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SPALLATION PRODUCTS OF ARSENIC WITH 190 MEV DEUTERONS

H. H. Hopkins, Jr.

July 7, 1949

Berkeley, California

SPALLATION PRODUCTS OF ARSENIC WITH 190-Mev DEUTERONS

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July 7, 1949

Recent investigations[1] of the nuclei formed when arsenic is bombarded with 190-Mev deuterons in the 184-inch cyclotron have been extended.

The target material consisted of twice sublimed arsenic. Spectrographic analysis[2] showed no impurity in sufficient quantity to account for the formation of any of the isotopes reported here with the observed yields.

The use of improved chemical separations and counting techniques has enabled the identification of 38 nuclear species among the elements from chromium through selenium. Table I lists the isotopes identified, the observed and literature half-lives[3], and the yields relative to that of As^{72}. Since some of the yield figures depend on the extent of electron capture, the percentage of electron capture used in the yield calculation is indicated after the yield figure in parentheses. The yields reported here are all accurate to within a factor of two and most are accurate to within 30%. The uncertainties lie in the electron-capturing ratios and counting efficiencies.

Table I contains two changes in isotope assignment differing from those previously reported.[1] The 44-minute selenium and 52-minute arsenic daughter are placed at mass 70 since careful separations revealed no active germanium daughter. The 40-hour germanium cannot be found when germanium is chemically separated from the 60-hour As^{71}, so is assigned to mass 69, in agreement with the work of Pool.[4]

Table 1

Isotopes Produced by $_{33}As^{75} + D^{+}$ (190 Mev)

Isotope	Radiation Type	Lit. Half-Life[3]	Obs. Half-Life	Yield Rel. As^{72} (5)
$_{34}Se^{75}$	K	127 days	120 days	0.14 (100%)
Se^{73}	β^+,K	6.7 hrs.	6.7 hrs.	0.27 (~70%)
Se^{72}	K	9.5 days	9.7 days	0.077(6)
Se^{70}	β^+	44 min.	~44 min.	0.004
$_{33}As^{74}$	β^+,β^-	17.5 days	19 days	1.25
As^{73}	K	90 days	(long)	2
As^{72}	β^+	26 hrs.	26.7 hrs.	1.00
As^{71}	K	60 hrs.	60 hrs.	0.72(6)
As^{70}	β^+	52 min.	52 min.	0.1
$_{32}Ge^{71}$	K	11 days	11 days	2.0(100%)
Ge^{69}	β^+,K	39.7 hrs.	40 hrs.	0.95 (~70%)
Ge^{68}	K	250 days	250 days	0.29(6)
Ge^{67}	β^+	23 min.	21 min.	0.1
Ge^{66}	β^+(?)	140 min.	~150 min.	0.008
$_{31}Ga^{70}$	β^-	20.3 min.	20 min.	0.018
Ga^{68}	β^+	68 min.	70 min.	0.56
Ga^{67}	K	78.3 hrs.	80 hrs.	1.0(100%)
Ga^{66}	β^+,K	9.4 hrs.	9 hrs.	0.56 (~70%)
$_{30}Zn^{72}$	β^-	49 hrs.	~50 hrs.	0.00022
Zn^{69m}	I.T.	13.8 hrs.	13.5 hrs.	0.015
Zn^{65}	K	250 days	(long)	0.2 (100%)
Zn^{63}	β^+	38 min.	39 min.	0.02
Zn^{62}	K	9.5 hrs.	10 hrs.	0.002(6)
$_{29}Cu^{67}$	β^-	56 hrs.	61 hrs.	0.013
Cu^{64}	β^+,β^-,K	12.8 hrs.	12.8 hrs.	0.20(~50%)
Cu^{62}	β^+,K	10.5 min.	10 min.	0.10
Cu^{61}	β^+	3.4 hrs.	3.3 hrs.	0.03
$_{28}Ni^{66}$	β^-	56 hrs.	56 hrs.	0.0006
Ni^{65}	β^-	2.6 hrs.	2.6 hrs.	0.0030
Ni^{57}	β^+	36 hrs.	34 hrs.	0.00003
$_{27}Co^{61}$	β^-	1.75 hrs.	1.83 hrs.	0.014
Co^{58}	β^+,K	72 days	long	0.006 (~85%)
Co^{55}	β^+	18.2 hrs.	~18 hrs.	0.0002
$_{26}Fe^{59}$	β^-	46.3 days	46 days	0.005
$_{25}Mn^{56}$	β^-	2.59 hrs.	2.6 hrs.	0.0026
Mn^{52}	β^+,K	5.8 days	6.2 days	0.0003(~65%)
$_{24}Cr^{51}$	K	26.5 days	25 days	0.002(100%)
Cr^{49}	β^+	41.9 min.	40 min.	0.00006

It is reasonable to assume that stable nuclei are formed in the spallation process with yields not far different from those of the adjacent isotopes. On this basis we assign a yield to each isotope which we cannot observe, following the trends apparent among the observed isotopes. The resultant yield pattern can be described as follows:

(1) For each element below arsenic, the yields of the isotopes increase towards the line of nuclear stability.

(2) For each mass number the yields of isobars increase towards the line of stability.

(3) The lower the atomic number, the lower becomes the total yield of a given element.

From a consideration of the Q values of the reactions and the energy necessary for coulombic barrier penetrations, we conclude:

(1) Reactions leading to arsenic, germanium, and gallium isotopes are mostly non-capture excitation reactions, in which only a fraction of the deuterons energy is imparted to the nucleus. These comprise $>90\%$ of all the reactions

(2) Less likely processes involving preliminary capture of the deuteron lead to isotopes of lower lying elements.

(3) The formation of nuclear species lower than Fe^{57} involves the emission of one or more alpha-particles. Such reactions occur $\sim 1\%$ of the time.

This work was performed under the auspices of the United States Atomic Energy Commission.

References

(1) H. H. Hopkins, Jr. and B. B. Cunningham, Phys. Rev. 73, 1406 (1948).
(2) Analysis performed by Mr. John Conway.
(3) Taken from G. T. Seaborg and I. Perlman, Revs. Mod. Phys. 20, 585 (1948).
(4) D. A. McCown, L. L. Woodward and M. L. Pool, Phys. Rev. 74, 1311 (1948).
(5) Absolute yield of As^{72}: 0.02 barns.
(6) Observed radiation only of daughter.