APPLICATION OF AN ELECTROMAGNETIC FORCE TO "THERMOBALANCE."

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Introduction. The "thermobalance" invented by Prof. Honda[1] has wide applications in chemical and metallurgical experiments. But, to our regret, the following defects are met with in its use. (1) By magnifying the sensibility of the balance, the movements on its scale are multiplied even by a small change of weight, and hence it is necessary to interrupt the measurement and change its weight, on the beam of the balance during an experiment. (2) And during this manipulation, the change in the weight of a sample cannot be measured. (3) As the up and down movements of the arms of the balance cause the spring to stretch and contract, the hysteresis of the spring causes an error. (4) The thermocouple cannot be fixed with the sample, so that when the position of the latter is displaced by the change in its weight, it recedes from the former, and the exact reacting temperature is not observable by the thermcouple.

To remedy the above obstacles, the present writers made the following improvements by using an electromagnet.

In our improved apparatus, a current is adjusted in the observing position so that the scale is always set at the zero point. The change in the weight of the sample can be indirectly found from the amount of the current, the sensibility can be magnified, the hysteresis eliminated, and the temperature of the reaction can be found exactly.

Apparatus and Manipulation. The "thermobalance" used in this experiment was that invented by Prof. Honda, and an electromagnet was attached to one side of the beam.

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(1) Honda, *Science Reports of the Tohoku Imperial University*, **4** (1915), 97.

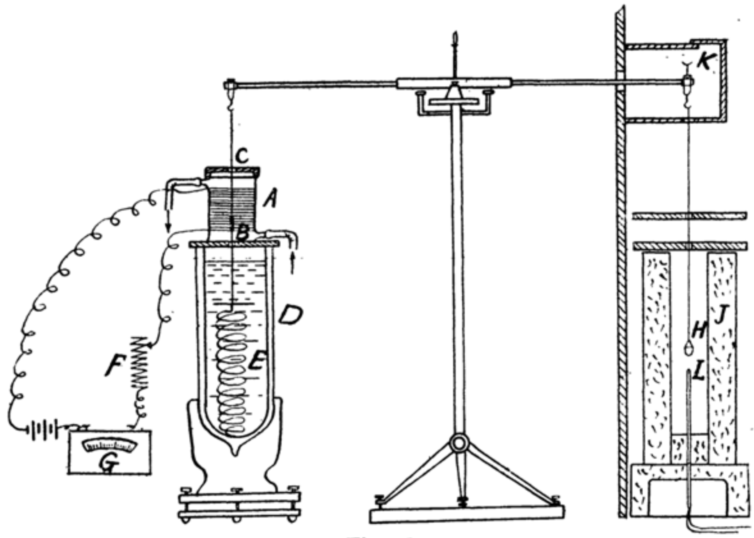

Fig. 1.

Fig. 1 shows the apparatus in which A is a coil wound with silk-wrapped copper wire on a glass cylinder 4.7 cm. in diameter and 6 cm. in length. It is double-walled, and between the walls water is passed to avoid the heating by the current. C is a brass cap and in its centre a small hole is bored, through which passed a slender copper wire. The upper end of the wire is fixed to one arm of the balance and the lower bound to the damper plate, passing through a mild steel rod B, which is 0.4 cm. in diameter and 1.4 cm. in length. Under the plate the upper end of the spring E is fixed. The sensibility of the balance is intensified by using a somewhat weak spring and a less viscous oil, mixed an equal volume of the transformer oil with the petroleum. B is placed downwards from the centre of the coil, to pull it upwards, when the current is passed. The current was lead from a 6 volt battery, and observed with an exact ammeter. The adjustment of the current is easily made by several slide resistances. L is a thermocouple and J a furnace. The parts hatched protect the apparatus from the vibration of the balance by a convection current of air.

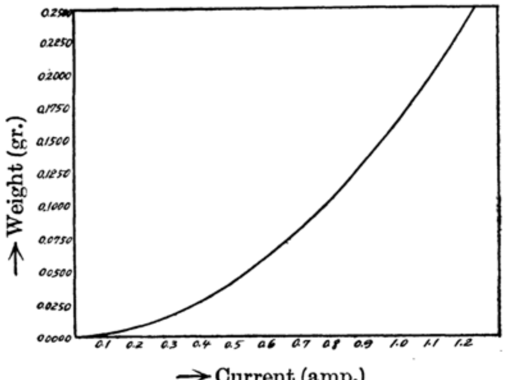

Fig. 2.

In order to obtain the relation between the current and the weight, 0.3 gr. of the weight is placed on K, and riders on the other side of the arm, to keep the scale at zero, and then on decreasing the weight on K we determine the amount of current sufficient to keep the scale at zero. The results are shown in Table 1 and Fig. 2.

TABLE 1.

Weight gr.	Current amperes	Weight gr.	Current amperes	Weight gr.	Current amperes
0.0000	0.000	0.0700	0.640	0.1600	0.982
0.0010	0.053	0.0750	0.664	0.1650	0.997
0.0020	0.087	0.0800	0.687	0.1700	1.014
0.0030	0.112	0.0850	0.708	0.1750	1.029
0.0050	0.152	0.0900	0.730	0.1800	1.043
0.0080	0.199	0.0950	0.751	0.1850	1.058
0.0100	0.225	0.1000	0.772	0.1900	1.074
0.0150	0.283	0.1050	0.791	0.1950	1.087
0.0200	0.331	0.1100	0.812	0.2000	1.102
0.0250	0.392	0.1150	0.829	0.2050	1.116
0.0300	0.412	0.1200	0.846	0.2100	1.130
0.0350	0.445	0.1250	0.864	0.2150	1.143
0.0400	0.475	0.1300	0.882	0.2200	1.154
0.0450	0.508	0.1350	0.898	0.2250	1.167
0.0500	0.537	0.1400	0.915	0.2300	1.181
0.0550	0.563	0.1450	0.932	0.2350	1.193
0.0600	0.591	0.1500	0.949	0.2400	1.207
0.0650	0.615	0.1550	0.965	0.2450	1.219
—	—	—	—	0.2500	1.232

Results of Experiments. To determine the accuracy of the improved "thermobalance" the present writers determined the decomposition curves of the following five compounds of "Kahlbaum zur analyse."

The thermocouple used was calibrated in the range 300–1200° C. with the Pt-PtRh thermocouple which was certificated at the "Deutsche physikalische-technische Reichsanstalt," and below 300°C. calibrated with the boiling points of water and naphthalene. In the following figures, the ordinates represent the decrease of the weight of the sample, and the abscissa the temperature. The shapes of the decomposition curves are of course somewhat liable to the heating velocity. In the present experiments, it was generally 2 degrees per minute, and at the point where a vigorous decomposition took place 1 degree or less per minute.

Calcium carbonate, $CaCO_3$. The decomposition curve of calcium carbonate is shown in Fig 3 (B). Its decomposition begins at about 400°C., reaches a maximum at 700°C., and finishes at 780°C. to become CaO. The calculated and the observed values of decomposed CO_2 are given below.

$CaCO_3$	CO_2		
	Calculated value	Observed value	Error
0.3175	0.1396	0.1399	+0.0003

Copper sulphate, $CuSO_4{\cdot}5H_2O$. The decomposition curve for the copper sulphate is shown in Fig. 3 (A). The stage of the decomposition is denoted as follows.

$$CuSO_4{\cdot}5H_2O \rightarrow CuSO_4{\cdot}H_2O \rightarrow CuSO_4 \rightarrow CuO \rightarrow Cu_2O.$$

The first stage of the reaction occurs at 75–120°C. four molecules of water being removed and one remaining molecule of water escapes at 230–255°C. The anhydrous salt begins to decompose gradually at 600°C. evolving SO_3, and at 760°C. it changes completely to CuO and on further heating it is decomposed to Cu_2O at 1040–1060°C.

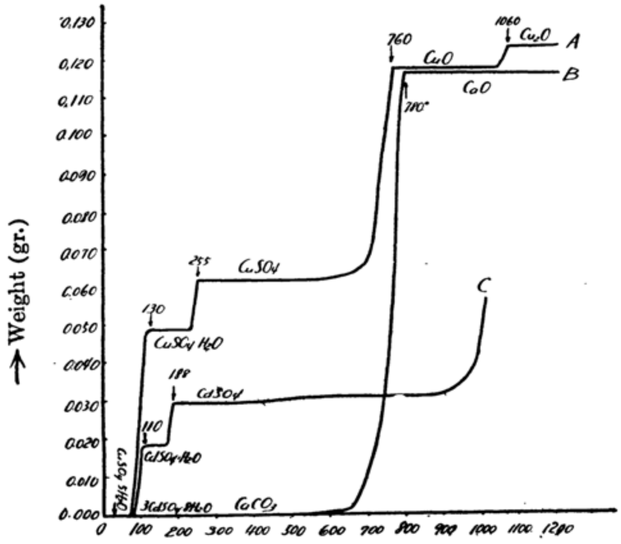

Fig. 3. → Temp. (°C.)

The observed data are shown in the following table.

$CuSO_4{\cdot}5H_2O$	$4H_2O$	H_2O	SO_3	$\frac{1}{2}O_2$
0.1723	Calculated value 0.0497	Calculated value 0.0124	Calculated value 0.0553	Calculated value 0.0055
	Observed value 0.0495	Observed value 0.0127	Observed value 0.0556	Observed value 0.0060
	Error −0.0002	Error +0.0003	Error +0.0003	Error +0.0005

Cadmium sulphate, $3CdSO_4{\cdot}8H_2O$. The decomposition curve of this salt is shown in Fig. 3 (C). Cadmium sulphate leaves its crystallising water at two stages, 80–110°C. and 170–190°C. On elevating the temperature, the anhydrous salt begins to decompose at 900°C. The observed data are as follows:—

$3CdSO_4 \cdot 8H_2O$	$5H_2O$			$3H_2O$		
	Calc. val.	Obs. val.	Error	Calc. val.	Obs. val.	Error
0.1614	0.0189	0.0186	+0.0003	0.0113	0.0113	0.0000

Barium chloride, $BaCl_2 \cdot 2H_2O$. The decomposition curve of barium chloride is shown in Fig 4 (D). This salt loses one molecule of water at 70°–100°C. and then its weight begins gradually to decrease above 500°C. The observed data are as follows :—

$BaCl_2.2H_2O$	H_2O			H_2O		
	Culc. val.	Obs. val.	Error	Calc. val.	Obs. val.	Error
0.2581	0.0191	0.0190	−0.0001	0.0191	0.0192	+0.0001

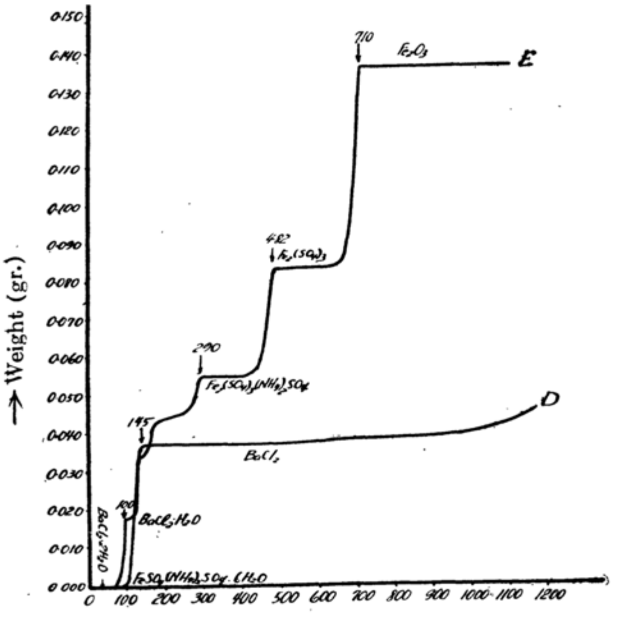

Fig. 4. → Temp. (°C.)

Mohr salt, $FeSO_4(NH_4)_2SO_4.6H_2O$. The decomposition curve of this salt is shown in Fig. 4 (E). The crystallising water is removed at 100°C., one part of ammonia is given off and at the same time is oxidised to ferric salt at 170°C. At 290°C. it becomes $Fe_2(SO_4)_3(NH_4)_2SO_4$, at 420–490°C. $(NH_4)_2SO_4$ is lost remaining ferric sulphate, and at 650–710° decomposes to ferric oxide. The observed results are as follows :—

$FeSO_4 \cdot (NH_4)_2 \cdot SO_4 \cdot 6H_2O$	$6H_2O + NH_4$			$(NH_4)_2SO_4$			SO_3		
	Cal.	Obs.	Err.	Cal.	Obs.	Err.	Cal.	Obs.	Err.
0.1700	0.0547	0.0553	+0.0006	0.0286	0.0287	+0.0001	0.0521	0.0528	+0.0007

Summary.

The present writers have applied an electromagnet to the "thermo-balance" to remove the previous defects and succeeded in elevating its sensibility to that of the chemical balance. To determine its accuracy, the decomposition curves of the following five compounds have been determined: calcium carbonate, copper sulphate, cadmium sulphate, barium chloride and Mohr salt.

In conclusion, the authors express their hearty gratitude to Prof. Oishi and Prof. Murakami for their kind directions.

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