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Recycling Polymer Materials in Design, Construction and Trial Application of Positive Pressure Laboratory Dispenser

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ABSTRACT

A positive pressure pneumatic device sourced mostly from used plastics and glass was constructed for use as dispenser in the laboratory. Here reagents for routine laboratory use were tested in the equipment to determine its applicability. Systematic studies were carried out on the comparative stability of analytical reagents in conventional titrimetric method on one hand and pneumatic dispenser on the other hand using both oxidation/reduction and acid/base reactions as the basis of the study. The titre values of 12.00, 12.00, 12.00 and 12.00 cm^3 were recorded respectively in conventional titration, while 12.00, 12.00, 12.00, and 12.00 cm^3 titres were recorded respectively using stabilized oxidation/reduction titration. In the case of (HCl/K_2CO_3 couple) reaction, the following titre values were recorded for conventional titrimetric method; 20.00, 20.00, 20.00, 20.00 and 20.00 cm^3 while the equivalent value for the pneumatic dispenser were; 20.00, 20.00, 20.00, 20.01, and 20.00 cm^3. Results showed no difference between the two trials made using the two methods of analysis. Therefore, the equipment is suitable for the intended purpose.

1. Introduction

Dispensers are technical instruments that are usually covered by intellectual property rights law. For this reason scanty information are available with respect to the technical details of their design and assemblage. A dispenser (titrator) was described as having the following features; automatically and continuously displays fluid volume dispensed in increment of 0. l cm^3 with an accuracy of 0. 1%. The equipment‘s burette has no meniscus, thus helping to improve accuracy of titration over the conventional method. The display is said to be accurate even if the titrator is refilled [1]. The above instrument relies heavily on digital/electronic control systems. However basic experimental techniques exist in the chemical laboratory and on whose principles a pneumatic titrator can be assembled.

A method of measuring the volume of hydrogen displaced in a reaction between magnesium and hydrochloric acid was described [2] as shown in (Figure 1).

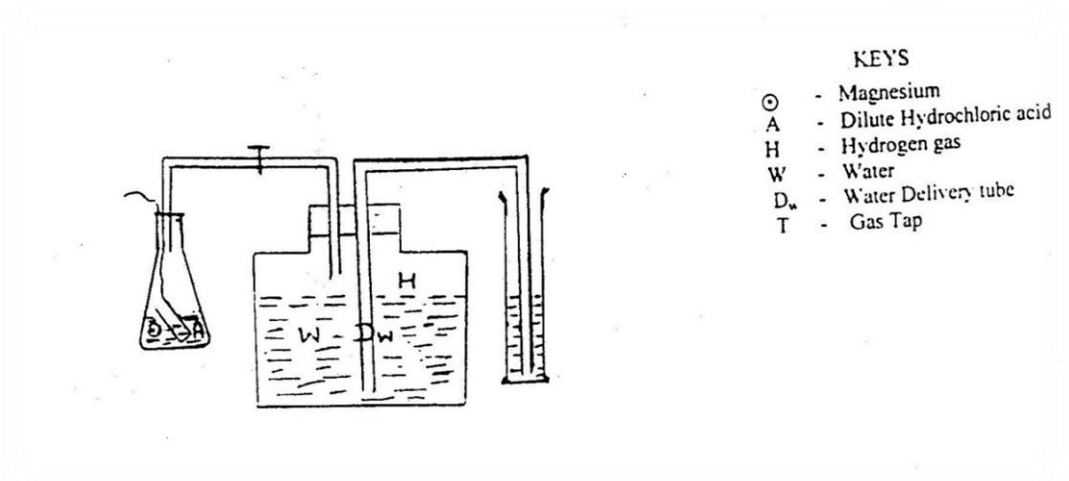

Figure 1: *Apparatus for determination of volume of hydrogen produced in a reaction between magnesium and hydrochloric acid. Source* [2]

This shows that gas pressure can be used to do work by lifting a liquid through pipe. Similarly, air pressure can equally be used in this way to lift a liquid into a tank above the liquid‘s reservoir and to sustain it there.

When a liquid is suspended at a height, it is acted upon by its weight, the gravity and the pressure of air/its vapour above it. The liquid will remain suspended if this pressure is below atmospheric. This information is vital in control of flow in and out of a suspended container. Typical examples given by [2], as shown in Figure 2, illustrate this satisfactorily.

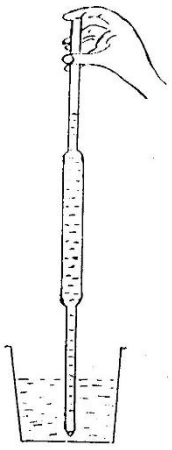

Figure 2: *Use of pipette to lift liquid*. **Source** [2]

A precise volume can be transferred using a pipette. The pipette is immersed in the liquid to be transferred; the free end of the pipette is aspirated thus lifting the liquid into the pipette. As the air pressure inside the pipette drops, the liquid rises to take its place. With the liquid drawn to the set point and placing a finger to disallow air from flowing inside, the pipette can

be transferred with its content into another container (3) as shown in Figure 3. Similarly, hypodermic syringes and pumps are examples of solid plunger displacing fluid.

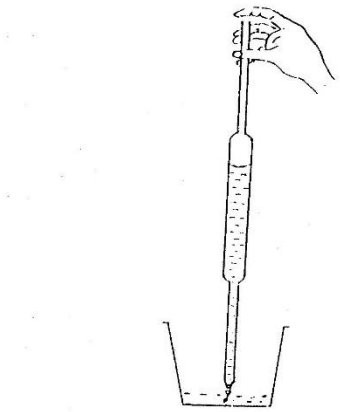

Figure 3: *Transfer of liquid in pipette to a container*. **Source** [3]

Soxhlet apparatus, Figure 4, is used for continuous extraction of solid using liquid solvents. Vapour from the solvent passes from the flask C to a condenser through E where it is condensed into the thimble A and slowly fills the volume of the Soxhlet. When the solvent reaches the top of the tube F, it siphons over into the flask C.

This study aims at using chemical principles and instrumentations at the basic level to design, construct and test a positive pressure liquid dispenser that is useful for titrimetric work using discarded plastic materials. In addition, emphasis was given to establish uses for used plastics.

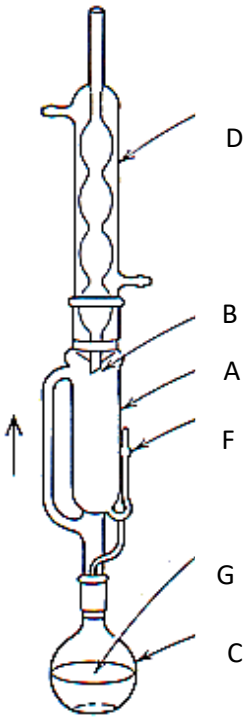

Figure 4: *Soxhlet apparatus*. **Source** [4]

1.1. Principle and description of design

1.1.1. Design principle: Pneumatic dispensers use pressurized air source to force liquids out or into a container in a controlled manner. They are used for uniform metering of fluids, especially liquids into a container. The container may be a burette, pipette, calibrated measuring cylinder or volumetric flask.

The pneumatic dispenser described here has an inbuilt attribute of zeroing itself, so that instead of charging aqueous reagents into a burette through a funnel (as in the conventional method), the reagent is metered from the storage tank by either positive or negative pressure applications. The applied pressure forces the liquid through a pipe (projecting from the centre of the storage tank down to its bottom) into an overhead tank from where the liquid is admitted into the burette. Any excess reagent left in the tank is returned to the storage tank including the over fill from the burette by suction. The over fill from the burette is returned to the storage. This action is possible via the overhead tank through a hollow pipe (or capillary).

Positive pressure is applied at the storage tank using pipette filler, foot pump or air pump. Part of the pumped air is diverted to the overhead tank via the upper layer of the burette. Additional provision is made for pressure reduction in the storage tank through a valve that communicates with the overhead tank.
The overhead tank contains a trap that enters into the burette. It is from here that the burette is fed with the liquid from the storage tank. The tube from the storage tank is led into the top of the overhead tank and touches its bottom. This serves two purposes; as feed tube and as return tube.

1.1.2. Description of the design

The above operational principle of Soxhlet apparatus was modified and applied in the design of an aspect of the titrator. The feed is admitted into an overhead tank and it can exit either through it or into an opening at the base of the tank through a capillary tube which empties into the burette, Figure 5.

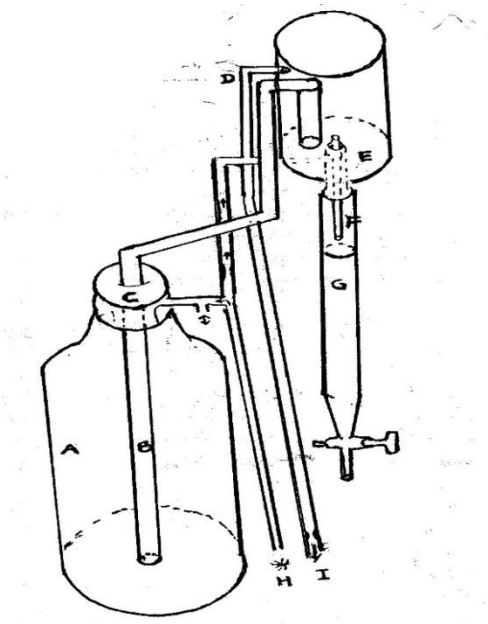

Figure 5: *Diagram of the designed pneumatic dispenser*

Pumping air into the reservoir *A* forces the liquid through the pipe *B* and through *C* into the overhead tank *E*. As the tank fills, the pressure above the liquid in the tank rises thus forcing the liquid to exit through *H* and the capillary outlet *I*. If the burette *G* is filled the excess liquid in the overhead tank is forced back into the reservoir by suction through *F*. The burette is usually slightly over filled, the excess liquid in the burette above the zero mark is returned to the storage tank via the overhead tank by capillary action [5] and by pressure equalization through *D*.

The storage tank was made with a rigid, brown coloured reagent bottle of 2.5 liters capacity, Figure 6. It was fitted with a rubber stopper which was bored in two ways; centrally to hold the feed tube and side way to divert pressure from the storage tank. The pressure divert tube communicates pneumatically with the overhead tank, the burette and the exhaust valve. Another rubber part connects the overhead tank and the burette.

Figure 6: *The photograph of the designed positive pressure dispenser*

Finally, the dispenser was used to carry-out oxidation/reduction and acid/base titrimetry using the procedures outlined below. The results obtained were compared with similar results using the conventional method of titration.

2. Materials And Method

2.1.Materials

The dispenser (titrator) was designed using materials sourced locally from used plastics, glass bottle and tyre valves. Components such as the rubber parts were either processed in or sourced from the laboratory. The overhead tank was sourced from used mobile mosquito flit cover.

The storage tank (2.5 litres brown colored reagent bottle) fitted with a rubber stopper bearing two bored holes to hold the feed tube centrally and side way to divert pressure from the storage tank. Burette and the exhaust valve (Rubber tubes or catheter).
All joints were bonded using two composite adhesives available commercially; Super glue and rubber solution. There are two considerations here, super glue bonds rigidly but it has low resistance to flexing and humidity, rubber solution on the other hand, bonds well and form bond that is flexible with greater resistance to humidity but offers lower resistance at elevated temperature. Thus blending them together gave a hybrid that offers desirable attributes.

All the other chemical reagents were sourced from the Chemistry Laboratory, Kogi State University, Anyigba. Nigeria.

2.2.Method

2.2.1. Procedure for redox titrimetry

Freshly prepared 0.1 M $Na_2S_2O_3$ was introduced into a burette in the conventional way. In a beaker 20 ml of 0.01 M solution of KlO_3 was introduced. This was followed by the addition of l0ml (5 % KI) and 4 ml of 0.l M H_2SO_4 in the dark. Finally, two drops of starch indicator was added. The content of the beaker was titrated upon with the thiosulphate in the burette after the beaker and its contents had been left in the dark for about 5 minutes.

The same procedure was repeated by filling the burette of the dispenser pneumatically with thiosulphate. This was titrated against the contents of the beaker similar to the above. The two end point results were evaluated and compared.

$$IO_3^- + 8I^- + 6H^+ \longrightarrow 3I_3^- + 3H_2O \quad \text{.....Eq. 1}$$
$$I_3^- + 2S_2O_3^{2-} \longrightarrow 3I^- + S_4O_6^{2-} \quad \text{.....Eq. 2}$$
$$1 \text{ mol } IO_3^{1-} = 6 \text{ mol } S_2O_3^{2-}$$

$$\text{Molar ratio} = \frac{\text{Moles } (S_2O_3^{2-}) \text{ X Volume } (S_2O_3^{2-})}{\text{Moles } (IO_3^{1-}) \text{ x Volume}(IO_3^{1-})} = 6/1$$

2.2.2. Procedure for acid/base titrimetry

Into a conventional burette was added a solution of 0.1 M HCI to mark. Similarly, 20 ml of 0.1 M K_2CO_3 was transferred into a beaker. Into this beaker was added 3 drops of methyl orange. This was titrated upon by HCI in the burette to its end point.
This procedure was repeated by using the HCI in the dispenser to titrate the content of the beaker to its end point.

$$2HCI + K_2CO_3 \longrightarrow 2KCI + H_2O + CO_2 \quad \text{.....Eq. 3}$$

$$\text{Molar ratio} = \frac{\text{Moles (acid) X Volume (acid)}}{\text{Moles (base) X Volume (base)}} = 2/1$$

3. Results and Discussion

The result of the analysis obtained from the titre values of this investigation shows that both methods gave equivalent results within seven days that the reagent was prepared (Table 1). Inspection of table 1 shows that there is gradual rise in the titre values of the reagent after the

first one week of its preparation and as the solution ages, the increment in the titre values is marginally more pronounced in the solution that is contained in the pneumatic dispenser. This may be explained on the account of the positive pressure that is forced into the system to lift it up into the overhead tank. This may have forced carbon dioxide into the solution thereby reducing its concentration through chemical reaction with it.

Table 1: Titre values of un-stabilized thiosulphate solution

Duration	Methods	Titre values (cm^3)				Average titre values (cm^3)
One week	*A	12.0	12.1	12.1	12.0	12.05
	*B	12.0	12.0	12.1	12.0	12.03
Four weeks	A	12.3	12.3	12.3	12.3	12.30
	B	12.3	12.1	12.1	12.1	12.15
Seven weeks	A	13.0	12.8	12.9	13.0	12.93
	B	12.5	12.5	12.4	12.5	12.47

Keys: (*)
A: Dispenser Method
B: conventional method

When the thiosulphate solution was stabilized the results obtained in both the conventional and pneumatic titration showed no difference all through the four weeks that the test covered. The explanation for this could lie in the fact that addition of stabilizer effectively raised the pH, screened it from the effect of carbon dioxide and prevented *thiobacter* from colonizing the solution (Table 2).

Table 2: Titre values of stabilized thiosulphate solution

Duration	Methods	Titre values (cm^3)				Average titre values (cm^3)
One week	A	12.0	12.0	12.0	12.0	12.00
	B	12.0	12.0	12.0	12.0	12.00
Four weeks	A	12.0	12.0	12.0	12.1	12.03
	B	12.0	12.0	12.0	12.0	12.00

Keys:
A: Dispenser Method
B: conventional method

When the reagents were changed to strong acid and weak base, we recorded no difference in the titre values in conventional titration as well as the pneumatic dispenser titration (Table 3). This is expected as there is no report of instability of any of the said reagents in solution.

Table 3: Titre values of Hydrochloric acid on potassium carbonate

Duration of solution	Methods	Titre values (cm^3)				Average titre values (cm^3)
Seven weeks	A	20.00	20.00	20.00	20.00	20.00
	B	20.00	20.00	20.00	20.00	20.00

Keys:
A: Dispenser Method
B: conventional method

4. Conclusion

From the foregoing, it can be concluded that the designed system, which was used to carry out titrimetric analysis gave results and outcome that bears similarity with the conventional titration methods. This preliminary result shows that the designed equipment is suitable for titrimetary works in reactions involving acid/base, but in oxidation/reduction reaction especially the one under study, there is need to stabilize the solution in order to have reproducible results with little error margin.

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