GASES AND HOW THEY COMBINE

VOL 12

SUMMARY:

First, some properties that allow us to distinguish gases from each other are shown. Then, the volumes of ammonia and hydrogen chloride that combine are measured quantitatively. The volume ratio is found to be 1.0 to 1.0. In a similar way, simple integer volume ratios are measured for the combination of hydrogen with oxygen, of nitric oxide with oxygen, and of hydrogen with chlorine. These simple integer ratios are interpreted in terms of Avogadro's hypothesis.

SPECIAL NOTE:

The presentation is organized so that the viewing may be interrupted after the experimental evidence has been shown. The narrator will indicate the appropriate time. The class can then discuss the observed volume ratios in terms of the particle model of gases.

PURPOSE:

To show experimental evidence that gases combine in small whole-number ratios, and to explain this evidence in terms of Avogadro's hypothesis and the particle model of gases.

OUTLINE:

I. *Qualitative observations on a collection of gases:* NO, Cl_2, HCl, NH_3, O_2, H_2, NO_2:

A. Color is observed:

1. NO_2 is brown.
2. Cl_2 is pale green.
3. NO, HCl, NH_3, O_2 and H_2 are colorless.

B. Solubility in water is observed:

1. NO_2 is very soluble.
2. O_2 has low solubility (approx. 1 mol/liter at room temp.)
3. HCl is very soluble.
4. Of the remaining gases not tested, only NH_3 would be found to be appreciably soluble.

C. Glowing splint test is used:

1. Splint ignites in O_2.
2. Splint loses its spark in HCl.
3. Splint causes explosion in H_2 because air (containing O_2) mixes with the H_2 which then ignites.
4. NO gas turns brown when splint test is attempted because the NO reacts spontaneously with the O_2 of the air to form brown NO_2.

D. Bromcresol green, an indicator dye, is used:

1. NH_3 turns the orange dye to blue.
2. HCl turns the dye back to orange.
3. A bromcresol green test of a mixture of the above gases is prepared; however, a white smoke forms upon mixing, preventing the test.

II *Quantitative study of the volume ratios of combining gases:*

A. $NH_3 + HCl$

1. 21 ml of NH_3 are reacted with HCl.
2. 22 ml of HCl are required.
3. The experiment is repeated. This time 30 ml of HCl combine with 30 ml of NH_3.
4. Since the precision of measurement is given as ±1 ml, we can see that the experiments yield a volume ratio of 1.0/1. 0 = 1 in both cases.

B. $H_2 + O_2$

1. 10 unit volumes of each gas are mixed together in a chamber.
2. The reaction is ignited with a spark.
3. 4.9 unit volumes of a gas remain; the splint test shows it to be O_2. (The reaction product, H_2O, has condensed to liquid water.)
4. The ratio of the volumes of H_2 and O_2 combining is 10.1/ 5.1 =2.

C. $NO + O_2$

1. Equal volumes of the two gases are mixed by forcing the O_2 into the cylinder containing the NO.
2. The appearance of brown color shows that the combination has produced NO_2. As water enters the reaction chamber, the gas volume decreases as the NO_2 dissolves in the water and the color disappears. One half a volume of colorless gas remains.
3. The splint test shows this gas to be O_2.
4. The ratio of the volumes of NO and O_2 combining is 1.0/ 0.5 = 2.

D. $H_2 + Cl_2$

1. Equal volumes of the two gases are mixed together.
2. The reaction is initiated by a spark.
3. No gas is left. The reaction product is HCl, which dissolves in the water. The ratio of the volumes of H_2 and Cl_2 combining is 10/10 = 1.

It is at this point that the viewing may be interrupted for discussion. In each experiment, the final volume is less than the sum of the volumes mixed. Elicit from the students the answer to the question of where the missing gas has gone. (In every case, the reaction product is a substance known to dissolve in water.) See suggestion under " Supplementary Material."

III. *Interpretation of experimental observations:*

A. $NH_3 + HCl$

1. A chalkboard picture is used showing NH_3 as a collection of colored dots, with HCl differently colored.
2. We use our volume ratio of 1 to assume that the product of the above reaction consists of 1 of each of the two particles.
3. This interpretation is consistent with Avogadro's hypothesis.

B. $H_2 + O_2$

1. A chalkboard picture is used to illustrate combination of two volumes of H_2 with 1 volume of O_2.
2. This result is also consistent with Avogadro's hypothesis since the reaction product, H_2O consumes two atoms of H for each atom of O.

22 MINUTES IN COLOR

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