Physicochemical measurement of the dose deposited by accelerated ions

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Why to study accelerated ions' effects?

To see the behaviour of molecules upon irradiation

Why do we need to know?

1. hadron therapy - what is formed in the human body
2. degradation of materials (e.g. in nuclear reactors, space)
3. effects of radioactivity on environment

Aim:

To measure the dose deposited by accelerated ions

Tasks:

1. To prepare the irradiation setup
2. Irradiate the **Fricke** solution with increasing fluences
3. Determination of the energy of the protons in the solution
4. Determination of the dose deposited in the solution

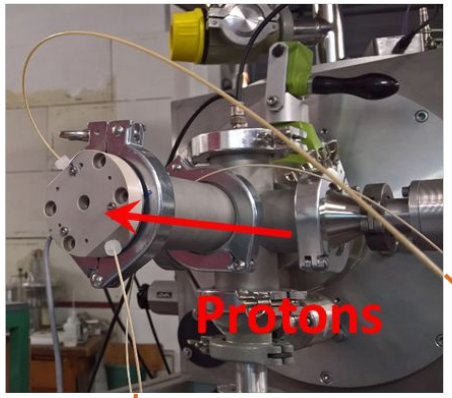
Experimental methodology

Particle accelerator: 4 MV Van de Graaff. ACACIA

Particles: H^+ Energy : 2 MeV (0.5 – 3.5 MeV)

Closed loop. solution streaming. Irradiation of the solution with increasing dose

Irradiation cell



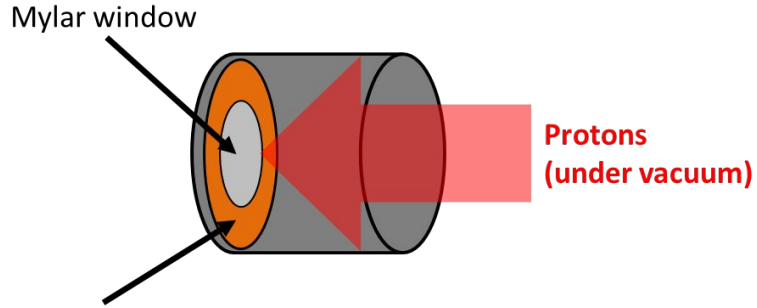
Beam line under vacuum
12 µm aluminized mylar window

Sample

Peristaltic pump

Determination of the fluence

Definition Fluence: Number of particles per cm²



Faraday cup
→ measure of the ions' current during the irradiation
Surface of the Faraday cup: 8.4 cm²
Surface of the mylar window: 1.74 cm²

Charge counter:
Count proportional to the electric charge in nC

Fricke dosimeter

= chemical dosimeter

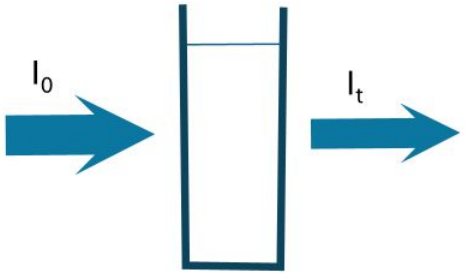
Fricke solution composition:

In ultrapure (MilliQ)Water

Mohr salt: $Fe(NH_4)_2(SO_4)_2$	10^{-3} mol/L
Sufuric acid	0.4 mol/L
Sodium chloride	10^{-3} mol/L

Principle:

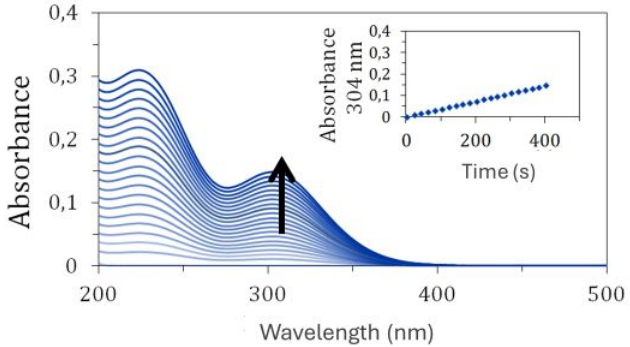
- radiolysis of water causes oxidation of Fe^{II} to Fe^{III}
- Fe^{III} complexes absorb light in the UV range
- quantity of produced Fe^{III} can be measured by UV-Vis



$$A = \log\left(\frac{I_0}{I_t}\right) = \varepsilon . l . [Fe^{3+}]$$

Beer-Lambert's law

Fe^{3+} : ε(304 nm) = 2197 $M^{-1}.cm^{-1}$

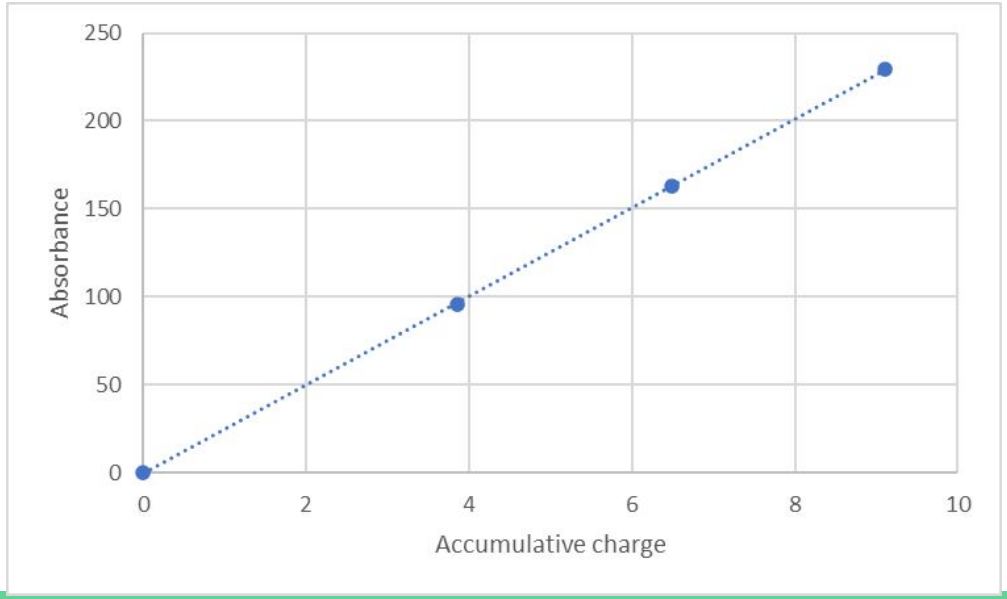


Dose measurement

- counting signal on the Faraday cup ➜ theoretical dose
- calculation from the conversion of Fricke ➜ measured

Results

	Charge (nC)	Accumulative charge (nC)	Absorbance	# of ions	Energy (eV)	Dose (Gy)	Theoretical dose (Gy)
Dose 1	2.528	3.856	0.194	7.28E-05	0.672E+19	95.81	144.01
Dose 2	2.634	6.49	0.306	0.000124	1.142E+19	62.88	242.39
Dose 3	2.623	9.113	0.417	0.000174	1.608E+19	229.35	340.35

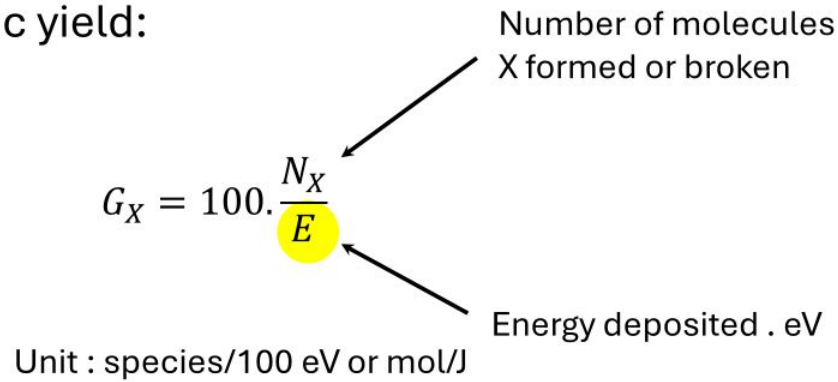


Difference of theoretical and practical dose value of up to 33%

Thank you

Determination of radiolytic yields

Definition of the radiolytic yield:



Determination of the energy deposited → Dose measurement / Dosimetry

Dose : energy deposited by the ionizing radiation per mass unit: Gray. Gy

$$G_{Fe3+} = 100.\frac{N_{Fe3+}}{E} \rightarrow \mathrm{E} = 100.\frac{N_{Fe3+}}{G_{Fe3+}}$$