

VOLUMETRIC DETERMINATION OF THE PERCENT-AGE OF OXYGEN IN THE AIR.—CAN HIGH SCHOOL STUDENTS OBTAIN RELIABLE RESULTS, USING THE PHOSPHORUS METHOD?

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Introduction

A great many high school chemistry manuals contain an experiment relative to the amount of oxygen in the air by volume.

The usual plan of procedure may be described as follows: About 50 cc. of air are entrapped in a eudiometer and placed over water that has been allowed to attain room temperature. Levels are adjusted, and the volume is read at room temperature and pressure. The volume of the entrapped air is then reduced to standard conditions. A small piece of phosphorus is inserted into the air column by means of a flexible wire and placed in a fixed position at about the 30 cc. mark. At the next laboratory period (24 hrs. later) the phosphorus is removed, levels adjusted, and the volume of the remaining gases read at room conditions. This volume is then reduced to standard conditions.

Since the phosphorus combines with the oxygen in the air column to form P_2O_5 , a compound that is readily soluble in water, a volume of water will rise in the tube during the oxidation period that will equal the volume of oxygen consumed. The per cent of oxygen in the air sample may then be obtained from the following formula:

$$V_1 - V_2$$

$$\text{Per cent oxygen} = \frac{V_1 - V_2}{V_1} \times 100, \text{ where } V_1 \text{ is the standard volume of}$$

air sample and V_2 is the standard volume of residue.

High School Students' Results

Many years of service in the high school laboratory have convinced the writer that students not only obtain a variety of results from the above procedure, but that the *average* of their results is far below the established amount of oxygen in the air (21.0% by volume) as it is recorded in text books.

For a number of years I simply ignored these inconsistencies, and ascribed the variations to errors in reading the eudiometers and in calculating results. I have even gone so far as to give a pupil a failing grade on his experiment sheet for a result that was far different from the text book standard. However, wide percentage ranges, year after year, caused me to adopt the rather tedious and laborious plan of reading each eudiometer with the student and then checking his calculations. Another precaution that I have practiced is to have students work the experiment in pairs, thus checking each other before a final verification by the instructor.

This apparently "fool-proof" plan has failed to give results that are appreciably more consistent than those of former years. Table I shows the oxygen determinations that were made by students in Valparaiso High School during the week of October 14-18, 1935.

The students worked in pairs. Eudiometer readings and calculations were made in duplicate and then were verified by the instructor. The water used in the tests had been standing in the room for 48 hours. The phosphorus bits were cut from a piece of phosphorus that had been kept in a sealed can and under water. It appeared to be pure white phosphorus. The thermometers had been tested for freezing point and boiling point accuracy, and the regularity of the temperatures as found by the students showed that there could have been very little inaccuracy from that source. Hence, it would seem that every precaution possible was used to insure accurate and uniform results.

Two of the students' results have been omitted from Table I. One of these showed a percentage of 24.4, and the other, 12.9. These two pairs of students read their eudiometers without being checked by the instructor. Since their findings are far different from the others, I have purposely omitted them. In all, 46 students participated in the determinations shown in Table I.

TABLE I. Volumetric Determination of the Per Cent of Oxygen in the Air by Phosphorus Method as Calculated by Students in Valparaiso High School

(Each air sample was exposed to phosphorus for 24 hours)

Students worked in couples, each checked his partner's result, and then each result was verified by instructor.

Couple	% Oxygen	Couple	% Oxygen
No. 1.....	15.5	No. 13.....	18.9
No. 2.....	20.3	No. 14.....	18.7
No. 3.....	18.3	No. 15.....	18.5
No. 4.....	17.5	No. 16.....	19.2
No. 5.....	18.3	No. 17.....	19.1
No. 6.....	18.2	No. 18.....	18.5
No. 7.....	19.3	No. 19.....	18.5
No. 8.....	19.2	No. 20.....	19.4
No. 9.....	16.4	No. 21.....	19.1
No. 10.....	17.4	No. 22.....	20.3
No. 11.....	17.9	No. 23.....	17.4
No. 12.....	17.3		

Average amount of oxygen in air of chemical laboratory from above data—18.4%.

Instructor's Results

The writer decided to make some determinations of the oxygen content of the laboratory air in order to compare his results with those of the students and also to ascertain the seat of the difficulty, if possible. Since each student's reading had been checked by his partner, and then

verified by the instructor, there could be little chance for error in the calculations of the students. Why, then, was there such comparatively wide range of results? Why was each result below the established percentage for oxygen content? Was there some error in the technique? Could it be possible that the oxygen content of the laboratory is below that of ordinary air? The room is occupied just 80 minutes of the day, and then by only about 25 pupils. Besides, it is ventilated by a Johnson forced feed circulation. Hence it would seem that the oxygen content should be very close to normal.

Table II shows the results of my efforts. This study has extended over a period of three weeks. Every possible precaution was used to insure accurate results: eudiometers were cleansed with cleaning solution; each reading was taken over water that had been standing in the room for at least 48 hours; calculations were made by logarithms and checked by slide rule; and levels were carefully adjusted in each trial. I have made several readings of the same sample at different times in order to determine the value of the time factor (See Table II).

TABLE II. Instructor's Results on the Per Cent of Oxygen in Air of Chemical Laboratory, by Volume, Using Phosphorus Method

Same plan of procedure was used as that from which students obtained the results shown in Table I, except that the phosphorus was allowed to oxidize for longer periods of time.

Sample	Oxidation Periods			
	24 Hours	48 Hours	72 Hours	120 Hours
No. 1.....	19.3%	.....	19.4%	.....
No. 2.....	.....	.....	.....	.....
No. 3.....	19.9%	19.5%	19.7%	19.7%
No. 4.....	*10.3%	19.0%	19.8%	19.3%
No. 5.....	18.8%	19.9%	18.4%	.....
No. 6.....	18.0%	18.5%	19.0%	.....
No. 7.....	16.7%	18.5%	18.9%	.....
No. 8.....	18.3%	18.1%	18.4%	.....
Average.....	18.5%	18.9%	19.0%	19.5%

(*Not used in average).

Conclusions

1. The period of oxidation as prescribed in manuals is probably too short a time. Three or four days at least, and preferably a week, should be allowed for the oxygen in the tube to be completely consumed.

2. There is some doubt in my mind as to whether this method per-

mits a complete removal of the oxygen in the eudiometer. I have noticed that the piece of phosphorus becomes coated with a brownish coloration. Perhaps this coating prevents free contact between the phosphorus and the air. Further investigation should be made in order to determine the nature of this coloration.

3. Although it may not be possible for high school students to obtain absolutely accurate results in this experiment, yet the procedure affords an opportunity for the student to apply his knowledge of the gas laws in a practical way, and impresses him with the value of accuracy in reading instruments and in making calculations.

4. Since this is one of the few quantitative experiments performed in high school chemistry, it serves as a guide post for the student and assists him in deciding whether or not he is interested in this phase of scientific work.

5. The student should not always be censured because he obtains a low percentage of oxygen. Probably sufficient time has not been allowed for complete oxidation of the phosphorus in the sample.

6. Some further investigation should be made as to why the oxidation proceeds much more rapidly in some tubes than in others. I have found cases in which the oxygen was only half exhausted in 24 hours while another would be almost completed in the same time, although the two set-ups seemed to be identical.