The Discoverers of the Platinum Isotopes

THE DISCOVERY OF THE THIRTY SEVEN KNOWN PLATINUM ISOTOPES BETWEEN 1935 AND 1996

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The history of the discovery of the isotopes of platinum, made over some 61 years between 1935 and 1996, can be gleaned from the various editions of the monograph "Table of Isotopes" (1–8). However, except for a few cases, in general, little attempt has been made to correlate the circumstances of the discoveries of the isotopes of individual elements. In this article attention is drawn to the work of pioneering scientists who in a comparatively short period of creativity discovered the majority of the isotopes of platinum.

There are thirty-seven known isotopes of platinum and six of these occur naturally with the authorised isotopic abundances stated below (9).

The Naturally Occurring Isotopes of Platinum	
Mass number	Isotopic abundance, %
^{190}Pt	0.014
^{192}Pt	0.782
^{194}Pt	32.965
^{195}Pt	33.832
^{196}Pt	25.142
^{198}Pt	7.163

Of these, the five major isotopes were discovered by Dempster at the University of Chicago, Illinois, in 1935 using a new type of mass spectrograph; however, he only identified the mass numbers (10). The actual isotopic abundances were measured using the same technique by Sampson and Bleakney in 1936 (11), although earlier in the same year Jaeckel and Kopfermann (12) and Kopfermann and Krebs (13) had obtained reasonable estimates of the relative isotopic ratios of the four major isotopes (the last four) by a study of the hyperfine structure of the neutral platinum spectra. An earlier attempt by Venkatesachar and Sibaiya to use this technique for platinum led to a misidentification of the mass numbers of the major isotopes (14).

The rare isotope, ^{190}Pt, was identified by Duckworth, Black and Woodcock (15) at the Wesleyan University, Middletown, Connecticut, in 1949 using the mass spectrographic technique and was shown to be radioactive by Porschén and Riezler in 1954 (16). The half-life of ^{190}Pt is currently accepted as 6.5×10^{11} years (650 Gy) (17).

Artificial Platinum Isotopes

In 1935, the possible existence of radioactive platinum isotopes was inferred by McLennan, Grimmett and Read (18) at the Radium Institute, London, and also by Amaldi and colleagues (19) in the Physics Laboratory at the University of Rome by slow neutron bombardment of the metal. However, the mass numbers could only be guessed at until later in the same year when Dempster identified the major naturally occurring isotopes using his new type of mass spectrograph.

The first definite identification of a radioactive platinum isotope was probably in 1936 by Cork and Lawrence (20) in the Department of Physics of the University of California who produced an isotope with a half-life of 14.5 hours. They used chemical means to identify the isotope as platinum and assigned it to the 'missing' ^{197}Pt.

A year later, McMillan, Kamen and Ruben (21) at the same Department of Physics produced an isotope which had a half-life of 18 hours. This was also chemically identified as platinum and assigned to ^{197}Pt. Although both set of claims were initially tentative, the two teams of claimants have subsequently been credited with the discovery of this isotope in the "Table of Isotopes" (1–8).

The major period of discovery was, however, in the 1960s when sixteen new isotopes were

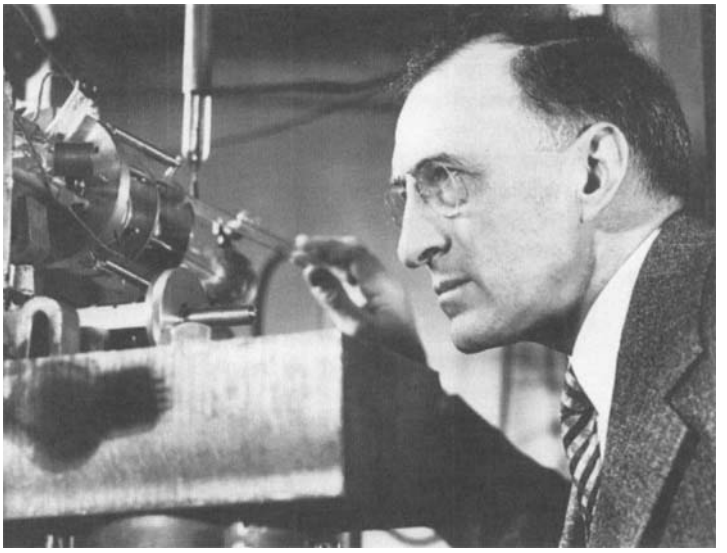
The Discoverers of the Platinum Isotopes						
Mass number	Half-life	Decay modes	Year of discovery	Discoverers	Ref.	Notes
166	300 μs	α	1996	Bingham *et al.*	25	
167	700 μs	α	1996	Bingham *et al.*	25	
168	2.0 ms	α, EC + β^+ ?	1981	Hofmann *et al.*	26	A
169	3.7 ms	α, EC + β^+ ?	1981	Hofmann *et al.*	26	
170	14.7 ms	α, EC + β^+	1981	Hofmann *et al.*	26	
171	38 ms	α, EC + β^+	1981	Hofmann *et al.*	26	B
172	98 ms	α, EC + β^+	1975	Cabot *et al.*	27	C
173	363 ms	α, EC + β^+	1966	Siivola	22	D
174	898 ms	α, EC + β^+	1966	Siivola	22	
175	2.52 s	α, EC + β^+	1966	Siivola	22	
176	6.33 s	EC + β^+, α	1966	Siivola	22	
177	10.0 s	EC + β^+, α	1966	Siivola	22	
178	21.1 s	EC + β^+, α	1966	Siivola	22	
179	21.2 s	EC + β^+, α	1966	Siivola	22	
180	52 s	EC + β^+, α	1966	Siivola	22	
181	51 s	EC + β^+, α	1966	Siivola	22	
182	2.2 min	EC + β^+, α	1963	Graeffe	23	
183	6.5 min	EC + β^+, α	1963	Graeffe	23	
183m	43 s	EC + β^+, IT ?	1978	Visvanathan *et al.*	28	
184	17.3 min	EC + β^+, α	1963	Graeffe	23	E
184m	1.01 ms	IT	1966	Burde, Diamond and Stephens	29	
185	70.9 min	EC + β^+, α	1960	Albouy, Gusakow and Poffé	30	
185m	33.0 min	EC + β^+, IT ?	1970	Finger *et al.*	31	
186	2.08 h	EC + β^+, α	1960	Albouy, Gusakow and Poffé	30	F
187	2.35 h	EC + β^+	1960	1: Albouy, Gusakow and Poffé	30	
				2: Baranov *et al.*	32	
				3: Malysheva *et al.*	33	
188	10.2 d	EC, α	1954	Naumann	34	
189	10.87 d	EC + β^+	1955	Smith and Hollander	35	
190	650 Gy	α	1949	Duckworth, Black and Woodcock	15	G
191	2.80 d	EC	1947	Wilkinson	36	
192	Stable	–	1935	Dempster	10	
193	50 y	EC	1956	Naumann	37	H
193m	4.33 d	IT	1947	Wilkinson	36	
194	Stable	–	1935	Dempster	10	
195	Stable	–	1935	Dempster	10	
195m	4.02 d	IT	1951	Huber *et al.*	38	I
196	Stable	–	1935	Dempster	10	
197	19.892 h	β^-	1936	Cork and Lawrence	20	J
197m	95.4 min	IT, β^-	1952	Christian, Mitchell and Martin	39	K
198	Stable	–	1935	Dempster	10	
199	30.8 min	β^-	1937	McMillan, Kamen and Ruben	21	L
199m	13.6 s	IT	1959	Walgren and Meinke	40	
200	12.5 h	β^-	1956	Roy, Roy and Merritt	41	
201	2.5 min	β^-	1962	Facetti *et al.*	42	
202	44 h	–	1992	Shi *et al.*	43	

s is second, min is minute, h is hour, d is day, y is year
ms is millisecond (10^{-3} s), μs is microsecond (10^{-6} s), Gy is gigayear (10^9 y)

Arthur Jeffrey Dempster
1886–1950

The U.S. physicist Arthur Dempster joined the faculty of the Department of Physics at the University of Chicago, Illinois, in 1919. He developed the double focusing mass spectrograph in 1935 and used it to make the first isotopic analyses of platinum, iridium, palladium and gold. Between 1920 and 1939 he is credited with the discovery or co-discovery of forty-five naturally occurring isotopes of nineteen elements. At his death A. J. Dempster was Professor of Physics at the University of Chicago

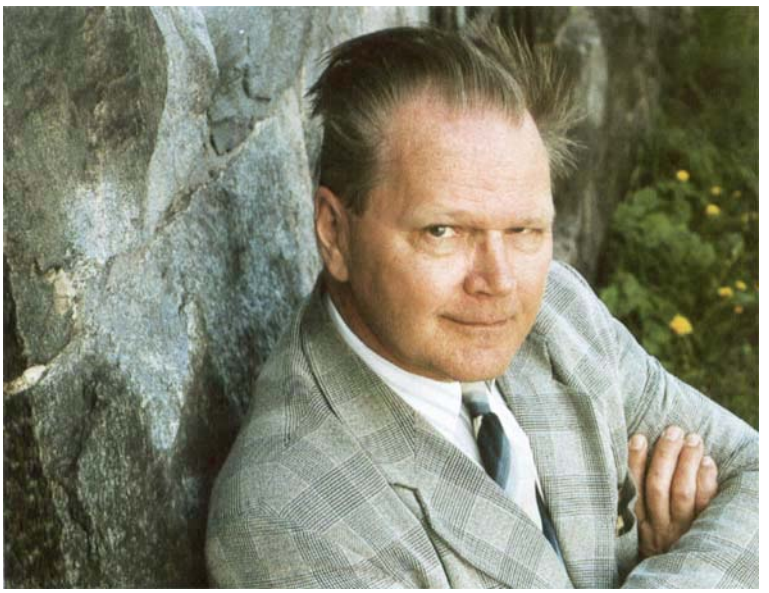
University of Chicago, courtesy of AIP Emilio Segrè Visual Archives



announced. In 1966, the Finnish physicist, Antti Siivola, working at the Lawrence Radiation Laboratory, University of California, announced the production and identification of nine new isotopes of platinum (22). He also confirmed three others which had been discovered by Graeffe in 1963 at the University of Helsinki (23).

More recently work has been concentrated on discovering the light isotopes and although such isotopes have half-lives in the millisecond region they are all alpha emitters, so that for platinum the proton drip line (see Appendix) has not yet been crossed. The latest research to take place will be looking for the isotope ^{165}Pt, which is likely to decay by alpha emission. This work is connected with experiments which are searching for the proton emitting isotope ^{164}Ir.

The actual methods for the production and



Antti Siivola

From 1963 to 1965 the Finnish physicist worked at the Lawrence Radiation Laboratory, Berkeley, University of California, later returning to the University of Helsinki. Between 1966 and 1968 he announced the production and identification of nine new isotopes of platinum, seven of iridium, seven of gold, five of lead and six of bismuth (six ground state isotopes and three isomeric states). Antti Siivola became Professor of Physics, Head of the Department of Physics and Dean of the Faculty of Science at the University of Helsinki. He retired from the University of Helsinki in October 1999

(Lehtikuva Oy) Rex Features

Notes to the Table

A	^{168}Pt	Alpha energy only, the half-life was measured by Bingham *et al.* in 1996 (25).
B	^{171}Pt	Alpha energy only, the half-life was measured by Della Negra *et al.* in 1981 (44) and Enge *et al.* in 1981 (45).
C	^{172}Pt	Alpha energy only, the half-life was measured by Enge *et al.* in 1980 (45, 46).
D	^{173}Pt	Alpha energy only, the half-life was measured by Cabot *et al.* in 1975 (27).
E	^{184}Pt	The half-life, determined by Graeffe at 20 minutes, was confirmed by Siivola in 1966 (22). Other reported values are 2.6 hours by Malysheva *et al.* in 1960 (33) and 42 minutes by Qaim in 1964 (47).
F	^{186}Pt	Smith and Hollander first characterised this isotope in 1955 but incorrectly assigned the mass number as 187 (35). This mistake was indirectly corrected by Scharff-Goldhaber *et al.* in 1957 (48) who reassigned the mass number of a daughter isotope from ^{187}Ir to ^{186}Ir.
G	^{190}Pt	The radioactive nature of this naturally occurring isotope was discovered by Porschén and Riezler in 1954 (16).
H	^{193}Pt	Naumann only determined the half-life to be less than 500 years. The accepted value was determined by Soy, Ravn and Bøgeholt in 1971 (49).
I	^{195m}Pt	Non-specified activities of 3.3 days by McMillan, Kamen and Ruben in 1937 (21) and 3.45 days by Hole in 1948 (50) were assigned to ^{195m}Pt by the "Table of Isotopes".
J	^{197}Pt	Although the claimed discovery by Cork and Lawrence was tentative (20), a later assignment by McMillan Kamen and Ruben in 1937 was equally tentative (21).
K	^{197m}Pt	Non-specified activities of 80 minutes by Sherr, Brainbridge and Anderson in 1941 (51), 78 minutes by Hole in 1948 (50) and 87 minutes by Mock *et al.* in 1948 (52) were assigned to ^{197m}Pt by the "Table of Isotopes".
L	^{199}Pt	Non-specified activities of 36 minutes by McLennan, Grimmett and Read (18) and 50 minutes by Amaldi *et al.* (19), both in 1935, were assigned to ^{199}Pt by the "Table of Isotopes".

Decay Modes

α	Alpha decay is the emittance of alpha particles which are ^{4}He nuclei. Thus the atomic number of the daughter nuclide is lower by two and the mass number is lower by four.
β^-	Beta or electron decay for neutron-rich nuclides is the emittance of an electron (and an anti-neutrino) as a neutron decays to a proton. The mass number of the daughter nucleus remains the same but the atomic number increases by one.
β^+	Beta or positron decay for neutron-deficient nuclides is the emittance of a positron (and a neutrino) as a proton decays to a neutron. The mass number of the daughter nucleus remains the same but the atomic number decreases by one. However, this decay mode cannot occur unless the decay energy exceeds 1.022 MeV (twice the electron mass in energy units). Positron decay is always associated with orbital electron capture (EC).
EC	Orbital electron capture. The nucleus captures an extranuclear (orbital) electron which reacts with a proton to form a neutron and a neutrino, so that, as with positron decay, the mass number of the daughter nucleus remains the same but the atomic number decreases by one.
IT	Isomeric transition, in which a high energy state of a nuclide (isomeric state or isomer) usually decays by cascade emission of γ (gamma) rays (the highest energy form of electromagnetic radiation) to lower energy levels until the ground state is reached. However, certain low level states may also decay independently to other nuclides.
p	The emittance of protons by highly neutron-deficient nuclides. As the neutron:proton ratio decreases a point is reached where there is insufficient binding energy for the last proton which is therefore unbound and is emitted. The point at which this occurs is known as the proton drip line and such nuclides are said to be "particle unstable".
n	The emittance of neutrons from highly neutron-rich nuclides. As the proton:neutron ratio decreases a point is reached where there is insufficient binding energy for the last neutron which is therefore unbound and is emitted. The point at which this occurs is known as the neutron drip line. The heaviest platinum isotopes still have half-lives in the minutes to hour region and it is therefore likely that many more neutron-rich isotopes remain to be discovered before the neutron drip line is reached.

Appendix

Some of the Terms Used for this Review

Atomic number	the number of protons in the nucleus
Mass number	the combined number of protons and neutrons in the nucleus
Nuclide and isotope	A nuclide is an entity characterised by the number of protons and neutrons in the nucleus. For nuclides of the same element the number of protons remains the same but the number of neutrons may vary. Such nuclides are known collectively as the isotopes of the element. Although the term isotope implies plurality it is sometimes used loosely in place of nuclide.
Half-life	the time taken for the activity of a radioactive nuclide to fall to half of its previous value
Electron volt (eV)	the energy acquired by any charged particle carrying a unit (electronic) charge when it falls through a potential of one volt. It is equivalent to 1.602×10^{-19} J. The more useful unit is the mega (million) electron volt, MeV.

identification of the isotopes are given in the original reports and summarised in the Table of The Discoverers of the Platinum Isotopes.

In this Table the mass number of each isotope is listed together with the half-life as selected by the compilers of the NUBASE Data Base (17). However, the data for ^{170}Pt comes from a more recent review (24). Isomeric states (indicated by the suffix "m") are included if their half-lives exceed one millisecond or if they are a significant fraction of the half-life of the ground state, if the latter is also short. The principal decay modes are listed in order of abundance, with a question mark indicating that the decay type is either expected or has been detected but that the percentage abundance has not been measured.

The year of discovery of an isotope is generally taken to be the year in which the discovery was placed in the public domain and is therefore either a manuscript date or a conference report date. If the discovery was announced by different groups at the same time, but independently, then all are included in an order which makes use of the above dating system.

Criteria for Discovery

Most important are the criteria for the correct identifications of the atomic number and the mass number of isotopes, although the sequence of discovery is not considered to be complete until an important radiation property, such as the half-life, or in the case of alpha emitters, for example, the unique alpha energy spectrum, has been measured. In the 'Notes to the Table' if the alpha energy spectrum was found first, the first determination of the half-life is also included. For naturally-occurring isotopes, discovery is considered to be the first identification by mass spectrography.

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