mesothorium II. If we call its γ-activity unity at this time, its activity, A, after an interval, t, is given by the equation

$$A = f_1 + 1.81 f_2,$$

where, at time t, f_1 is the fraction of the initial amount of mesothorium and f_2 is the fraction of the amount of radiothorium that would be in equilibrium with the initial amount of mesothorium in a mineral. On account of the short periods of all products intervening between radiothorium and thorium D, we may make the calculation as if radiothorium itself gave the γ-rays produced by thorium. Taking the period of mesothorium as 5.5 years[1] and that of radiothorium as 737 days,[2] we get the results shown in the following table:

TABLE II.

The Change of Gamma Ray Activity of Mesothorium with Time.

Time in years.	Ms I.	Th D.	Total.
0	1.000	0.000	1.000
1	0.881	0.489	1.370
2	0.777	0.781	1.558
3	0.685	0.935	1.620
4	0.604	1.000	1.604
5	0.532	1.007	1.538
6	0.469	0.973	1.442
7	0.413	0.921	1.334
8	0.364	0.855	1.219
9	0.321	0.786	1.107
10	0.283	0.715	0.998

CHICAGO, ILL.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF MCGILL UNIVERSITY.]

AUTOMATIC VARIATION OF GAS PRESSURE AND ITS APPLICATION TO A VACUUM PUMP, CIRCULATION OF GASES, MAGNETIC STIRRER.

BY O. MAASS.

Received October 22, 1918.

A Geissler water suction pump can be used as a convenient source of energy for such continuous processes as the stirring of liquids, the circulation of gases and the manipulation of mercury vacuum pumps. The first apparatus about to be described may be looked upon as the control which makes the above mentioned applications practicable. By means of this device the pressure established by a Geissler, or any other suction pump, can be automatically varied between definite limits and the period of each variation can be adjusted to any desired length of time.

The apparatus is represented by Fig. 1. It is not essential that the various parts be made exactly proportional to the sizes indicated by the

[1] McCoy and Ross, THIS JOURNAL, 29, 1709 (1907).

[2] Blanc, *Physik. Z.*, 8, 321 (1907).

diagram as quite a large variation is possible without impairing the efficiency of "the control" as this device may conveniently be called. At the start Tap 1 is closed, or opened to a closed piece of apparatus, and Tap 2, leading to a suction pump, is opened. Then the requisite amount of mercury is introduced through Tube T; namely enough to fill Tubes R, H, B and E to an extent indicated in the diagram. The apparatus is now ready for use. Suction is continuously applied by means of a suction pump attached through Tap 2, so that the mercury rises in Tubes B and E and drops in R and H. When the atmospheric pressure has been reduced by an amount equivalent to a column of mercury equal in length to Tube B, the mercury in H is drawn through B into E until the mercury in E is at level *a* and in R at level *b*, the difference between these levels being again equal to the length of Tube B. The mercury having left H, air is now free to enter the suction pump through T, H and B, and the pressure throughout is atmospheric. The mercury in the U-Tube formed by Tubes E and R will seek its own level, and therefore rise in Tube R and fall in Tube E. The relative sizes of these tubes is such that when the mercury in E has sunk to level *d*, the mercury in R will be at level *c* and consequently mercury siphons over into H out of R. The ingress of air through H to the suction pump is shut off, and the pressure falls in that part of the apparatus thus shut off, with the result, that the mercury again rises in Tubes E and B and the whole operation is repeated through another cycle. The relative volumes of the upper parts of Tubes E and

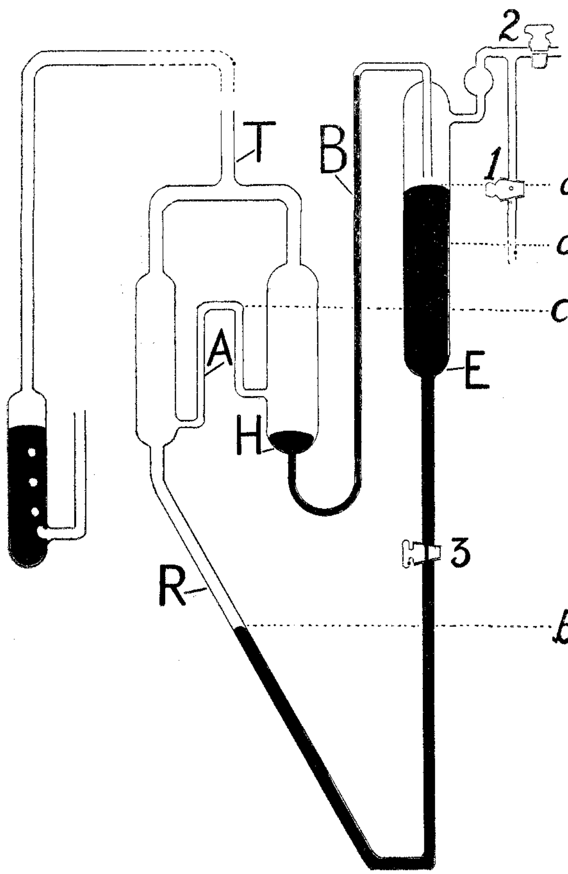

Fig. 1.

R are such that a small drop in the level of the mercury in E is sufficient to completely fill R to the level *c*. The amount of mercury which siphons over through A is sufficient to completely fill Tube B; and to insure this the siphon A is necessary, since the level in R starts to fall immediately when some mercury has entered H.

The result of the whole proceeding described above is that the pressure in any closed apparatus connected through Tap 1 to the control would vary periodically between atmospheric pressure and this pressure lowered by an amount equivalent to a column of mercury equal in height to Tube B. Each cycle through which the control passes may be regarded as being divided into two parts: namely, the time of evacuation and the time that all parts of the apparatus are under atmospheric pressure. The time of evacuation is regulated by the degree to which Tap 2, leading to the suction pump, is opened. If quite open the evacuation is rapid, if only slightly opened, slow, depending of course in part on the volume of the apparatus and the nature of the suction pump. The time that all parts of the apparatus are under atmospheric pressure is regulated by Tap 3. When this is wide open the mercury rises very rapidly in Tube R and closes H. By half closing Tap 3 the friction offered to the passage of the mercury through the constriction thus formed prevents the mercury from rising rapidly in Tube R, and the time it takes to rise to level *c* determines the length of this part of the cycle. Each part of the cycle can be adjusted within wide limits.

By attaching to T a tube containing a column of mercury (in a manner indicated in the diagram) the maximum and minimum pressure in each cycle is decreased by an amount equivalent to the length of this column of mercury. Thus the pressure as registered by a manometer attached to Tap 2 can be made to vary periodically between any two pressures lower than atmospheric and the time of each part of the period can be regulated by Taps 2 and 3. When once adjusted the control works regularly and does not require any further attention.

Automatic Mercury Pump.

The control described above can be used to make any Töpler mercury pump automatic. The reservoir of the pump has to be permanently placed at such a level that the distance between the top of the barrel of the pump and the bottom of the reservoir is about 45 cm. Also the capillary tube of the pump is shortened to about 12 cm., and connected through a mercury trap to the same suction pump which is attached to the control. The latter is connected to the mercury reservoir of the pump through Tap 1. Tube B (Fig. 1) is made 70 cm. long. When the water suction pump is started air is drawn out of the body of the pump, and through the control out of the mercury reservoir until a pressure of

6 cm. is reached; then the mercury is drawn out of B, and air enters through Tubes T, H, B and Tap 1 into the reservoir of the mercury pump, driving the mercury therein into the pump barrel, since the mercury trap, mentioned above, prevents air from entering the latter through the capillary tube. Tap 3 of the control is adjusted according to the period of the pump, namely, in such a way that the time taken by the mercury to rise in the control to close H is equal to the time required for the mercury to completely drive the gas out of the pump barrel, whereupon suction is again applied and the mercury drawn out of the pump barrel into the reservoir.

A pump such as described above has been in use for a long time and was found to have many advantages as compared, for example, with an automatic mercury pump previously described.[1] It is simpler to construct and more compact; the whole pump and connecting tubing need not be higher than 100 cm. Then the mercury in the control is quite separate from the mercury in the pump proper. But the outstanding advantage is to be found in the speed of action; for instance, with a pump barrel of 700 cc. capacity the pump can be made to pass through a complete cycle in 25 seconds. When an ordinary Töpler pump is highly evacuated great care has to be taken that the mercury in the barrel moves slowly when it reaches the top, otherwise the glass cannot stand the shock. Generally this shock is avoided by a constriction in the tubing connecting the mercury reservoir to the pump barrel. But this entails a slow period for the pump. With the control described above this constriction is not necessary, and the reservoir and pump barrel can be connected by a broad tube, so that the mercury rushes up with great speed when atmospheric pressure is applied to the mercury in the reservoir. Now, to prevent the jar due to its striking the top, Tap 3 of the control is opened somewhat more so that atmospheric pressure is applied to the mercury in the reservoir for a shorter time than it takes the mercury to completely fill the barrel. Therefore, towards the last, suction is applied and the mercury slowed up before it strikes the top, the momentum of the mercury being just sufficient to carry it over into the capillary outlet tube. Thus the mercury fills the greater part of the barrel very rapidly and is slowed up only towards the very last.

The control has made it possible to use other liquids than mercury in a Töpler pump in which case Tube T is attached to the mercury wash bottle shown in the diagram, the length of the column of mercury depending on the specific gravity of the liquid in the Töpler pump. This will be made the subject of a separate paper, as the results obtained prove to be of great use in experimental manipulation.

[1] This Journal, 37, 2654 (1915).

Circulation of Gases.

The following device can be used where at regular intervals a definite quantity of gas is to be taken out of some reservoir and forced through some apparatus, or is to be circulated through it repeatedly:

Represented by Fig. 2, this device, as in the case of the control, can have its relative parts varied in size to suit the particular experiments it is to be used for, and various connections and parts, if desired, can be made of rubber tubing. Tap 1 of the control (Fig. 1) is connected to D (Fig. 2), one arm of the U-tube C D, which is partly filled with mercury. F and G are mercury traps. K is a wash bottle which may be taken as representing a piece of apparatus through which a gas is to be circulated. The control is made so that Tube B (Fig. 1) is shorter than Tube D (Fig. 2), and Tap 3 is adjusted so that the time of evacuation is equal to the time that atmospheric pressure is established throughout. During the time that suction is applied by the control, the mercury rises in C and gas is drawn from K through M, F into D. Gas cannot be drawn from G, the mercury rising in L. When, through the control, atmospheric pressure is again exerted on the top of the mercury in C, the mercury seeks its own level forcing out the gas, which had been drawn into D, through L, G into K, the mercury rising in M and preventing the gas from being driven in that direction. By means of a constriction in C regulated by Tap 4, the rate of fall of the mercury can be made equal to the rate at which it rose. The gas in the apparatus is thus continuously circulated in the direction indicated by the arrows.

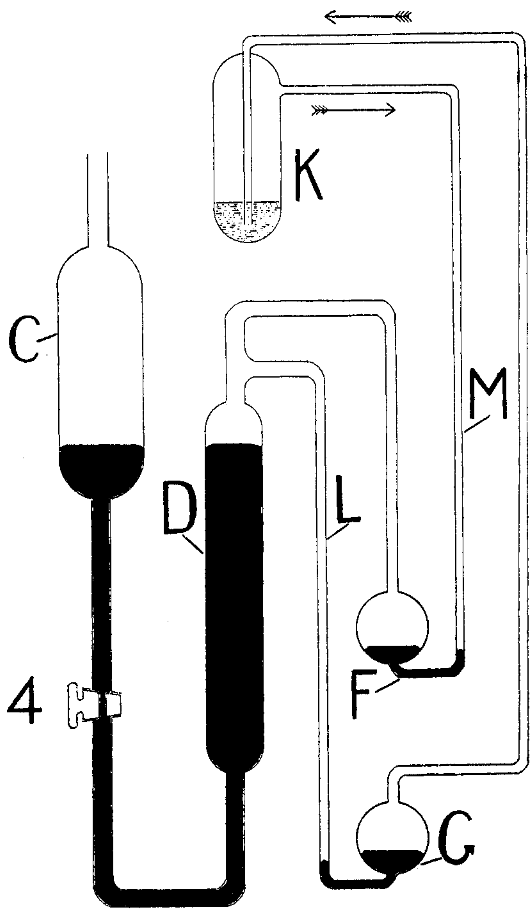

Fig. 2.

The gas may be circulated at any desired pressure by changing the relative lengths of the arms of the U-tube C D; space does not permit a detailed description of this or of other variations. Instead of mercury any other liquid may be employed according to the nature of the gas to be circulated.

Magnetic Stirrer.

In the use of a magnetic stirrer an arrangement is necessary whereby the electric current which is sent through the magnet may be turned on and off. This can be conveniently done by attaching the control to the apparatus depicted in Fig. 3. This device will handle large electric currents at the voltage of the electric lighting system, and can be synchronized with great exactness to the natural period of the stirrer itself.

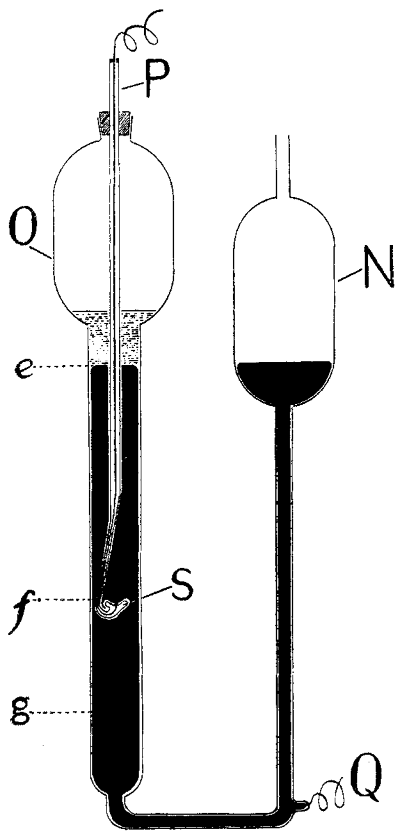

Fig. 3.

A U-tube whose arms end in bulbs N and O is filled with mercury to the level *e*. N is attached to the control through Tap 1 in the latter. Tap 3 is opened wide, or left out altogether, and Tube B made shorter than the length of the mercury column in the U-tube (Fig. 3). P is a glass tube, held in place by a cork loosely fitted into O, serving to insulate a wire sealed into the cup form S at the end of Tube P. O is filled with air, except for a small amount of water covering the mercury. When the control is started the mercury falls from level *e* to level *g*, being drawn into N at a constant rate until the control establishes atmospheric pressure in N, whereupon the mercury rises to its original level very rapidly. There being no constriction in Arm E of the control, suction is again applied almost instantaneously, and the mercury level again is lowered. If Q and P are part of an electric circuit the latter will be broken the moment the mercury passes S at the level *f*, and contact is again made when the mercury returns to its original level. The ratio of the length of time that the current is on to that when it is off will be proportional to the ratio of the distance between levels *e* and *f* to the distance between levels *f* and *g*, and this latter ratio can be adjusted in any desired manner by raising or lowering Tube P. If it is necessary to stir a viscous liquid a metronome is useless because, making contact only momentarily, the stirrer would not have time to start moving. Suppose for instance that for a definite current it requires 10 seconds for the magnet to draw the stirrer up the proper distance and 20 seconds for the stirrer to drop back again due to its own weight. The natural period of the stirrer is then 30 seconds and the control is first of all regulated by means of Tap 2 leading to the suction pump to give this period, *i. e.*, go through a complete cycle every half minute. Then Rod P is adjusted so that S is below level *c* about a third of the distance between levels *e* and *g*. Then the current will be on one-third of the time, *i. e.*, 10 seconds, and off two-thirds of the time, *i. e.*, 20 seconds. Another advantage is to be found in the fact that where large currents, say 10 amperes under a voltage of 110 or more volts, are used no relay is required. At the moment of break there is a small spark between the mercury left in cup S and the column of mercury moving downwards. But this spark occurs in the water which, as was mentioned above covers the mercury in O, and the only effect is that in time a minute amount of mercury becomes colloidal; this colloidal mercury is reabsorbed and does not accumulate. An apparatus as described above was in continuous use for several months without requiring any readjustment or addition of fresh mercury.

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[CONTRIBUTION FROM THE WOLCOTT GIBBS MEMORIAL LABORATORY OF HARVARD UNIVERSITY.]

COMPRESSIBILITY OF AQUEOUS SOLUTIONS, ESPECIALLY OF URETHANE, AND THE POLYMERIZATION OF WATER.[1]

BY THEODORE W. RICHARDS AND SVEN PALITZSCH.

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In previous papers from this laboratory[2] a marked relation between compressibility and surface tension, as far as certain pure liquids are concerned, has been pointed out. This relation may be expressed approximately by the empirical equation $\beta.\gamma^{4/3} = k$, where β represents the compressibility and γ the surface tension. In mixtures of two liquids, however, the conditions are less simple and the relation between surface

[1] The measurements in the present and a following paper were carried out at the Wolcott Gibbs Memorial Laboratory during the winter of 1915–16, when S. Palitzsch was at work at Harvard University as Fellow of the American Scandinavian Foundation, having leave from Carlsberg Laboratorium, Köbenhavn; they may be considered as the beginning of a research to be carried out in the future on the volume condition in solution of organic substances, especially those of biochemical significance. Responsibility for the theoretical part of the paper must be borne entirely by the senior author, because the present difficulty of communication has rendered the complete interchange of views impracticable.

[2] THIS JOURNAL, 30, 11 (1908); *Z. physik. Chem.*, 61, 451 (1908).