Nuclear levels in ^{191,193,195,197}Pt excited via neutron pickup

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The (p,d) reaction has been performed at 26 MeV incident energy on targets of ^{196}Pt (97.5%), ^{194}Pt (97.4%), and ^{192}Pt (57%) and natural Pt. The deuterons were detected in the focal plane of the split pole magnetic spectrometer with a resolution of 16 to 20 keV full width at half maximum. In ^{193}Pt, 32 levels, 23 of which are observed for the first time, are populated below 1250 keV; in ^{195}Pt, 24 levels are observed below 1200 keV; in ^{191}Pt, due to low enrichment and target uniformity problems, only 7 levels are clearly separated. Comparison of the measured angular distributions with distorted-wave Born-approximation calculations allows parity assignments and spin limits for most of the final levels. Spectroscopic factors are deduced. A cursory investigation of the (d,t) reaction on the same targets with about 10 keV resolution has permitted us to separate several clustered low lying levels and to identify and study, using a ^{198}Pt target, a few levels of ^{197}Pt.

[NUCLEAR REACTIONS $^{198,196,194,192}(p,d)(d,t)^{197,195,193,191}$Pt, $E=26$ MeV; measured $\sigma(\theta)$; ^{197}Pt, ^{195}Pt, ^{193}Pt, ^{191}Pt levels deduced, J, π, C^2S. Natural and separated targets.]

I. INTRODUCTION

The platinum nuclei lie in a very interesting transitional region, between the strongly deformed and the spherical nuclei. It seems now established that an "oblate" to "prolate" shape transition takes place as predicted by Kumar and Baranger[1] when going from the heavy to the light isotopes and many studies of the properties of the levels of the even and odd platinum isotopes have been done using heavy ion reactions and γ-ray spectroscopy. Emphasis has been put in these studies on high spin levels and their description as semidecoupled bands.[2,3] The high spin level spectra in odd A nuclei can be accounted for in terms of the coupling of an $i_{13/2}$ neutron hole to a triaxially deformed core.[4,5] Quite amazingly, when this work was started, only a poor resolution study using transfer reactions had been published[6] and it was considered worthwhile to study simultaneously the (p,t) and (p,d) reactions on the even Pt targets with good resolution and high incident energy. During the analysis of our data, Yamazaki and Sheline published[7] results concerning ^{195}Pt, obtained using the (d,t) and (d,p) reactions. The present paper reports on results obtained mainly in the (p,d) reaction and concerning the levels of ^{191,193,195,197}Pt. Analysis of these data evidenced the need to perform complementary (d,t) measurements.

In the next two sections, the experimental procedure and the analysis of the data are described. The spectroscopic results obtained from the (p,d) reaction on the isotopically enriched ^{196,194,192}Pt targets are given in Sec. IV. Additional spectroscopic information obtained from the cursory study of the (d,t) reaction are given in Sec V. Section VI is devoted to spectroscopic results concerning ^{197}Pt obtained by means of both the (p,d) reaction on the natural platinum target and the (d,t) reaction on the separated ^{198}Pt target. The following sections are devoted to discussion and summary.

II. EXPERIMENTAL PROCEDURES AND RESULTS

A. General description

A 26 MeV proton beam from the Orsay MP tandem accelerator has been used to study the (p,d) and (p,t) reactions on a natural target and on isotopically enriched targets of the three even isotopes ^{196,194,192}Pt. The isotopic abundances and thicknesses are listed in Table I. The experimental setup and procedures have already been described.[8] The beam intensity was typically of the order of 300 nA, limited by the targets. Emitted tritons and deuterons were analyzed by the split-pole magnetic spectrometer and simultaneously detected using, respectively, five and

TABLE I. Isotopic analysis of the platinum targets (as given by ORNL, supplier of the isotopic material).

Target A	(at. %) 192	194	195	196	198	Thickness ($\mu g/cm^2$)
Natural Pt	0.78	32.9	33.8	25.3	7.21	240±40
192	57.30	26.05	11.04	4.74	0.87	34±6
194	0.015	97.41	1.99	0.52	0.06	123±20
196	<0.01	0.63	1.57	97.51	0.29	34±6
198	0.01	0.79	1.18	2.18	95.83	

three solid-state position-sensitive detectors at different locations in the focal surface. The solid angle was 1.7 msr. As the primary aim was the study of the (p,t) reaction,[9] data have only been recorded at six angles, most appropriate to characterize $L=0$ transfer in the (p,t) reaction.

Levels in the residual nuclei were observed up to 1250 and 1200 keV, respectively, in ^{193}Pt and ^{195}Pt and only up to about 750 keV in ^{191}Pt. The limitation in this last case is due to the poor enrichment (and uniformity) of the ^{192}Pt target, the contaminant peaks from the other Pt isotopes obscuring a large part of the spectrum. Levels in ^{197}Pt were extracted up to 400 keV only on the spectra from the natural platinum target, the region beyond being hidden by peaks originating from the reaction on ^{196}Pt. The peaks have a resolution of about 16 keV (full width at half maximum—FWHM) for the (p,d) reaction on the ^{196}Pt and ^{194}Pt targets, 18 keV for the reaction on the natural platinum target and 20 keV for the reaction on the ^{192}Pt target. A typical energy spectrum of deuterons emitted in the ^{194}Pt$(p,d)^{193}$Pt reaction at $\theta_{lab}=30°$ is shown in Fig. 1.

Analysis of the (p,d) reaction data revealed that several already known closely spaced low-lying levels could not be separated and among them were the first $J^\pi=\frac{5}{2}^-$ levels in ^{193}Pt and ^{191}Pt. It was considered worthwhile to try to observe these levels and to measure the corresponding spectroscopic factors. The (d,t) reaction at 26 MeV was chosen because the predicted angular distributions were more structured than the (p,d) ones and strongly favored $l=3$ over $l=1$ at $\theta_{lab}=15°$, where a cursory measurement could be done. It proved possible to get a very good energy resolution (≈10 keV, FWHM) using a small solid angle (0.42 msr). Spectra at $\theta_{lab}=15°$ are shown in Fig. 2 for the reactions ^{194}Pt$(d,t)^{193}$Pt and ^{198}Pt$(d,t)^{197}$Pt.

B. Energy determination

An energy calibration has been performed using known-energy α particles at various magnetic fields; a computer code using this calibration then gives for each magnetic field used in the ex-

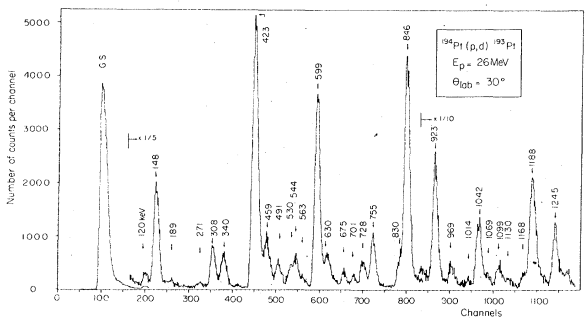

FIG. 1. Energy spectrum of emitted deuterons from the ^{194}Pt$(p,d)^{193}$Pt reaction at $\theta_{lab}=30°$. Peaks are labeled by excitation energy in keV of levels in the final nucleus.

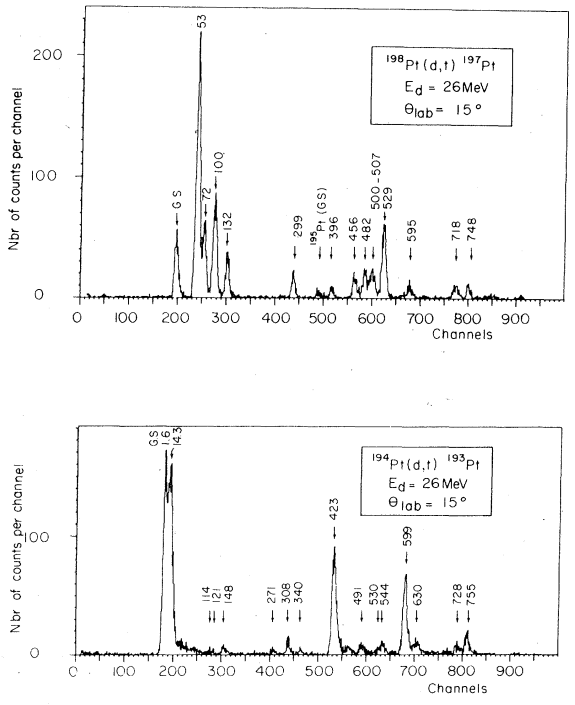

FIG. 2. Energy spectra of emitted tritons from the ^{194}Pt$(d,t)^{193}$Pt and ^{198}Pt$(d,t)^{197}$Pt reactions at $\theta_{lab}=15°$. Peaks are labeled by excitation energy in keV of levels in the final nucleus.

periment the energies of the outgoing particles corresponding to different peak positions. On the other hand, ground state peaks are easy to identify; so are some large cross-section peaks (such as the ones at 99 and 130 keV in ^{195}Pt for example) whose energies are well known from decay studies.[10] These peak energies are used as a check of the energy determination from the α calibration. The excitation energies have thus been determined for a number of levels listed in Table III-VI; except for the weak transitions, the uncertainty is estimated to be ±2.5 keV up to about 600 keV excitation energy and ±5 keV above.

On the spectra corresponding to natural platinum and to ^{192}Pt targets, the same reference peaks from the (p,d) reaction on the different platinum isotopes are apparent and permit a comparison of the Q values. Experimentally:

$$Q(^{196}\text{Pt}(p,d)^{195}\text{Pt}) - Q(^{198}\text{Pt}(p,d)^{197}\text{Pt}) = -365 \pm 3 \text{ keV},$$

$$Q(^{194}\text{Pt}(p,d)^{193}\text{Pt}) - Q(^{196}\text{Pt}(p,d)^{195}\text{Pt}) = -445 \pm 3 \text{ keV},$$

$$Q(^{194}\text{Pt}(p,d)^{193}\text{Pt}) - Q(^{192}\text{Pt}(p,d)^{191}\text{Pt}) = +307 \pm 3 \text{ keV}.$$

If we adopt for the ^{196}Pt$(p,d)^{195}$Pt reaction the value of Ref. 11: $Q = -5696.3 \pm 1$ keV, we finally obtain

$$Q(^{198}\text{Pt}(p,d)^{197}\text{Pt}) = -5331 \pm 4 \text{ keV},$$

$$Q(^{194}\text{Pt}(p,d)^{193}\text{Pt}) = -6141 \pm 4 \text{ keV},$$

$$Q(^{192}\text{Pt}(p,d)^{191}\text{Pt}) = -6448 \pm 5 \text{ keV}$$

to be compared with the previously known values[11] of, respectively, -5338 ± 19, -6142 ± 9, and -6431 ± 16 keV.

C. Cross-section measurements

Data concerning the (p,d) reaction on the natural and the enriched platinum targets were recorded at six angles: 5°, 9°, 15°, 30°, 45°, and 55°. For each level of each isotope a cross section relative to the total integrated beam charge was first extracted; the comparison of the different yields from the four targets for the following levels, ground state, 99 and 130 keV in ^{195}Pt; ground state and 846 keV in ^{193}Pt; and ground state in ^{191}Pt, permits knowing the different isotopic abundances, to determine the relative thicknesses of the different targets and to get the relative cross sections for the different isotopes with 3% uncertainty.

Two independent measurements of the thickness of the natural platinum target have been made, with an α gauge and from the elastic scattering of low energy particles. They differ by less than 20%. The resulting thicknesses are listed in Table I. The absolute values of the cross section are given in column 2 of Tables III-V; the estimated uncertainty reaches 20% on absolute results whereas the uncertainty on relative results is far lower as indicated in some cases.

III. ANALYSIS OF THE (p,d) DATA

A. Empirical determination of the transferred angular momenta

Angular distributions of deuteron groups from the (p,d) reaction on the ^{196,194,192}Pt targets are shown on Figs. 3 to 7. In spite of the lack of experimental points at some key angles, most of these distributions can be classified into one, and one only, of four groups containing:

(a) angular distributions with a sharp maximum in cross section at 10° to 15° (Fig. 3),

(b) relatively structureless angular distributions having a primary maximum around 45° (Fig. 4),

(c) more or less forward peaked angular distributions having a first minimum around 15° (Fig. 5), and

(d) angular distrubutions having a broad maximum around 30° (Fig. 6).

The observation of Figs. 3 to 6 reveals only small differences from one isotope to the other and only slight variation with excitation energy. This fact clearly indicates that the corresponding transitions are direct and can be associated with a unique l transfer for each group.

For the first two groups (a) and (b) there is no difficulty as the J^π values are known for one or more of the corresponding final levels: it follows that all the distributions grouped in Fig. 3 are $l=1$ transitions and lead to $J^\pi = \frac{1}{2}^-$ or $\frac{3}{2}^-$ final levels. In the same manner, the final levels corresponding to the distributions of Fig. 4 have $J^\pi = \frac{13}{2}^+$ (or perhaps $\frac{11}{2}^+$) the transitions being $l=6$.

The data points being a little sparse, the angular distributions of Fig. 5 seems not very structured; anyhow, they all look the same and their shapes are indisputably different from any of the other groups (Figs. 3, 4, and 6). As there are among them several known $l=3$ transitions, it is reasonable to assign them all as $l=3$. However, among these smooth angular distributions, those corresponding to low cross section (i.e., $\sigma < 0.1$

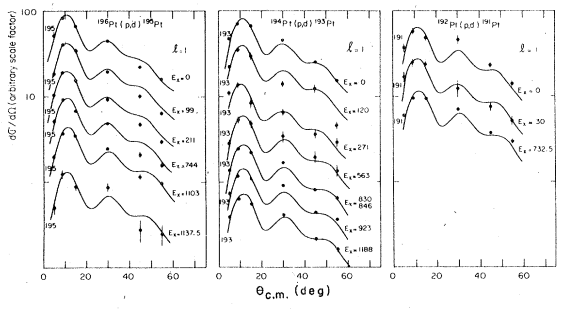

FIG. 3. Angular distributions for transitions to the major p ($\frac{1}{2}$ or $\frac{3}{2}$) levels of ^{195,193,191}Pt arranged in order of excitation energy. The curves are the results of the DWBA calculations.

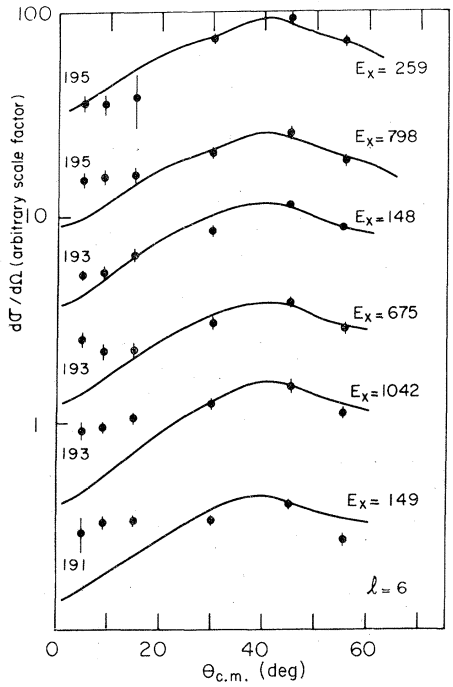

FIG. 4. Angular distributions for the observed $l=6$ transitions in the reactions ^{196,194,192}Pt$(p,d)^{195,193,191}$Pt. On the left hand side is indicated in each case the mass number A of the final nucleus and on the right hand side the excitation energy of the final level. The curves are the results of the DWBA calculations.

mb/sr at the angle of the maximum) may come from non direct processes; hence the l assignment is to be considered as tentative and has been put within parentheses in Table III–VI.

A difficulty arises for the transitions grouped in Fig. 6. The four experimental shapes are just the same and seem to correspond to the same

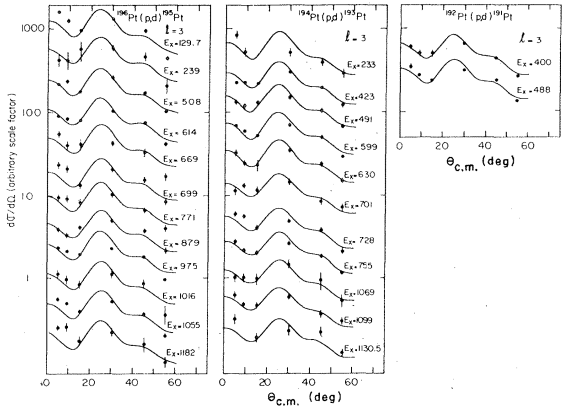

FIG. 5. Angular distributions for the transitions to the known or supposed f ($\frac{5}{2}$ or $\frac{7}{2}$) levels of ^{195,193,191}Pt arranged in order of excitation energy. The curves are the results of the $l=3$ DWBA calculations.

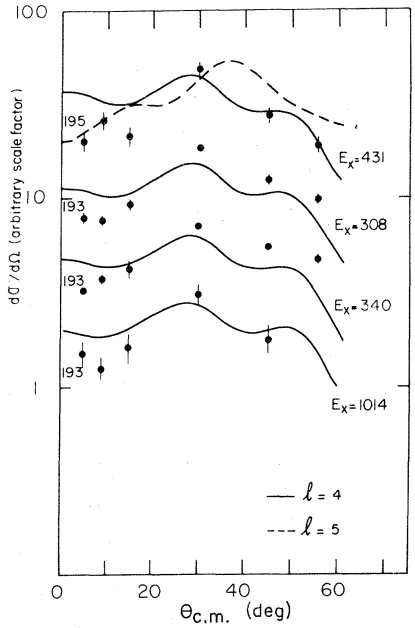

FIG. 6. Angular distributions which have been analyzed as $l=(4)$ or (5) transitions. On the left hand side is indicated in each case the mass number A of the final nucleus and on the right hand side the excitation energy of the final level. The curves are the results of the DWBA calculations.

transfer. The level at 431 keV of ^{195}Pt is most probably the level observed at 432.0 keV in decay study[12] and assigned $J^{\pi}=(\frac{11}{2},\frac{13}{2})^{+}$ and the other three states were previously unknown. Though the experimental angular distributions have been measured at a limited number of angles, the transitions gathered on Fig. 6 are definitely different from those on Figs. 3–5 and therefore the possibility of ($l=1,3,6,$) transfer is excluded. These levels will be discussed further in Sec. IV.

Finally, a small number of distributions cannot be classified in one of the preceding groups. Four of them (Fig. 7) clearly correspond to unresolved doublets: the doublets at 459 keV in ^{193}Pt and at 452 keV in ^{191}Pt could not be resolved; the two levels at 530 and 544 keV in ^{193}Pt and the two levels at 925 and 931 keV in ^{195}Pt have been unfolded afterwards and the corresponding angular distributions are shown in Fig. 7 together with the angular distributions of their sums. Their shapes are the same as those of Figs. 3 and 5, which indicates $l=1$ and $l=(3)$ transitions. The shapes of the angular distributions corresponding to the levels at 459 keV in ^{193}Pt and 452 keV in ^{191}Pt are well fitted by simple addition with appropriate weights of the experimental angular distributions of Figs. 3 and 5 and should, therefore, also correspond to a sum of $l=(1)$ and $l=(3)$ transitions. There remain three angular distributions whose shapes are not clearly

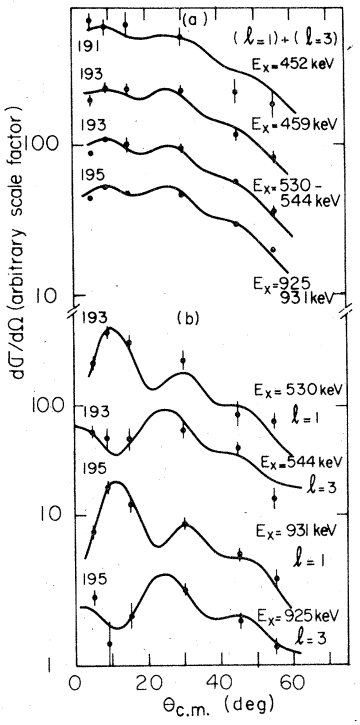

FIG. 7. (a) Doublets: The solid curves result from the mixing of $l=1$ and $l=(3)$ experimental distributions with percentages corresponding to the spectroscopic factors indicated in tables. (b) Four levels have been separated and are compared with the DWBA fits corresponding to $l=1$ and $l=3$ transitions.

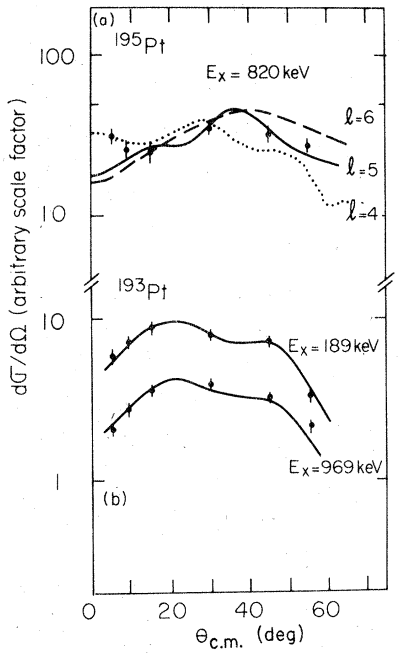

FIG. 8. Non-l-assigned transitions. (a) ^{195}Pt: The angular distribution corresponding to the level at 820 keV is compared with the DWBA fits $l=4$, 5, and 6. (b) ^{193}Pt: The same solid lines have been drawn through the two experimental distributions corresponding to the levels at 189 and 969 keV.

identified (Fig. 8); they correspond to the levels at 820 keV in ^{195}Pt and at 189 and 969 keV in ^{193}Pt, the last two distributions having the same shape.

B. Distorted-wave Born approximation analysis

The J^π values from some levels in ^{195}Pt are firmly determined by decay study and other investigations[12] and these levels are clearly resolved with fairly good statistics in our experiment. A (p,d) transition from ^{196}Pt to a known J^π final state of ^{195}Pt has, of course, a unique well defined l value; three of them have been chosen to test the distorted-wave Born-approximation (DWBA) calculations to the ground state with $l=1$, to the $\frac{5}{2}^-$ level at 129 keV with $l=3$, and to the $\frac{13}{2}^+$ level at 259 keV with $l=6$.

The DWBA analysis has been performed using the program DWUCK.[13] The bound state potential was of the usual Woods-Saxon type, its depth being adjusted in order to reproduce the neutron separation energy. Nonlocal and finite-range factors have been tried but were not used as these corrections did not bring any improvement.

Different sets of optical model parameters are available,[14] either determined from elastic scattering measurements, used previously for analyzing stripping or pick-up reactions, or interpolated in systematic variations studies. Many of them have been tried on our three test cases: They generally reproduce the $l=1$ experimental angular distribution, fail in fitting the $l=3$ one, and give for the $l=6$ transition a broad maximum at about 45°, but with a bad fit.

Most of the recent potentials appear with spin-orbit parameters: Using or omitting this term changes almost nothing in the calculated angular distributions and subsequently, for simplification purpose, it has not been used.

Important improvement in the fits was expected from the introduction of a radial cutoff.[15] This procedure has been tried with $R=5$ to 8 fm and results in changing the angular distributions shapes, but no really better fit is obtained. Calculated cross sections differ by about 5% but not all in the same direction. All the further calculations have been done without a cutoff radius.

The optical model parameters were finally chosen from systematic studies[14] and are listed in Table II. The calculations reproduce fairly well the $l=1$ transitions (Fig. 3) and not too badly the others (Figs. 4 and 5). According to Ref. 14, the deuteron well was slightly adjusted for each isotope and final level; this variation was very

TABLE II. Optical model parameters for the (p,d) reaction.

	V (MeV)	r (fm)	a (fm)	W (MeV)	$4W_D$ (MeV)	r_W (fm)	a_W (fm)
p [a]	52	1.25	0.65	0	40	1.25	0.76
d [a]	~103 [b]	1.15	0.81	0	~76 [b]	1.34	0.68
n	c	1.25	0.65				

[a] Reference 14.
[b] Adjusted with A and E_{ex} according to Ref. 14.
[c] Adjusted to reproduce the separation energy.

small ($V = 103.5$ to 103.8 MeV) and could well have been omitted.

The spectroscopic factors are obtained by using the relation

$$\frac{d\sigma}{d\Omega} = NC^2 S_{lj} \sigma_{DW}^{lj}(\theta),$$

where N is a normalization factor [$N = 2.29$ as usual for the (p,d) reaction] and σ_{DW}^{lj} is obtained from the DWBA calculations.

IV. SPECTROSCOPIC RESULTS FROM THE (p,d) REACTION ON THE ^{196,194,192}Pt TARGETS

A number of $l = 1$ unambiguous transitions are seen (Fig. 3) corresponding to spin-parity assignment of $\frac{1}{2}^-$ or $\frac{3}{2}^-$ for the final levels. Our results do not permit a choice and, unless otherwise mentioned, we assume $J^\pi = \frac{3}{2}^-$ in the calculation of the spectroscopic factor. The transitions in Fig. 5 correspond to $l = (3)$ angular momentum transfer; the supposed J value used in each case for calculations is indicated in the tables. For the $l = 6$ transitions of Fig. 4, a spin $J = \frac{13}{2}$ is assumed.

A. ^{195}Pt

The absolute spectroscopic factors extracted from the present (p,d) experiment are listed in column 5 of Table III. In order to facilitate comparison with the recent (d,t) results,[7] the same J^π values as in Ref. 7 have been used for the calculations and the (d,t) spectroscopic factors of Yamazaki and Sheline[7] have been normalized to our value of 0.90 for the ground state transition (column 13 in Table III). The comparison of the energies, momentum transfer, and relative spectroscopic factors shows a very good detailed agreement between the two experiments. This indicates that both reactions are essentially direct, that multistep processes are probably negligible and that, although our angular distributions are not always well fitted by the DWBA calculations, it is possible to determine the transfered momentum and to extract reliably at least relative values of the spectroscopic factors. This is important especially in the case of the transitions of Fig. 5 for which the data point is missing at the angle where the $l = 3$ prediction has a maximum. It should be mentioned that our absolute spectroscopic factors are not in agreement with those of Yamazaki and Sheline[7]; in fact, the factor S of Ref. 7 is the coefficient C_{jl}^2 appearing in the unified model formalism[16] where the spectroscopic factor is written: $S_{lj} = C_{jl}^2$ and what should be compared to our spectroscopic value of 0.90 for the ground state is $2S$ (Ref. 7) = 0.6.

Let us now discuss in more details some of the results, mainly for levels corresponding to close doublets, not observed previously or which l assignment is somewhat doubtful.

The levels at 199.5 and 211 keV were not easily separated and only at some angles, and the angular distribution was constructed for the sum. However, as they are both known to be $J^\pi = \frac{3}{2}^-$ levels and therefore populated through the same $l = 1$ transfer, it has been possible to extract a spectroscopic factor for each level, though with a larger uncertainty, using only the first three angles where they are resolved; the relative spectroscopic factors are in good agreement with those of Ref. 7.

The spin and parity of the level at 431 keV were assigned $J^\pi = (\frac{11}{2}, \frac{13}{2})^+$ from decay study[12] and, in their (d,p) and (d,t) study,[7] Yamazaki and Sheline proposed $J^\pi = \frac{9}{2}^+$ for this level. The experimental (p,d) angular distribution is shown in Fig. 6, together with the others having the same broad maximum at about 30°; they all seem to have the same l value but it is not possible to make a choice between $l = 4$ and $l = 5$ for these levels. A $\frac{9}{2}^+$ state is known in ^{191}Pt at 306.27 keV[17]—a comparable excitation energy—and two states of similar energy in ^{193}Pt (Fig. 6) are possible candidates to be the corresponding $\frac{9}{2}^+$ states. With this ($l = 4$) assumption, our relative spectroscopic factor would be in good agreement with the (d,t) result[7] (Table III).

The levels seen at 449.7 and 455 keV in decay study[12] and as a doublet at 453 keV in the (d,t) reaction[7] are obscured in the present study by the

TABLE III. Levels of ^{195}Pt observed in neutron pick-up reactions.

^{196}Pt(p,d)^{195}Pt [a]					^{196}Pt(d,t)^{195}Pt [a]		Decay [b]		^{196}Pt(d,t)^{195}Pt [c]			
E_{ex} (keV)	$\sigma(9°)$ (mb/sr)	l	J^π	C^2S	$\sigma(15°)$ (mb/sr)	C^2S [d]	E_{ex} (keV)	J^π	E_{ex}	l	J^π	C^2S [e]
0	2.42	1	$\frac{1}{2}^-$	0.90	1.65	1.08	0	$\frac{1}{2}^-$	0	1	$\frac{1}{2}^-$	0.90
99	3.30	1	$\frac{3}{2}^-$	1.17	1.98	1.21	98.9	$\frac{3}{2}^-$	99.1	1	$\frac{3}{2}^-$	1.08
129.7	1.08	3	$\frac{5}{2}^-$	2.53	3.40	2.27	129.7	$\frac{5}{2}^-$	129.9	3	$\frac{5}{2}^-$	2.34
199.5	0.70	1 [f]	$\frac{3}{2}^-$	0.18	0.25	0.15	199.6	$\frac{3}{2}^-$	199.7	1	$\frac{3}{2}^-$	0.18
211	0.71			0.31	0.43	0.26	211.3	$\frac{3}{2}^-$	212.2	1	$\frac{3}{2}^-$	0.30
239	0.147	3	$\frac{5}{2}^-$	0.44	0.60	0.41	239.3	$\frac{5}{2}^-$	238	3	$\frac{5}{2}$	0.45
259	0.153	6	$\frac{13}{2}^+$	4.15	0.19	6.30	259.2	$\frac{13}{2}^+$	259.4	6	$\frac{13}{2}^+$	4.75
Not seen							389.2		Not seen			
431	0.082	(4,5)	$(\frac{7}{2},\frac{9}{2})^+$	0.20 [j]	0.23		432.0	$(\frac{11}{2},\frac{13}{2})^+$	431	(4)	$(\frac{9}{2},\frac{11}{2},\frac{13}{2})^+$	0.24 [j]
452 [f]	0.071				0.11	0.07 [h]	(449.7)	$(\frac{5}{2},\frac{7}{2})^-$	453 [f]	(3)	$(\frac{5}{2},\frac{7}{2})^-$	0.06 [h]
							455	$(\frac{5}{2})^-$				
508	0.38	3	$(\frac{5}{2},\frac{7}{2})^-$	0.92 [h]			507.9	$(\frac{5}{2},\frac{7}{2})^-$	508.1	3	$(\frac{5}{2},\frac{7}{2})^-$	0.87 [h]
Not seen							547	$(\frac{11}{2}^+)$	Not seen			
Not seen							562.2	$(\frac{9}{2})^-$	Weak			
614	0.34	3	$(\frac{5}{2},\frac{7}{2})^-$	0.80 [i]			612.7	$(\frac{5}{2},\frac{7}{2})^-$	612.6	3	$(\frac{5}{2},\frac{7}{2})^-$	0.66 [i]
669	0.076	(3)	$(\frac{5}{2},\frac{7}{2})^-$	0.18 [h]					663			
699	0.100	3	$(\frac{5}{2},\frac{7}{2})^-$	0.125 [i]			695.2	$(\frac{5}{2},\frac{7}{2})^-$	694	3	$(\frac{5}{2},\frac{7}{2})^-$	0.15 [i]
744	0.42	1	$(\frac{1}{2},\frac{3}{2})^-$	0.16 [g]					738.9	1	$(\frac{1}{2},\frac{3}{2})^-$	0.15 [g]
771	0.12	3	$(\frac{5}{2},\frac{7}{2})^-$	0.255 [i]					765.8	3	$(\frac{5}{2},\frac{7}{2})^-$	0.21 [i]
798	0.092	6	$(\frac{13}{2})^+$	1.83					793			
820	0.06	(4,5)					814.6	$(\frac{9}{2})^-$	816	(5)		
Not seen							821.9		Not seen			
879 [f]	0.075	(3)	$(\frac{5}{2},\frac{7}{2})^-$	0.22 [i]					875			
Not seen							895.4	$(\frac{9}{2})^-$	Not seen			
Not seen									915			
925	0.08	(3)	$(\frac{5}{2},\frac{7}{2})^-$	0.295 [i]								
931	0.325	1	$(\frac{1}{2},\frac{3}{2})^-$	0.105 [g]					927.7	1–3		0.12
Not seen							930.7	$(\frac{9}{2})^-$				
975	0.215	3	$(\frac{5}{2},\frac{7}{2})^-$	0.46 [i]					971.3	3		0.39
1016	0.043	(3)	$(\frac{5}{2},\frac{7}{2})^-$	0.08 [h]					Not seen			
1055	0.33	3	$(\frac{5}{2},\frac{7}{2})^-$	0.54 [h]					1049.3			
1103	1.24	1	$(\frac{1}{2},\frac{3}{2})^-$	0.50 [g]					1098	(1)		0.39
1137.5	0.21	1	$(\frac{1}{2},\frac{3}{2})^-$	0.085 [g]					Not seen			

TABLE III. (*Continued*)

^{196}Pt$(p,d)^{195}$Pt [a]					^{196}Pt$(d,t)^{195}$Pt [a]		Decay [b]		^{196}Pt$(d,t)^{195}$Pt [c]			
E_{ex} (keV)	$\sigma(9°)$ (mb/sr)	l	J^π	C^2S	$\sigma(15°)$ (mb/sr)	C^2S [d]	E_{ex} (keV)	J^π	E_{ex}	l	J^π	C^2S [e]
Not seen									1156	(3,4)		
1182	0.11	(3)	$(\frac{5}{2},\frac{7}{2})^-$	0.22 [h]								

[a] Present work [S factors extracted from (p,d) and (d,t) reactions are absolute values].
[b] Reference 10.
[c] Reference 7.
[d] These factors, extracted at only one angle, should be considered with some caution (see text).
[e] Spectroscopic factors normalized to the value 0.90 for the ground state [the absolute value for the g.s. is 0.6 (Ref. 7)].
[f] Unresolved doublet.
[g] Calculated assuming the spin-parity to be $\frac{3}{2}^-$.
[h] Calculated assuming the spin-parity to be $\frac{5}{2}^-$.
[i] Calculated assuming the spin-parity to be $\frac{7}{2}^-$.
[j] Calculated assuming the spin-parity to be $\frac{9}{2}^-$.

peak originating from the ^{194}Pt$(p,d)^{193}$Pt$_{g.s.}$ reaction.

Though their spectroscopic factors are not smaller than those corresponding, for example, to the levels at 699 and 771 keV, two levels at 669 and 879 keV had been seen in the study of Yamazaki and Sheline[7] but the transferred momentum had not been determined. They both correspond to an $l=(3)$ transfer (see Fig. 5 and Table III); the level at 879 keV is probably a close doublet.

A level is seen in our (p,d) experiment at 798 keV; it is to be identified with the level at 793 $\pm$ 2 keV just seen in the (d,t) reaction and not observed in the (d,p) reaction.[7] According to its characteristic $l=6$ angular distribution (see Fig. 4), we propose a $J^\pi=\frac{13}{2}^+$ assignment for this level.

We observe a level at 820 keV which is probably the 814.6 keV level assigned $J^\pi=(\frac{9}{2})^-$ in decay study[12] and the level seen at 816 keV with $l=(5)$ in the (d,t) experiment.[7] The corresponding (p,d) angular distribution does not correspond to $l=1$, 3, and 6 angular momentum transfer and the most reasonable thing appears to admit an $l=(5)$ transfer. The DWBA fit is not bad [Fig. 8(a)], but an $l=4$ transfer cannot be excluded.

A close doublet at 925-931 keV has eventually been separated and the angular distributions are well fitted by, respectively, $l=(3)$ and $l=1$ DWBA calculations (Fig. 7). The 931 keV level is probably the level seen at 927.7 $\pm$ 0.8 keV in the (d,t) reaction[7] the l assignment and relative spectroscopic factors being in good agreement. The 925 keV level had not been previously observed. Neither has the level at 1137.5 keV, fed by a very weak $l=1$ transition.

Three other levels with $l=(3)$ transfer, at 1016, 1055, and 1182 keV correspond to small spectroscopic factors and had not been previously seen, with the exception of the 1055 keV level which is probably the 1049 keV level of Ref. 7.

B. ^{193}Pt

Little was known[18] about the levels of ^{193}Pt. Using the (p,d) reaction, we see a large number of levels with a good energy resolution. As for ^{195}Pt, the angular distributions are generally characteristic of a unique l transfer and there is only, as usual, an ambiguity of the J value of the final level; absolute spectroscopic factors extracted are displayed in Table IV. Some details about doublets or levels previously unknown are given below.

The first three levels at 0., 1.64, and 14.27 keV[18] are not resolved in our (p,d) study and the total corresponding angular distribution is well fitted by a DWBA curve corresponding to an $l=1$ angular momentum transfer (Fig. 3). This indicates that the cross section of the $l=3$ transition to the $\frac{5}{2}^-$ level at 14.27 keV[18] is very small which is due to the better momentum matching of the $l=1$ transition; then, no spectroscopic factor could be extracted for this $\frac{5}{2}^-$ level. Since the two $l=1$ levels are unresolved, the simplest hypothesis—consisting of assuming half of the cross section for each—has been made in Table IV in order to extract two spectroscopic factors for these levels.

The next two levels are not separated and the angular distribution corresponding to the doublet at 120 keV is well fitted by an $l=1$ DWBA calcula-

TABLE IV. Levels of ^{193}Pt observed in neutron pick-up reactions.

	^{194}Pt(p,d)^{193}Pt [a]				^{194}Pt(d,t)^{193}Pt [a]		Decay [b]	
E_{ex} [a] (keV)	σ(9°) (mb/sr)	l	J^π	C^2S	σ(15°) (mb/sr)	C^2S [c]	E_{ex} (keV)	J^π
0	5.75 ±0.04 [d]	1	$(\frac{1}{2})^-$	1.08	3.260	1.15	0	$(\frac{1}{2}^-)$
			$(\frac{3}{2})^-$	1.10		1.20	1.64	$(\frac{3}{2}^-)$
(14)			$(\frac{5}{2})^-$		2.30	1.70	14.27	$(\frac{5}{2}^-)$
114	0.11 ±0.05 [d]	1	$(\frac{1}{2},\frac{3}{2})^-$	0.07 [e]	0.04	0.03 [e]	114.15	$(\frac{3}{2}^-)$
121					0.04	0.03 [e]	121.3	
148	0.177±0.007	6	$\frac{13}{2}^+$	4.24	0.13	5.83	149.78	$(\frac{13}{2}^+)$
189	0.032±0.003						187.81	$(\frac{3}{2}^-)$
233	0.015±0.002	(3)	$\frac{5}{2}^-$	0.03			232.15	$(\frac{3}{2},\frac{5}{2}^-)$
271	0.054±0.004	1	$\frac{3}{2}^-$	0.02			269.84	$(\frac{5}{2},\frac{3}{2}^-)$
308	0.048±0.003	(5,4)		0.14 [i]				
340	0.056±0.002	(5,4)		0.16 [i]				
423	0.570±0.011	3	$(\frac{5}{2},\frac{7}{2})^-$	1.71 [f]	1.73	1.46 [f]		
							439.04	$(\frac{3}{2}^-)$
459 [d]	0.155±0.009	1	$(\frac{1}{2},\frac{3}{2})^-$	0.033 [e]				
		(3)	$(\frac{5}{2},\frac{7}{2})^-$	0.18 [f]	0.18	0.16 [f]		
491	0.066±0.004	(3)	$\frac{5}{2}^-$	0.18	0.19	0.16	491.25	$(\frac{3}{2},\frac{5}{2}^-)$
							522.54	$(\frac{5}{2},\frac{3}{2}^-)$
530±3	0.098±0.007	1	$(\frac{1}{2},\frac{3}{2})^-$	0.03 [e]	0.105	0.07 [e]		
544±3	0.061±0.009	(3)	$(\frac{5}{2},\frac{7}{2})^-$	0.17 [f]	0.156	0.13 [f]		
563	0.041±0.004	1	$(\frac{1}{2},\frac{3}{2})^-$	0.02 [e]				
599	0.462±0.009	3	$(\frac{5}{2},\frac{7}{2})^-$	1.035 [g]	1.26	0.85 [g]		
630	0.082±0.008	3	$(\frac{5}{2},\frac{7}{2})^-$	0.22 [g]	0.26	0.17 [g]		
675	0.035±0.003	6	$(\frac{11}{2},\frac{13}{2})^+$	0.76 [h]				
701	0.035±0.003	(3)	$(\frac{5}{2},\frac{7}{2})^-$	0.075 [g]				
728	0.094±0.005	3	$(\frac{5}{2},\frac{7}{2})^-$	0.16 [g]	0.19	0.12 [g]		
755	0.136±0.005	3	$(\frac{5}{2},\frac{7}{2})^-$	0.315 [g]	0.336	0.23 [g]		
830	0.051±0.020	(3)	$(\frac{5}{2},\frac{7}{2})^-$	0.10 [g]				
846	1.030±0.020	1	$(\frac{1}{2},\frac{3}{2})^-$	0.44 [e]				
923	0.245±0.005	1	$(\frac{1}{2},\frac{3}{2})^-$	0.11 [e]				
969	0.024±0.002							
1014	0.10 ±0.001	(5,4)		0.05 [i]				
1042	0.076±0.003	6	$(\frac{11}{2},\frac{13}{2})^+$	1.65 [h]				
1069	0.016±0.002	(3)	$(\frac{5}{2},\frac{7}{2})^-$	0.05 [g]				
1099	0.034±0.002	(3)	$(\frac{5}{2},\frac{7}{2})^-$	0.09 [g]				
1130	0.016±0.005	(3)	$(\frac{5}{2},\frac{7}{2})^-$	0.04 [g]				
1168	0.040±0.007	(1)	$(\frac{1}{2},\frac{3}{2})^-$	0.02 [e]				
1188 [d]	0.273±0.008	1	$(\frac{1}{2},\frac{3}{2})^-$	0.13 [e]				
(1225)								

TABLE IV. (*Continued*)

	^{194}Pt$(p,d)^{193}$Pt [a]				^{194}Pt$(d,t)^{193}$Pt [a]		Decay [b]	
E_{ex} [a] (keV)	$\sigma(9°)$ (mb/sr)	l	J^π	C^2S	$\sigma(15°)$ (mb/sr)	C^2S [c]	E_{ex} (keV)	J^π
1245	0.072±0.007	(3)	$(\frac{5}{2},\frac{7}{2})^-$	0.22 [g]				
(1259)								

[a] Present work [S factors extracted from (p,d) and (d,t) reactions are absolute values].
[b] Reference 18.
[c] Spectroscopic factors are assigned from one angle in the (d,t) reaction. As this angle corresponds to the maximum of the angular distribution only for $l=3$, the values may be unprecise for the other l transfers.
[d] Unresolved doublet; for the first two levels (ground state and 1.64 keV), only the sum of the two spectroscopic factors is well determined and the distribution between the two is arbitrary.
[e] Calculated assuming $J^\pi=\frac{3}{2}^-$.
[f] Calculated assuming $J^\pi=\frac{5}{2}^-$.
[g] Calculated assuming $J^\pi=\frac{7}{2}^-$.
[h] Calculated assuming $J^\pi=\frac{13}{2}^+$.
[i] Calculated assuming $J^\pi=\frac{9}{2}^+$.

tion; in view of the proposed $J^\pi=\frac{3}{2}^-$ attribution for the level at 114.15 keV and of the energy of the observed peak, it is probable that the level at 121.3 keV [16] has $J^\pi=(\frac{1}{2},\frac{3}{2})^-$.

The angular distribution for the peak at 459 keV does not correspond to a single l transfer, but to a mixing of $l=1$ and $l=(3)$ transfers; this peak corresponds then to two unresolved levels. The DWBA fit permits one to extract the two spectroscopic factors as was done for the sum of the two peaks corresponding to the levels at 530 and 544 keV (see Fig. 7).

TABLE V. Levels of ^{191}Pt observed in neutron pickup reactions.

	^{192}Pt$(p,d)^{191}$Pt [a]				^{192}Pt$(d,t)^{191}$Pt [a]		Decay [b]	
E_{ex} [a] (keV)	$\sigma(9°)$ (mb/sr)	l	J^π	C^2S	$\sigma(15°)$ (mb/sr)	C^2S [c]	E_{ex}	J^π
0	2.50±0.20 [d]	1	$\frac{3}{2}^-$	0.97	1.685	1.19	0	$\frac{3}{2}^-$
(9.5)					2.31	1.85	9.56	$\frac{5}{2}^-$
30	2.28±0.23	1	$\frac{1}{2}^-$	0.98	1.78	1.38	30.36	$\frac{1}{2}^-$
Not seen							100.67	$\frac{9}{2}^-$
149	0.46±0.02	6	$\frac{13}{2}^+$	6.74			149.04	$\frac{13}{2}^+$
Not seen							Many levels	
400	0.55±0.05	3	$\frac{5}{2}^-$	1.64	1.84	1.70	399.9	$\frac{5}{2}^-$
452 [d]	0.41±0.05	1	$\frac{3}{2}^-$	0.11			451.8	$\frac{3}{2}^-$
		(3)	$(\frac{5}{2},\frac{7}{2})^-$	0.36 [e]			453.7	$\frac{7}{2}^+$
488	0.58±0.05	3	$\frac{7}{2}^-$	1.27	1.38	0.99	487.6	$\frac{7}{2}^-$
732.5	0.85±0.02	1	$(\frac{1}{2},\frac{3}{2})^-$	0.39 [f]			732.4	$(\frac{1}{2},\frac{3}{2})^-$

[a] Present work (spectroscopic factors are absolute values).
[b] Reference 17.
[c] Spectroscopic factors are assigned from one angle in the (d,t) reaction. As this angle corresponds to the maximum of the angular distribution only for $l=3$, the values may be unprecise for the other l transfers.
[d] Unresolved doublet.
[e] Calculated assuming the spin-parity to be $\frac{7}{2}^-$.
[f] Calculated assuming the spin-parity to be $\frac{3}{2}^-$.

Three levels (Fig. 5) correspond to $l=6$ transitions; only the first one at 148 keV was known to have $J^\pi=\frac{13}{2}^+$; the other two, at 675 and 1042 keV have possibly the same J^π value.

Finally, two weak levels at 189 and 969 keV have the same angular distribution which does not fit any of the DWBA calculations (Fig. 8); the first one might be identified to the 187.81 keV($\frac{3}{2}^-$) level but the angular distribution is not that of a direct $l=1$ transition.

C. ^{191}Pt

A preliminary analysis of our results has already been reported.[19] A decay study, published later,[17] has established the positions, spins, and parities of many ^{191}Pt levels. The results are compared in Table V. As was already stressed, our (p,d) results are clearly of worse quality than those concerning ^{195}Pt and ^{193}Pt.

The first two levels are unresolved and the corresponding angular distribution is characteristic of an $l=1$ momentum transfer (Fig. 3); as for ^{193}Pt, and for the same reasons, the spectroscopic factor corresponding to the $J^\pi=\frac{5}{2}^-$ first excited level cannot be obtained. The spectroscopic factor for the $J^\pi=\frac{3}{2}^-$ ground state is almost the same as for the corresponding $J^\pi=\frac{3}{2}^-$ levels in ^{195}Pt and ^{193}Pt. The same conclusion is true for the $J^\pi=\frac{1}{2}^-$ level at 30 keV.

Some other $l=1$ and $l=(3)$ angular distributions are displayed in Figs. 3 and 5; final J^π are known[17]: The agreement is a confirmation of the validity of the assignments proposed in the preceding paragraph for most of the levels of ^{193}Pt. Two levels at 451.8 and 453.7 keV were not separated in our study, but the unique angular distribution has the same shape as the sum of two experimental distributions [namely, the $l=1$ and $l=(3)$ transitions to the 488 and 732 keV levels]; the two spectroscopic factors have therefore been extracted in this way.

The angular distribution corresponding to the $\frac{13}{2}^+$ level at 149 keV is not as well fitted by the DWBA calculations as the other five curves of Fig. 4, but it cannot be anything other than an $l=6$.

Since the $\frac{9}{2}^+$ level at 306.27 keV is not seen in the (p,d) spectra, it is not possible to check the angular momentum assignments of the transitions in Fig. 6. If its cross section was the same as that of the other three levels, it should be very small and not detectable in our spectra, the reason for that being the relatively poor enrichment of our ^{192}Pt target.

For the same reason, the region where the $\frac{9}{2}^-$ level at 100.67 keV[17] should appear is obscured by a peak from the ^{194}Pt$(p,d)^{193}$Pt reaction, and many other levels are either not seen or too mixed with contaminant peaks to allow a meaningful analysis. As already mentioned, no level could be extracted from the spectra above 750 keV.

V. ANALYSIS OF THE (d,t) DATA FOR THE ^{196,194,192}Pt TARGETS

As indicated in Sec. II a short complementary (d,t) experiment has been performed at 26 MeV and $\theta_{lab}=15°$, the immediate aim being to observe the first $J^\pi=\frac{5}{2}^-$ level in ^{191,193}Pt and to extract the corresponding spectroscopic factors. The angle was chosen for this purpose: the DWBA calculations performed with the optical model parameters used in Ref. 7 to analyze the ^{196}Pt$(d,t)^{195}$Pt reaction at 13.5 MeV indicate that it corresponds to a maximum for the $l=3$ and to a minimum for the $l=1$ angular distributions. The same targets as in the (p,d) reaction were used. The spectroscopic factors were extracted using the DWBA calculations performed in the local zero range approximation with the parameters of Ref. 7, the same bound state wave function as used for the (p,d) reaction (see Table II), and the usual normalization factor $N=3.33$. The analysis of the ^{196}Pt

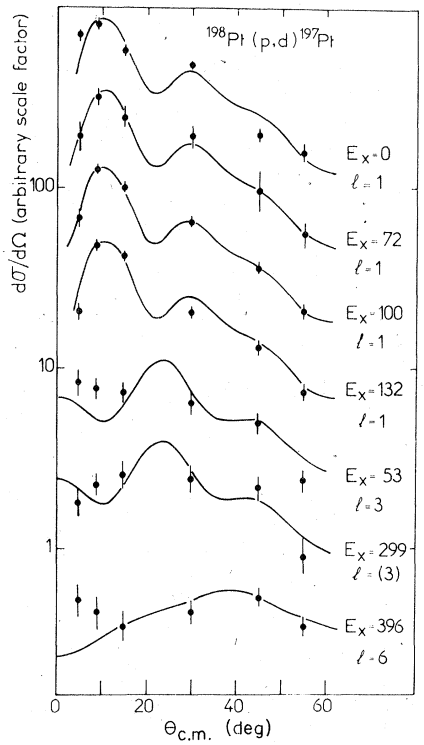

FIG. 9. Angular distributions for transitions to the different levels of ^{197}Pt in the reaction ^{198}Pt$(p,d)^{197}$Pt. The absolute cross sections are indicated in Table VI.

TABLE VI. States in ^{197}Pt.

^{198}Pt$(p,d)^{197}$Pt [a]					^{198}Pt$(d,t)^{197}$Pt [a]		Decay [b]	
E_{ex} (keV)	$\sigma(9°)$ (mb/sr)	l	J^π	C^2S	E_{ex} (keV)	C^2S [c]	E_{ex}	J^π
0	1.548	1	$\frac{1}{2}^-$	0.55	0	0.67	0	$\frac{1}{2}^-$
53	1.351	3	$\frac{5}{2}^-$	2.60	53	2.60	52.35	$\frac{5}{2}^-$
72	2.019	1	$(\frac{3}{2}^-)$	0.66	73	0.65	74	
100	2.755	1	$(\frac{1}{2},\frac{3}{2})^-$	0.875 [d]	101	1.01 [d]		
132	1.083	1	$(\frac{1}{2},\frac{3}{2})^-$	0.31 [d]	133	0.38 [d]		
Not seen					Not seen		183.2	
299	0.128	(3)	$(\frac{5}{2},\frac{7}{2})^-$	0.28 [e]	299	0.23 [e]	299.5	
396	0.356	6	$\frac{13}{2}^+$	4.0	395	5.13	399.5	$\frac{13}{2}^+$

[a] Present work.
[b] Reference 20.
[c] Normalized to the $C^2S = 2.60$ value obtained in the (p,d) reaction for the $\frac{5}{2}^-$ level at 53 keV. These factors, extracted at only one angle, should be considered with some caution (see text).
[d] Calculated assuming $J^\pi = \frac{3}{2}^-$.
[e] Calculated assuming $J^\pi = \frac{5}{2}^-$.

$(d,t)^{195}$Pt spectrum taken as a test case confirms the enhancement of the well separated peak corresponding to the first $J^\pi = \frac{5}{2}^-$ level and shows that, although the extraction of spectroscopic factors from a single angle may appear as an unwarranted procedure, their absolute values are in good agreement with those obtained from the (p,d) reaction and with renormalized results of Ref. 7 (Table III). In fact, our (d,t) results were only used to determine spectroscopic factors for transitions whose l values were already known from our (p,d) results or from preceding studies. It should here be emphasized that the better resolution in this (d,t) experiment allowed the separation of some doublets, e.g., the 199.5-211 keV doublet in ^{195}Pt.

Although the separation of the first $J^\pi = \frac{5}{2}^-$ level is not complete in the spectra obtained in the ^{194}Pt $(d,t)^{193}$Pt and ^{192}Pt$(d,t)^{191}$Pt reactions, the corresponding peak is, however, clearly visible (see Fig. 2) and it is possible to unfold the doublets. The spectroscopic factors extracted as above are given in Tables IV and V. The agreement between the spectroscopic factors obtained in the (p,d) and (d,t) experiments is fairly good, at least for the strong transitions, and especially for those corresponding to $l = 3$ transfer, which angular distributions have a maximum at the angle of the (d,t) measurement.

VI. SPECTROSCOPIC RESULTS FOR ^{197}Pt

Many levels are known[20] in ^{197}Pt from β and γ decay and poor resolution (d,p) and (d,t) studies, but most of them without J^π assignment. Several peaks, possibly corresponding to the ^{198}Pt(p,d) ^{197}Pt reaction, have been tentatively identified in the spectra originating from the natural platinum target and the angular distributions and excitation energies determined. Due to the small percentage (7.2%) of ^{198}Pt in the natural Pt it was, however, impossible to be sure that these peaks were not due, at least partly, to reactions on ^{195}Pt. A (d,t) spectrum was, therefore, taken at 26 MeV and $\theta_{lab} = 15°$ (see Fig. 2) on an enriched ^{198}Pt target (95.8%). The peaks observed in the (p,d) reaction are also observed in the (d,t) reaction and the energies are in good agreement. The momentum transfers are determined from the (p,d) angular distributions (see Fig. 9) and absolute spectroscopic factors extracted in the same way as for the (p,d) reaction on the three other isotopes. For the (d,t) reaction, the relative spectroscopic factors are calculated as in Sec. V at the angle $\theta_{lab} = 15°$, and the results normalized to the spectroscopic factor obtained in the (p,d) reaction for the $\frac{5}{2}^-$ level at 53 keV. The results are given in Table VI and the good agreement confirms that the two levels at 100 and 132 keV, previously unknown, actually belong to ^{197}Pt. Beyond 400 keV, peaks in the (p,d) reaction are obscured by deuterons from the reaction on ^{196}Pt, and no l assignment can therefore be given.

VII. DISCUSSION

In Ref. 7, Yamazaki and Sheline compare the levels and spectroscopic factors of ^{195}Pt with the

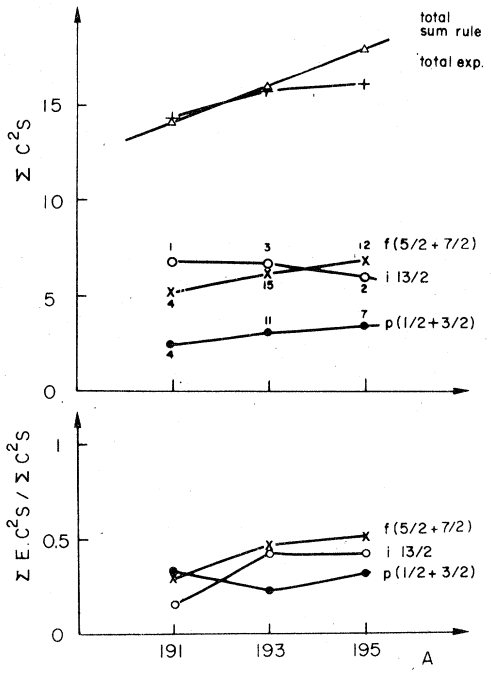

FIG. 10. (a) Upper part: summed strengths measured in the present experiment for the $p_{1/2}+p_{3/2}$, $f_{5/2}+f_{7/2}$, and $i_{13/2}$ transitions and total experimental strengths compared with the sum rule limits (see text). (b) Lower part: energy centroids for the $p_{1/2}+p_{3/2}$, $f_{5/2}+f_{7/2}$, and $i_{13/2}$ transitions. The figures represent for each experimental point the number of observed levels.

predictions of several models. Clearly, the description as the coupling of an odd particle to an asymmetric core in the manner of Davidov[21] or equivalently of Hecht and Satchler[22] is ruled out. Two other descriptions, the Nilsson model including Coriolis and pairing interactions and the Faessler and Greiner model of a soft fluctuating nucleus give about equivalent results, at least for the low-lying levels. Yamazaki and Sheline[7] tentatively explain several discrepancies concerning levels (e.g., 211 and 239 keV) with relatively large experimental spectroscopic factors—the theoretical estimate being very small—as due to multistep processes. We find, however, exactly the same spectroscopic factors for these levels as Yamazaki and Sheline: This agreement is simply normal for a direct process but there is no reason at all that multistep processes give exactly the same results in two different reactions at quite different energies. We therefore conclude that our results are not in agreement with the hypothesis proposed by Yamazaki and Sheline and that the discrepancies between experiment and theory are real. We then consider that the agreement between the experimental results and the two models, as shown in Table III of Ref. 7 is not very good. It is quite clear also that the core-excitation description[23] of ^{195}Pt is in complete disagreement with the large spectroscopic factors measured for the first excited levels. In conclusion, there seems to be presently no model giving a very good description of ^{195}Pt. We shall therefore not attempt to compare our results for the other odd Pt isotopes to models, but instead shall try to study, as systematically as possible, the variation of the experimental properties from isotope to isotope.

The summed strengths and energy centroids determined in the present experiments for ^{191,193,195}Pt are shown in Fig. 10. Also shown in Fig. 10 are the sum rule limits assuming that the particles are picked in the $p_{1/2}$, $p_{3/2}$, $f_{5/2}$, and $i_{13/2}$ orbitals only and that the strength corresponding to the $f_{7/2}$ orbital would appear higher in energy than the limits of our detection system in the present experiment. The fact that the total experimental strength equals the sum rule limit for ^{193}Pt and even for ^{191}Pt, where we observe only a limited number of levels, already indicates that a part of the observed $l=(3)$ strength corresponds to pickup in the $f_{7/2}$ shell. This is confirmed by the fact that 25% of the observed $l=(3)$ strength in ^{191}Pt corresponds to a transition to a known $J^\pi=\frac{7}{2}^-$ level. It is very reasonable to assume that, above about 500 keV, many of the observed $l=3$ transitions correspond to $J^\pi=\frac{7}{2}^-$ levels. More precisely, if we try to follow the systematics of the levels in Fig. 11 which

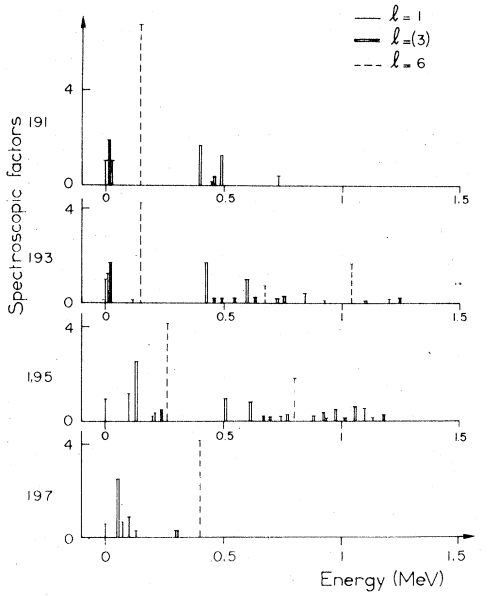

FIG. 11. Repartition of the observed strengths as a function of excitation energy for the $l=1$, $l=3$, and $l=6$ transitions. Spectroscopic factors smaller than 0.1 have been omitted.

shows the distribution of the strengths for the odd platinum isotopes studied, it appears for the large $l=(3)$ components that the levels at 508 keV in ^{195}Pt and 423 keV in ^{193}Pt most probably correspond to the level $J^\pi=\frac{5}{2}^-$ at 400 keV in ^{191}Pt and that the level at 614 keV in ^{195}Pt and 599 keV in ^{193}Pt most probably correspond to the level $J^\pi=\frac{7}{2}^-$ at 488 keV in ^{191}Pt.

If one looks at the energy spectra of the even Pt isotopes it is clear that—apart from the 0^+ excited levels, especially the first one whose energy varies quite strongly—there is no drastic change as one goes from ^{194}Pt to ^{190}Pt, but a slight and gradual decrease in all the energies. A more abrupt change in properties (energies of the first 0^+ and second 2^+ levels, branching ratios,...) is apparent, however, when one goes from ^{194}Pt to ^{196}Pt. The same general feature of relatively smooth variation appears if one looks at Fig. 11: Although it is not possible to make a one to one correspondence, the individual levels show a tendency to go down in energy when one goes from ^{195}Pt to ^{191}Pt and a relatively smooth variation is observed for the strengths of the lowest levels. A change is observed, however, between ^{195}Pt and ^{197}Pt in the population of the first $J^\pi=\frac{1}{2}^-,\frac{3}{2}^-$ levels, which could correspond to the change observed in "core" properties. The strength of the first $J^\pi=\frac{1}{2}^-$ and $\frac{3}{2}^-$ levels in ^{197}Pt decreases, but the strength is apparently transfered to the two new levels with $J^\pi=\frac{1}{2}^-$ or $\frac{3}{2}^-$ observed at 100 and 132 keV, the total strength of the first four $l=1$ transitions being about the same as in ^{195}Pt.

A last systematic variation apparent in Fig. 11 is that of a level with large $l=1$ strength, observed at 1103 keV in ^{195}Pt, 846 keV in ^{193}Pt, and 732 keV in ^{191}Pt.

Finally, it should be remarked that there is a striking qualitative similarity between the first low-lying levels of the odd Pt and Hg isotopes with $N=117$ and 119, this being true for the level sequences and the spectroscopic factors known[20,24] from the ^{200,198}Hg$(d,t)^{199,197}$Hg reactions. Higher in excitation energy the l assignment is somewhat doubtful in Ref. 24, but the levels observed at 675 and 1120 keV in ^{197}Hg with large $l=3$ strength could well correspond to the two levels at 508 and 614 keV in ^{195}Pt.

VIII. SUMMARY

Many levels, some of which previously unknown, have been observed in ^{191,193,195,197}Pt. The analysis of the experimental angular distributions has permitted one to assign parities and spin limits to most of them and to extract spectroscopic factors. Recent results[7] on ^{195}Pt using the (d,t) reaction are in very good agreement with the present work, buttressing up our l assignments and leading us to conclude that in both cases multistep processes are negligible. In ^{193}Pt and ^{195}Pt new levels with tentative assignment $J^\pi=(\frac{13}{2}^+)$, populated with non-negligible strength, are observed above the well known isomeric level. The systematics of the variation of the energies of the levels, summed strengths and centroids, when one goes from ^{195}Pt to ^{191}Pt, shows the following:

1. a total experimental strength exhausting 90% to 100% of the sum rule limit for pickup in the $p_{1/2}$, $p_{3/2}$, $f_{5/2}$, and $i_{13/2}$ orbitals.
2. only a relatively small variation in the energy centroids, except for the $i_{13/2}$ orbital which clearly goes down in ^{191}Pt, and
3. a smaller fragmentation of the strengths in ^{191}Pt.

An extension of the present experiments to lighter and heavier odd Pt isotopes would be clearly desirable; it would also be interesting to verify the $l=6$ assignments made in the present work for new levels, using the $(^3\mathrm{He},\alpha)$ reaction.[25]

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