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INTERACTION OF ATOMIC ENERGY LEVELS

THE present investigation is a continuation of the work we have already reported,[1] undertaken with a view to obtain information regarding the mutual influence of atomic energy states. The general method is to excite the spectra of two elements and then the spectrum of their mixture, all under identical conditions; a comparison of the relative intensities of the lines in the spectra of the individual elements with the relative intensities of the same lines in the spectrum of the mixture gives the required information.

Winans and Williams[2] have compared the relative intensities of tin lines obtained from a carbon arc containing tin with those from a Tesla discharge through a tube containing tin and mercury, when the latter was irradiated by λ2537 of Hg. The dispersion used by them was very small. In our experiments the spectra of the individual elements and of their mixture have been obtained under similar conditions for all, and the dispersion employed is quite large.

RESULTS

The lines of tin and mercury that suffered modification in intensity by mixture are given below:—

TIN LINES

Strengthened:

2839·99	$5p^2\ {}^3P_2 - 5p6s\ {}^3P_2{}^\circ$
2850·61	$5p^2\ {}^1D_2 - 5p5d\ 1_2{}^\circ$
3034·12	$5p^2\ {}^3P_1 - 5p6s\ {}^3P_0{}^\circ$
3175·04	$5p^2\ {}^3P_2 - 5p6s\ {}^3P_1{}^\circ$
3262·33	$5p^2\ {}^1D_2 - 5p6s\ {}^1P_1{}^\circ$

Weakened:

2317·21	$5p^2\ {}^1D_2 - 5p6d\ 4_3{}^\circ$
2334·80	$5p^2\ {}^3P_1 - 5p5d\ 3_1{}^\circ$
2354·84	$5p^2\ {}^3P_1 - 5p5d\ 2_2{}^\circ$
2421·69	$5p^2\ {}^1D_2 - 5p5d\ 11_3{}^\circ$
2429·49	$5p^2\ {}^3P_2 - 5p5d\ 4_3{}^\circ$
2483·5	Sn II.
2495·72	$5p^2\ {}^1D_2 - 5p5d\ 9_2{}^\circ$
2546·55	$5p^2\ {}^3P_0 - 5p6s\ {}^1P_1{}^\circ$
2571·60	$5p^2\ {}^1D_2 - 5p6d\ 6_3{}^\circ$
2594·43	$5p^2\ {}^1D_2 - 5p6d\ 5_2{}^\circ$
2661·25	$5p^2\ {}^3P_1 - 5p6s\ {}^1P_1{}^\circ$
4524·74	$5p^2\ {}^1S_0 - 5p6s\ {}^1P_1{}^\circ$

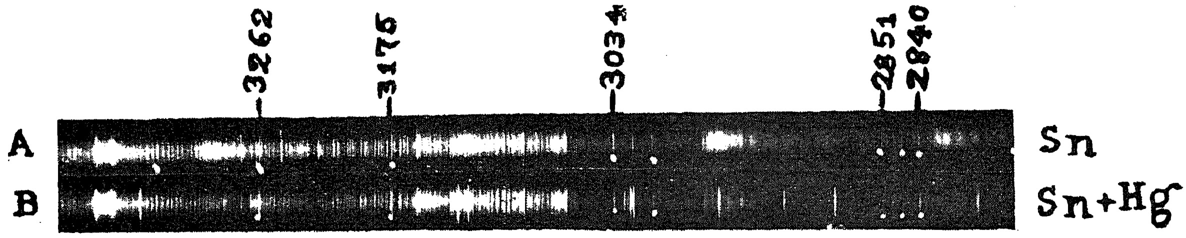

FIG. 1

A—Tin
B—Tin and Mercury Mixture

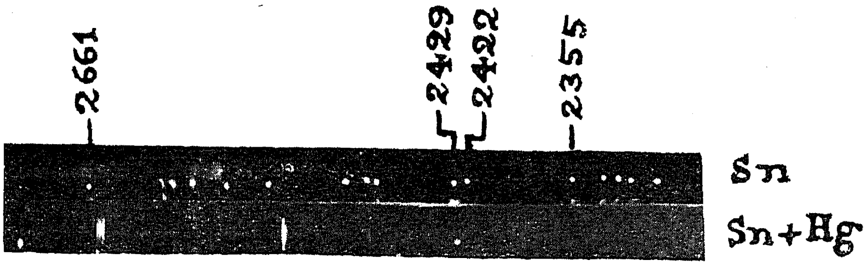

FIG. 2

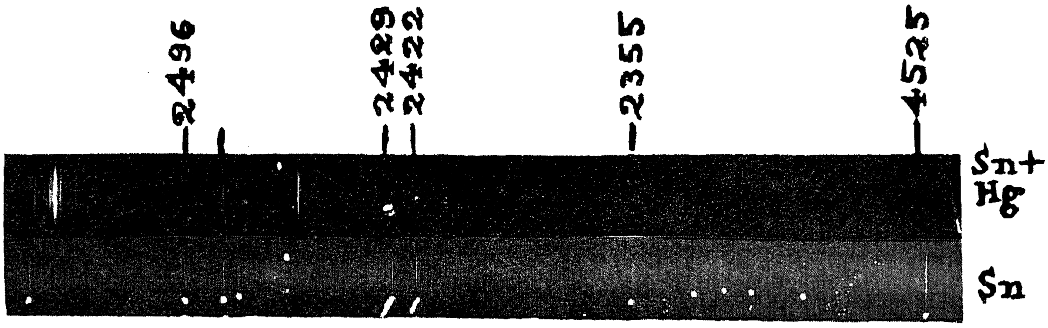

FIG. 3

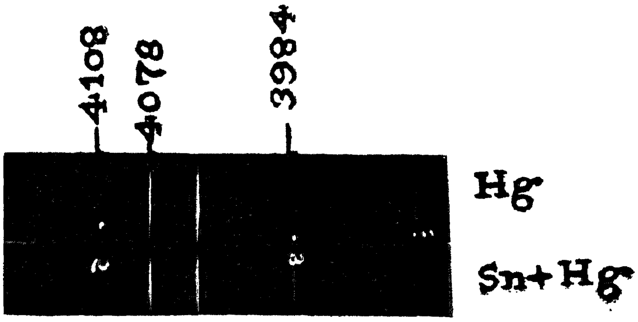

FIG. 4

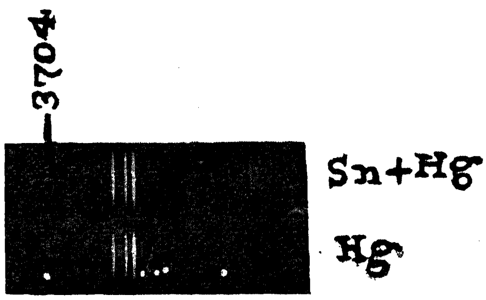

FIG. 5

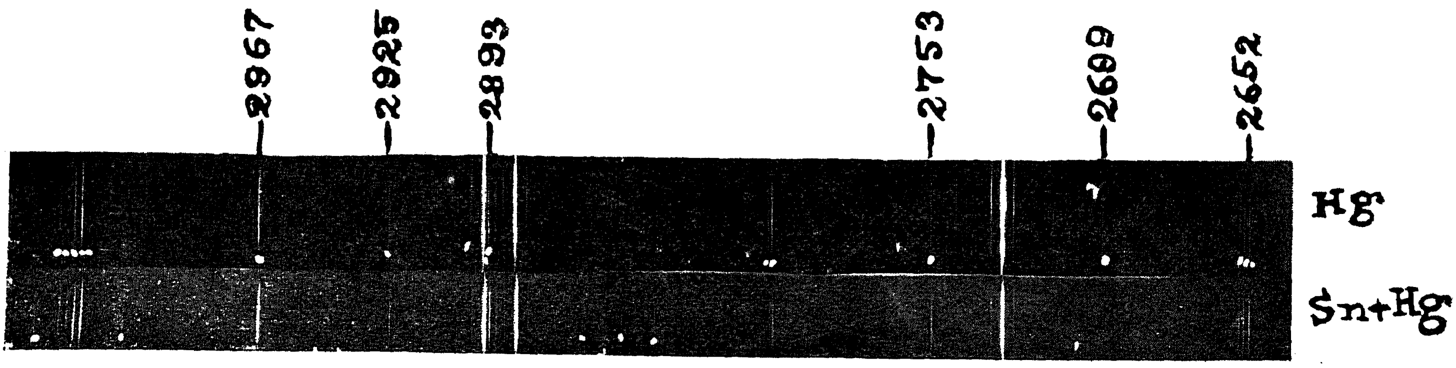

FIG. 6

MERCURY LINES

Strengthened:

2464·02	$6^3P_0 - 9^3S_1$
2536·52	$6^1S_0 - 6^3P_1$
2652·04	$6^3P_1 - 7^3D_2$
2653·68	$6^3P_1 - 7^3D_1$
2655·13	$6^3P_1 - 7^1D_2$
2752·77	$6^3P_0 - 8^3S_1$
2856·94	$6^3P_1 - 8^1S_0$
2893·62	$6^3P_1 - 8^3S_1$
2925·41	$6^3P_2 - 9^3S_1$
2967·28	$6^3P_0 - 6^3D_1$
3983·96	Hg II
4077·83	$6^3P_1 - 7^1S_0$
4108·08	$6^1P_1 - 9^1S_0$

Weakened:

2400·52	$6^3P_1 - 9^1D_2$
2639·93	$6^3P_2 - 10^3D_3$
2698·85	$6^3P_2 - 9^3D_{2\|3}$
3704·25	$6^1P_1 - 9^1D_2$

DISCUSSION

In considering the explanation for these facts we must take into account the processes that occur in the discharge tube. Mercury and tin atoms are being raised to excited levels by electron impacts and there are also impacts between normal and excited tin and mercury atoms. Of these impacts, those involving atoms in metastable states are of greater interest. Now mercury has two metastable levels at 37642·3 and 44040·2 cm.$^{-1}$ respectively above the ground state and tin has four such levels at 1692·0, 3428·0, 8613·5 and 17163·0 cm.$^{-1}$ respectively. Now all the tin lines that are strengthened have upper levels near the two metastable levels of mercury as can be seen from the previous table. Hence their strengthening must be explained as due to impacts of normal tin atoms with metastable mercury atoms in which the latter give their energy to the former. The brightening of the tin lines may also be due to impacts of normal tin atoms with mercury atoms in the $6\,^3P_1$ state, but this process does not seem to be very frequent since 2536 ($6\,^3P_1 - 6\,^1S_0$) is brightened instead of becoming weaker. This strengthening of 2536 must be due to increased production of the $6\,^3P_1$ state by impacts with tin atoms in the 5p6s $^1P_1^\circ$ state. The energy of the latter state is very close to that required to excite $6\,^3P_1$ and two tin lines having that state as the upper level have become weaker. But 3262 of tin which involves the same upper level is brightened. This must be explained by the fact that for this line the transition probability being larger, the transition takes place before the energy of the upper state is destroyed by collisions. Taking the upper states of the other tin lines which have been weakened, we find that they have energies near 44000, 47000, 49000 and 52000 cm.$^{-1}$ The first of these may be used up in producing metastable mercury atoms in the $6\,^3P_2$ state. The other energies when added to the energies of the $6\,^3P_0$ metastable state of mercury amount to 82000, 85000, 87000 and 90000 cm.$^{-1}$ respectively and are quite sufficient to ionise the mercury atom (energy required for ionisation 84178·5 = cm.$^{-1}$). That such ionisation does take place seems to be corroborated by the strengthening of the mercury spark line 3984. The four lines of mercury which are weakened have upper states of energy about 81000 which when enriched by impacts with metastable tin atoms particularly in the $^3P_2$ state (3428 cm.$^{-1}$) will lead to the ionisation of the mercury atom. This serves to explain why the corresponding mercury lines are weakened. As for the mercury lines which are strengthened, we have already explained the strengthening of 2536. Taking the others we find the enriched upper levels having energies of 64000, 71000, 74000, 77000 and 78000 cm.$^{-1}$ respectively. These states must arise from mercury atoms taking up the requisite energy from tin atoms. The probable states can only be guessed. Mercury atoms in the $6\,^3P_2$ state taking the energy of the metastable $^1S_0$ state of tin lead to an energy equal to 61000 cm.$^{-1}$ The $6\,^3P_0$ state of mercury by taking the energy of tin atoms in the $^1P_1^\circ$ state can be raised to a level = 77000 cm.$^{-1}$ Mercury atoms in the $6\,^1P_1$ state can, by taking the energy of tin atoms in the metastable $^1D_2$

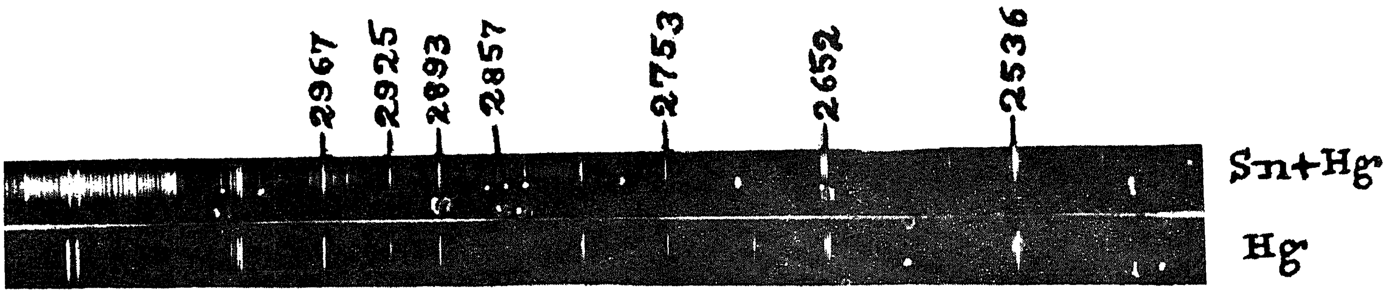

FIG. 7

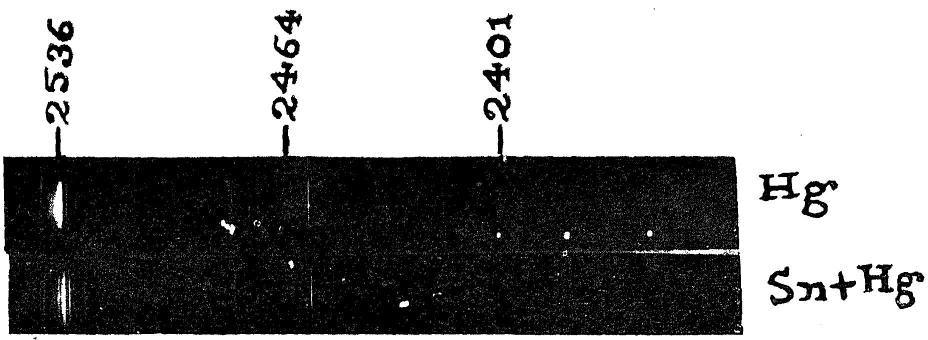

FIG. 8

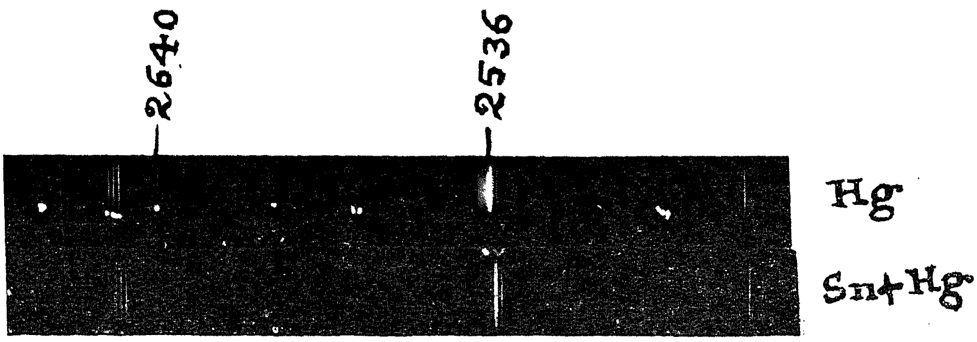

FIG. 9

state, be raised to 63000 cm.$^{-1}$ while, by taking energy from the metastable $^1S_0$ state of tin, they can be raised to 71000 cm.$^{-1}$ Whether these processes actually occur cannot be further corroborated by our experiments, since transitions from the 6 $^1P_1$ state are beyond the range of our instruments. Other mercury levels near 77000 cm.$^{-1}$ also do not give lines accessible to our observation. Some mercury lines such as 3663, 3654 and 3651 Å, as well as 5791, 5789 and 5770 Å do not show any appreciable change in intensity although their upper levels are near 71000 cm.$^{-1}$ Such preferential interaction of levels, leading to changes in the population of some levels and none in other levels very close to the first, occurs also in the other mixtures studied by us. The regularities underlying such preferential interaction can only be perceived when much more extensive data have been accumulated, but a tentative explanation may be offered by noting that the transition probabilities for the lines 3650, 3654, etc., are larger than those for 2967 and hence there is a greater chance for 2967 to be affected.

In conclusion, it is a pleasure to record our thanks to Professor A. Venkat Rao Telang for much encouragement and many facilities.

T. S. SUBBARAYA.
K. SESHADRI.
N. A. NARAYANA RAO.

Physics Department,
Central College,
Bangalore,
January 27, 1941.

1 *Curr. Sci.* 1939, **8**, 508; 1940 **9**, 14; 1940, **9**, 173.
2 *Physical Review*, 1937, **52**, 930.