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Charge plate technique in recoil study: Evidence for collection of recoil charged species from solid targets on metal electrodes

SHUDDHODAN P MISHRA* and JYOTI SINGH

Nuclear and Radiation Chemistry Laboratory, Department of Chemistry, Banaras Hindu University, Varanasi 221 005, India

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Abstract. The occurrence of charge on recoil ^{56}Mn produced by the (n,γ) reaction in polycrystalline potassium permanganate has been examined using the 'charge plate technique'. From considerations of capture gamma ray decay schemes and internal conversion it appears that, in a condensed medium, the recoil atom develops charge after losing much of its initial kinetic energy which allows collection on charged electrodes.

Keywords. Recoil ^{56}Mn; $KMnO_4$; charge plate technique.

1. Introduction

Continuing problems in the field of chemical effects of nuclear transformation have centred around the kinetic energy and charge of recoil atoms in determining their ultimate chemical fate. As a result of nuclear activation an atom acquires recoil energy and a portion of this energy becomes associated with the chemical bond or bonds joining the activated atom to the molecule which leads to the rupture of one or more of these bonds (IAEA 1961, 1965; Harbottle 1965; Maddock and Wolfgang 1968; Harbottle and Maddock 1979).

In order to study the charge nature of the initial recoil species following (n,γ) reaction, Wexler and Davies (1952) worked with gaseous ethyl halides at low pressures in a vessel fitted with electrically charged collector plates. Yosim and Davies (1952) made a similar study on recoil atoms from the (n,γ) reaction escaping from thin metallic films. The use of Ag/AgX charged plates in the collection of radiohalogen charged species (anionic & cationic) from (n,γ) activated liquid alkyl halide systems has been well demonstrated and the results explained (Arnikar and Lal 1960; Lal 1967, 1970; Pandey 1978; Singh 1981; Mishra and Singh 1981; Zaman 1990).

The present work is an attempt to apply the 'charge plate technique' and demonstrate the collection of recoil species on metal electrodes when a polycrystalline solid target ($KMnO_4$) is subjected to thermal neutron activation.

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* For correspondence

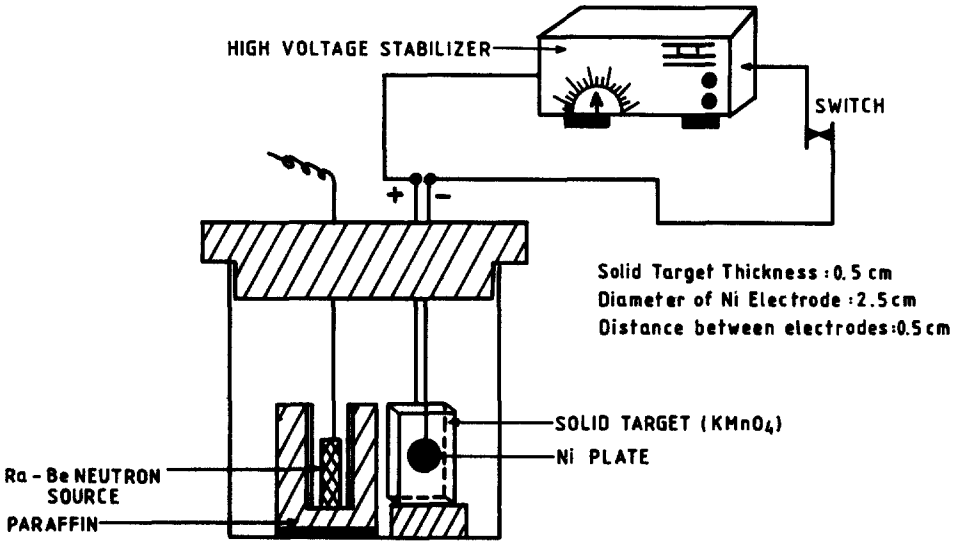

Figure 1. Arrangement for neutron activation and collection of (n, γ) recoil species ($^{56}Mn^*$) of $KMnO_4$ on nickel plates.

2. Experimental

A thin layer (thickness: 0·5 cm) of $KMnO_4$, was packed in filter paper and irradiated with the help of a 300 mCi (Ra–Be) neutron source having an integral flux of $3{\cdot}2 \times 10^6\,n\,cm^{-2}\,s^{-1}$ for up to 24 h. Two nickel electrodes of 2·5 cm diameter were placed parallel to each other in contact with the filter paper jacket. The distance between two electrodes was 0·5 cm. An electric field of 1000 or 1500 volts (DC) from a stabilized power supply was applied across the electrodes during the end period of irradiation (figure 1). The radioactivities collected on the nickel electrodes were quickly counted with the help of an end-window G.M. counter under conditions of constant geometry and necessary corrections applied.

3. Results and discussion

The data in table 1 indicate the yield ratio of recoil atoms collected that are charged with the variation of applied voltage and period of collection. The counting assembly had a constant reproducible low background ($\approx$ 10c/min) and no activities were collected on the electrodes in the absence of an electric field. Activities collected on Ni electrodes, though of low order, were reproducible for the $KMnO_4$ target and could be well relied upon. The collection is apparently independent of time of collection and field applied and a slightly greater fraction of negatively charged species than positively charged ones get collected (*cf* table 1). Building-up of positive charge on a large fraction of the recoil atoms due to the internal conversion process is to be expected. Charge build-up takes place long after the recoiling atom has been brought to thermal energy by collision, and has had some opportunity to reach a chemically stable state.

The origin of charge on recoil atoms has been discussed in some early papers

Table 1. Recoil charged ^{56}Mn species collected on Ni-electrodes.
Target: $KMnO_4$; Neutron Source: Ra–Be $-3{\cdot}2 \times 10^6\, n\,cm^{-2}\,s^{-1}$; Background: 10 c/min (Averaged on c/10 min)

Field applied across electrodes (DC/V)	Period of collection (h)	Number of determinations	Plate activity (average)								Fractional yield on anode (anode/total activity collected on electrodes)
			Anode				Cathode				
			Total		Net		Total		Net		
			c/10 m	(c/min)	c/10 m	(c/min)	c/10 m	(c/min)	c/10 m	(c/min)	
1000	3·0	6	200	20	100	10	170	17	70	7	0·59
1000	6·0	3	230	23	130	13	190	19	90	9	0·59
1000	20·0	3	210	21	110	11	180	18	80	8	0·58
1500	6·0	3	200	20	100	10	170	17	70	7	0·59
1500	24·0	3	210	21	110	11	170	17	70	7	0·61

(Yosim and Davies 1952; Wexler 1962; Thompson and Miller 1963) and the idea used in subsequent works. The neutron capture gamma ray spectrum of ^{56}Mn is fairly well known (Bartholomew *et al* 1967). In more than 27% of all cases the initial de-excitation step is the emission of hard gammas of more than 6·75 MeV, which provides the ^{56}Mn nucleus with an outward velocity of more than $3{\cdot}86 \times 10^6$ cm/s. Using the Sietz (1949) treatment for the determination of the energy loss of "hot" atoms in a lattice it would seem reasonable to assume that only ^{56}Mn recoil species originating in the upper layers (polycrystalline $KMnO_4$ surface) can emerge with enough residual energy to reach the electrodes and the rest (rather the majority) will be stopped in the $KMnO_4$ bulk. Thompson and Miller (1963) found that the fraction of charged species is independent of the nature of the source material which has been the case for Mn, Mn metal films or $KMnO_4$. Somewhat similar findings on the lack of physical parameters on the fraction of charged ^{56}Mn recoils collecting on electrodes is visualized in the present work also, as time of collection or field do not seem to affect the fractional yield ($\approx 0{\cdot}59$) on the anode (*cf* table 1).

From these results it would appear that the ^{56}Mn particles which escape are not affected by the availability of free electrons, which can be expected only if the recoiling atoms leave the surface in a neutral state. The internal conversion process which is known to be delayed by 10^{-13} s or more will occur most probably after the recoil particle has left the surface and travelled some distance away from the surface. Thus, recoil ^{56}Mn situated on or near the surface may have some chance of escaping and travelling towards Ni-electrodes on a flight requiring time of the order of microseconds.

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