored if it were carried out within a superheated chamber?

70. Why do exothermic reactions typically favor the formation of products?

**9.5 Entropy and Chemical Reactions**

71. What role does entropy play in chemical reactions?

72. Under what conditions will a hot pie not lose heat to its surroundings?

73. As the Sun shines on a snow capped mountain, much of the snow sublimes instead of melts? How is this favored by entropy?

74. Estimate whether entropy increases or deceases with the following reaction? Use data from Table 9.1 to confirm your estimation.

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

75. According to the second law of thermodynamics, exothermic reactions, such as the burning of wood, are favored because they result in the dispersal of energy. Wood, however, will not spontaneously burn even when exposed to pure oxygen, $O_2$. Why not?

76. Wild plants readily grow "all by themselves" yet the molecules of the growing plant have *less* entropy than the materials used to make the plant. How is it possible for there to be this *decrease* in entropy for a process that occurs all by itself?

**9.6 Chemical Kinetics**

77. In the laboratory, endothermic reactions are usually preformed at elevated temperatures, while exothermic reactions are usually performed at lower temperatures. What are some possible reasons for this?

78. Does a refrigerator prevent or delay the spoilage of food? Explain.

79. Why does a glowing splint of wood burn only slowly in air but burst into flames when placed in pure oxygen?

80. Give two reasons why heat often added to chemical reactions performed in the laboratory?

## 9.7 Chemical Catalysts

81. Explain the connection between photosynthetic life on the Earth and the ozone layer.

82. Does the ozone pollution from automobiles help alleviate the ozone hole over the South Pole? Defend your answer.

83. Chlorine is put into the atmosphere by volcanoes in the form of hydrogen chloride, HCl, but this form of chlorine does not remain in the atmosphere for very long. Why?

84. In the following reaction sequence for the catalytic formation of ozone from molecular oxygen, which chemical compound is the catalyst: nitrogen monoxide or nitrogen dioxide:

$$O_2 + 2\ NO \rightarrow 2\ NO_2$$

$$2\ NO_2 \rightarrow 2\ NO + 2\ O$$

$$2\ O + 2\ O_2 \rightarrow 2\ O_3$$

## 9.8 Chemical Equilibrium

85. What can be assumed about a chemical reaction with a very high equilibrium constant?

86. Nitrogen, $N_2$, reacts with hydrogen, $H_2$, to form ammonia, $NH_3$, according to the following balanced equation:

$$N_2\ (g) + 3\ H_2\ (g) \rightarrow 2\ NH_3\ (g)$$

However, this chemical reaction can also be accurately written as:

$$1/2\ N_2\ (g) + 3/2\ H_2\ (g) \rightarrow NH_3\ (g)$$

Will both these equations have the same equilibrium constant, $K_{eq}$? Please explain.

87. The equilibrium constant, $K_{eq}$, for the conversion of nitrogen oxide, $NO_2$, to dinitrogen tetroxide, $N_2O_4$, is 170.

$$NO_2\,(g) \; + \; NO_2\,(g) \; \leftrightarrows \; N_2O_4\,(g)$$

Suppose within a sealed flask there are the following concentrations:

$NO_2$ (g) = 0.015 moles per liter

$N_2O_4$ (g) = 0.025 moles per liter

Is this mixture at chemical equilibrium? If not, what happens next to the concentrations of these chemicals?

88. One of the top chemicals produced worldwide is ammonia, $NH_3$, which is widely used for fertilizer and other purposes. It can be produced from nitrogen, $N_2$, and hydrogen, $H_2$, as per the following equation:

$$N_2\,(g) \; + \; 3\,H_2\,(g) \; \rightarrow \; 2\,NH_3\,(g)$$

How many moles of reactants are there? How many moles of product? Which occupies more volume: the reactants or the products? If you shrunk the volume of the reaction vessel you would thereby increase the pressure. Would this kind of stress favor the formation of reactants or products?

## Discussion Questions

89. Discuss how any device that keeps track of time is dependent upon an increase in entropy.

90. Many people hear about atmospheric ozone depletion and wonder why we don't simply replace that which has been destroyed. Knowing about chlorofluorocarbons and knowing how catalysts work, explain how this would not be a lasting solution.

91. Throughout the history of life on Earth there have been at least 6 major mass extinctions. The largest mass extinction occurred about 450 million years ago and may have been initiated by an intense burst of ozone depleting gamma rays produced by the explosion of a near-by star. Scientists point to the most recent sixth mass extinction as occurring right now. Discuss possible causes of this mass extinction. What creatures might survive? Should humans do anything to minimize this mass extinction or should they just accept it as a natural course of Earth's history?

# Solutions to Chapter 9 Review

## Solution to Calculation Corner, Masses of Reactants and Products

1. With an unlimited amount of $O_2$ available, 35.8 g of $Fe_2O_3$ can be produced:

$$(25.0\ \cancel{g\ Fe})\left(\frac{1\ \cancel{mole\ Fe}}{55.8\ \cancel{g\ Fe}}\right)\left(\frac{2\ \cancel{moles\ Fe_2O_3}}{4\ \cancel{moles\ Fe}}\right)\left(\frac{159.7\ g\ Fe_2O_3}{1\ \cancel{mole\ Fe_2O_3}}\right) = 35.8\ g\ Fe_2O_3$$

2. With an unlimited amount of Fe available, 83.2 g of $Fe_2O_3$ can be produced:

$$(25.0\ \cancel{g\ O_2})\left(\frac{1\ \cancel{mole\ O_2}}{32.0\ \cancel{g\ O_2}}\right)\left(\frac{2\ \cancel{moles\ Fe_2O_3}}{3\ \cancel{moles\ O_2}}\right)\left(\frac{159.7\ g\ Fe_2O_3}{1\ \cancel{mole\ Fe_2O_3}}\right) = 83.2\ g\ Fe_2O_3$$

3. The 25.0 g of Fe will require 10.8 g of $O_2$:

$$(25.0\ \cancel{g\ Fe})\left(\frac{1\ \cancel{mole\ Fe}}{55.8\ \cancel{g\ Fe}}\right)\left(\frac{3\ \cancel{moles\ O_2}}{4\ \cancel{moles\ Fe}}\right)\left(\frac{32\ g\ O_2}{1\ \cancel{mole\ O_2}}\right) = 10.8\ g\ O_2$$

4. From the previous question we know that 25.0 g of Fe requires 10.8 g of $O_2$. For this question, however, we were supplied with 25.0 g of $O_2$, which is much more than is needed. After the reaction is complete, there should be 25.0 g – 10.8 g = 14.2 g of $O_2$ remaining after the reaction is complete.

## Solutions to Odd Numbered Review Questions

### Basic Questions

#### 9.1 Chemical Equations

1. Coefficients are used to show the ration in which reactants combine and products for in a chemical reaction.

3. A chemical equation must be balanced because the law of conservation of mass says that mass can neither be created nor destroyed. There must be the same number of each atom on both sides of the equation.

**9.2 Measuring Molecules**

5. The relative mass of golf balls is greater than that of ping pong ball balls therefore, it would take more ping pong balls to equal the same mass of golf balls.

7. The formula mass of NO is 30.006 amu

**9.3 Grams to Moles**

9. For water, 18 grams is one mole.

11. One mole of water has $6.02 \times 10^{23}$ water molecules.

**9.4 Exothermic or Endothermic**

13. The amount of energy released when the bond is formed equals the amount of energy needed to break the bond, which is 436 kJ.

15. Energy is consumed by an endothermic reaction.

**9.5 Entropy and Chemical Reactions**

17. The net entropy of the universe is always increasing.

**9.6 Chemical Kinetics**

19. Reactants must collide in a certain orientation with enough energy in order to react.

21. Assuming the reactant molecules are already mixed together, the first to react are those with sufficient kinetic energy and the proper orientation.

**9.7 Chemical Catalysts**

23. Atomic chlorine is a catalyst for the destruction of ozone.

25. A catalyst is unchanged by a chemical reaction.

**9.8 Chemical Equilibrium**

27. The rate of forward and reverse reactions is equal.

29. Nitrogen dioxide, $NO_2$, is deeper brown in color.

**Quantitative Questions**

31. (5.00 g gold)(1 mole gold/197 g gold)($6.02 \times 10^{23}$ atoms/1 mole) = $1.53 \times 10^{22}$ gold atoms

33. The coefficients within this balanced equation tell us the ratio by which reactants react to form products. Accordingly, three moles of oxygen gas are produced for the reaction of every two moles of $KClO_3$ solid. Do you also see that only 1.5 moles of oxygen gas would be produced from the reaction of one mole of $KClO_3$ solid?

35. Use the periodic table to find the masses of all the atoms within each molecule. Add these masses together and you'll come up with the given formula masses. Use these masses to help answer the next question.

37. For this reaction, is there enough oxygen to react with all of the methane? Is there enough methane to react with all of the oxygen? The sure-fire way is to work out how much of one reactant is needed in order for all of the other reactant to be consumed. According to the following calculation, 16 g of $CH_4$, would require 64 g of $O_2$:

(16 g $CH_4$)(1 mole $CH_4$/16 g $CH_4$)(2 moles $O_2$/1 mole $CH_4$)(32 g $O_2$/1 mole $O_2$) = 64 g $O_2$

But there is only 16 g of $O_2$, which means that not all of the $CH_4$ is going to be able to react. How much of the $CH_4$ will react? That can be calculated as follows:

(16 g $O_2$)(1 mole $O_2$/32 g $O_2$)(1 mole $CH_4$/2 mole $O_2$)(16 g $CH_4$/1 mole $CH_4$) = 4 g $CH_4$

The maximum amount of $CO_2$ that can be formed is calculated as follows:

(16 g $O_2$)(1 mole $O_2$/32 g $O_2$)(1 mole $CO_2$/2 mole $O_2$)(44 g $CO_2$/1 mole $CO_2$) = 11 g $CO_2$

39a. Energy to break bonds: Energy released from bond formation:

| | |
|---|---|
| N-N = 159 kJ | |
| N-H = 389 kJ | |
| N-H = 389 kJ | H-H = 436 kJ |
| N-H = 389 kJ | H-H = 436 kJ |
| N-H = 389 kJ | NºN = 946 kJ |
| Total = 1715 kJ absorbed | Total = 1818 kJ released |

NET = 1715 kJ absorbed - 1818 released = -103 kJ released (exothermic)

39b. Energy to break bonds: Energy released from bond formation:

| | |
|---|---|
| O-O = 138 kJ | |
| H-O = 464 kJ | O=O = 498 kJ |
| H-O = 464 kJ | H-O = 464 kJ |
| O-O = 138 kJ | H-O = 464 kJ |
| H-O = 464 kJ | O-H = 464 kJ |
| H-O = 464 kJ | O-H = 464 kJ |
| Total = 2132 kJ absorbed | Total = 2354 kJ released |

NET = 2132 kJ absorbed - 2354 kJ released = -222 kJ released (exothermic)

41. For the reverse reaction, the products become the reactants and the reactants become the products. To calculate the equilibrium constant in such a situation, the products and reactant switch places in the equilibrium constant expression—products are placed in the denominator, while the reactants are placed in the numerator. The equilibrium constant of $3.5 \times 10^8$ therefore transforms into $1/(3.5 \times 10^8)$. = $2.9 \times 10^{-9.}$

43. C < A < B. The endothermic reaction, C, will likely talk place slower than the exothermic reaction, A, because it requires a decrease in entropy. The fastest of these reactions will be B, which has no energy of activation.

45. Contrary to popular opinion, the entropy of a deck of playing cards has nothing to do with it being shuffled or not. Historically there has been a misplaced association between entropy and disorder. But now you know better. Entropy has nothing to do with what our minds perceive as being orderly or disorderly. From the point of view of the molecules within the cards, it makes no difference whether the deck is shuffled or not. Entropy is merely a measure of the tendency of energy to disperse. The greater the difference between the temperature of the cards and the room, the greater the amount of energy that gets dispersed. Thus, in order of increasing entropy: C < A < B. Of course, a burning deck of cards (at 233°C, which is 451°F) would result in an even greater dispersal of energy.

## Challenging Questions

### 9.1 Chemical Equations

47. a) 2,3,1 b) 1,6,4 c) 2,1,2 d) 1,2,1,2

49. Only two diatomic molecules are represented (not three!). These are the two shown in the left box, one of which is also shown in the right box. Remember, the atoms before and after the arrow in a balanced chemical equation are the same atoms only in different arrangements.

51. Equation "d" best describes the reacting chemicals

53. $Fe_2O_3 + 3\ CO \rightarrow 2\ Fe + 3\ CO_2$

55.

Step 1 (Balance Fe): $2\ FeS_2 + O_2 \rightarrow Fe_2O_3 + SO_2$

Step 2 (Balance S): $2\ FeS_2 + O_2 \rightarrow Fe_2O_3 + 4\ SO_2$

Step 3 (Use a fraction to balance O): $2\ FeS_2 + 11/2\ O_2 \rightarrow Fe_2O_3 + 4\ SO_2$

Step 4 (Multiply entire equation by 2): $2\ [2\ FeS_2 + 11/2\ O_2 \rightarrow Fe_2O_3 + 4\ SO_2]$

Step 5 (Equation Balanced): $4\ FeS_2 + 11\ O_2 \rightarrow 2\ Fe_2O_3 + 8\ SO_2$

### 9.2 Measuring Molecules

57. (a) There is one mole of N2 in 28 grams of N2. (b) There is one mole of O2 in 32 grams of O2. (c) There are two moles of CH4 in 32 grams of CH4, (d) There is one mole of F2 in 38 grams of F2

59. A single water molecule has a very small mass of 18 amu.

61. No, because this mass is less than that of a single oxygen atom.

### 9.3 Grams to Moles

63. There are 69.7g of gallium, Ga (atomic mass 69.7 amu) in 145g sample of gallium arsenide, GaAs. Note that 145g is the formula mass for this compound.

65. As the carbon-based fuel combusts it gains mass as it combines with the oxygen from the atmosphere to form carbon dioxide, $CO_2$, which comes out in the exhaust.

**9.4 Exothermic or Endothermic**

67. The chemical reactions within a disposable battery are exothermic as evidenced by as evidenced by the electrical energy they release.

69. The superheated chamber dampens the ability of the energy from the reaction to be dispersed. This, in turn, makes the reaction less favorable. This is one reason why chemists carry out most of their exothermic reactions within a cooled environment, such as within a reaction vessel submerged within an ice bath. Another reason is for safety—they don't want the reaction vessel to explode!

**9.5 Entropy and Chemical Reactions**

71. The entropy change determines whether or not the chemical reaction is favorable. If there is an overall increase in entropy, then the reaction will be favorable, which means that the reaction can proceed on its own. If there is an overall decrease in entropy, then the reaction will only proceed with the help of a continual source of energy, which will necessarily be coming from some entropy increasing process, such as the combustion of a fuel.

73. The solar energy is more readily dispersed by the water molecules in the gaseous phase.

75. A chemical reaction may be favored and proceed on its own, but often there is an energy of activation that must be first overcome. The flammable red chemicals found at the tip of a match are very ready to ignite, but they too need the input of a little bit of energy to overcome their energy of activation. You are providing this when you strike the match against the proper surface. The heat from these burning chemicals then boosts the cellulose molecules in the matchstick to start reacting with the oxygen in the atmosphere. Once a little flame is formed, then bigger flames can form. In other words, once initiated, the burning perpetually kick starts itself and is thus sustainable. Good news for a campfire. Not so good news for a brush or forest fire out of control.

**9.6 Chemical Kinetics**

77. Endothermic reactions require the input of energy, which can include the input of thermal energy. This gives the molecules greater kinetic energy, which can help their collisions to be more effective. The elevated temperature also helps to minimize the unfavorable decrease in entropy due to the heat absorbed by the reaction. Some exothermic reactions are so exothermic that they explode if not run at cold temperatures. The cold temperatures slow the reactive molecules down, which gives the chemist greater control. Also, the heat generated by the reaction is more efficiently dispersed under the colder conditions. This allows for a greater increase in entropy, which helps with the formation of products.

79. In pure oxygen there is a greater concentration of one of the reactants (the oxygen) for the chemical reaction (combustion). As discussed in this chapter, the greater the concentration of reactants, the greater the rate of the reaction.

**9.7 Chemical Catalysts**

81. Photosynthesis produces oxygen, O2, which migrates from the Earth's surface to high up in the stratosphere where it is converted by the energy of ultraviolet light into ozone, O3. Plants and all other organisms living on the planet's surface benefit from this ozone because of its ability to shade the planet's surface from ultraviolet light.

83. Hydrogen chloride, HCl, does not stay in the atmosphere for extended periods of time because this compound is quite soluble in water as can be deduced from its polarity (See Chapter 6). Thus, atmospheric hydrogen chloride mixes in with atmospheric moisture and precipitates with the rain.

### 9.8 Chemical Equilibrium

85. The concentration of products is much higher than the concentration of reactants.

87. Plug these concentrations into the equilibrium constant equation:

$[N_2O_4]/[NO_2][NO_2] = (0.025)/(0.015)(0.015) = 110$

The resulting number is *less* than the equilibrium constant. This tells us that the system is not yet at equilibrium. What would have to happen next? To reach equilibrium the result needs to increase from 110 to 150. This means the numerator must get bigger while the denominator gets smaller. This is to say, the concentration of $N_2O_4$ will be increasing while the concentration of $NO_2$ will be decreasing. This will continue until a steady $K_{eq}$ of 170 is reached.

## Discussion Questions

89. A time-keeping device, such as a clock, requires a source of energy to keep it running. This energy comes from exothermic reactions that occur because of a net increase in universal entropy. This is true for whether the clock is plugged into a power outlet, runs off of a battery, or has solar photovoltaic cells. Even a sundial depends upon the light energy coming from the Sun. A living body can also be a time-keeping device (heart beats, mental counting), but, of course, the living body also requires energy that must come from some net increase in universal entropy. The concepts of time and entropy are intricately connected.

91. The cause of the current mass extinction is the destruction of habitats brought on by the exponential rise of the human population. According to some projections, about 20% of all plant and animal species on Earth will be extinct within the next 25 years. On a geologic time scale, this is faster than the blink of an eye. Creatures that survive will be those that thrive off our wastes or those that don't compete with us directly or indirectly. Of course, there is also the dark possibility that we humans, like proliferating rabbits on an isolated island, might face extinction due to a depletion of resources. In the words of Harvard biologist E.O. Wilson: "If all mankind were to disappear, the world would regenerate back to the rich state of equilibrium that existed ten thousand years ago. If insects were to vanish, the environment would collapse into chaos."