SEEING WITH He ATOMS

2 He 4.0026

Creating an Image

How do we make sure the helium atom beam will produce an image with enough detail for us to do cutting edge research on our samples?

Overview: **Beam Energy** | Stage 1: **Beam Source** | Stage 2: **Creating the Beam** | Stage 3: **Contrast** | Stage 4: **Creating an Image**

GCSE Physics	Lorentz Force[1]	$F = IlB$	Newton's Second Law	$F = ma$	Ionisation	$^{4}_{2}\mathrm{He} + \mathrm{e}^- \rightarrow {}^{4}_{2}\mathrm{He}^+ + 2\mathrm{e}^-$	
A Level Physics	Lorentz Force[1]	$F = qvB$	Newton's Second Law	$F = ma$	Circular Motion	$a = \frac{mv^2}{r}$	

Introduction & context

How is it possible to measure how many helium atoms are scattered from a surface, given that they are neutral and unreactive? The pressure of helium that is being measured is typically about more than 10^{15} times lower than atmospheric pressure, so a standard mechanical pressure gauge will not be sensitive enough and a much more sensitive gauge is needed.

Ionisation

Detectors in ***electron*** microscopes are able to measure the number of particles because the ***electrons*** have a charge and therefore interact with electric and magnetic fields. To use similar techniques in a helium microscope, we need to ionise the neutral helium atoms. When the particle is charged we can measure the number of ions per second (ion current).

Related Questions

Ionisation Energy

The helium atoms are ionised with a beam of high energy electrons that is directed into the gas (electron ionisation). When high energy electrons collide with a helium atom, one of the electrons in the helium's outer shell is removed, forming a helium ion.

$$^{4}_{2}\mathrm{He} + \mathrm{e}^- \rightarrow {}^{4}_{2}\mathrm{He}^+ + 2\mathrm{e}^-$$

Mass filtering

The vacuum chamber does also include some other contaminant gases (e.g. hydrogen) and unfortunately, the electrons also ionize these gases creating other positively charged ions. We want to count the current of positive helium ions only and therefore need to separate these from the large number of other positive ions.

[1] The Lorentz force is the force on a moving charge, or current carrying wire, in a magnetic field.

A magnetic field can be used to select ions with a specific mass-to-charge ratio (as in a mass spectrometer) because a moving charged particle in a magnetic field experiences a force, the Lorentz force. The size of the Lorentz force, F, is given by

$$F = qvB$$

where q is the charge of the ion, v is the velocity of the ion and B is the magnetic field strength in the region.

The direction of the Lorentz force is always perpendicular to the velocity of the ion, which means that the Lorentz force acts as a centripetal force and causes the ion to move in a circle. The radius of this circle will depend on the mass of the ion and its charge. Using Newton's Second Law, we can calculate the radius of the circle

$$F = ma$$

$$qvB = m\frac{v^2}{r}$$

$$r = \frac{m}{q}\frac{v}{B}$$

where, m is the mass of the ion and r is the radius of the circle.

From this relationship, we can see that if the ion has a larger mass-to-charge ratio then the radius of the circle will be larger. Therefore, provided that the positive ions all reach the magnetic field with the same velocity, then they will be separated depending on their mass-to-charge ratio.

For example, hydrogen gas becomes H_2^+ which has a mass of $2m_u$ and a charge of $1e$. The helium ions however have a mass of $4m_u$ and $1e$. The radius of the helium arc is therefore twice as large as for the hydrogen arc. Some ions are multiply ionised, although not usually helium.

Related Concepts

Magnetic Fields
Lorentz Force
GCSE Book Section 18: Moving in a Circle
Circular Motion

Related Questions

Starting with the Basics
A Mass Spectrometer

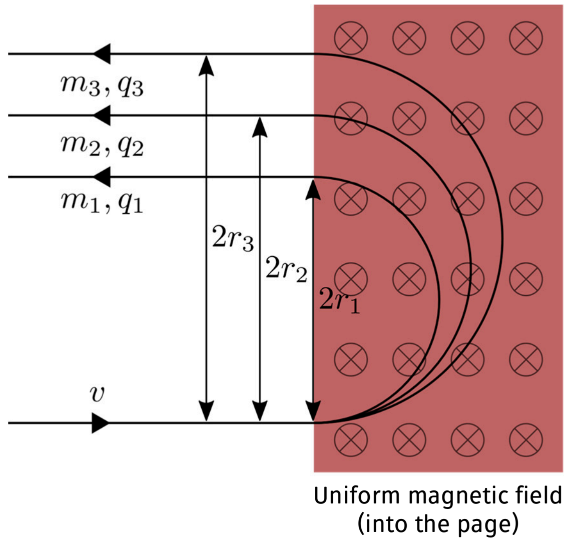

Diagram showing the deflection of ions in a uniform magnetic field that is perpendicular to the direction of motion of the ion. The ion experiences a centripetal force due to the magnetic field and undergoes circular motion with a radius determined by the mass to charge ratio of the ion.

So, in the helium microscope the mixed ion beam is fed into a uniform magnetic field, with the velocity perpendicular to the magnetic field direction. The ions then exit the magnetic field travelling in the opposite direction. All ions entered the magnetic field at the same point but now the exit position of the different ions is separated according to their mass-to-charge ratio.

By placing a small hole at the output from the magnetic field, it is then possible to select one specific mass to charge ratio, which for He^+ is a ratio of $m/q = 4$ (where m is in units of $m_u = 1.66 \times 10^{-27}$kg and q is in units of electron charge, $e = 1.60 \times 10^{-19}$ C).

Creating the image?

Using a mass spectrometer to separate out the helium ions enables us to count the number of atoms per second that have been scattered by our sample. The count is then passed to the control computer which generates an image where the brightness of a pixel in the image is based on the number count – the more counts the brighter the pixel.

Related Questions

Deflecting Ions
Deflection of a Charged Particle
Electron in a Magnetic Field
A Charge in a Magnetic Field