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Chapter 2 Exercises

Exercises #1:

1. What is the *law of conservation of mass?*

2. Show that the results of the following experiments illustrate the *law of conservation of mass*.

   Experiment #1: a 5.00-g sample of pure calcium carbonate is heated and decomposed, which produces 2.80 g calcium oxide and 2.20 g carbon dioxide.
   Experiment #2: 1.00 g of pure calcium oxide is reacted with 2.00 g carbon dioxide and the result shows that 1.78 g calcium carbonate is formed and 1.22 g of carbon dioxide is unreacted.
   Experiment #3: 2.00 g of pure calcium oxide is reacted with 1.00 g carbon dioxide and the result shows that 2.27 g of calcium carbonate is formed and 0.73 g carbon dioxide is unreacted.

3. In an experiment, a 25.0-g sample of mercury is reacted with 5.0 g of oxygen. At the end of the reaction 6.2 g of mercury and 3.5 g of oxygen were found unreacted. According to the *law of conservation of mass*, how many grams of mercury oxide are formed? (Assume mercury oxide in the only product in this reaction.)

4. What is the *law of constant composition* (also known as the *law of definite proportion*)?

5. Three samples of pure sodium carbonate obtained from various sources were analyzed for the elemental compositions. Show that the results illustrate the *law of constant* (*fixed*) *composition* (within experimental error)
   Sample-1 contains 1.95 g Sodium, 0.51 g Carbon, and 2.04 g Oxygen.
   Sample-2 contains 1.52 g Sodium, 0.40 g Carbon, and 1.58 g Oxygen.
   Sample-3 yields 1.30 g Sodium, 0.34 g Carbon, and 1.36 g Oxygen.

6. Three samples, X, Y, and Z, were analyzed for their elemental compositions. Sample X is found to contain 1.00 g Calcium, 0.30 g Carbon, and 1.20 g Oxygen. Sample Y contains 1.41 g Calcium, 0.84 g Carbon, and 2.25 g Oxygen. Sample Z contains 1.60 g Calcium, 0.48 g Carbon, and 1.92 g Oxygen. Determine whether X, Y, and Z are samples of the same compound, they are samples of different compounds, or only two of them belong to the same compound.

7. What is the *law of multiple proportions*?

8. Suppose that three different compounds composed of only nitrogen and oxygen were analyzed and the following masses of oxygen were found to have combined with 1.000 g of nitrogen:

	Oxygen of Oxygen
Compound-A	0.571 g
Compound-B	1.144 g
Compound-C	2.286 g

(a) Show that this data is consistent with the law of multiple proportions.

(b) If compound-B has the formula NO, what are the formulas of compounds A and C?

9. Reactions between chromium and oxygen yield two different products with the following compositions (by mass percent):

Compound-A: 76.47% Chromium and 23.53% Oxygen;
Compound-B: 68.42% Chromium and 31.58% Oxygen.

(a) Show that the above data support the *law of multiple proportions*.
(b) Derive simple formula for compounds A and B based on this data.

10. The following data illustrate Gay-Lussac law of combining volume, which indicate volume relationships between gaseous reactants and products under identical conditions obtained for reactions between nitrogen and oxygen gases.

(*i*) 2 L of nitrogen gas react with 1 L of oxygen gas to yield 2 L of compound-I
(*ii*) 1 L of nitrogen gas reacts with 1 L of oxygen gas to yield 2 L of compound-II.
(*iii*) 1 L of nitrogen gas reacts with 2 L of oxygen gas to yield 2 L of compound-III.

Derive the formula of each compound formed in the above reactions and write their chemical equations.

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Exercises #2:

1. The following are statements in Dalton's atomic theory:

   (*i*) Each element is made up of tiny particles called atoms.
   (*ii*) Atoms cannot be created or destroyed.
   (*iii*) The atoms of a given element are identical; the atoms of different elements are different.
   (*iv*) Chemical compounds are formed when atoms of different elements combine with each other. A given compound always has the same relative numbers and types of atoms.
   (*v*) Chemical reactions involve re-organization of the atoms – changes in the way they are bound together. The atoms themselves are not changed in a chemical reaction.

   _____

   (a) Which Dalton's statement(s) explain the *law of conservation of mass*?

   (b) Which Dalton's statement(s) explain the *law of constant composition*?

   (c) Which Dalton's statement is no longer true in its stated form? Why?

2. What are the fundamental characteristics of cathode-rays?

3. Describe briefly the Thomson's "plum-pudding" model and Rutherford's nuclear model of an atom.

4. Robert Millikan performed the "oil-drop" experiments, which enable him to calculate the charge of an electron? Suppose that 6 oil drops were analyzed and the following charges were measured:

Oil drop #	1	2	3	4	5	6
Charge (C x 10^{-19})	6.4	8.0	9.6	14.4	19.2	25.6

   Using this data, calculate the magnitude of electron's charge.

   (Answer: 1.6 x 10^{-19} C)

5. In a neutral atom, which two sub-atomic particles must always be equal in numbers? In what parts of the atom are these two sub-atomic particles found?

6. The number of which sub-atomic particles determines the identity of the atom?

7. The number of which sub-atomic particles distinguishes the different isotopes of an element?

8. What information is provided by the mass number A and atomic number Z in the symbol ${}^{A}_{Z}X$?

9. Write the symbols of isotopes that contain the following:

(a) 10 protons, 10 neutrons, and 10 electrons.

(b) 12 protons, 13 neutrons, and 10 electrons.

(c) 15 protons, 16 neutrons, and 15 electrons.

(d) 17 protons, 18 neutrons, and 18 electrons.

(e) 24 protons, 28 neutrons, and 21 electrons.

10. Indicate the number of protons, neutrons, and electrons in each isotope with the following symbols.

(a) ${}^{60}_{28}\mathrm{Ni}$:

(b) ${}^{239}_{94}\mathrm{Pu}^{4+}$:

(c) ${}^{79}_{34}\mathrm{Se}^{2-}$:

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Exercises #3:

1. Write formulas for the following compounds or polyatomic ions:

(a) Nitrate ion:_____: (b) Aluminum nitrate:_____

(c) Carbonate ion:_____; (d) Magnesium carbonate: _____

(e) Calcium Sulfate:_____; (f) Hydrogen phosphate ion:_____

(g) Acetate ion:_____; (h) Lead(II) acetate: _____

(*i*) Mercury(I) nitrate:_____: (j) Sodium hydrogen carbonate: _____

2. Name the following compounds or give the name of each polyatomic ion in this list:

(a) Al_2O_3:_____; (b) CrO_4^{2-} :_____

(c) Cu_2S:_____; (d) KH_2PO_4:_____;

(e) N_2O_5:_____; (f) $Cr_2O_7^{2-}$:_____;

(g) SiF_6:_____; (h) ClO_4^-: _____

(*i*) $KClO_3$:_____; (j) HNO_3:_____

(*k*) H_3PO_4:_____; (*l*) $HC_2H_3O_2$:_____

(m) $HCN_{(aq)}$: _____; (n) MnO_4^-:_____

3. Write the formula of the following compounds:

(a) Perchloric acid: _____; (b) Hydrosulfuric acid: _____

(c) Hydrobromic acid: _____; (d) Bromous acid:_____

(e) Sulfuric acid: _____; (f) Acetic acid:_____

(g) Dinitrogen tetroxide:_____; (h) Phosphorus pentachloride:_____

(*i*) Nickel(II) nitrate:_____; (j) Cobalt(II) chloride hexahydrate:_____:

(k) Titanium(IV) oxide:_____; (*l*) Iron(III) sulfate pentahydrate: _____;

4. Combine the following pairs of ions to form the correct formulas of the compounds and give their names.

Cations	Anions	Compound's Formula	Compound's Name
Ag^{+}	Br^{-}	_____	_____
Al^{3+}	SO_4^{2-}	_____	_____
Ba^{2+}	OH^{-}	_____	_____
Ca^{2+}	ClO^{-}	_____	_____
Cr^{3+}	NO_3^{-}	_____	_____
Cu^{+}	S^{2-}	_____	_____
Fe^{3+}	O^{2-}	_____	_____
Hg_2^{2+}	Cl^{-}	_____	_____
K^{+}	MnO_4^{-}	_____	_____
Li^{+}	CO_3^{2-}	_____	_____
Mg^{2+}	N^{3-}	_____	_____
Na^{+}	HPO_4^{2-}	_____	_____
Na^{+}	$Cr_2O_7^{2-}$	_____	_____
NH_4^{+}	PO_4^{3-}	_____	_____
Pb^{2+}	$C_2H_3O_2^{-}$	_____	_____
Sn^{4+}	O^{2-}	_____	_____
Zn^{2+}	$C_2O_4^{2-}$	_____	_____

Answers:

Exercise #1:

1. In a chemical reaction, the total mass of substances before and after reaction remains constant; they may appear in different forms.

2. #1: 5.00 g = 2.80 g + 2.20 g;
   #2: 1.00 g + 2.00 g = 1.78 g + 1.22 g;
   #3: 2.00 g + 1.00 g = 2.27 g + 0.73 g.
   (For each experiment, the total mass after the reaction is equal to that before the reaction. So, mass is conserved.)

3. Mass of mercury oxide = **20.3 g**

4. A given compound has a fix composition regardless of its origin;

5. Sample-1: Na = 43.3%; C = 11%; O = 45.3%;
   Sample-2: Na = 43.4%; C = 11%; O = 45.1%;
   Sample-3: Na = 43.3%; C = 11%; O = 45.3%.
   Samples 1, 2 and 3 are the same compound.

6. Sample-X: Ca = 40.0%; C = 12%; O = 48.0%
   Sample-Y: Ca = 31.3%; C = 19%; O = 50.0%;
   Sampale-Z: Ca = 40.0%; C = 12%; O = 48.0%
   X and Z are same compound, but Y is a different compound.

7. If two elements form more than one compounds, and if we fix the mass of one of the elements in all the compounds, the masss of the second element in all the compounds show simple whole number ratio, such as 1:2, 1:3, 2:3, 3:4, 3:5, etc.

8. Determine the ratios of masses of oxygen in A, B and C, which yields 1:2:4. Simple ratios illustrate the *Law of Multiple Proportion*.
   (b) Formula: if B = NO, then A = N_2O, and C = NO_2.

9. (a) First fix the Cr content in A and B, and then determine the ratio of mass of oxygen in A and B, such that B/A = 3/2 (a simple, whole number ratio), which illustrates the *law of multiple proportions*;
   (b) Formula: if A = CrO, B = $CrO_{1.5}$ (incorrect formula) = Cr_2O_3 (correct formula)

10. Using the concept that equal volumes of gases at same temperature and pressure contain the same numbers of molecules, we can use volume ratios as molecular ratios. This yields the following equations:
    (*i*) $2\ N_2 + O_2 \rightarrow 2N_2O$; (*ii*) $N_2 + O_2 \rightarrow 2NO$; (*iii*) $N_2 + 2\ O_2 \rightarrow 2NO_2$.

Exercise #2:

1. (a) statements *i*, *ii*, and *v*; (b) statements *i*, *ii*, and *iv*; (c) statements *ii* and *iii*.
2. (read lecture note)
3. (read lecture note)
4. Find a common denominator that represents the charge of one electrons, which yields 1.6×10^{-19} C.
5. There must be same number of protons and electrons in a neutral atom; proton is in nucleus and electron is outside nucleus.

6. The number of proton, called the "atomic number" (Z), represents the identity of the element.
7. Different isotopes of a given element have different number of neutrons in the atoms.
8. A = # of protons + # of neutron; Z = # of protons. (# of neutrons = A – Z)
9. (a) $^{20}_{10}Ne$ (b) $^{25}_{12}Mg$ (c) $^{31}_{15}P$ (d) $^{35}_{17}Cl^{-}$ (e) $^{52}_{24}Cr^{3+}$
10. (a) 28 p, 32 n, and 28 e; (b) 94 p, 145 n, and 90 e; (c) 34 p, 45 n, and 36 e.

Exercise #3

1. (a) NO_3^- (b) $Al(NO_3)_3$ (c) CO_3^{2-} (d) $MgCO_3$ (e) $CaSO_4$
   (f) HPO_4^{2-} (g) $C_2H_3O_2^-$ (h) $Pb(C_2H_5O_2)_2$ (*i*) Hg_2Cl_2 (j) $NaHCO_3$

2. (a) Aluminum oxide (b) Chromate ion (c) Copper(I) sulfide
   (d) Potassium dihydrogen phosphate (e) dinitrogen pentoxide (f) Dichromate ion
   (g) Sulfur hexafluoride (h) Perchlorate ion (*i*) Potassium chlorate
   (j) Nitric acid (k) Phosphoric acid (*l*) Acetic acid
   (m) Hydrocyanic acid (n) Permanganate ion

3. (a) $HClO_4$ (b) H_2S (c) HBr (d) $HBrO_2$ (e) H_2SO_4 (f) $HC_2H_3O_2$
   (g) N_2O_4 (h) PCl_5 (*i*) $Ni(OH)_2$ (j) $CoCl_2 \cdot 6H_2O$ (k) TiO_2 (*l*) $Fe_2(SO_4)_3 \cdot 5H_2O$

4. AgBr = Silver bromide
   $Ba(OH)_2$ = barium hydroxide
   $Cr(NO_3)_3$ = Chromium(III) nitrate
   Fe_2O_3 = Iron(III) oxide
   $KMnO_4$ = Potassium permanganate
   Mg_3N_2 = Magnesium nitride
   $Na_2Cr_2O_7$ = Sodium dichromate
   $Pb(C_2H_3O_2)_2$ = lead(II) acetate
   ZnC_2O_4 = Zinc oxalate
   $Al_2(SO_4)_3$ = Aluminum sulfate
   $Ca(ClO)_2$ = calcium hypochlorite
   Cu_2S = Copper(I) sulfide
   Hg_2Cl_2 = Mercury(I) chloride
   Li_2CO_3 = Lithium carbonate
   NaH_2PO_4 = Sodium dihydrogen phosphate
   $(NH_4)_3PO_4$ = Ammonium phosphate
   SnO_2 = Tin(IV) oxide