regard to the breadth and over-all extent of the 2.9-Mev level. In Fig. 4 this level does not contribute to the yield above $E_{ex}=3.5$ Mev. This is contrary to the evidence in Figs. 2 and 3, unless one attributes the entire yield above $E_{ex}=3.5$ Mev to the presence of levels which are very much broader than those observed by Inall.

The logarithmic plot of the data in Fig. 5 serves to emphasize some very broad structure in the region of $E_{ex}=10$ Mev. A level in Be^8 in this vicinity has been observed through other reactions. There is an indication of similar structure in the alpha spectrum of the $Li^8(\beta)Be^{8*}(\alpha)He^4$ decay.[7] Recently Moak and Wisseman[8] with the $Li^6(He^3,p)Be^8$ reaction, and Nilson and Jentschke[9] from alpha-alpha scattering, have given evidence for a level at about 12 Mev. Some older measurements locate a level at 11 Mev.[1] In view of the great breadth of the level and the incomplete coverage of it in the present experiment, it is probable that the same level is involved in all these experiments.

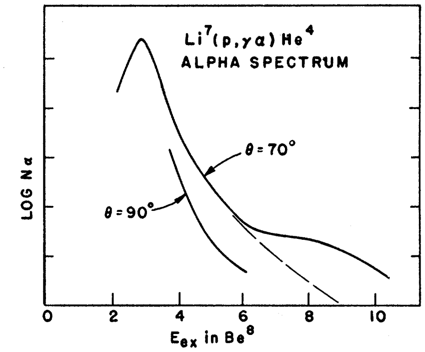

FIG. 5. Semilogarithmic plot of the spectra. The vertical displacement of the curves is, of course, arbitrary. The dashed line is merely a visual extrapolation.

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PHYSICAL REVIEW VOLUME 103, NUMBER 1 JULY 1, 1956

Atomic Masses of Ni^{58} and Ni^{60}†

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(Received March 20, 1956)

Mass spectrographic measurements are reported of the mass differences $C_2H_4O_2-Ni^{60}$ and $C_3H_6O-Ni^{58}$. These results are used, together with existing data, to discuss certain discrepancies between transmutation and mass spectroscopically determined masses in the Fe-Ni-Zn section of the atomic mass table.

I. INTRODUCTION

IT has been pointed out[1,2] that in the Fe-Ni-Zn section of the atomic mass table there exist discrepancies between mass spectroscopic and transmutation data. Further, these differences suggest that the masses of the nickel isotopes, as determined by mass spectroscopic methods, may be too low by $\sim$0.6 mmu. If such an error indeed be present in these mass values, its correction would cause the disappearance of most of the discrepancies in this region. With this in mind, some new mass studies of nickel isotopes were undertaken in this laboratory, and are reported herein.

II. EXPERIMENTAL

The masses of Ni^{58} and Ni^{60} have been redetermined using only hydrocarbons as comparison and dispersion lines. The hydrocarbons C_4H_9 and C_3H_6O, came from pump oil vapor, while $C_2H_4O_2$ was obtained from glacial acetic acid, introduced into the source region through a slow leak from a variable temperature reservoir. Nickel ions were obtained from $NiCl_2$ in the crucible of a modified Shaw source.[3] The mass spectrograph was a Dempster double-focusing instrument[4] possessing a resolution of about 1 part in 7000.

The effect on the doublet spacing of pressure changes in the analyzer section of the mass spectrograph has also been investigated, and will be reported in the *Canadian Journal of Physics*.

III. MASS OF Ni^{58}

Several photographs of the $Ni^{58}-C_3H_6O$ doublet were obtained in March, 1955 and May, 1955. From these were chosen the eight best-matched, low-pressure doublets, which were then measured by four individual observers. After routine statistical analysis, the following mass difference was obtained: $C_3H_6O-Ni^{58}=106.52$ ±15 mmu. From this, the Ni^{58} mass is calculated to be 57.95380 ± 15 amu. C^{12} and H^1 were taken to be

† This research was supported by the U. S. Air Force through the Air Force Office of Scientific Research of the Air Research and Development Command, the National Research Council of Canada, and the Shell Oil Company of Canada.
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TABLE I. Comparison of the new Ni^{60} and Ni^{58} atomic mass values with some others previously reported.

	Nier[a]		Duckworth[b]		New values		
Nuclide	Mass (amu)	Comparison mass	Mass (amu)	Comparison mass	Mass (amu)	Comparison mass	Mass difference (mmu)
Ni^{60}	59.94887±29	C_5	59.94926±14	Si^{30}	59.94939±15	$C_2H_4O_2$	90.82±15
Ni^{58}	57.95333±10	C_4H_{10}	57.95375±15	Si^{29}, COH, C_2H_5	57.95380±15	C_3H_6O	106.52±15

[a] See reference 6.
[b] For doublets including Si^{29} and Si^{30}, see reference 8. For doublets including COH and C_2H_5, see reference 7.

12.0038174±18 and 1.0081439±5 amu, respectively, as recently determined[5] by Scolman, Quisenberry, and Nier. The dispersion line was C_4H_9.

IV. MASS OF Ni^{60}

Twelve well-matched $Ni^{60}-C_2H_4O_2$ doublets were selected from plates taken in September, 1955, and January, 1956. These were measured by three observers whose weighted result was $C_2H_4O_2-Ni^{60}=90.82\pm15$ mmu, which leads to the mass value $Ni^{60}=59.94939\pm15$ amu. In this case, the dispersion line was C_3H_6O.

V. DISCUSSION OF RESULTS

Table I gives a comparison of our new mass values with those of Nier[6] and Duckworth[7,8] which have been corrected using the carbon and hydrogen values mentioned above. These new masses agree well with the previous values from this laboratory, which were obtained from different doublets. Our considered mass values for these two nuclides are now $Ni^{58}=57.95378\pm12$ amu and $Ni^{60}=59.94932\pm11$ amu. These, as before, are higher than those obtained by Nier and his colleagues.

We had hoped that this work would remove the discrepancy between the mass spectroscopic and transmutation values for the $Ni^{60}-Ni^{58}$ mass difference. However, as can be seen from Table II, this is not the case. Instead, we have obtained identically the same answer as Nier and his colleagues, which differs from the transmutation value by ~0.45 Mev. This discrepancy is particularly disturbing when one reflects that these two nuclides are connected, transmutation-wise, by a series of four reactions, for each of which the Q value has been determined[9,10] with high precision.

TABLE II. The $Ni^{60}-Ni^{58}$ mass differences, as derived from transmutation and mass spectrographic data.

Source of data	$Ni^{60}-Ni^{58}$ (amu)
Transmutation[a]	1.99606±1
Nier (Minnesota)[b]	1.99554±14
Duckworth (McMaster)[c]	1.99554±16

[a] See reference 11.
[b] See reference 6.
[c] Considered values, this paper.

Some months ago we reported[11] the new mass value $Zn^{64}=63.94909\pm15$ amu, from which, using accurate transmutation data, one may compute $Cu^{63}=62.94923\pm15$ amu. This may be combined with the new Ni^{60} value to compute the energy difference

$$(Cu^{63}+H^1)-(Ni^{60}+He^4)=3.9\pm0.2 \text{ Mev.}$$

This figure is of interest in connection with the Ghoshal experiment[12] for testing the compound-nucleus theory. In this experiment, the compound nucleus, Zn^{64}, was formed by both proton bombardment of Cu^{63} and by alpha-particle bombardment of Ni^{60}. To produce the same degree of excitation of the compound nucleus as that produced by protons, the alpha particles should require additional energy of this amount, that is, 3.9±0.2 Mev. This energy shift has been found experimentally to be 7±1 Mev (Ghoshal) or 6.4±1.0 Mev (John[13]), seriously disagreeing with the value derived from mass data, and, possibly, representing a black mark against the compound-nucleus concept. An increase in the values of the nickel masses by 0.6 mmu. would make this disagreement greater. Moreover, it would not improve the $Ni^{60}-Ni^{58}$ mass spectrographic mass difference relative to that derived from transmutation data. This makes the previously suggested[1,2] changes in the nickel masses somewhat less attractive.

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