Solutions to the Extra Problems for Chapter 6

1. The temperature is 23.9 °C. We can convert between Fahrenheit and Celsius with Equation (6.1):

$$°F = \frac{9}{5}(°C) + 32$$

Putting in the Fahrenheit temperature:

$$75.0 = \frac{9}{5}(°C) + 32$$

Now we have to use algebra to solve the equation. First, we subtract 32 from both sides:

$$75.0 - 32 = \frac{9}{5}(°C)$$

Then we multiply both sides by 5/9:

$$\frac{5}{9}(75.0 - 32) = °C$$

Since addition and subtraction go by different rules from multiplication and division, we will have to take care of significant figures twice: once after we subtract and then again after we multiply. The 32 is exact, so the precision of 75.0 determines the precision of the answer. It must be reported to the tenths place:

$$\frac{5}{9}(43.0) = °C$$

The 5 and 9 are exact, so the only important number from a significant figures standpoint is 43.0, which has three. Thus, our answer must have three: 23.9 °C.

2. The temperature is 2,590 °F. This requires Equation (6.1):

$$°F = \frac{9}{5}(°C) + 32 = \frac{9}{5}(1{,}420) + 32$$

Since addition and subtraction go by different rules from multiplication and division, we will have to take care of significant figures twice: once after we multiply and again after we add. The 9 and 5 are exact, so 1,420 is the key for significant figures. It has three, so the answer must have three:

$$°F = 2{,}560 + 32$$

Now we are adding, so we go by precision. The 32 is exact, so the only thing that matters is the 2,560. It has its last significant figure in the tens place, so the answer must go to the tens place: 2,590 °F.

3. The lower the temperature, the slower the molecular motion. However, to compare the temperatures, they need to be in the same unit. You can convert either to compare, but Equation (6.1) makes it easier to convert to °F, so that's what I will do:

$$°F = \frac{9}{5}(°C) + 32 = \frac{9}{5}(700.0) + 32 = 1{,}292\ °F$$

That's hotter than 1,115 °F, so the sample at 1,115 °F has molecules that are moving more slowly.

4. In a heating curve, the flat parts represent phase changes. The lower-temperature phase change will be melting, while the higher-temperature one will be boiling. Therefore:

a. It melts at 40 °C, because the first flat portion of the heating curve is at 40 °C.
b. It boils at 160 °C, because the second flat portion of the heating curve is at 160 °C.
c. At 20 °C, the graph is before the first phase change (melting). That means it has not melted yet, so it is solid.

5. a. The balanced equation is $2Al\ (s) + 6HBr\ (l) \rightarrow 2AlBr_3\ (aq) + 3H_2\ (g)$. Hydrogen monobromide has one H and one Br, so it is HBr. For aluminum bromide, Al is in Group 3A, so it becomes 3+ in ionic compounds. Br is in Group 7A, so it becomes 1-. That means aluminum bromide is $AlBr_3$. Hydrogen as an element is a homonuclear diatomic, so it is H_2. The unbalanced equation, then, is:

$$Al\ (s) + HBr\ (l) \rightarrow AlBr_3\ (aq) + H_2\ (g)$$

Atomic Symbol	Number on the reactants side	Number on the products side
Al	1×1 = 1	1×1 = 1
H	1×1 = 1	1×2 = 2
Br	1×1 = 1	1×3 = 3

The Al atoms are balanced, but the H atoms are not. We can fix that:

$$Al\ (s) + \mathbf{2}HBr\ (l) \rightarrow AlBr_3\ (aq) + H_2\ (g)$$

Atomic Symbol	Number on the reactants side	Number on the products side
Al	1×1 = 1	1×1 = 1
H	**2**×1 = 2	1×2 = 2
Br	**2**×1 = 2	1×3 = 3

The easiest way to balance the Br's now is to multiply $AlBr_3$ by 2/3:

$$Al\ (s) + 2HBr\ (l) \rightarrow (\mathbf{2/3})AlBr_3\ (aq) + H_2\ (g)$$

Atomic Symbol	Number on the reactants side	Number on the products side
Al	1×1 = 1	**(2/3)**×1 = 2/3
H	2×1 = 2	1×2 = 2
Br	2×1 = 2	**(2/3)**×3 = 2

But now we have to multiply Al by 2/3:

$$\mathbf{(2/3)}\text{Al (s)} + 2\text{HBr (l)} \rightarrow (2/3)\text{AlBr}_3\text{ (aq)} + \text{H}_2\text{ (g)}$$

Atomic Symbol	Number on the reactants side	Number on the products side
Al	**(2/3)**×1 = 2/3	(2/3)×1 = 2/3
H	**2**×1 = 2	1×2 = 2
Br	**2**×1 = 2	(2/3)×3 = 2

Now everything is balanced, but we have to multiply by 3 to get rid of the fractions:

$$2\text{Al (s)} + 6\text{HBr (l)} \rightarrow 2\text{AlBr}_3\text{ (aq)} + 3\text{H}_2\text{ (g)}$$

b. The balanced equation is $\underline{3KOH + H_3PO_4 \rightarrow 3H_2O + K_3PO_4}$. We already have the unbalanced equation:

$$KOH + H_3PO_4 \rightarrow H_2O + K_3PO_4$$

Atomic Symbol	Number on the reactants side	Number on the products side
K	1×1 = 1	1×3 = 3
O	1×1 + 1×4 = 5	1×1 + 1×4 = 5
H	1×1 + 1×3 = 4	1×2 = 2
P	1×1 = 1	1×1 = 1

We need to balance the K's:

$$\mathbf{3}KOH + H_3PO_4 \rightarrow H_2O + K_3PO_4$$

Atomic Symbol	Number on the reactants side	Number on the products side
K	**3**×1 = 3	1×3 = 3
O	3×1 + 1×4 = 7	1×1 + 1×4 = 5
H	3×1 + 1×3 = 6	1×2 = 2
P	1×1 = 1	1×1 = 1

Normally, we would skip the O's and H's, since they appear multiple times. However, the P's are balanced, so we have to deal with either O or H. We will do H, since it appears fewer times:

$$3KOH + H_3PO_4 \rightarrow \mathbf{3}H_2O + K_3PO_4$$

Atomic Symbol	Number on the reactants side	Number on the products side
K	3×1 = 3	1×3 = 3
O	3×1 + 1×4 = 7	**3**×1 + 1×4 = 7
H	3×1 + 1×3 = 6	**3**×2 = 6
P	1×1 = 1	1×1 = 1

Now everything is balanced.

c. The balanced equation is $SeCl_6 + O_2 \rightarrow SeO_2 + 3Cl_2$.

$$SeCl_6 + O_2 \rightarrow SeO_2 + Cl_2$$

Atomic Symbol	Number on the reactants side	Number on the products side
Se	1×1 = 1	1×1 = 1
Cl	1×6 = 6	1×2 = 2
O	1×2 = 2	1×2 = 2

The only thing we need to do is balance the Cl's:

$$SeCl_6 + O_2 \rightarrow SeO_2 + \mathbf{3}Cl_2$$

Atomic Symbol	Number on the reactants side	Number on the products side
Se	1×1 = 1	1×1 = 1
Cl	1×6 = 6	**3**×2 = 6
O	1×2 = 2	1×2 = 2

Now everything is balanced.

d. The balanced equation is $C_9H_{20} + 14O_2 \rightarrow 9CO_2 + 10H_2O$.

$$C_9H_{20} + O_2 \rightarrow CO_2 + H_2O$$

Atomic Symbol	Number on the reactants side	Number on the products side
C	1×9 = 9	1×1 = 1
H	1×20 = 20	1×2 = 2
O	1×2 = 2	1×2 + 1×1 = 3

Starting with the C's:

$$C_9H_{20} + O_2 \rightarrow \mathbf{9}CO_2 + H_2O$$

Atomic Symbol	Number on the reactants side	Number on the products side
C	1×9 = 9	**9**×1 = 9
H	1×20 = 20	1×2 = 2
O	1×2 = 2	**9**×2 + 1×1 = 19

Moving on to the H's:

$$C_9H_{20} + O_2 \rightarrow 9CO_2 + \mathbf{10}H_2O$$

Atomic Symbol	Number on the reactants side	Number on the products side
C	1×9 = 9	9×1 = 9
H	1×20 = 20	**10**×2 = 20
O	1×2 = 2	9×2 + **10**×1 = 28

Now the O's:

$$C_9H_{20} + \mathbf{14}O_2 \rightarrow 9CO_2 + 10H_2O$$

Atomic Symbol	Number on the reactants side	Number on the products side
C	1×9 = 9	9×1 = 9
H	1×20 = 20	10×2 = 20
O	14×2 = 28	9×2 + 10×1 = 28

e. The balanced equation is Fe_2O_3 (s) + 3CO (g) → 2Fe (s) + 3CO_2 (g). Iron (III) oxide means iron is in the 3+ state. Oxygen is in Group 6A, so it takes on a 2- charge in ionic compounds, making iron (III) oxide Fe_2O_3. Carbon monoxide is CO, and carbon dioxide is CO_2. That means the unbalanced equation is:

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

Atomic Symbol	Number on the reactants side	Number on the products side
Fe	1×2 = 2	1×1 = 1
O	1×3 + 1×1 = 4	1×2 = 2
C	1×1 = 1	1×1 = 1

Balancing the Fe's is easy:

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

Atomic Symbol	Number on the reactants side	Number on the products side
Fe	1×2 = 2	2×1 = 2
O	1×3 + 1×1 = 4	1×2 = 2
C	1×1 = 1	1×1 = 1

Now it becomes difficult. The C's are balanced, but the O's are not. You might try balancing the O's this way:

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

Atomic Symbol	Number on the reactants side	Number on the products side
Fe	1×2 = 2	2×1 = 2
O	1×3 + 1×1 = 4	2×2 = 4
C	1×1 = 1	2×1 = 2

Now the O's are balanced, but the C's aren't. I don't want to mess with the Fe's, because they have been balanced already. So let's just try playing with the C's and O's. I need more C's on the reactants side, so let's just multiply CO by 2:

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

Atomic Symbol	Number on the reactants side	Number on the products side
Fe	1×2 = 2	2×1 = 2
O	1×3 + 2×1 = 5	2×2 = 4
C	2×1 = 2	2×1 = 2

The C's are balanced again, but now I need more O's on the products side. Let's make more O's:

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

Atomic Symbol	Number on the reactants side	Number on the products side
Fe	1×2 = 2	2×1 = 2
O	1×3 + 1×2 = 5	**3**×2 = 6
C	1×2 = 2	**3**×1 = 3

What good did that do? Look what happens when I now make more C's and O's on the reactants side:

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

Atomic Symbol	Number on the reactants side	Number on the products side
Fe	1×2 = 2	2×1 = 2
O	1×3 + **3**×1 = 6	2×3 = 6
C	**3**×1 = 3	3×1 = 3

Now everything is balanced. Sometimes, this kind of trial and error is the only way to balance these reactions.

6. a. The balanced equation is $\underline{2Na\ +\ N_2\ +\ 3O_2\ \rightarrow\ 2NaNO_3}$. A formation reaction forms the compound from its elements. $NaNO_3$ has the elements sodium, nitrogen, and oxygen. Remember, however, that oxygen and nitrogen are homonuclear diatomics:

$$Na\ +\ N_2\ +\ O_2\ \rightarrow\ NaNO_3$$

Atomic Symbol	Number on the reactants side	Number on the products side
Na	1×1 = 1	1×1 = 1
N	1×2 = 2	1×1 = 1
O	1×2 = 2	1×3 = 3

The easiest way to balance the N's without upsetting the Na's is to multiply N_2 by 1/2:

$$Na\ +\ \mathbf{(1/2)}N_2\ +\ O_2\ \rightarrow\ NaNO_3$$

Atomic Symbol	Number on the reactants side	Number on the products side
Na	1×1 = 1	1×1 = 1
N	**(1/2)**×2 = 1	1×1 = 1
O	1×2 = 2	1×3 = 3

The easiest way to balance the O's is to multiply O_2 by 3/2:

$$Na\ +\ (1/2)N_2\ +\ \mathbf{(3/2)}O_2\ \rightarrow\ NaNO_3$$

Atomic Symbol	Number on the reactants side	Number on the products side
Na	1×1 = 1	1×1 = 1
N	(1/2)×2 = 1	1×1 = 1
O	**(3/2)**×2 = 3	1×3 = 3

Now we just multiply by 2 to get rid of the fractions:

$$2Na + N_2 + 3O_2 \rightarrow 2NaNO_3$$

b. The balanced equation is $\underline{2C_3H_8O \rightarrow 6C + 8H_2 + O_2}$. Decomposition means starting with the compound (C_3H_8O) and producing its elements – carbon, hydrogen, and oxygen. We have to remember that hydrogen and oxygen are homonuclear diatomics.

$$C_3H_8O \rightarrow C + H_2 + O_2$$

Atomic Symbol	Number on the reactants side	Number on the products side
C	1×3 = 3	1×1 = 1
H	1×8 = 8	1×2 = 2
O	1×1 = 1	1×2 = 2

Balancing the C's:

$$C_3H_8O \rightarrow \mathbf{3}C + H_2 + O_2$$

Atomic Symbol	Number on the reactants side	Number on the products side
C	1×3 = 3	**3**×1 = 3
H	1×8 = 8	1×2 = 2
O	1×1 = 1	1×2 = 2

Balancing the H's:

$$C_3H_8O \rightarrow 3C + \mathbf{4}H_2 + O_2$$

Atomic Symbol	Number on the reactants side	Number on the products side
C	1×3 = 3	3×1 = 3
H	1×8 = 8	**4**×2 = 8
O	1×1 = 1	1×2 = 2

Balancing the O's:

$$C_3H_8O \rightarrow 3C + 4H_2 + \mathbf{(1/2)}O_2$$

Atomic Symbol	Number on the reactants side	Number on the products side
C	1×3 = 3	3×1 = 3
H	1×8 = 8	4×2 = 8
O	1×1 = 1	**(1/2)**×2 = 1

Now just multiply by 2 to get rid of the fraction:

$$2C_3H_8O \rightarrow 6C + 8H_2 + O_2$$

c. The balanced equation is $\underline{2C_3H_8O\ (g) + 9O_2\ (g) \rightarrow 6CO_2\ (g) + 8H_2O\ (g)}$. Complete combustion means reacting the fuel (C_3H_8O) with oxygen (a homonuclear diatomic) to get carbon dioxide and water. Remember that the carbon dioxide and water are gases, as is oxygen. The problem tells us that the fuel is a gas, so the unbalanced equation is:

$$C_3H_8O\ (g) + O_2\ (g) \rightarrow CO_2\ (g) + H_2O\ (g)$$

Atomic Symbol	Number on the reactants side	Number on the products side
C	1×3 = 3	1×1 = 1
H	1×8 = 8	1×2 = 2
O	1×1 + 1×2 = 3	1×2 + 1×1= 3

To balance the C atoms, we must multiply CO_2 by 3:

$$C_3H_8O\ (g) + O_2\ (g) \rightarrow \mathbf{3}CO_2\ (g) + H_2O\ (g)$$

Atomic Symbol	Number on the reactants side	Number on the products side
C	1×3 = 3	**3**×1 = 3
H	1×8 = 8	1×2 = 2
O	1×1 + 1×2 = 3	**3**×2 + 1×1= 7

Now we balance the H's:

$$C_3H_8O\ (g) + O_2\ (g) \rightarrow 3CO_2\ (g) + \mathbf{4}H_2O\ (g)$$

Atomic Symbol	Number on the reactants side	Number on the products side
C	1×3 = 3	3×1 = 3
H	1×8 = 8	**4**×2 = 8
O	1×1 + 1×2 = 3	3×2 + **4**×1= 10

To balance the O's, we don't want to mess with C_3H_8O, since that will throw off the C's and H's. To get 10 O's on the reactants side, then, we need 9 of them to come from O_2:

$$C_3H_8O\ (g) + \mathbf{(9/2)}O_2\ (g) \rightarrow 3CO_2\ (g) + 4H_2O\ (g)$$

Atomic Symbol	Number on the reactants side	Number on the products side
C	1×3 = 3	3×1 = 3
H	1×8 = 8	4×2 = 8
O	1×1 + **(9/2)**×2 = 10	3×2 + 4×1= 10

Now we just multiply by 2 to get rid of the fraction:

$$2C_3H_8O\ (g) + 9O_2\ (g) \rightarrow 6CO_2\ (g) + 8H_2O\ (g)$$

7. a. The Cl's move from the Cu to the Mg, so it is a single displacement reaction.

b. This takes elements and makes a compound, so it is a formation reaction.

c. The Ag and Na change places, so this is a double displacement reaction.

d. This takes a compound and adds oxygen to it, so it is a kind of combustion reaction. However, CO_2 is not made. Instead, it is CO. That makes this an incomplete combustion reaction.

e. This starts with a single compound and makes elements, so it is a decomposition reaction.