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The Electronic Microbalance for Atomic Beam Density Measurements

In order to obtain absolute oscillator strength of spectral line in atomic beam, by means of absorption method, the total absorption A and the product $N \cdot l$ should be determined (N being the density of absorbing atomic beam and l — the thickness of absorbing layer). The electronic microbalance of the authors' construction was used for the measurement of $N \cdot l$ value. The mass of the atoms of the given element, deposited on the microbalance scale, can be measured with accuracy to 10^{-5} g.

1. Construction and principle of the microbalance operation

The main mechanical part is a quartz beam supported below its centre of gravity with a mirror fastened in the middle. At its one end a cylindrical ferrite magnet (M) is fastened and the scale made of mica plate at the other. The block scheme of the microbalance electronic part is shown in Fig. 1. The parallel light beam reflected from the mirror illuminates two photodetectors (Ph). The signals detected in each of them are amplified by the differential amplifier (DA). The output of this amplifier

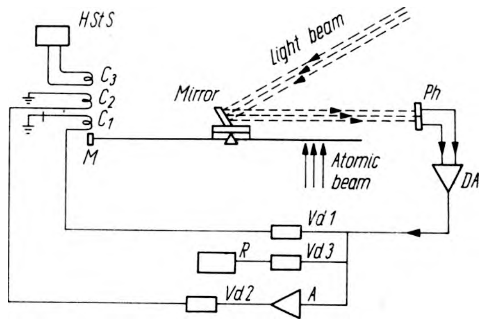

Fig. 1. Block scheme of the microbalance electronic part

Ph — photodetectors; *DA* — differential amplifier; *A* — amplifier which differentiates photodetector signal; *M* — magnet; *C*1, *C*2, *C*3 — magnetic coils; *H St S* — highly stabilized *dc* supply: *vd*1, *vd*2, *vd*3 — voltage dividers; *R* — recorder

is connected through a voltage divider ($vd1$) with the coil ($C1$) producing heterogeneous magnetic field and placed just above the magnet (M). In the state of equilibrium both photodetectors are illuminated identically and the output signal of amplifier (DA) equals zero. When some weight is put on the scale, the beam declines from the equilibrium position and the non zero output signal produces a magnetic field acting on the magnet (M). The coil ($C1$) is connected in such a way that the acting force compensates partially the weight on the scale. Using the voltage divider ($vd1$) this feedback may be tuned. The recorder (R) is parallelly connected to the output of the amplifier (DA). This allows a continuous recorder control of the coil ($C1$) current, the latter being proportional to the mass deposited on the scale. In order to make vibration damping more effective the electronic damping was used. To this end the second coil ($C2$) was wound round the first ($C1$) coil parallely to it. The signal from photodetectors was differentiated by amplifier (A) and then directed to the coil ($C2$). The damping can be controlled by means of the voltage divider ($vd2$). The third coil ($C3$) was used for preliminary balancing of the microbalance placed in the vacuum.

2. The calibration of the microbalance

The microbalance was calibrated in the air before and after each measurement. The weights used ranging from $2 \cdot 10^{-4}$ g to $4 \cdot 10^{-4}$ g were made of 0.05 mm in diameter copper wire. They were cut from the uniform pieces of wire 30 cm long which had been weighed on the analytic balance with the accuracy of 10^{-5} g. The deflection of balance caused by putting the separate weights was registered by the same recorder (R) which was used for detection of the mass of atoms deposited on the scale during the measurement carried out in vacuum. The range 0 to $1.5 \cdot 10^{-3}$ g was sufficient for the measurements of an atomic beam density. Within this range the microbalance worked linearly.

In order to control the operation of atomic beam apparatus the oscillator strength for indium resonance line $\lambda = 4101.76$ Å in temperature range 1065–1138 K was measured by means of absorption method. In this method the total absorption A in atomic beam and the product $N \cdot l$ were measured

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simultaneously. Typical results of the recording of the mass of indium atoms deposited on the scale of microbalance are shown in Fig. 2. The results obtained are gathered in Table, where $\dot{G}$ is the condensation rate of indium atoms on the scale, $N \cdot l$ is calculated atomic beam density in the volume in which the light

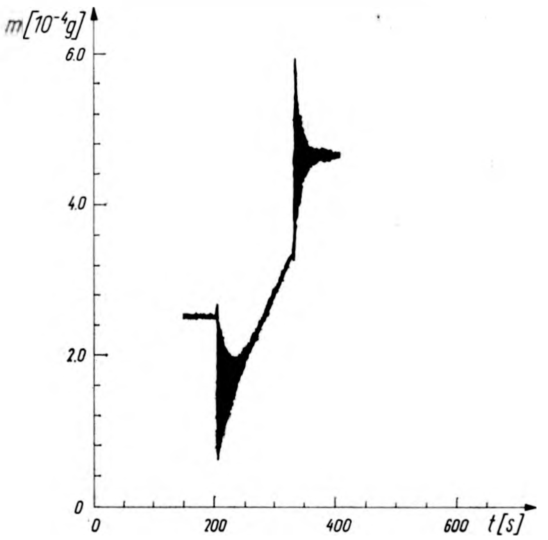

Fig. 2. The record of the mass m of indium atoms deposited on the microbalance scale; the jump s caused by atomic momentum in the beam is visible

The oven temperature T K	$\dot{G}$ [mass/time] g/s	$N \cdot l \cdot 10^{10}$ at/cm²	Total absorption	X %	Oscillator strength f
1063	$5.400 \cdot 10^{-7}$	2.70	0.02688	26	0.13 ± 0.03
1088	$1.184 \cdot 10^{-6}$	6.23	0.04890	20	0.11 ± 0.02
1118	$1.700 \cdot 10^{-6}$	8.66	0.07260	22	0.11 ± 0.02
1138	$2.180 \cdot 10^{-6}$	10.00	0.08615	28	0.11 ± 0.02

beam passes through the atomic beam (l- the thickness of absorbing layer), X — reflection coefficient in per cent for the atoms reflected from the scale. This coefficient is calculated from the measurements of momentum transferred from condensating atoms to the scale.

Our results are in a good agreement with the results obtained earlier by G. M. Lawrence, J. K. Link and R. B. King [2]. They used the same method as ours and obtained the value $f = 0.11 \pm 0.01$. The value obtained by P. T. Cunningham and J. K. Link [3] from lifetime measurement was $f = 0.12$.

The results obtained by using the first electronic microbalance constructed in this laboratory were published in [4]. Since, however, this microbalance never operated correctly, the results of [4] are meaningless.

Электронные микровесы для измерения плотности атомной частицы

Для получения абсолютной интенсивности спектральной линии осциллата в атомной энергии методом поглощения, следует определить полное поглощение A и произведение $N \cdot l$ (где N — плотность поглощающего атомного пучка, l — плотность поглощающего слоя). Электронные микровесы, построенные автором, были применены для измерения значения $N \cdot l$. Масса атомов данного элемента, помещенная на чашке микровесов, может быть измерена с точностью до 10^{-5} г.

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