Concepts of Physics: Homework 2

Due: 7 September 2022

1 Mass ratios in compounds

The mass of a single oxygen atom is 16 time the mass of a single hydrogen atom. The mass of a single carbon atom is 12 times that of a single hydrogen atom. Therefore the mass of a single carbon atom is 3/4 times that of a single oxygen atom.

a) Some hydrogen peroxide (H_2O_2) is decomposed into hydrogen and oxygen, producing 3 lb of hydrogen. What is the mass of the oxygen produced? Explain your answer.

b) Some carbon monoxide (CO) is decomposed into carbon and oxygen, producing 12 lb of oxygen. What is the mass of the carbon produced? Explain your answer.

c) Some methane (CH_4) is decomposed into carbon and hydrogen, producing producing 8 lb of hydrogen. What is the mass of the carbon produced? Explain your answer.

2 Composition of water

Water can be decomposed (by a process called electrolysis) into hydrogen gas and oxygen gas. Conversely, combining only hydrogen and oxygen produces water. These observations indicate that a water molecule consists of hydrogen and oxygen atoms. The issue is the way in which the two types of atoms combine to produce water. One possibility would be that one atom of hydrogen (H) and one atom of oxygen (O) combine to produce the molecule H_2O_2. Alternatively two atoms of hydrogen (H) and one atom of oxygen (O) combine to produce the molecule H_2O. The issue is to determine which of this is possibly correct. Suppose that are able to decompose water into hydrogen gas and oxygen gas and that you can capture all of these gases that are produced. Knowing that the mass of an oxygen atom is 16 times that of an hydrogen atom, describe how you could determine which of the two types of molecules (H_2O_2 or H_2O) represents water. Your answer must include a description of *what you do to the water, what you would measure, and how the results of these measurements would tell you which type of molecule is correct.*

3 Hobson, *Physics, Concepts and Connections, 5ed*, Ch. 2 Review Question 2, page 51. This is asking for a phenomena that can be observed using light either with the naked eye or else some sort of optical microscope.

4 Microscopic description of air pressure

Air pressure, such as that which you measure for your car tires is a *macroscopic* quantity that has an explanation in terms of the *microscopic* picture of the gas as a collection of atoms. This exercise is intended to enable you to provide the connection between the microscopic and macroscopic pictures.

To answer these questions you will have to access the animation "Gas Properties" provided by the PhET group at the University of Colorado. The animation is available at:

https://phet.colorado.edu/sims/html/gas-properties/latest/gas-properties_en.html

The animation has several options, listed in the opening window or at the bottom. Select the tab labeled "Ideal." Most of this animation can be controlled using the panel on the right. The reset button at the bottom removes all the molecules. A given number of molecules can be supplied by opening the "Particles" tab and adjusting "Heavy". In this exercise you will need to keep the temperature constant. To do so, after you have added molecules, select "Temperature" from the "Hold Constant" section - this must be set throughout the exercise.

a) Supply 100 heavy species molecules and observe the temperature ("K" means Kelvin, a scientific unit of temperature) and pressure ("Atm" means atmospheres, a unit of pressure). When these have settled, note the numbers. Now reset and inject 200 heavy species molecules. How do the temperatures and the pressures compare in the two cases (same, larger, smaller)?

b) To explain the change in pressure consider reducing the number of molecules. Reset and inject 5 heavy species molecules and observe their collisions with the left wall (the collisions between particles are irrelevant). Do the same with 20 heavy species molecules. How do the typical speeds with which the molecules move for the "5" and "20" cases compare (same, larger, smaller)? How do the speeds with which they hit the wall compare (same, larger, smaller)? How do the frequencies with which they collide with the wall (number of collisions in a set time period) compare (same, larger, smaller)?

c) The pressure is related the typical speed with which the molecules collide with the wall *and* how frequently they collide. Specifically, as either of these increases, the pressure increases (this is a *microscopic description of pressure*). Is this consistent with your observations from the previous part?

d) Reset and inject 100 molecules. Note the pressure. Now move the left wall inward. How does the pressure compare after this adjustment to before (same, larger, smaller)? Describe why this occurred using the microscopic description of pressure.

5 Heating air

A bottle is filled with air and then sealed. Does the pressure of the air inside increase, decrease or stay the same if heat is added to the bottle? Explain your answer in terms of the motion of the air molecules.

6 Multiplication and division with powers of ten

The usefulness of powers of ten is illustrated via an example on page 38 of Hobson, *Physics: Concepts and Connections.* The aim of this exercise is to follow that method. Consider the numbers 534 and 165.

a) Multiply 534 and 165, using your calculator.

b) Express each of 534 and 165 in the form: number $\times 10^2$ where, in each case, the number is a decimal number.

c) Use the method of multiplying with powers of ten to multiply 534 and 165 and check that your answer is the same as that of part (a).

d) Divide 5340 by 1335, using your calculator.

e) Use the method of dividing with powers of ten to divide 5340 by 1335 and check that your answer is the same as that of part (d).

7 Hobson, *Physics, Concepts and Connections, 5ed*, Ch. 2. Conceptual Exercise 32, page 52.

8 Estimating number of atoms

A bacterium has width approximately 1.0 micrometer $= 1.0 \times 10^{-6}$ m. An atom has width approximately 10^{-9}m. Estimate the number of atoms that span the width of the bacterium. Explain your answer.

9 Reading exercise: Galileo's thought experiments

Read section 3.2 on pages 55-57. This series of exercises offers examples and exercises that you could construct to check that you understand the content of the text correctly. The questions focus on the thought experiments involving balls sliding along ramps conducted by Galileo.

a) Galileo considered three experiments involving balls sliding on ramps. Describe the three experiments and the differences between them.

b) What idealization about the balls and ramps did Galileo make in order to simplify his thinking? According to him, what did this imply about the motion of a ball rolling along a horizontal surface?

c) What was different about Galileo's prediction (for the ball sliding along the horizontal surface) and that made according to Aristotle's theory?

d) Do Conceptual Exercise 1 on page 68. Check whether your answer agrees with the solution offered in the back of the text.