Simulation

Answers

Solutions to test questions on simple mass spectrometer

a)

The kinetic energy absorbed by particles at rest in an electric field is given by

$$W_{kin} = \frac{1}{2} \cdot m \cdot v^2 = q \cdot U$$

Solving for *v* $\quad v = \sqrt{2 \cdot U_B \cdot \frac{e}{m}}$.

with $\quad U_B = 100V, \quad v = \sqrt{2 \cdot 100V \frac{1{,}6 \cdot 10^{-10} C}{6{,}65 \cdot 10^{-27} kg}} = 69368{,}8 \frac{m}{s}$

b)

In the condenser, the ions are exposed to

the homogeneous electric field

$F = q \cdot E = \frac{U_K}{d} \cdot q_e$ and

the Lorentz force

$$F_L = q \cdot v \cdot B .$$

For a straight-line path, the two forces must be equal but in opposed directions.
The top condenser plate must therefore be positive and the bottom plate negative.

By insertion of equal terms

$$q_e \cdot v \cdot B = \frac{U_K}{d} \cdot q_e \Leftrightarrow v = \frac{U_K}{B \cdot d} = \sqrt{2 \cdot U_B \cdot \frac{q_e}{m_{Ion}}} .$$

Solving the same equation $\quad U_B = \frac{U_K^2 \cdot m}{2 \cdot d^2 \cdot B^2 \cdot q_e}$.

The calculation of v_{Ion} and U_B is:

$$v = \frac{U_K}{B \cdot d} = \frac{50V}{2{,}15 \cdot 10^{-2} T \cdot 0{,}01m} = 232558{,}14 \frac{m}{s} .$$

$$U_B = \frac{U_K^2 \cdot m}{2 \cdot d^2 \cdot B^2 \cdot q_e} = \frac{50^2 V^2 \cdot 6{,}65 \cdot 10^{-27} Kg}{2 \cdot 0{,}01^2 m^2 \left(2{,}15 \cdot 10^{-2} T\right)^2 1{,}6 \cdot 10^{-19} C} = 1123{,}9V.$$

c)

Following the velocity filter, the ions are exposed to the Lorentz force as a result of the magnetic field: this forces the ions onto a cycloidal path. The centripetal force is therefore equal to the Lorentz force.

$$F_Z = \frac{m \cdot v^2}{r} = n \cdot q_e \cdot v \cdot B \Leftrightarrow m = \frac{Z \cdot e \cdot B \cdot r}{v} \quad \text{und mit} \quad v = \frac{U_K}{B \cdot d}$$

$$m = \frac{n \cdot q_e \cdot B^2 \cdot d}{U_K} \cdot r$$

(n is the number of elementary charges of the ion)

Inserting the data

$$m = \frac{n \cdot q_e \cdot B^2 \cdot d}{U_K} \cdot r = \frac{1{,}6 \cdot 10^{-19} C \cdot \left(2{,}15 \cdot 10^{-2} T\right)^2 \cdot 0{,}01 m}{50 V} \cdot 0{,}083 m = 1{,}22 \cdot 10^{-27} \text{ kg.}$$

d)

For the De Broglie wavelength

$$\lambda = \frac{h}{m \cdot v} \quad .$$

- with $v = \frac{U_K}{B \cdot d}$ the result is $\lambda = \frac{h \cdot B \cdot d}{m \cdot U_K}$.

- The following therefore applies to the first minimum

$$\sin \alpha = \frac{\lambda}{b} = \frac{h \cdot B \cdot d}{m \cdot U_K \cdot b} = \frac{6{,}625 \cdot 10^{-34} Js \cdot 0{,}0215 T \cdot 0{,}01 m}{6{,}65 \cdot 10^{-27} kg \cdot 50 V \cdot 0{,}001 m} = 4{,}28 \cdot 10^{-10} \quad .$$

- The result is $\alpha = 2{,}45 \cdot 10^{-8}$ °, there is therefore no inaccuracy caused by diffraction.

