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Discovery of the Platinum Isotopes

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Thirty-nine platinum isotopes have so far been observed; the discovery of these isotopes is discussed. For each isotope a brief summary of the first refereed publication, including the production and identification method, is presented.

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CONTENTS

1. INTRODUCTION

The discovery of the platinum isotopes is discussed as part of the series of the discovery of isotopes which began with the cerium isotopes in 2009 [1]. The purpose of this series is to document and summarize the discovery of the isotopes. Guidelines for assigning credit for discovery are (1) clear identification, either through decay curves and relationships to other known isotopes, particle or γ-ray spectra, or unique mass and Z-identification, and (2) publication of the discovery in a refereed journal. If the first observation was not confirmed or found erroneous in the subsequent literature, the credit was given to the correct measurement. These cases are specifically mentioned and discussed. Thus the assignment for the more recent papers is subject to confirmation. The authors and year of the first publication, the laboratory where the isotopes were produced as well as the production and identification methods are discussed. When appropriate, references to conference proceedings, internal reports, and theses are included. When a discovery includes a half-life measurement the measured value is compared to the currently adopted value taken from the evaluation of nuclear and decay properties of nuclides in their ground and isomeric states NUBASE [2] which is based on the "Evaluated Nuclear Structure Data Files" ENSDF database [3].

2. DISCOVERY OF $^{166-204}$PT

Thirty-nine platinum isotopes from A = 166 – 204 have been discovered so far; these include 6 stable, 26 neutron-deficient and 7 neutron-rich isotopes. Many more additional neutron-rich nuclei are predicted to be stable with respect to neutron-emission and could be observed in the future. The mass surface towards the neutron dripline (the delineation where the neutron separation energy is zero) becomes very shallow. Thus the exact prediction of the location of the dripline is difficult and can vary substantially among the different mass models. As one example for a mass model we selected the HFB-14 model which is based on the Hartree-Fock-Bogoliubov method with Skyrme forces and a δ-function

pairing force [4]. According to this model ^{261}Pt should be the last odd-even particle stable neutron-rich nucleus while the even-even particle stable neutron-rich nuclei should continue through ^{264}Pt. Along the proton dripline four more isotopes ($^{162-165}$Pt) are predicted to be particle stable. In addition, it is estimated that 5 additional nuclei beyond the proton dripline could live long enough to be observed [5]. Thus about 68 isotopes have yet to be discovered corresponding to 64% of all possible platinum isotopes.

In 2000, J.W. Arblaster published a review article entitled "The Discoverers of the Platinum Isotopes" [6]. Although he selected slightly different criteria for the discovery, our assignments agree in most of the cases. Since then only two additional isotopes (^{203,204}Pt) were discovered.

Figure A summarizes the year of first discovery for all platinum isotopes identified by the method of discovery. The range of isotopes predicted to exist is indicated on the right side of the figure. The radioactive platinum isotopes were produced using heavy-ion fusion-evaporation reactions (FE), neutron capture reactions (NC), light-particle reactions (LP), spallation (SP), and projectile fragmentation of fission (PF). The stable isotopes were identified using mass spectroscopy (MS) or atomic spectroscopy (AS). Heavy ions are all nuclei with an atomic mass larger than A=4 [7]. Light particles also include neutrons produced by accelerators. In the following, the discovery of each platinum isotope is discussed in detail (See table 1).

$^{166-167}$Pt

$^{166-167}$Pt was discovered by Bingham et al. in 1996 and published in the paper "Identification of ^{166}Pt and ^{167}Pt" [8]. A ^{92}Mo metal foil was bombarded by 357 and 384 MeV ^{78}Kr beams at the ATLAS accelerator facility at Argonne National Laboratory. ^{166}Pt and ^{167}Pt were produced in fusion evaporation reactions and identified with the FMA fragment mass analyzer. "These two figures demonstrate unambiguously the assignments of the 6832 and 6988 keV peaks to ^{168}Pt and ^{167}Pt, respectively. We deduced half-lives of 2.0(4) ms for ^{168}Pt and 0.7(2) ms for the new isotope, ^{167}Pt. ...we assign the previously unobserved 7110(15)-keV α peak to the new isotope ^{166}Pt whose half-life was determined to be 0.3(1) ms." The deduced half-lives of 0.3(1) ms for ^{166}Pt and 0.7(2) ms for ^{167}Pt are the currently accepted values.

$^{168-171}$Pt

Hofmann et al. first identified ^{168}Pt, ^{169}Pt, ^{170}Pt, and ^{171}Pt in 1981. They published their results in "New Neutron Deficient Isotopes in the Range of Elements Tm to Pt" [9]. A ^{58}Ni beam impinged on a tin target at the UNILAC linear accelerator. The α-decay spectra of the evaporation residues were measured after the velocity filter SHIP. "The lighter isotopes down to mass number 169 were identified in correlations to their well established daughters $^{167-165}$Os. The lightest isotope, ^{168}Pt, could be identified by 4 correlated events to the daughter ^{164}Os." The measured half-lives of $2.5^{+2.5}_{-1.0}$ ms (^{169}Pt) and 6^{+5}_{-2} ms for (^{170}Pt) are close to the currently accepted values of 7.0(2) ms and 13.8(5) ms, respectively. It should be mentioned that ^{171}Pt was independently observed by Della Negra et al. [10] and submitted less than two month after Hofmann et al.

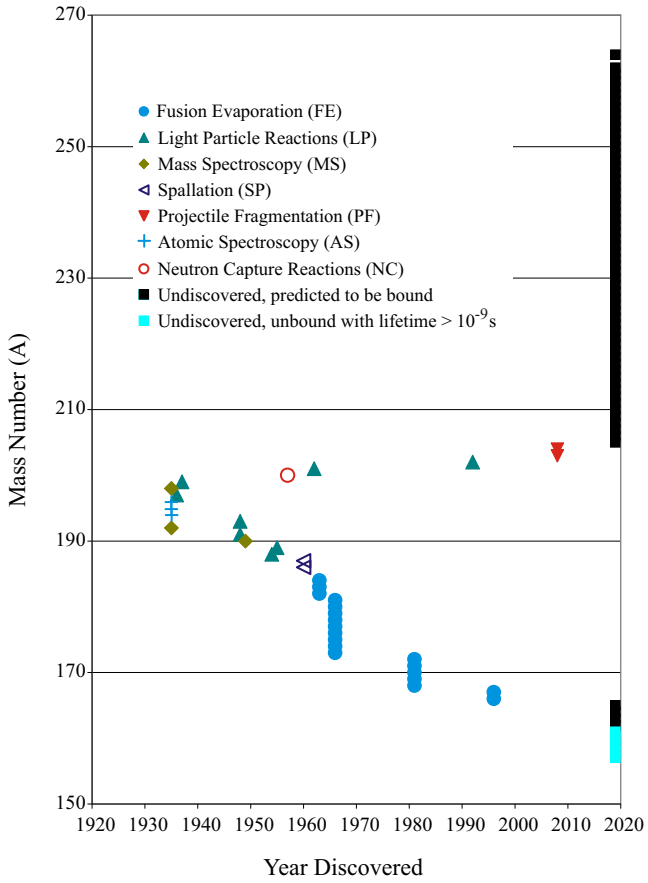

FIG. A. Platinum isotopes as a function of time when they were discovered. The different production methods are indicated. The solid black squares on the right hand side of the plot are isotopes predicted to be bound by the HFB-14 model. On the neutron-deficient side the light blue squares correspond to unbound isotopes predicted to have lifetimes larger than $\sim 10^{-9}$ s.

^{172}Pt

The discovery of ^{172}Pt was reported in the 1981 article "Alpha Decay Characteristics of Neutron Deficient Isotopes of Pt Isotopes Produced in ^{63}Cu Induced Reactions on ^{112}Sn and ^{113}In Targets" by Della Negra et al. [10]. ^{112}Sn and ^{113}In targets were bombarded with 245-300 MeV ^{63}Cu beams from the ALICE accelerator at Orsay. The evaporation residues were transported with a helium jet and deposited onto a metallic surface in front of an annular silicon detector. "^{173}Pt is produced in this case by the reaction ^{112}Sn(^{63}Cu,pn) and the two other curves corresponding to (Cu,p2n) and (Cu,p3n) leading to ^{172}Pt and ^{171}Pt. The identification was confirmed by the study of [the] ^{113}In(Cu,xn)Pt^{176-x} excitation function for $3 \leq x \leq 5$." The measured half-life of 120(10) ms is close to the currently accepted half-life of 96(3) ms.

$^{173-181}$Pt

Siivola first observed $^{173-181}$Pt in 1966 and reported his results in "Alpha-active Platinum Isotopes" [11]. The Berkeley Heavy Ion Linear Accelerator HILAC was used to bombard ^{168,170,172}Yb and ^{162,164}Er targets with beams of ^{16}O and ^{20}Ne, respectively. The reaction products were deposited on an aluminum plate by helium gas flow. Alpha-particle decay was measured with a surface barrier counter and the isotopes were identified by excitation function measurements. "We conclude that the reaction observed in the ^{16}O + Yb bombardments at 106 MeV excitation energy is (^{16}O,8n), and the others, with their maxima at 93 and 80 MeV, are (^{16}O,7n) and (^{16}O,6n), respectively. This and the regular behaviour of the Yb(^{16}O,xn) reactions give unambigously the mass numbers down to ^{176}Pt. The three lighter isotopes were assigned in a similar way using ^{20}Ne + Er bombardments." The half-lives of 0.7(2) s, 2.1(2) s, 6.0(5) s, 6.6(10) s, 21.3(15) s, 33(4) s, 50(5) s and 51(5) s are in general agreement with the accepted values of 0.889(17) s, 2.53(6) s, 6.33(15) s, 10.6(4) s, 20.7(7) s, 21.2(4) s, 56(2) s and 52.0(22) s, respectively, for A = 174−181.

$^{182-184}$Pt

^{182}Pt, ^{183}Pt, and ^{184}Pt were first observed by Graeffe in 1963. He reported his results in "On the Alpha Activities of Platinum Isotopes" [12]. An iridium target was bombarded by 50-150 MeV protons from the Gustav Werner Institute synchrocyclotron at Uppsala, Sweden. The α-decay spectra were measured following chemical separation. "The absence of an alpha activity due to Pt^{184} is unlikely, so that the 20 min activity can be tentatively assigned to Pt^{184}... The hindered 6.5 min activity, whose alpha energy (4.74 MeV) exceeds that of the 20 min activity assigned to Pt^{184} can be tentatively assigned to the next lighter odd isotope Pt^{183}, and the 2.5 min activity to the following even isotope Pt^{182}." The reported values of 2.5(5) m, 6.5(10) m and 20(2) m agree with the currently accepted values of 3.0(2) m, 6.5(10) m and 17.3(2) m, respectively, for A = 182−184. An earlier measurement of 2.5(5) h [13] for the half-life of ^{184}Pt could not be confirmed.

^{185}Pt

^{185}Pt was first observed by Albouy et al. in 1960 with spallation reactions: "Noveaux isotopes de période courte obtenus par spallation de l'or" [14]. The gold targets were bombared with 155 MeV protons from the Orsay synchro-cyclotron. "L'intensité obtenue pour les masses 187, 186 et 185 rend peu précise la détermination des énergies des raies γ correspondant aux masss 187 et 186 et ne nous a pas permis d'indentifier des raies γ pour la chaîne de masses 185." (The intensity obtained for the masses 187, 186 and 185 makes a precise determination of the γ-ray energies corresponding to masses 187 and 186 possible but has not allowed us to identify γ-rays for the mass of 185.) The quoted half-life of 1.2 h agrees with the accepted value of 70.9(2.4) m.

^{186,187}Pt

Baranov et al. reported the first identification of ^{186}Pt and ^{187}Pt in the 1960 article "New Iridium and Platinum Isotopes: Ir^{184} and Pt^{187}" [15]. The isotopes were produced by bombarding a gold target with 660 MeV protons from the Dubna Joint Institute for Nuclear Research synchrocyclotron and identified following chemical separation. "The period determined in this manner for Pt^{187} was 2.0±0.4 hours. For control purposes we also determined the period of the known platinum isotope Pt^{186}, from the intensity

of the L-137 line belonging to Ir^{186}. We obtained for Pt^{186} a period of 2.5±0.3 hours, which is in good agreement with the data of Smith & Hollander." Smith & Hollander [16] had assigned a half-life of 2.5 h to ^{187}Pt based on the γ-ray spectra of the daughter ^{187}Ir. However, the assignment of the observed γ-rays was later changed to ^{186}Ir [17]. Similar half-lives were reported by some of the same authors in the same issue [13]. About 6 month later the observation of ^{186}Pt and ^{187}Pt was independently reported by Albouy et al. [14]. The half-lives of 2.5(3) h (^{186}Pt) and 2.0(4) h (^{187}Pt) agree with the presently accepted values of 2.08(5) h and 2.35(3) h, respectively.

^{188}Pt

Naumann was the first to observe ^{188}Pt and reported his results in the 1954 paper "Identification of Platinum-188" [18]. 50-MeV protons from the Nevis and Harvard synchrocyclotrons bombarded a metallic iridium foil. Decay curves were measured with an Amperex 200C Geiger-Müller counter. "The reappearance of the 10-day decay component preceded by the short period growth suggests that this half-life be assigned to Pt^{188}." The reported half-life of 10.3(4) d agrees with the currently accepted value of 10.2(3) d.

^{189}Pt

The discovery of ^{189}Pt was reported in "Radiochemical Study of Neutron-Deficient Chains in the Noble Metal Region" by Smith and Hollander in 1955 [16]. A set of stacked iridium and aluminum foils were bombarded with 32-MeV protons from the Berkeley proton linear accelerator. Decay curves of the chemical separated reaction products were recorded with a Geiger counter. "An ∼12-hour activity in platinum was first observed in 1950 by Thompson and Rasmussen from 50-Mev proton bombardments of iridium, but a mass assignment was not made at that time. With the aid of J.O. Rasmussen, this activity has now been assigned to Pt^{189} by means of proton excitation function experiments in which its yield from iridium is compared with that of 3.0-day Pt^{191} produced from the (p,3n) reaction on Ir^{193}." The reported half life of 10.5(10) h is consistent with the currently accepted value of 10.87(12) h. The reference mentioned in the quote was unpublished [19].

^{190}Pt

^{190}Pt was first reported by Duckworth et al. in "A New Stable Isotope of Platinum" [20] in 1949. Platinum isotopes were produced in an ion source and detected and analyzed by a double-focusing mass spectrograph. "With a spark between a platinum-iridium and a copper electrode a faint line appeared at mass 190 after an exposure of three hours. The electrodes were replaced by pure platinum electrodes. With an hour's exposure the faint 190 appeared. Similarly with two platinum electrodes of commercial purity the line at 190 was clearly visible after an hour's exposure."

^{191}Pt

In 1947 Wilkinson described the first observation of ^{191}Pt in "Some Isotopes of Platinum and Gold" [21]. Platinum and iridium targets were bombarded with α-particles, deuterons and neutrons from the 60-inch Crocker Laboratory cyclotron. Decay curves were measured following chemical separation. "*3.0-day platinum.*—Previously unreported, this isotope which is distinguished from the 4.3-day isotope

by its 0.5-Mev electron and strong 0.57-Mev γ-ray has been observed in low yield in Pt+d, Pt+fast neutron, and Ir+α bombardments... The activity has been assigned provisionally to mass 191." The measured half-life of 3.00(2) d is consistent with the currently accepted value of 2.83(2) d.

^{192}Pt

Dempster identified ^{192}Pt for the first time in the 1935 article "Isotopic Constitution of Platinum and Rhodium" [22]. An alloy of platinum with 10% rhodium were used as electrodes of a spark for the source of a spectrograph. "The analysis of the platinum ions from a high-frequency spark, using a new spectrograph, shows that this element consists of five isotopes with masses 192, 194, 195, 196, 198."

^{193}Pt

In 1947 Wilkinson described the first observation of ^{193}Pt in "Some Isotopes of Platinum and Gold" [21]. The 60-inch Crocker Laboratory cyclotron bombarded platinum and iridium targets with α-particles, deuterons and neutrons. Decay curves were measured following chemical separation. "...The activity is attributed to Pt^{193} decaying by orbital electron capture for the following reasons. The isotope is formed in the deuteron, fast and thermal neutron bombardments of platinum, and also the deuteron and α-particle bombardment of iridium in yields agreeing with allocation to mass 193." The reported half-life of 4.33(3) d corresponds to an isomeric state. A previously measured half-life of 49 m [23] could not be confirmed.

$^{194-196}$Pt

^{194}Pt, ^{195}Pt and ^{196}Pt were first identified by Fuchs and Kopfermann in the 1935 article "Über die Isotopen des Platins" [24]. The masses of these isotopes were determined by measuring the isotope shift of the visible platinum lines. "In der Erwartung, daß im Spektrum des Platins eine an schweren Elementen häufig beobachtete Isotopieverschiebung auftreten würde, haben wir, um das Isotopenproblem dieses Elementes zu lösen, eine Hyperfeinstrukturanalyse der im Sichtbaren gelegenen PtI-Linien durchgeführt... Der Vergleich mit dem chemischen Atomgewicht (195.2) läßt nur die Deutung zu, daß es sich bei den drei gefundenen Isotopen um die Pt-Isotopen mit den Massenzahlen 194,195 und 196 handelt, deren Mischungsverhähltnis auf Grund unserer Intensitätsschätzungen ungefähr 5:8:8 beträgt." [With the expectation that the spectra of platinum will exhibit an isotope shift common to many of the heavy elements, we conducted a hyperfine structure analysis of the visible PtI lines in order to solve the isotope problem of this element... The only interpretation from the comparison with the chemical atomic weight (195.2) is that the three observed isotopes correspond to the Pt-isotopes with the mass numbers 194, 195, and 196; according to our intensity estimates the abundance ratio is approximately 5:8:8.] The mass spectroscopic identification of these isotopes were submitted less than two weeks later [22].

^{197}Pt

Cork and Lawrence reported the discovery of ^{197}Pt in the 1936 publication "The Transmutation of Platinum by Deuterons" [23]. Deuterons accelerated to 5 MV by a magnetic resonance accelerator bombarded a stack of platinum foils. The resulting isotopes were separated by chemical means and

the decay curves of the individual foils were recorded. "Because of the greater abundance of Pt^{196} the 14.5-hr. electron activity of platinum can be reasonably ascribed to Pt^{197}, which decays to gold..." The reported half-life of 14.5 hr is close to the currently accepted value of 19.8915(19) h.

^{198}Pt

Dempster identified ^{198}Pt for the first time in the 1935 article "Isotopic Constitution of Platinum and Rhodium" [22]. An alloy of platinum with 10% rhodium were used as electrodes of a spark for the source of a spectrograph. "The analysis of the platinum ions from a high-frequency spark, using a new spectrograph, shows that this element consists of five isotopes with masses 192, 194, 195, 196, 198."

^{199}Pt

McMillan et al. observed ^{199}Pt in the 1937 article "Neutron-Induced Radioactivity of the Noble Metals" [25]. Slow neutrons irradiated platinum targets which were subsequently chemical separated and their activity was measured. "Reference to the isotope chart show that one would expect Pt^{199} to form unstable Au^{199}. We made successive separations of gold from activated platinum to find which platinum period is its parent, and found that it does not come from the 18-hr. period, but most probably does come from the 31-min. period." The reported half life of 31 min is in agreement with the currently accepted value of 30.80(21) min. Two activities of 50 min [26] and 36 min [27] had previously been reported for platinum without mass assignment. Also, a half-life of 49 min had been assigned to ^{193}Pt [23].

^{200}Pt

Roy et al. described the discovery of ^{200}Pt in "New Radioisotope of Platinum$-Pt^{200}$" [28]. ^{198}Pt targets were irradiated by neutrons from the Chalk River NRX reactor to produce ^{200}Pt by successive neutron capture. The presence of ^{200}Pt was determined by milking the ^{200}Au daughter and measuring the activities. "Parent-daughter isolation experiments were performed to establish both the half-life of Pt^{200} and its genetic relationship to Au^{200}... The average value for the half-life of Pt^{200} is 11.5 ± 1.0 hr." This half-life agrees with the currently accepted value of 12.6(3) h.

^{201}Pt

^{201}Pt was first reported by Facetti et al. in the 1962 report "A New Isotope, Pt^{201}" [29]. Neutrons from the Puerto Rico Nuclear Center nuclear reactor were used to irradiate mercury compounds. The activated samples were chemically separated and their decay was measured with a GM counter. "From all these facts, it follows that the observed half-life of 2.3 ± 0.2 min is due to the disintegration of a new isotope: Pt^{201}." The reported half-life of 2.3(2) m is in good agreement with the currently accepted value of 2.5(1) m.

^{202}Pt

The first observation of ^{202}Pt was described in 1992 by Shi et al. in "Identification of a New Neutron Rich Isotope ^{202}Pt" [30]. 250 MeV protons from the Shanghai Institute of Nuclear Research K=40

cyclotron bombarded a beryllium target to produce neutrons, which then irradiated a mercury target. ^{202}Pt was identified by measuring the γ-ray spectra of the chemically separated activities with a HpGe detector. "The gamma ray 439.6 keV from the decay ^{202}Pt $\rightarrow$^{202}Au $\rightarrow$^{202}Hg was detected... The half-life of ^{202}Pt is determined to be 43.6$\pm$15.2 h." This half-life is the currently accepted value.

^{203,204}Pt

The first refereed publication of the observation of ^{203}Pt and ^{204}Pt was the 2008 paper "Single-particle Behavior at N = 126: Isomeric Decays in Neutron-rich ^{204}Pt" by Steer et al. [31]. A 1 GeV/A ^{208}Pb beam from the SIS-18 accelerator at GSI impinged on a ^{9}Be target and the projectile fragments were selected and identified in flight by the FRagment Separator FRS. The observation of ^{203}Pt is not specifically mentioned but ^{203}Pt events are clearly visible and identified in the particle identification plot in the first figure. Details of the ^{203}Pt had previously been published by the same group in two different conference proceedings [32,33]."The results for ^{204}Pt were obtained from four different magnetic rigidity settings of the FRS. A total of 9.3 $\times 10^4$ ^{204}Pt ions was implanted in the stopper." The ^{204}Pt data also had been presented previously in two conference proceedings [33,34].

3. SUMMARY

The discoveries of the known platinum isotopes have been compiled and the methods of their production discussed. Most of the assignments agree with the review article by Arblaster [6]. The exceptions are: (1) ^{172}Pt where Arblaster credits unpublished work by Cabot as quoted in an overview paper by Gauvin et al. [35]; (2) ^{186}Pt which is credited to Albouy et al. [14], however the identification by Baranov et al. [15] published a few months earlier is correct; and (3) the stable isotopes $^{194-196}$Pt where we found a paper by Fuchs and Kopfermann [24] which was submitted less than two weeks prior to the mass spectroscopic work by Dempster [22]. In addition, the half-lives for ^{184}Pt and ^{193}Pt were first reported incorrectly and ^{186}Pt was first identified as ^{187}Pt. The half-life of ^{199}Pt was initially measured without mass identification. Finally, ^{203}Pt has yet to be specifically described in the refereed literature.

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EXPLANATION OF TABLE

TABLE I. Discovery of platinum isotopes

Isotope	Platinum isotope
Author	First author of refereed publication
Journal	Journal of publication
Ref.	Reference
Method	Production method used in the discovery: FE: fusion evaporation LP: light-particle reactions (including neutrons) MS: mass spectroscopy SP: spallation reactions AS: atomic spectroscopy PF: projectile fragmentation or fission NC: neutron-capture reactions
Laboratory	Laboratory where the experiment was performed
Country	Country of laboratory
Year	Year of discovery

TABLE I. Discovery of Platinum Isotopes

See page 12 for Explanation of Tables

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Isotope	Author	Journal	Ref.	Method	Laboratory	Country	Year
^{166}Pt	C.R. Bingham	Phys. Rev. C	Bin96	FE	Argonne	USA	1996
^{167}Pt	C.R. Bingham	Phys. Rev. C	Bin96	FE	Argonne	USA	1996
^{168}Pt	S. Hofmann	Z. Phys. A	Hof81	FE	Darmstadt	Germany	1981
^{169}Pt	S. Hofmann	Z. Phys. A	Hof81	FE	Darmstadt	Germany	1981
^{170}Pt	S. Hofmann	Z. Phys. A	Hof81	FE	Darmstadt	Germany	1981
^{171}Pt	S. Hofmann	Z. Phys. A	Hof81	FE	Darmstadt	Germany	1981
^{172}Pt	S. Della Negra	Z. Phys. A	Del81	FE	Orsay	France	1981
^{173}Pt	A. Siivola	Nucl. Phys.	Sii66	FE	Berkeley	USA	1966
^{174}Pt	A. Siivola	Nucl. Phys.	Sii66	FE	Berkeley	USA	1966
^{175}Pt	A. Siivola	Nucl. Phys.	Sii66	FE	Berkeley	USA	1966
^{176}Pt	A. Siivola	Nucl. Phys.	Sii66	FE	Berkeley	USA	1966
^{177}Pt	A. Siivola	Nucl. Phys.	Sii66	FE	Berkeley	USA	1966
^{178}Pt	A. Siivola	Nucl. Phys.	Sii66	FE	Berkeley	USA	1966
^{179}Pt	A. Siivola	Nucl. Phys.	Sii66	FE	Berkeley	USA	1966
^{180}Pt	A. Siivola	Nucl. Phys.	Sii66	FE	Berkeley	USA	1966
^{181}Pt	A. Siivola	Nucl. Phys.	Sii66	FE	Berkeley	USA	1966
^{182}Pt	G. Graeffe	Ann. Acad. Sci. Fenn.	Gra63	FE	Uppsala	Sweden	1963
^{183}Pt	G. Graeffe	Ann. Acad. Sci. Fenn.	Gra63	FE	Uppsala	Sweden	1963
^{184}Pt	G. Graeffe	Ann. Acad. Sci. Fenn.	Gra63	FE	Uppsala	Sweden	1963
^{185}Pt	G. Albouy	J. Phys. Radium	Alb60	LP	Orsay	France	1960
^{186}Pt	V.I. Baranov	Izvest. Akad. Nauk.	Bar60	SP	Dubna	Russia	1960
^{187}Pt	V.I. Baranov	Izvest. Akad. Nauk.	Bar60	SP	Dubna	Russia	1960
^{188}Pt	R.A. Naumann	Phys. Rev.	Nau54	LP	Harvard	USA	1954
^{189}Pt	W.G. Smith	Phys. Rev.	Smi55	LP	Berkeley	USA	1955
^{190}Pt	H.E. Duckworth	Phys. Rev.	Duc49	MS	Middletown	USA	1949
^{191}Pt	G. Wilkinson	Phys. Rev.	Wil48	LP	Berkeley	USA	1948
^{192}Pt	A.J. Dempster	Nature	Dem35	MS	Chicago	USA	1935
^{193}Pt	G. Wilkinson	Phys. Rev.	Wil48	LP	Berkeley	USA	1948
^{194}Pt	B. Fuchs	Naturwiss.	Fuc35	AS	Berlin	Germany	1935
^{195}Pt	B. Fuchs	Naturwiss.	Fuc35	AS	Berlin	Germany	1935
^{196}Pt	B. Fuchs	Naturwiss.	Fuc35	AS	Berlin	Germany	1935
^{197}Pt	J.M. Cork	Phys. Rev.	Cor36	LP	Berkeley	USA	1936
^{198}Pt	A.J. Dempster	Nature	Dem35	MS	Chicago	USA	1935
^{199}Pt	E. McMillan	Phys. Rev.	McM37	LP	Berkeley	USA	1937
^{200}Pt	L.P. Roy	Phys. Rev.	Roy57	NC	Chalk River	Canada	1957
^{201}Pt	J. Facetti	Phys. Rev.	Fac62	LP	Mayaguez	Puerto Rico	1962
^{202}Pt	S. Shi	Z. Phys. A	Shi92	LP	Shanghai	China	1992
^{203}Pt	S.T. Steer	Phys. Rev.	Ste08	PF	Darmstadt	Germany	2008
^{204}Pt	S.T. Steer	Phys. Rev.	Ste08	PF	Darmstadt	Germany	2008

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