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NUCLEAR REACTIONS OF ARSENIC WITH 190 Mev DEUTERONS

By

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Berkeley, California

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Abstract

Isotopes formed in the bombardment of $_{33}As^{75}$ with 190 Mev deuterons range in atomic number up to twenty-four (or more) mass units lighter than As^{75}. Identification of these isotopes was based on chemical behavior and half-life determination. Relative yields have been calculated and show that 80% of the observed reactions produce isotopes within 8 mass units of As^{75}.

Three new isotopes have been observed: 9.5 d. Se^{72} (K), 44 m. Se^{71} (β^+), and 52 m. As^{71} (β^+).

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NUCLEAR REACTIONS OF ARSENIC WITH 190 Mev DEUTERONS

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January 21, 1948

Bombardment of pure arsenic ($_{33}As^{75}$) with 190 Mev deuterons has led to the observation of nuclear reactions in which some of the product nuclei are more than 20 mass units lighter than the target nucleus. Identification of these and of other reaction products was made by chemical separation of the various radioisotopes into elemental fractions, followed by an investigation of the radiations associated with each fraction.

The gross rate of decay of the radioisotopes in each elemental fraction was determined with argon-filled (10 cm. pressure) Geiger-Müller counting tubes of the thin window type (ca. 3 mg/cm.^{2} of mica). The half-lives obtained from the resolved decay curves formed the chief basis for identification of known isotopes. In those cases in which sufficient activity was available samples were placed in a crude beta-ray spectrometer and tested for positive or negative beta-particles.

Most of the radiations observed could be assigned to known isotopes; these isotopes are listed in the table below. The identifications of Zn^{72}, Cu^{60}, Ni^{57}, and Co^{55} are uncertain as they are based on half-lives obtained with low accuracy due to the high level of accompanying activities. The assignments of Mn^{52} and Cr^{51} are based on reliable half-life determinations from measurements of a small amount of activity in the Mn and Cr fractions. The identification of the remaining isotopes is beyond doubt.

Several new radioactivities have been observed. Mass assignments have been made by demonstration of the following decay chains.

(a) Se^{72} (new) $\xrightarrow[9.5\ d.]{K}$ As^{72} (known) $\xrightarrow[26\ hr.]{\beta^+}$ Ge^{72}

(b) Se^{71} (new) $\xrightarrow[44\ m.]{\beta^+}$ As^{71} (new) $\xrightarrow[52\ m.]{\beta^+}$ Ge^{71} (known) $\xrightarrow[40\ hr.]{\beta^+}$ Ga^{71}

(c) Ge^{68} (unassigned)(1) $\xrightarrow[250\ d.]{K}$ Ga^{68} (known) $\xrightarrow[68\ m.]{\beta^+}$ Zn^{68}

"Milkings" of As^{73} from Se^{73} (β^+,6.7 h.) have failed to produce measurable activity. This behavior is consistent with the assignment of the 100 d. activity[2] to As^{73}.

Rough values for the yields of the isotopes have been determined. The figures presented in the table are ratios relative to the yield of As^{72}, and are average figures for several bombardments. The calculations are only approximate because of errors due to (a) self absorption and absorption in air, (b) scattering, and (c) unknown counting efficiencies for orbital electron capturing isotopes.

In the column "Reaction Δ" are given the differences in mass and charge between the product isotopes and the target nucleus, $_{33}As^{75}$. Due to the time required for chemical separations, no activities of less than about 15 minutes half-life would have been seen. Isotopes of half-life greater than about 200 days formed in yield less than 0.05 that of As^{72} would not have been detected.

Salient features of the data are: (a) the low yield of selenium isotopes as compared with arsenic isotopes (b) the predominance of neutron deficient isotopes from selenium to gallium and (c) the presence of proton deficient isotopes of the elements below zinc in yields comparable to those of the neutron deficient isotopes.

It will be noted that over 80% of the reactions observed produce isotopes within 8 mass units of As^{75}. Since these reactions require excitation of less than ~75 Mev, it appears that the high energy deuteron gives up only part of its energy in most of the reactions. This behavior is consistent with the picture of

high energy nuclear reactions recently proposed by Serber.[3]

This work was performed under Contract No. W-7405-Eng-48, with the Atomic Energy Commission in connection with the Radiation Laboratory of the University of California, Berkeley, California. The bombardments were conducted by Dr. Duane Sewell and the 184-inch cyclotron group.

ISOTOPES PRODUCED BY $_{33}As^{75}$ + 200 Mev D^+

Isotope	Type of Radiation[4]	Half-Life		Yield[6] Rel As^{72} [7]	Reaction Δ	
		Observed	Literature[5]		ΔZ	ΔA
$_{34}Se^{75}$	(K,γ,e^-)	120 d	160 d[8]	0.11 (5%)	+1	+0
$_{34}Se^{73}$	β^+	6.7 h	—	0.09	+1	-2
$_{34}Se^{72}$	K	9.5 d	—	0.1 (100%)	+1	-3
$_{34}Se^{71}$	β^+	44 m	—	0.01	+1	-4
$_{33}As^{74}$	β^-,β^+,γ	19.0 d	16 d	1.1	0	-1
$_{33}As^{72}$	β^+	26 h	26 h	1.00	0	-3
$_{33}As^{71}$	β^+	52 m	—	0.3	0	-4
$_{32}Ge^{71}$	β^+,K	38 h 11.4 d	40 h 11 d	2 ~2 (3%)	-1	-4
$_{32}Ge^{68}$	K	250 d	195 d	≈5 (100%)	-1	-6
$_{31}Ga^{68}$	β^+	68 m	68 m	0.2	-2	-7
$_{31}Ga^{67}$	K,γ,e^-	83 h	83 h	~3 (5%)	-2	-8
$_{31}Ga^{66}$	β^+	10 h	9.4 h	~0.1	-2	-9
$_{30}Zn^{72}$	(β^-,γ)	~50 h	49 h[9]	≤0.001	-3	-3
$_{30}Zn^{69}$	(β^-,I.T.,γ)	51 m 14 h	57 m 13.8 h	0.07 0.05	-3	-6
$_{29}Cu^{67}$	β^-	61 h	56 h[10]	0.02	-4	-8
$_{29}Cu^{64}$	(β^-,β^+,K,γ)	13 h	12.8 h	0.1	-4	-11
$_{29}Cu^{61}$	(β^+,K)	3.3 h	3.4 h	0.1 (100%)	-4	-14
$_{29}Cu^{60}$	(β^+)	~20 m	24.5 m[11]	0.06	-4	-15
$_{28}Ni^{66}$	β^-	56 h	56 h[10]	0.002	-5	-9
$_{28}Ni^{65}$	(β^-,γ)	2.6 h	2.6 h	0.001	-5	-10
$_{28}Ni^{57}$	β^+	34 h	36 h	0.0002	-5	-18
$_{27}Co^{61}$	(β^-)	1.8 h	1.75 h[12]	0.003	-6	-14
$_{27}Co^{56-58}$	(β^+,γ,K)	~80 d	72 d	0.06 (35%)	-6	-19 -17
$_{27}Co^{55}$	β^+,γ	~16 h	18.2 h	0.003	-6	-20
$_{26}Fe^{59}$	(β^-,γ)	43 d	47 d	0.005	-7	-16
$_{25}Mn^{56}$	(β^-,γ)	2.6 h	2.59 h	0.002	-8	-19
$_{25}Mn^{52}$	(β^+,γ,K)	6 d	6.5 d	0.0002 (40%)	-8	-23
$_{24}Cr^{51}$	(K,γ,e^-)	26 d	26.5 d	0.005 (5%)	-9	-24

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(1) Mann, W. B., Phys. Rev. 54, 649 (1938).

(2) Elliot, L. G. and M. Deutsch, Phys. Rev. 63, 457 (1943).

(3) Serber, R., Phys. Rev. 72, 1114 (1947).

(4) Parentheses signify identification based on half-life determination only.

(5) Seaborg, G. T., Rev. Mod. Phys., 16, 1-32 (1944).

(6) The yield of As^{72} corresponds to a cross-section of about 0.02×10^{-24} $cm.^2$

(7) Parenthesized figures signify assumed counting efficiencies.

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