So it was that the young scientist (Gay-Lussac) at the age of twenty-five received an offer to share with Berthollet, without cost, the equipment and laboratory space at Arcueil near Paris. He was to select a few others with whom to work. Berthollet would be working on problems in chemistry, but the others might take any problems in science that they wished. Gay-Lussac accepted gladly and remained at Arcueil for four years, working on the laws that governed gases. He had started with the problem of determining the increase of pressure needed to keep a gas being warmed from expanding. He had later repeated the experiment of Cavendish in which it was shown that exactly two volumes of hydrogen united with one volume of oxygen in forming water. "Are gases so constituted that a whole-number of pints of one kind of gas will unite always with a whole-number of pints of another kind of gas?" How strange that would be, If true-but how interesting! He wanted to try some other gases that combined with one another, to get their combining volumes. But he bad to make ready to leave Arcueil. Times were changing; he was needed again in the classroom. Perhaps with his teaching he could combine work in his own private laboratory; perhaps his assistants in the laboratory could be selected from members of his own classes. He was already wondering what experiments to perform in his lectures that would make chemistry more vital and thrilling. Dreaming of the future, he stepped into a linen draper's shop in Paris to get a linen kerchief. He was waited upon by a young lady of seventeen, who put down a book she had been reading. He asked about its title. It was a brief treatise on chemistry, giving some of the new ideas of the times. Was it interesting? Yes, very interesting, but parts were hard to understand. He suggested that possibly he could be of aid. After that he found numerous excuses for more visits at the shop, then at her home. She went back to school for a few extra courses. Then Gay-Lussac and Josephine were married. The young scientist was a great success as a teacher and as a trainer of scientists. At the age of thirty-one he was made professor of chemistry at his old school and lecturer in physics at the Sorbonne. At fifty-four he became professor of chemistry at the Jardin des Plantes. He also was soon given the additional position of assayer at the French mint, a work for which he devised a wholly new and rapid chemical plan for testing metal purity. He acted, too, as a consultant for industrial problems involving gases.

In 1808, the year that Dalton announced in full his atomic theory, Gay-Lussac reported the completion of a series of experiments on the combining volumes of gases. Several reactions had been used, a number of various gases studied. The results were strangely simple: When gases combine in a chemical way they always do so in an exact whole-number relation by volume; when gases are formed by a chemical change they are produced in an exact whole-number relation by volume. This was a law of nature. The combination of two pints of hydrogen gas with exactly one pint of oxygen gas was not, then, to be counted as something highly exceptional. It was in the nature of gases that they behaved in this whole-number way.

Avogadro's Hypothesis

Gay-Lussac's Law of Combining Gases was published in 1808. In 1811 an article by Amedeo Avogadro appeared In a French physics journal. Gay-Lussac had discovered by experiment the fact that went into his law; Avogadro had used his imagination to account for these facts. Gay-Lussac was a chemist and would use the facts that he had found, applying them in a chemical way; Avogadro was not a chemist, but what he put down was to become, in time, one of the foundation stones of chemical thinking.

Lorenzo Romano Amedeo Carlo Avogadro de Quaregna e di Cerreto—that was his full name—lived in the university town of Turin in northern Italy. He was thirty-five years old when the article was written. Today he would be referred to as a "brain". He began college at thirteen, graduated in law at sixteen, and received a doctor's degree in ecclesiastical law at twenty. He practiced law for a few years, but an interest in mathematics and science that had started as a hobby soon took most of his time. By the time he was thirty he gave up the practice of law and took up the teaching of mathematics and physics. At first he taught in a small local college. Then, as his fame grew, he was made professor of mathematical physics, a position created for him, at the large and important University of Turin. That position he held, with honor to himself and to the university, until his retirement at the age of seventy-four. He was never one to glory in having his name in the papers or in being elected to various offices. In fact, one who searches the records for facts about his life ends with such Items as these: he was noted for his "puckish" humor; his students liked him; he was happily married; he had six sons; he took part in various committees. In his life pattern one sees that of a great thinker, a fine teacher, and a conscientious citizen. Avogadro had complete sets of the scientific journals of his time as printed in Italian, French, German, and English. He had read in those journals that two volumes of hydrogen gas had been found to combine with one volume of oxygen gas in the formation of water. He had read, too, that some chemists argued that this proved that two atoms of hydrogen combine with one atom of oxygen in forming water particles. “But,” said Avogadro to himself, “do they not realize that by their argument a pint of hydrogen gas must contain exactly as many atoms as a pint of oxygen gas? Can nature be painstakingly accurate as to count out the number of atoms that go into a container, and to put just as many atoms of one kind into that container as it would another kind of atom?”

Then, reading on. Avogadro came to the report of Gay-Lussac in which be had elaborated upon the experiment of the combination of hydrogen and oxygen gases. By keeping the temperature high enough, he had kept the water formed from appearing as liquid; it remained as water vapor, a colorless gas. He measured its volume and found the same whole-number relation that had been discovered in the case of other gas reactions: 2 volumes of hydrogen gas with 1 volume of oxygen gas form 2 volumes of water vapor. “Perhaps nature is more painstakingly accurate in getting atoms into packages than I had thought,” declared Avogadro. “To be sure, all gases obey the law that Boyle found about pressure and volume. All gases expand at the same rate when heated. It might be all right to suppose that such things are true because every gas has the same number of atoms in a pint space. Would that explain the results that Gay-Lussac found?” He picked up a pencil and drew some boxes, all of the same size. “Two will be for the hydrogen gas, one for the oxygen gas. On the right will be two for the water vapor formed. Each box contains the same number of atoms. He immediately sensed a difficulty. Water is composed of both hydrogen and oxygen atoms; that complicated the idea. He changed the supposition he had made. “Apparently every gas has the same number of particles in a pint of space, not necessarily the same number of atoms. The particle might be a single atom in some cases; in other cases there could be two or three or more atoms to the particle.”

Going back to the picture of the boxes, he looked thoughtfully at them. “Let us suppose that nature is very accurate and puts as many particles of one kind of gas as of any other kind of gas in a pint space. Then two particles of hydrogen gas and one particle of oxygen gas will form two particles of water vapor, according to the experiment. That could not be true unless each particle of the hydrogen contained a pair of hydrogen atoms, and each particle of oxygen contained a pair of oxygen atoms.” The explanation satisfied Avogadro.

After that, he went over the full list of Gay-Lussac’s experiments in which he had measured gas volumes. He wished to see whether the same type of explanation applied to all. It did. He decided to write an article, giving his suppositions and explanations of the facts about chemical action of gases. In writing the article he made use of an important new word—molecule—derived from the Greek. It represented the particle that moved freely about in a gas. The molecule could be a single atom, or it could be a cluster of atoms moving about as a whole. Here was his supposition: Equal volumes of all gases under the same conditions of pressure and temperature have the same number of molecules. This is called today Avogadro’s principle. Here was a very important conclusion: Each molecule in hydrogen gas contains a pair of hydrogen atoms, and each molecule of oxygen gas contains a pair of oxygen atoms.

Upon the death of Avogadro, the eminent Italian scientist Stanislao Cannizzaro, professor of chemistry at the University of Rome, went to Turin to obtain material for an article he was to write about Avogadro. He went through the list of published articles—and found the one in 1811. He made a copy of it. The ideas in it were wonderful! Cannizzaro then took all the new information about the volumes of gases in chemical reactions that had accumulated in forty years and showed how the relations could be explained by Avogadro’s Ideas. He went further, indicating how those ideas could affect chemical theory. He appeared before chemical conventions and wrote scientific articles, and always he gave credit to Amedeo Avogadro and his explanation of the behavior of gases.