PHYSICS 1020

Homework set 2

28 August 1996

[2.1] Is the atomic theory known, for certain, to be true?
Answer:
No; a theory, as all scientific principles, is never certain. It is permanently subject to testing and experimental verification. Even if a theory is found to agree with all of the available observational data, and all of its predictions have been found to be "correct", i.e. borne out by all observations until today, it my yet be disproved by tomorrow's more precise observations. It is, in fact, the attempt to disprove the existing theories which is the purpose of most scientific experimentation.

[2.2] Carbon atoms are about 25% lighter than oxygen atoms (the ratio of their weights is 3 to 4). What is the weight ratio of the carbon and oxygen that go into the formation of carbon monoxide? Answer the same question for carbon dioxide.
Answer:
Carbon monxyde has the chemical composition CO, i.e. there is one carbon atom for every oxygen atom; therefore the weight ratio of carbon to oxygen in this compound is just the weight ratio of the atoms, i.e. 3 to 4. In carbon dioxide, CO_2, there are two oxyen atoms per carbon atom, so the carbon to oxygen weight ratio in carbon dioxide is 3 to 8.

[2.4] Which of these is a pure *compound*, which is an *element*, and which is neither: (a) pure water, (b) oxygen gas, (c) liquid mercury, (d) H_2SO_4, (e) U, (f) air,
(g) He, (h) carbon dioxide, (i) H_2, (j) polluted water?
Answer:

- **(a)** pure water is a pure *compound* (H_2O)
- **(b)** oxygen gas is a pure *element* (O_2)
- **(c)** liquid mercury is a pure *element* (Hg)
- **(d)** H_2SO_4 (sulphuric acid) is a pure *compound*
- **(e)** U (Uranium) is a pure *element*
- **(f)** air is a *mixture* of gases (elements and compounds): oxygen, nitrogen, carbon dioxide, water vapor, argon, and others
- **(g)** He (Helium) is a pure *element* – a "noble gas"
- **(h)** carbon dioxide is a pure *compound* (CO_2)
- **(i)** H_2 is a pure *element* – hydrogen
- **(j)** polluted water is a *mixture* of many things

[2.6] Helium is an inert gas, meaning that it does not readily enter into chemical reactions with other substances. List five other substances that you would expect to also be inert gases.
Answer:
All the elements in the same column in the periodic table ("in the same group") have similar chemical properties. Therefore we expect all the elements in the same group as Helium to share the poperty of being chemically inert. These elements are the "noble gases" helium, neon, argon, krypton, xenon, radon.

[2.8] In a typical large coal-fed electrical generating plant, a ton of coal is burned every ten seconds. About how many tons of carbon dioxide enter the atmosphere every hour from such a plant?

Answer:

Let's assume (as in exercise 2.7) that coal is nearly pure carbon, and that oxygen and carbon have the same weight. Since one ton of coal (i.e. carbon) is burned every ten seconds, 3 tons of carbon dioxide (CO_2) enter the atmosphere every ten seconds. One hour (3600 seconds) has 360 ten-second intervals, and thus the total amount of carbon dioxide emitted into the atmosphere per hour = 360 times 3 = 1080 tons. Using the correct mass ratio (3:4) between carbon and oxygen, one finds that the total mass of carbon dioxide is (4+4+3)/3 times that of carbon. Therefore the total amount of carbon dioxide emitted per hour = (11/3) times 360 = 1320 tons.

[2.14] If air is put into a sealed container that is then compressed (reduced in volume) what do you predict will happen to the air pressure on the container walls? Explain this from a microscopic view.

Answer:

Reducing the volume will increase the density, i.e. the number of molecules per unit volume will increase. In other words, the space available for each molecule's motion will be smaller than before. As a consequence, the number of collisions per unit time of molecules with the container wall will be higher then before. Since pressure is due to the force exerted by the molecules due to their collisions with the walls, an increased number of collisions will appear as higher pressure.

[2.15] If air is put into a sealed container and heated, what do you predict will happen to the air pressure on the container walls? Explain this from a microscopic view.

Answer:

Heating the air in the container will increase the average kinetic energy of random motion of the gas molecules in the container. As a consequence they will hit the container walls with higher speeds; this will appear as increased pressure.

[2.21] Making estimates: The smallest dust particle visible to the unaided human eye measures about 0.05 mm across. About how many atoms across is this – in other words, if we line up atoms side by side, about how many would it take to make a line of atoms 0.05 mm long?

Answer:

The diameter of an atom is about 10^{-10}m, and the dust particle measures 0.05 mm = 5×10^{-5}m across. Therefore the number of atoms needed to be lined up to make a length equal to the lenght of the dust particle is

$$\frac{5 \times 10^{-5}\text{m}}{10^{-10}\text{m}} = 5 \times 10^{5} = 500000.$$

It takes half a million atoms.

[**2.22**] Making estimates: Referring to the preceding exercise: Assume the small dust particle is shaped like a cube. About how many atoms does it contain?
Answer:
There are 5×10^5 atoms across each of the three sides (dimensions) of the cube. The volume of a cube = the "cube" (i.e. the third power) of the length of its side. Therefore the number of atoms in the cube is equal to the third power ("cube") of the number of atoms across one side, i.e.

$$= (5 \times 10^5)^3 = 5^3 \times 10^{5\times3} = 125 \times 10^{15} = 1.25 \times 10^{17}$$

[**2.25**] Gasoline is a hydrocarbon fuel. What are the main compounds created when gasoline burns in a car engine?
Answer:
A hydrocarbon is a compound consisting essentially of hydrogen H and carbon C. Burning means forming a new compound with oxygen. The compounds formed will be water and carbon dioxide (H_2O and CO_2).