# Simulation

Exercises

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## Test your knowledge by answering the following questions on a simple mass spectrometer

The mass spectrometer is shown in the sketch which is attached. Assume that all the ions have a single positive charge.

a) The formula $v = \sqrt{2 \cdot U_B \cdot \frac{q_e}{m}}$

applies to charged particles accelerated from rest in an electric field.

- Derive the formula.

- Calculate $v$ for a helium ion with a single positive charge

( $m = 6{,}65 \cdot 10^{-27}$ kg; $q_e = 1.6 \cdot 10^{-19}$ C; $U_B$ = 100V ).

b) The combination of magnetic and electric field in the condenser, shown in the sketch, makes up a velocity filter. At the values of $U_K$ and B mentioned above, ions with a certain speed pass through the combination in a straight line.

Explain why straight-line motion is possible in the condenser and derive the formulae

$v = \frac{U_K}{d} \cdot \frac{1}{B}$ and $U_B = \frac{U_K^2 \cdot m}{2 \cdot d^2 \cdot B^2 \cdot q_e}$ for this case.

Calculate v and $U_B$ for a helium ion.

( $m = 6{,}65 \cdot 10^{-27}$ kg ; $U_K$ = 50V ; $B = 2{,}150 \cdot 10^{-2}$ T; $d$ = 0,01m ).

c) A film placed in the position shown in the sketch is used to register the ions
In the case of a filter with fixed settings ( $U_K$ = 50 V; $B = 2{,}150 \cdot 10^{-2}$ T ), $U_B$ must be set to different values for different ions so that they can pass through the filter.
Ions which have passed through the filter are then separated by the magnetic field and recorded on the film.

Explain why the ions move on cycloidal paths after passing through the filter

and

- derive the formula $m = \frac{B^2 \cdot d \cdot q_e}{U_K} \cdot r$ .
- calculate $m$ for an ion species with $r$ = 8,3 cm

d) In order to make the measurement as accurate as possible, an ion beam that is as fine as possible is separated from the main beam using a slit with width b (see sketch). If the slit is too narrow, the measurement may be affected by diffraction effects.
The inaccuracy can be assessed on the basis of the angle to the first minimum, which is given by

$$\sin \alpha = \frac{\lambda}{b} .$$

- Show that the De Broglie wavelength of the ions is expressed by

$$\lambda = \frac{h \cdot d \cdot B}{m \cdot U_K}$$ and

- calculate the angle α to the first minimum for

$m$ = $6{,}65 \cdot 10^{-27}$ kg; $d$ = 0,01m; $U_K$ = 50V; $B$ = 0,0215T ; $b$ = 0,001m

- Assess whether the measurement is inaccurate as a result of diffraction.

**Sketch of mass spectrometer**
**The area surrounded by the dotted line is in a vacuum**