Military Technical College
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EPC-3

Comparison between Different Techniques in Purification of ^{18}O Enriched Water after Cyclotron Irradiation

M. S. Masoud [(a)], *A. S. El-Kholany [(b)], M. F. El- Shahat [(c)]

Abstract

In the synthesis of ^{18}F-FDG by nucleophilic substitution method, ^{18}O-H_2O is usually used as target water. The high cost of virgin ^{18}O-H_2O enriched water pointed to recycle process after the first irradiation for the production of radiopharmaceuticals. The irradiated ^{18}O-H_2O was contaminated by both organic substances (ethanol, acetonitrile, etc.) and inorganic ions ($Cd^{2+,}$ Na^+, K^+, Cl^-, etc). In our study different techniques (ozonolysis, UV, distillation and resin) were used to minimize the concentration of both organic substances and inorganic ions and evaluate the effectiveness of resin as method for the purification. The concentration of the TOC was decreased from 705 (mg/L) for the irradiated^{18}O water to 12.36 (mg/L) and 4.8 (mg/L) by using UV and ozonolysis respectively. While the concentration of metal ions decreased and the conductivity decreased from 487 µ Si/cm for the irradiated ^{18}O water to 51.9 µ Si/cm when regenerated resin was used and to 20.8 µ Si/cm by distillation.

a) Chemistry Department, Faculty of Science, Alexandria University, Alexandria, Egypt.
b) Medical Laboratory Technology Department, Faculty of Allied Medical Sciences, Pharos University, Alexandria, Egypt
c) Chemistry Department, Faculty of Science, Ain Shams University, Cairo, Egypt

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1. Introduction

It is known that, [^{18}O]-H_2O has become the most important target material for the production of [^{18}F] fluoride by bombardment with accelerated protons [1, 2].
The reactions between [^{18}F]-fluoride and different substrates permit the synthesis of many PET radiopharmaceuticals and, in particular, of [^{18}F]-FDG (2-deoxy-2-[^{18}F]-fluoro-D-glucose), a most important radiotracer for oncological applications. The high cost of virgin enriched water has stimulated research into methods to re-use it [3-7]. Numerous studies have suggested that ionic contaminants originating from the [^{18}O] water target affect the [^{18}F] fluoride chemistry, resulting in low and variable radiofluorination yields [8-10]. Metal ions in target water may reduce the availability of reactive fluoride by forming inactive metal-fluoride complexes. Inorganic and organic anions may compete with fluoride in the displacement reaction. In addition, organic impurities may cause target pressure and damage the target, and form radiolysis products that lower the fluorination yield **.** Solvents such as acetonitrile, acetone or ethanol, can be introduced during synthesis and some remain in the enriched water after recovery.
For all these reasons, despite the technical advances achieved during these years, irradiated water must be repurified after the first production run in order to obtain a comparable yield in the following preparation. The most common purification method consists of simple distillation with the possible addition of strong oxidizing agents such as $KMnO_4$, but these reagents have to be removed from the water during the treatment. At the moment this method has been replaced by distillation followed by photochemical degradation using UV radiation, electrolysis or ozonolysis [11]. It is now clear that distillation alone cannot eliminate all organic impurities and microorganisms neither can it remove solvents that form azeotropic mixtures with water. However, the reports on [^{18}F]-FDG production yields after different treatments are conflicting.

2. Aim of the work

The purpose of this study was to compare between different techniques (ozonolysis, UV, distillation and resin) that used to minimize the concentration of both organic substances and inorganic ions and evaluate the effectiveness of resin as method for the repurification of ([^{18}O] H_2O) after first irradiation.

3. Experimental:

After nearly 220 run of ^{18}F synthesis by CTI 18 mev cyclotron 250 ml of ^{18}O- water was collected after first irradiation. The collected ^{18}O- water was treated to eliminate the organic and the inorganic impurities by ozonolysis, UV, distillation and resin.

Conductivity, pH, organic and the inorganic impurities were determined for the collected and treated ^{18}O-H_2O.

3.1 Removal of organic impurities by ozonolysis and UV

Ozonlysis was carried out by passing O_3 which was generated by (Metra Ozonator Air Burifier Model 2186, O_3 output 400 mg/h) through the treated water for 30 min.
The UV irradiation consists of a metal cylinder, the inside of which is given a mirror finish and a UV Lampe in the center of the cylinder. The treated water was subjected to UV for 12 hour.

3.2 Removal of inorganic impurities: by distillation or by passing the treated water through resin column which consists of a mixture of AG11®A8 and AG 50 resins

3.3 Chemical Analyses:

Inorganic impurities were determined by ICP-MS (Aglint 7900-ICP-MS) and IC (VWD-DIONEX-ICS-300); while the organic impurities were determined by TOC technique at The Main Laboratory of the Chemical War.
Determination of the residual solvents (MeCN and EtOH) is done by GC (VARIAN 3900) at the International Medical Center.

3.4 Determination of radionuclides:

Radionuclides were determined by multi-channel analyzer (MCA- ORTEC DSPEC IR 2.9) at The Main Laboratory of the Chemical War.

4. Results and discussion:

4.1 Treatment of inorganic ions:

Two different techniques (distillation and resin) were used to decrease the concentration of the anions and the cations from the irradiated water. A comparison was made between the results of these techniques and shown in Table (1)
AG11 A8 and AG50W resin column were used to decrease the concentration of inorganic impurities from the irradiated water, Table (1)

AG 11 A8 ion retardation resin is extremely useful for chromatographic desalting, or removing acid from non-ionic molecules. It separates salts from organic materials by absorbing both anions and cations in equivalent amounts while allowing the organic compounds to pass through.
AG 11 A8 resin is made by polymerizing acrylic bead containing paired anion and cation exchange sites. The result is a styrene divinylbenzene crosslinked, rigid polymer lattice with attached quaternary ammonium groups (strongly basic anion exchange groups)

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within which weaves a trapped, linear, relatively flexible acrylicpolymer having carboxyl groups (weakly acidic cation exchange groups). Each resin bead is a molecular mixture of a cation and an ion exchanger. When the resin is free of absorbed salts, the self-absorbed form, each group is the counterion of the other form. Figure (1) shows the self-absorbed form of the resin.
AG 50W is a strong acid cation exchange resins are useful for single step purification methods, for concentrating cationic solutes, and for analytical determinations of various mixed cationic solutes.
The concentration of metal ions decreased except for Na its concentration increased from 57.5 mg/L in the irradiated water to 167.81 mg/L after the purification process and the conductivity decreased from 487 to 370 µ Si/cm.
Resin regeneration [BIO-RD catalog number 732-2032] was made by washing AG11®A8 resin several times with 1 N HCl to decrease the Na concentration to 4.04 mg/L and the conductivity reached to 51.9 µ Si/cm.

Distillation: the concentration of the metal ions in the irradiated water decreased after distillation, the conductivity decreased to 20.8 µ Si/cm and the concentration of the organic compounds decreased from 705 mg/L to 49.89 mg/L.

4.2 Determination of radionuclides:

Radionuclides in waste and treated ^{18}O- water were determined by gamma detector multi-channel analyzer, Figures (2-4), Table (2). The possible nuclear reactions that create the detected radioactive impurities were given in Table (2) [12]
Figures (2-4) show a typical γ-ray spectrum obtained with the MCA, labeled with the identified isotopic beaks.
The concentration of the radionuclides was decreased by distillation and resins as shown in Table (2).
The previous study, Tables (1, 2), assigned that AG 11 A8- AG 50W column risen more efficient than distillation.

4.3 Treatment of organic residues:

Two different techniques were compared to eliminate the organic residues from the irradiated water ozonolysis and UV irradiation, Table (4).
The concentration of the residual solvents was determined by GC, Figures (5). From table (4) it is concluded that ozonolysis is more effective and take much less time. So, the data concluded that AG 11 A8- AG 50W column risen more is efficient than distillation, and the concentration of the total organic carbon (TOC) in distillation is much smaller than in

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case of AG 11 A8- AG 50W column risen, So ozonolysis and distillation gave the best results in minimizing both organic substances and inorganic ions, respectively.

5. Conclusion:

From the previous study it is concluded that Ozonolysis and distillation gave the best results in minimizing both organic substances and inorganic ions respectively.

6. Refereneces

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Table 1: The results of the complete analysis of A, virgin water, B, water after the bombardment, C, water after passing through the resin column and D water after distillation. (Concentration after resin regeneration)

	A(mg/L)	B (mg/L)	C(mg/L)	D(mg/L)
Ca	<0.05	4.07	1.05	1.05
Na	<0.05	57.5	167.81-4.04*	1.92
Mg	<0.05	0.46	0.2	0.38
K	<0.05	194.7	0.34	0.74
pH	7.0	10.3	10.5	6.5
TOC	7.5	705	255	49.89
Conductivity	1 µ Si/cm	487 µ Si/cm	370 µ Si/cm	20.8

Table 2: The radionuclides analysis of A, waste ^{18}O- water, B distillated ^{18}O- water, C, water after passing through the resin column.

	A(Bq/l)	B(Bq/l)	C(Bq/l)
^{109}Cd	168569.3	58.84	39.94
^{57}Co	127.63	6.36	0.74
^{56}Co	27.793	6.07	-
^{54}Mn	167.393	-	-

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Table 3: Possible nuclear reactions create radioactive impurities.

Radionuclide	Nuclear reaction
^{109}Cd	^{109}Ag (p, n γ) ^{109}Cd
^{57}Co	^{57}Fe (p, n) ^{57}Co ^{58}Ni (n, p n) ^{57}Co ^{58}Ni (p.2p) ^{57}Co ^{60}Ni (p, α) ^{57}Co
^{56}Co	^{56}Fe (p, n) ^{56}Co
^{54}Mn	^{54}Cr (p, n) ^{54}Mn ^{54}Fe (n, p) ^{54}Mn ^{55}Mn (n, 2n) ^{54}Mn

Table 4: TOC, MeCN and EtOH analysis of:

A: virgin water
B: waste ^{18}O-water,
C: water after 12 houre of UV irradiation,
D: water after 1houre of ozonolysis and
E: water after both UV irradiation and ozonolysis

	A(mg/L)	B (mg/L)	C(mg/L)	D(mg/L)	E(mg/L)
MeCN	<0.05	0.21	0.014	0.006	0.003
EtOH	<0.05	0.837	0.32	0.04	0.036
TOC	7.5	705	12.63	4.8	4.5

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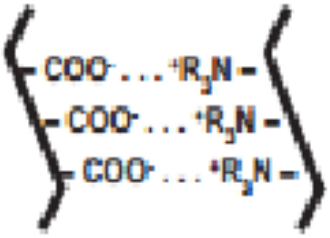

Fig (1): Structure of AG 11 A8 resin in the self-absorbed form.

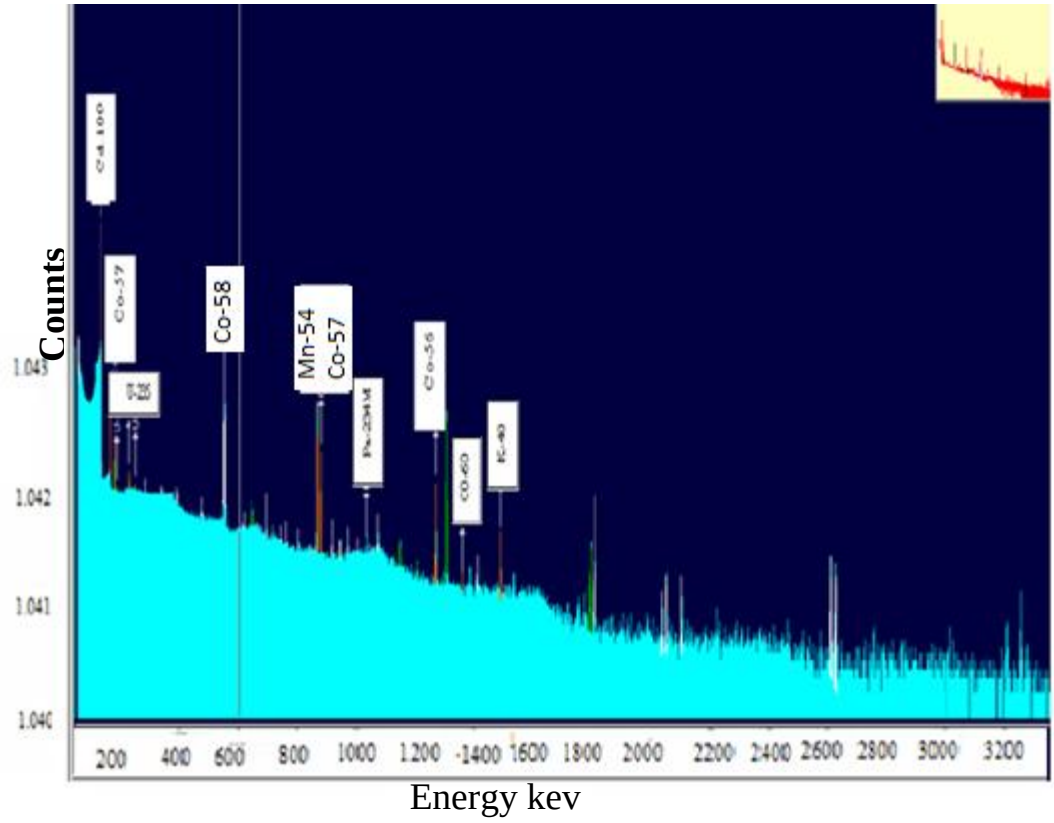

Fig (2): Recorded gamma spectrum of waste ^{18}O-water.

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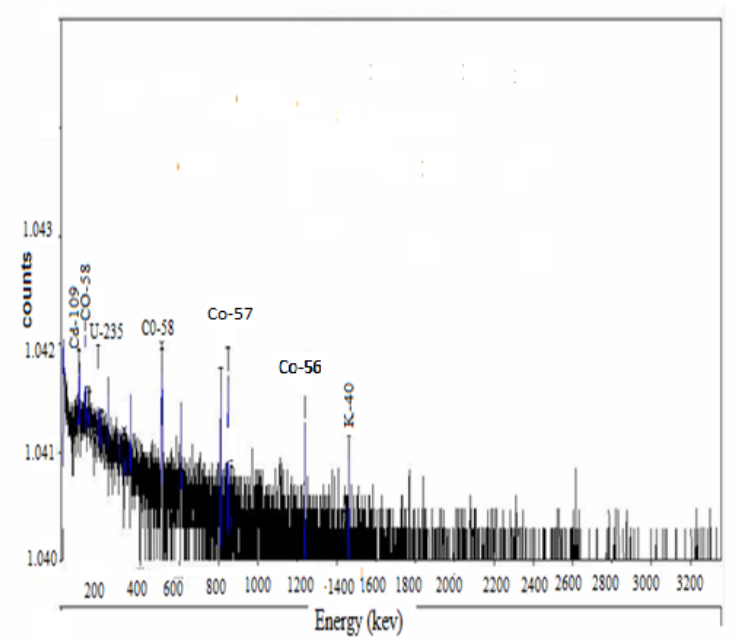

Fig (3): Recorded gamma spectrum of water after passing through the resin column.

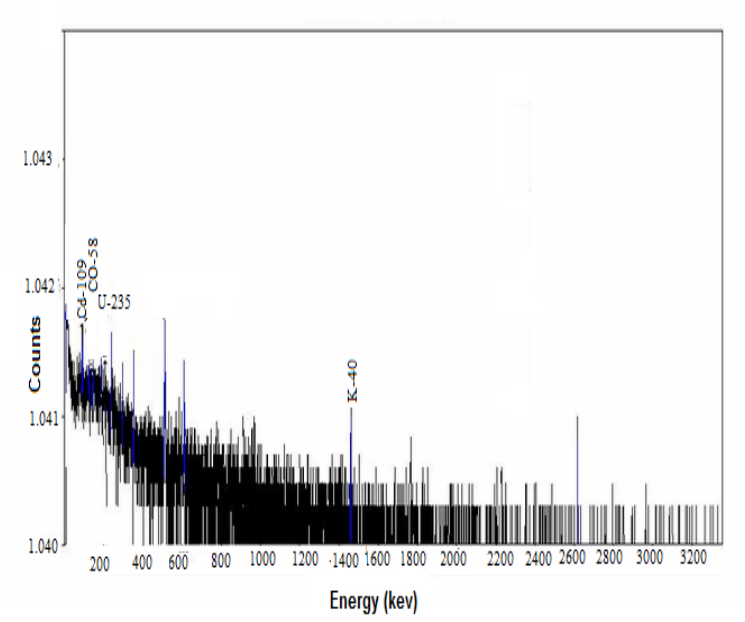

Fig (4): Recorded gamma spectrum of distillated ^{18}O-water.

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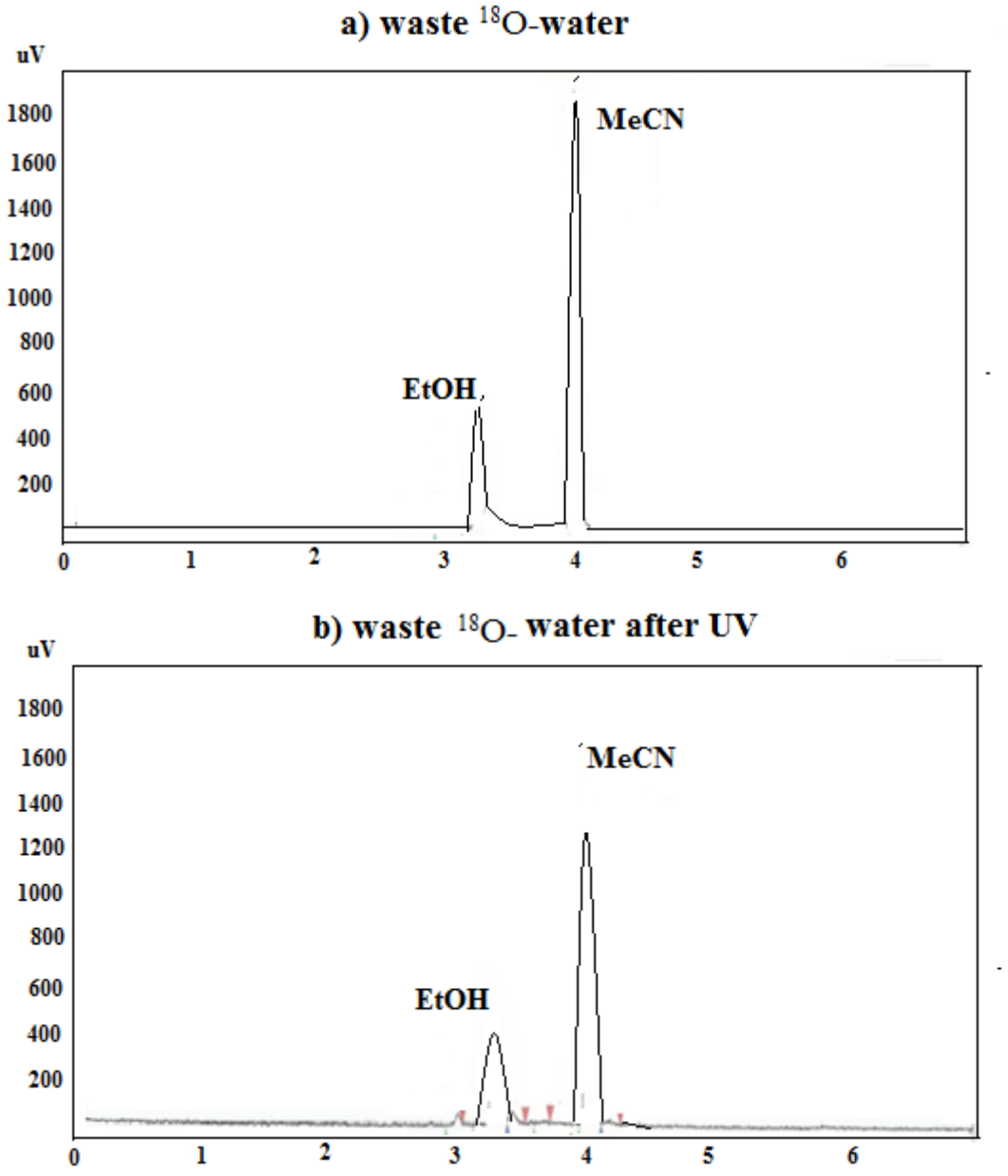

Fig (5): GC spectrum of a) west ^{18}O-water, b) water after 12 houre of UV irradiation

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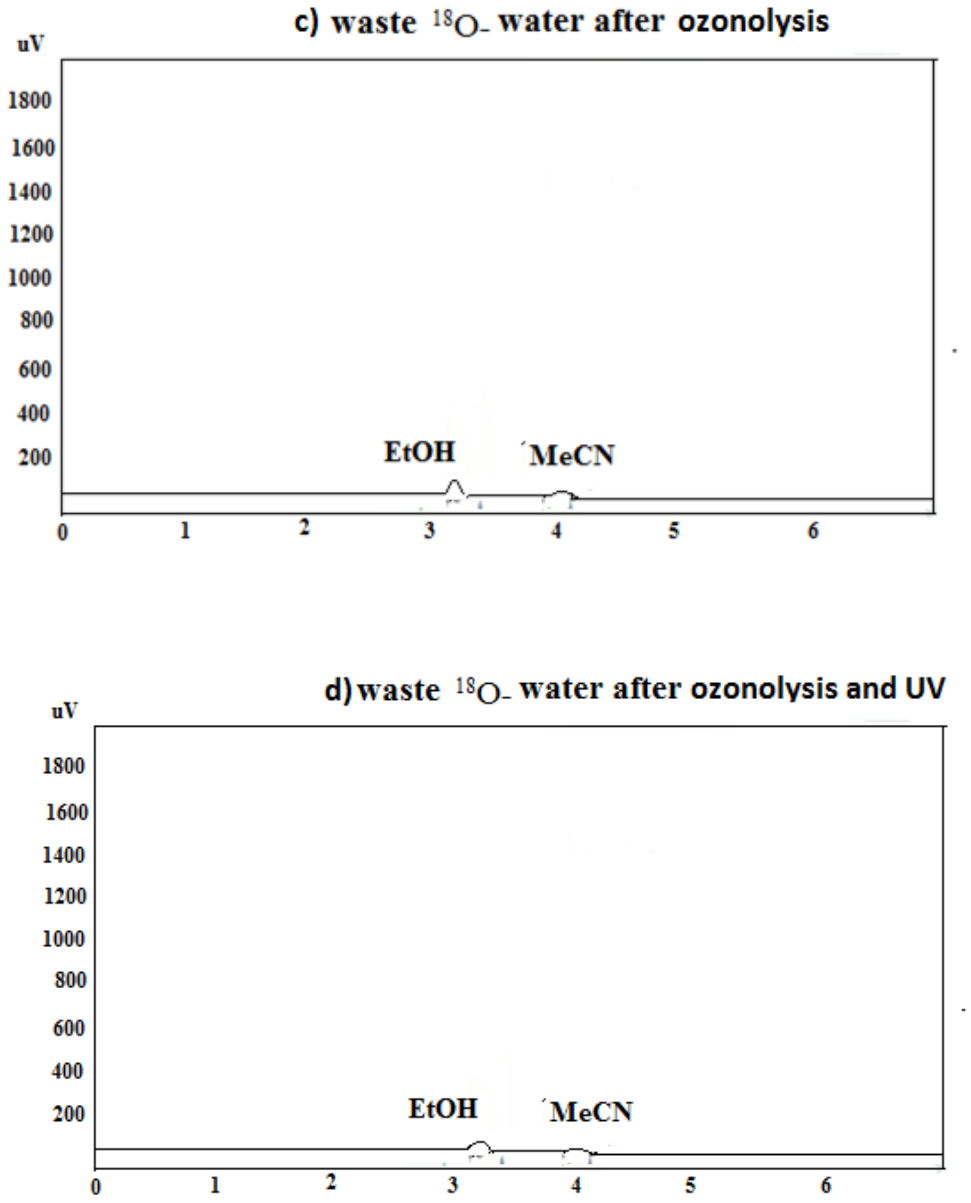

Fig. 5: GC spectrum of c) water after 1hour of ozonolysis and d) water after both UV irradiation and ozonolysis.