Jan. 7, 1969 A. F. FARR 3,420,224

APPARATUS FOR ANALYSIS OF RESPIRED GAS

Filed June 13, 1967 Sheet 1 of 2

FIG. 1.

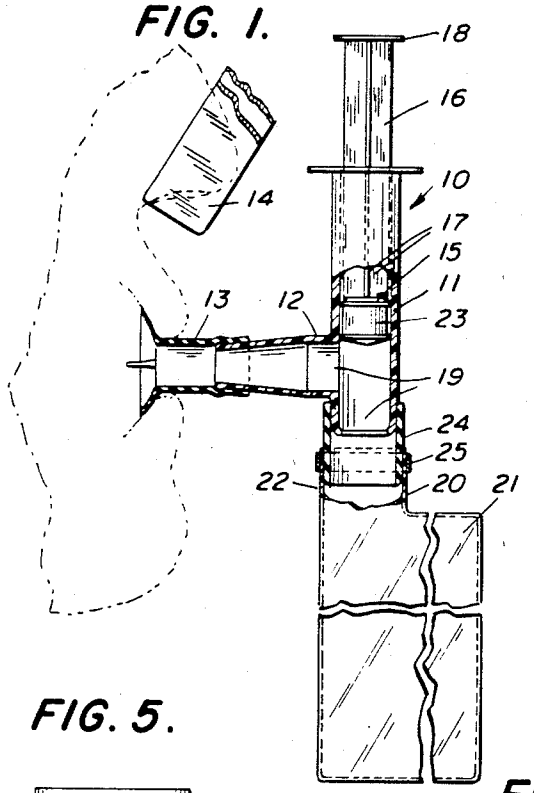


FIG. 2.

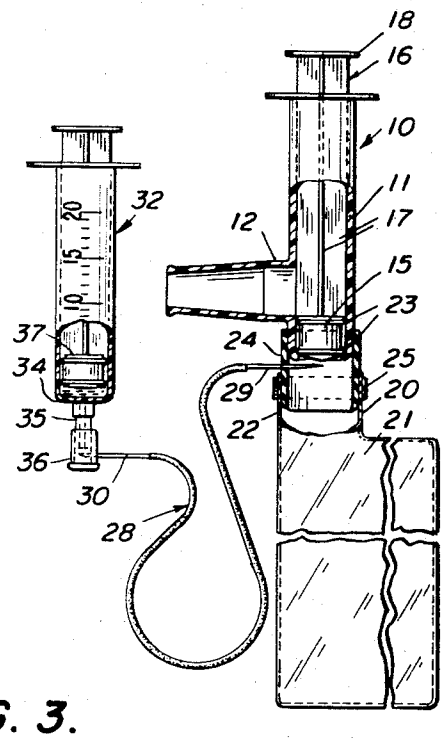


FIG. 5.

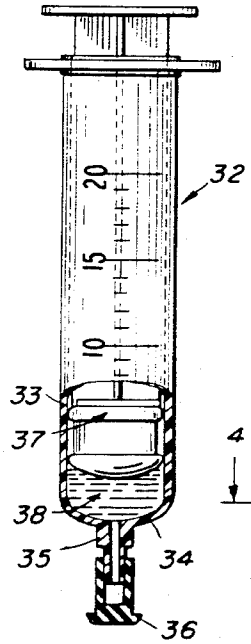


FIG. 3.

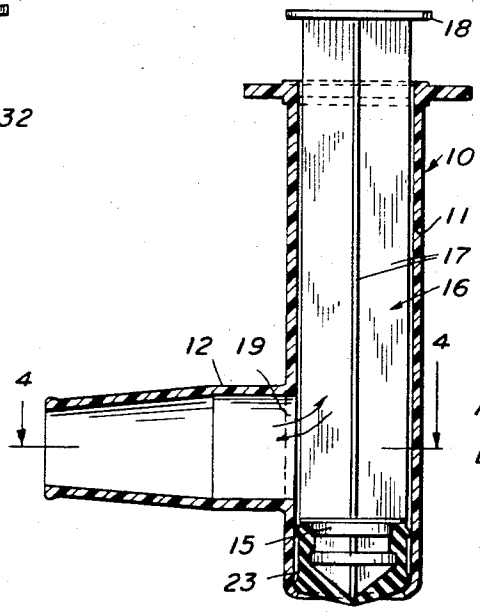
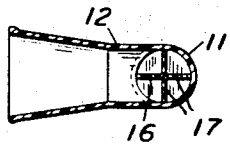


FIG. 4.



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Jan. 7, 1969 A. F. FARR 3,420,224

APPARATUS FOR ANALYSIS OF RESPIRED GAS

Filed June 13, 1967 Sheet 2 of 2

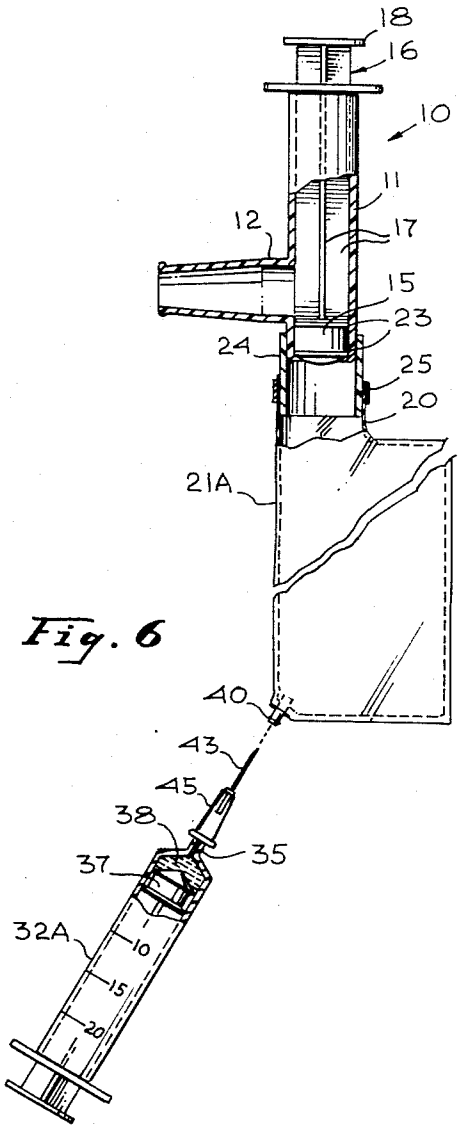

Fig. 6

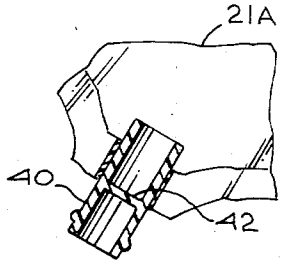

Fig. 7

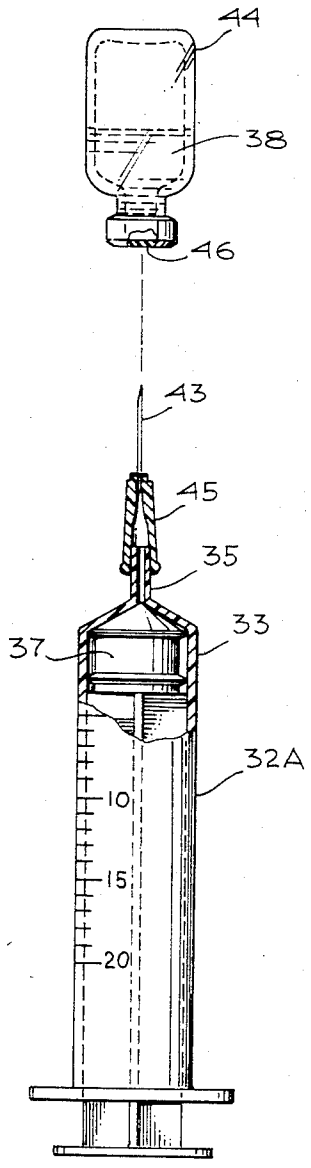

Fig. 8

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APPARATUS FOR ANALYSIS OF RESPIRED GAS

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Continuation-in-part of applications Ser. No. 295,058, July 15, 1963, and Ser. No. 626,280, Mar. 27, 1967. This application June 13, 1967, Ser. No. 645,666

U.S. Cl. 128—2.07 7 Claims

Int. Cl. A61b 5/00

ABSTRACT OF THE DISCLOSURE

Throw-away apparatus for immediate diagnostic analysis of respired air of a patient collected in a pliable breathing bag which at times communicates with a titrating syringe having a measured volume of an absorbing reagent for absorbing a known amount of a selected constituent of respired air, including means for measuring the residual volume of the respired air after contacting the reagent in the syringe; and a method for making an immediate diagnostic analysis of the respired air of a patient.

Cross-references to related applications

This application is a continuation in part of my pending application for patent Ser. No. 295,058, filed July 15, 1963, now abandoned and also of my pending application for patent, Ser. No. 626,280, filed Mar. 27, 1967.

Background for the invention

There is a need for an inexpensive, portable, lightweight, ready means for clinical analysis of the breath of a patient, which can be performed on the spot by a doctor or technician without the delay involved in collecting, transporting, and subsequent laboratory analysis with conventional apparatus, and in communicating the results back to the doctor for diagnosis.

Summary of the invention

This invention relates to a new method for gas analysis, and to new forms of apparatus for use in performing the analysis.

A principal object of the invention is to provide a new method and means for the chemical analysis of respired air samples.

One object of the invention is to provide a quick, inexpensive, and sufficiently accurate method and appartus for measuring the carbon dioxide content of expired air of patients, at homes or in a physician's office, where there is no access to complex and expensive analytical laboratory equipment.

Another object is to provide a method and means for use by a physician in critical or emergency cases of pulmonary or cardio-pulmonary disease, to make immediate analyses of expired air where there is not access to a clinical laboratory.

Another object is to provide a new quantitative analytical procedure for gas analysis wherein the gas itself is titrated into a fixed volume of absorbing reagent liquid to a determinable endpoint.

A further object is to provide simple, economical, portable and disposable equipment for bedside measurement of carbon dioxide in expired air.

Another object is to provide a disposable reagent-charged titration syringe for use in making gas analyses by my method.

The invention is particularly adapted for making bedside clinical analyses of respired air, and will be explained particularly in relation to this problem, but the invention is not limited to this use.

Brief description of the drawings

The invention will be understood from the following description of apparatus for the taking of respired air samples and the analysis thereof for carbon dioxide content, reference being made to the accompanying drawings, in which

FIG. 1 is a side elevational view partly in section showing the apparatus as used to take a rebreathing sample of respired air;

FIG. 2 is a plan view partly in section showing the complete assembly of sampling apparatus and titrating syringe apparatus;

FIG. 3 is a side elevational view partly in section showing a lightweight, quick-change, non-restrictive, disposable valve;

FIG. 4 is a cross-sectional view of the valve taken on the line 4—4 of FIG. 3;

FIG. 5 is a side elevational view partly in section showing a titrating syringe with a needle-penetrable rubber cap;

FIG. 6 is a disassembly view of a breathing bag and quick change valve as in FIG. 2, the bag having a self-sealing valve for delivery of the gas in the bag to a titarting syringe fitted with a hypodermic needle;

FIG. 7 is an enlarged side elevational view partly in section of the self-sealing valve in the breathing bag; and

FIG. 8 is a side elevational view in disassembly form of a titrating syringe, a sleeve mounted hypodermic needle, and an inverted bottle with a needle penetrable seal, containing reagent liquid to be transferred to the titrating syringe prior to inspirating gas from the collection bag into the syringe.

Referring to the drawings, the portable apparatus assembly for taking a sample of respired air from a subject, using one form of this invention, is shown in FIG. 1, and the complete portable assembly of apparatus for sample taking and making the analysis is shown in FIG. 2. Details of the titrating syringe and the valve means are shown in FIGS. 3, 4 and 5. The quick-change non-restrictive valve means **10** consists of a cylinder **11** having a tubular side arm **12** whose cross-sectional area is not substantially less than the cross-sectional area of the exhaust air channels of the valve cylinder **11**. The sidearm **12** is arranged for attachment to a rubber mouthpiece **13** which is placed in the subject's mouth, the nose of the subject being closed by the clamp **14** so that all breathing is through the mouthpiece **13**, following a common procedure. The piston **15** is slidably fitted by means of sealing rings **23** to the inside walls of the cylinder **11**, and is movable by means of the rod means **16** which consists of longitudinally welded diametrically disposed fins **17** which keep the piston **15** substantially aligned axially in the cylinder **11**, and yet allow free air flow out of the cylinder around the fins. An end disk **18**, outside the cylinder, serves as a handle means for the manual operation of the piston **15**. The side arm **12** is disposed so that the piston

15 may be positioned in the cylinder on either side thereof, to give unrestricted flow of air from the side tube either to the open air end 19 or to the bag connecting end 20 of the cylinder 11, which latter end discharges into the gas collection bag 21. This valve is very simple in construction and is light in weight, in contrast to those now in use.

In the form of this invention shown in FIGS. 1 to 5 inclusive, the gas collection bag 21 consists of a thin-walled plastic enclosure having a narrow neck 22 which is attached to the cylinder 11 at the bag-connecting end 20, there preferably being a needle-penetrable rubber collar 24 securely engaged around the end 20, the neck 22 fitting over said collar 24, with an elastic band 25 to secure the neck 22 of the bag 21. The collecting bag 21 may be fabricated from thin sheeted pliable polyethylene. Respired air may be breathed and rebreathed into and out of the bag when the piston 15 is in the position shown in FIG. 1, and free breathing to the atmosphere may take place when the piston is in the position shown in FIG. 2, in which latter position the piston 15 closes off the collected gas sample in the collection bag 21.

When the respired air sample has been collected in the collection bag 21, and is sealed off by the piston being positioned in the down position shown in FIG. 2, samples of the respired air may be withdrawn from the bag 21 by means of the flexible catheter or capillary tube 28, which is provided with hypodermic needles 29 and 30 at its two ends, so that the capillary tube communicates between the titrating syringe 32 and the collection bag 21.

The titrating syringe 32 used in the form of this invention shown in FIGS. 1 to 5 inclusive consists of a volume calibrated transparent or translucent cylindrical tube 33 which is provided with a piston means 37 and with an end closure 34 having a restricted outlet tube 35. A needle-penetrable rubber sealing cap 36 is provided to seal off the outlet tube 35. Communication between the collection bag 21 and the titrating syringe 32 is by means of the capillary tube 28, whose end hypodermic needles 29 and 30 are inserted respectively through the rubber collar 24 and through the sealing cap 36, the open inner ends of the needles being disposed to effect gaseous communication.

The titrating syringe 32 is provided, between the piston means 37 and the sealing cap 36, with a measured charge 38 of a selected liquid reagent which will absorb the selected gas whose concentration it is desired to ascertain. The reagent charge 38 also contains a color changing indicator compound dispersed therein, so that when the absorbing capacity of the charge has been reached during the gas titration, a visual change of color in the liquid in the syringe becomes apparent.

The process for the measurement of the concentration of carbon dioxide in the respired air of a subject consists first of collecting a large sample of respired air, either by simply breathing into a fully collapsed collection bag, or by rebreathing into the bag. The rebreathing technique is well known and has been heretofore used for obtaining information of the concurrent conditions existing in the circulating blood without resorting to the taking and analysis of blood samples. (See, for examples, Collier, Journal of Applied Physiology, vol. 1, pp. 25–29, 1956; and Hackney, Sears and Collier, Journal of Applied Physiology, vol. 12, pp. 425–430, 1958.)

After the sample gas has been collected, it must be analyzed for the desired constituent, usually carbon dioxide. Heretofore, it has been necessary to have the analyses made in clinical laboratories equipped with heavy, bulky and expensive equipment. The analysis method of this invention permits a physician to immediately measure the carbon dioxide content of the respired air of a patient, at the bedside, with equipment for collecting the sample, and for analysis, which are easily portable in a physician's bag.

Each analysis is made by the use of previously prepared known amount of a standardized absorbing reagent contained in a sealed disposable titrating syringe which is volume calibrated. A color-change pH indicator is also included with the absorbing reagent.

Successive small portions (for example, 0.25 ml.) of the collected respired air sample are drawn into the syringe by a small movement of the piston means, with vigorous shaking after each addition of gas to bring the gas into contact with the absorbing liquid. This is continued step by step until the color indicator indicates that the absorbing capacity of the absorbing reagent charge has been reached.

A larger quantity of the gas sample (for example, 5 ml.) may be initially drawn into the titrating syringe, followed by successive small portions (0.25 ml.) until the color change indicator has shown the titration end point. The volume of gas in the syringe at the end point is then measured. Because all measurements are made at ambient temperature and pressure, no corrections for change in volume need be applied. By using a relatively long capillary tube between the collection bag and the titrating syringe, and holding the syringe upright so that the liquid does not flow into the capillary tube, there is not requirement that the capillary tube be closed off during the step-by-step titration in the titrating syringe. The absolute accuracy of the analysis has been found to be sufficient for diagnostic purposes. The reproducibility of the measurements have been found to be within +0.3 ml.

Under some circumstances it may be desirable to make a quick qualitative screening type analysis for gross ventilatory abnormality, in which event suitable adjustment of reagents and indicators may be made in the charge in a titrating syring so that a specified volume of gas, (for example 15 ml.), will be drawn into the syringe, followed by shaking and observation of color change of the reagent. For example, no color change would indicate hyperventilation, one color change would indicate normal ventilation, and a different color change would indicate hypo-ventilation. This qualitative indication may, if required, then be followed by a more accurate quantitative analysis, as above described.

In the alternative arrangement of the slightly altered apparatus as shown in FIGS. 6, 7 and 8, the breadth collecting bag 21A is provided in one corner with a self-sealing valve 40, as shown in enlarged elevation partly in section in FIG. 7, having the needle penetrable self-sealing diaphragm 42. The modified titrating syringe 32A is provided with a sleeve mounted hypodermic needle 43 attachable to the syringe outlet 35, the same needle being used to introduce a measured volume of absorbing reagent 38 from the sealed bottle 44 with needle penetrable seal 46 into the reaction chamber below the piston 37 of the modiled titrating syringe 32A, by the suction created by moving the piston outwardly. After the reagent charge has been introduced into the titrating syringe, then the hypodermic needle 43 is inserted through the diaphragm 42 of the self-sealing valve 40 so that the breadth sample may be drawn into the titrating syringe 32A in the desired small portions. Shaking of the titrating syringe to facilitate the absorption of the carbon dioxide constituent in the sample is possible because of the easy pliability of the bag. Successive small portions of the breadth sample in the bag are drawn into the syringe and absorbed in the reagent in an analogous manner to that described above, until a color change is noted in the indicator dye in the absorbing agent. From the volume of residual gas remaining in the syringe, and the known absorbing capacity of the charge of reagent used, the percentage of carbon dioxide may be calculated by well known mathematical procedures.

The gas absorbing reagent may be selected for the particular analysis to be made, and reagent concentrations may be varied within certain limits for ease of standardization.

For the measurement of carbon dioxide in respired air, the preferred reagent contains aqueous barium hydroxide solution, and another soluble barium salt such as barium chloride, suitable concentrations being 5.0 grams of barium hydroxide and 15.0 grams of barium chloride per 100 ml. of reagent. The preferred indicator is a mixture of Thymol Blue and Propyl Red, although other well known pH color change indicators may be used. When the titrating syringe has a working chamber capacity of about 30 ml., a pre-measured charge of 0.5 ml. of the above preferred absorbing reagent for carbon dioxide absorption has been found to be satisfactory. Under these conditions, samples of known gas containing from 2.04 to 10.1 percent carbon dioxide have been analysed with deviations of not more than 0.5 ml. of carbon dioxide.

For the measurement of other constituents of the collected gas samples, other absorbing reagents may be used. For example, for determining oxygen, suitable concentrations of sodium hydrosulfite and sodium-beta-anthraquinone sulfonate in 1.0 molar aqueous potassium hydroxide may be used. For determining oxides of nitrogen in polluated air a number of reagent combinations employing diazotization and coupling reactions may be used, for example, appropriate concentrations of sulfonilamide and N-(1-naphthyl)-ethylenediamine dihydrochloride in aqueous phosphoric acid. For determining carbon monoxide, reagents prepared from phosphomolybdic acid and palladium chloride, following the usual practice, may be used. Ammonia gas may be determined by its reaction with triketohydrindene hydrate (ninhydrin) in aqueous solutions. Acetylene may be determined by reaction with ammoniacal solutions of cuprous salts.

The titrating syringes or the reagent bottles are precharged and sealed, for later use. The syringes may be made from molded plastic (for example, polyethylene) parts at low cost, and may be thrown away after an analysis. The other parts of the collection equipment may also be made of molded synthetic plastic, or fabricated sheet synthetic plastic, and may also be disposed of after each use, especially where communicable diseases are involved.

Previously prepared titrating syringes or reagent bottles containing other absorbing agents for use in the control of many gas reactions may be provided, so that gas titrations in a titrating syringe may be used, for examples in flue gas analyses, control of fermentation, control of welding gas mixtures, and in the measurements relating to air pollution. These analyses may be made with samples collected in collapsible polyethylene bags, as described, or by other sample collecting means.

The method and apparatus of this invention may be advantageously employed by an astronaut or other isolated person for making the necessary analyses of his environment to insure his own well being or for detecting and/or measuring noxious vapors or gases inside or adjacent to a space capsule, underground cavity, or the like.

The advantages of the invention will be apparent from the above description. The objectives set forth in the beginning have been attained.

What is claimed is:

1. A lightweight, single-use, synthetic plastic apparatus for the immediate diagnostic determination of a selected constituent in the respired air of a subject as for example by a visiting doctor in a home, comprising in combination

a rebreathing gas collection bag assembly including a gas collection bag, a lightweight synthetic plastic quick-change non-restrictive valve means including a subject's mouthpiece, said mouthpiece being disposed between said valve means and said gas-collection bag, said valve means alternately establishing communication between said mouthpiece and said bag and between said mouthpiece and the surrounding atmosphere;

a gas titrating syringe comprising essentially a graduated cylindrical member, a stemmed piston means in said cylindrical member, and an outlet tube integral with said member, said outlet tube being disposed opposite said piston means; and

means for communication between said gas collection bag and said outlet tube of said titrating syringe.

2. A lightweight, single-use, synthetic plastic apparatus for the immediate diagnostic determination of a selected constituent in the respired air of a subject, as for example by a visiting doctor in a home, comprising in combination a rebreathing gas collection bag assembly including a gas collection bag, a lightweight synthetic plastic quick-change non-restrictive valve means including a subject's mouthpiece, said mouthpiece being disposed between said valve means and said gas-collecting bag, said valve means alternately establishing comunication between said mouthpiece and said bag and between said mouthpiece and the surrounding atmosphere; a gas titrating syringe comprising essentially a graduated cylindrical member, having an integral outlet tube, a stemmed piston means in said cylindrical member, and a sealing cap on said outlet tube of said cylindrical member, said syringe containing a measured quantity of an absorbing reagent for said selected gas constituent disposed in said cylindrical member between said piston means and said sealing cap; and a removable flexible capillary tube communicating between said syringe outlet tube and said gas collection bag.

3. A lightweight, single-use, synthetic plastic apparatus for the immediate diagnostic determination of a selected constituent in the respired air of a subject, as for example by a visiting doctor in a home, comprising in combination a rebreathing gas collection bag assembly including a gas collection bag, a lightweight synthetic plastic quick-change non-restrictive valve means including a subject's mouthpiece, said mouthpiece being disposed between said valve means and said gas collecting bag, said valve means alternately establishing communication between said mouthpiece and said bag and between said mouthpiece and the surrounding atmosphere; a gas titrating syringe comprising essentially a graduated cylindrical member having an integral outlet tube, a stemmed piston means in said cylindrical member, and a needle-puncturable sealing cap on said outlet tube of said cylindrical member; a measured quantity of an absorbing reagent for said selected gas constituent disposed in said cylindrical member between said piston means and said sealing cap; and a removable flexible capillary tube communicating between said syringe outlet tube and said gas collection bag, said capillary tube being provided on both ends with hypodermic needles for penetrating said sealing cap by one needle and said collection bag by the other needle.

4. The apparatus defined in claim 3, in which the absorbing reagent disposed in said cylindrical member contains a visual color-change indicator.

5. The apparatus defined in claim 3, in which the selected gas constituent to be determined is carbon dioxide and the absorbing reagent disposed in said cylindrical member comprises aqueous barium hydroxide solution containing barium chloride and a visual color-change pH indicator.

6. A lightweight, single use, synthetic plastic apparatus for the immediate diagnostic determination of a selected constituent in the respired air of a subject as for example by a visiting doctor in a home, comprising in combination a rebreathing gas collection bag assembly including

a gas collection bag,

a lightweight synthetic plastic quick-change non-restrictive valve means including a subject's mouthpiece,

said mouthpiece being disposed between said valve means and said gas-collection bag,

said valve means alternately establishing communication between said mouthpiece and said bag and between said mouthpiece and the surrounding atmosphere;

a gas titrating syringe comprising essentially

a graduated cylindrical member, a stemmed piston means in said cylindrical member; an outlet tube integral with said member,

said outlet tube being disposed opposite said piston means; and a sleeve mounted hypodermic needle mounted on said outlet tube of said syringe, said needle making communication between the gas in said gas collection bag, and said titrating syringe.

7. The apparatus defined in claim 6 in which a needle-penetrable, self-sealing valve means is provided in said collection bag.

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U.S. Cl. X.R.

23—254; 73—421.5