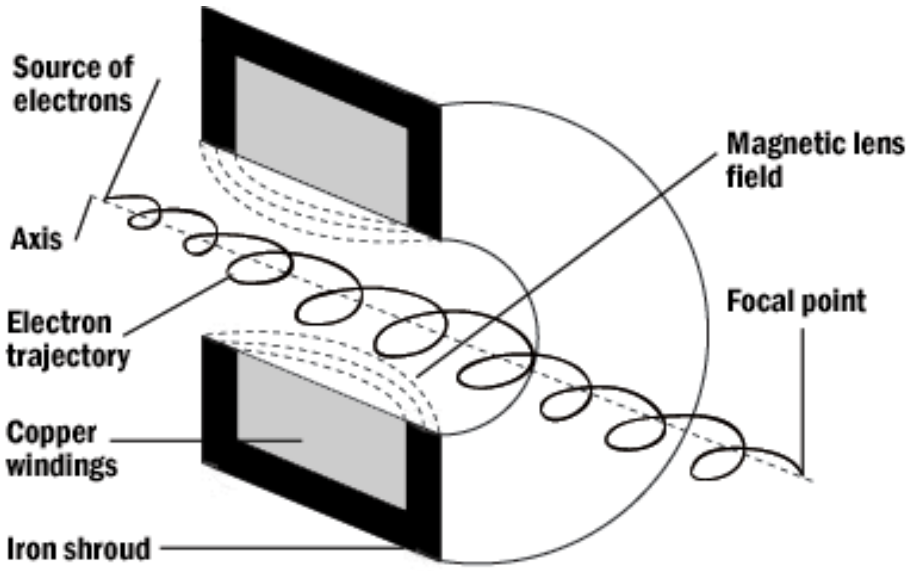
Class test 1: Sample questions

8 questions

Electron optics



The image shows the trajectory of an electron passing through an electromagnetic lens. Which statement is correct?

a) The field increases the energy of the electron.
b) The field increases the velocity of the electron.
c) The field increases the momentum of the electron.
d) The field does not change the electron energy.
e) The field decelerates the electron.

Lorenz force

Electron vs ion optics

Consider an objective lens in a scanning electron microscope, and one in a focused ion beam microscope. Which statement is true?

a) Magnetic lenses are typically used in ion beam microscopes because the Lorentz force experienced by an ion passing through the lens is greater than that experienced by an electron passing through the lens. → not used → moves slower so wrong

b) Electric lenses are typically used to focus electron beams because electric fields do not modify the velocity of electrons. → they do modify the velocity

c) Magnetic lenses are typically used to focus ion beams because magnetic fields accelerate ions.

d) Magnetic lenses are typically used to focus electron beams because magnetic fields do not accelerate electrons.

doesn't want to change the energy
- cause energy spread
- more energy in sample / not controlled
- chromatic abberations

the magnetic only changes the direction

Electron beam range (R_e) and energy (E_o)

You are using an electron microscope to perform elemental x-ray analysis of a sample that contains SiO_2, Pt and Fe impurities. This equation describes the electron beam range R_e in the sample, as a function of the electron beam energy E_o. Which statement is true?

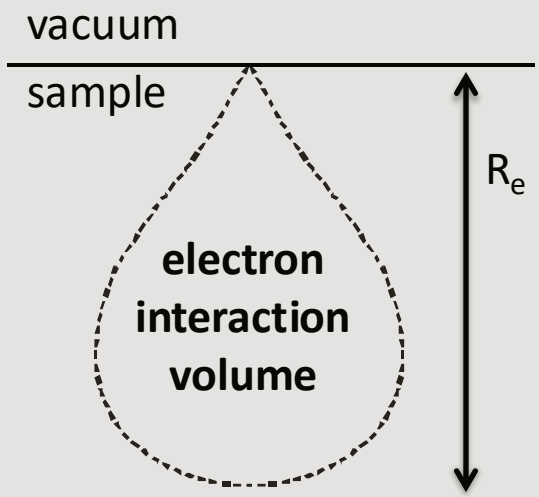
atomic weight [g/mol]

$$R_e(nm) = \frac{27.6 A E_o^{5/3}}{Z^{8/9} r}$$

energy of beam [keV]

atomic number

density g/cm³



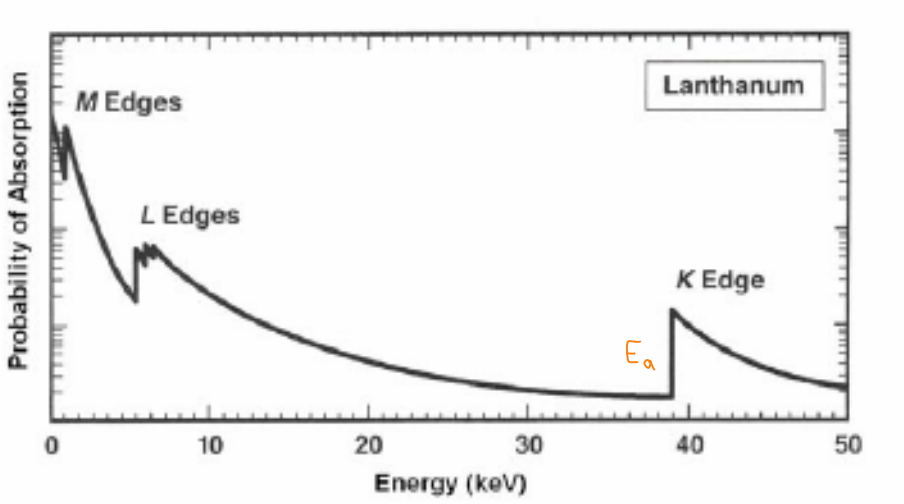
a) To detect Pt in the sample, R_e must be greater than the energy of x-rays emitted by Pt atoms. has nothing to do with x-ray

b) The quantities R_e and E_o are not relevant to x-ray analysis.

c) To detect all elements that are present in the sample, the energy E_o must be greater than the maximum energy of characteristic x-rays emitted by Si, O, Pt and Fe atoms. need enough energy to ionise the electron / conservation of energy

d) To detect Pt in the sample E_o must be smaller the energy of x-rays emitted by Pt atoms.

X-ray absorption: Sample test question



This x-ray absorption spectrum shows a number of so-called x-ray "absorption edges" for the element lanthanum. The edges are labelled K, L and M.

The K absorption edge is at energy Ea and the K x-ray has energy Ex.

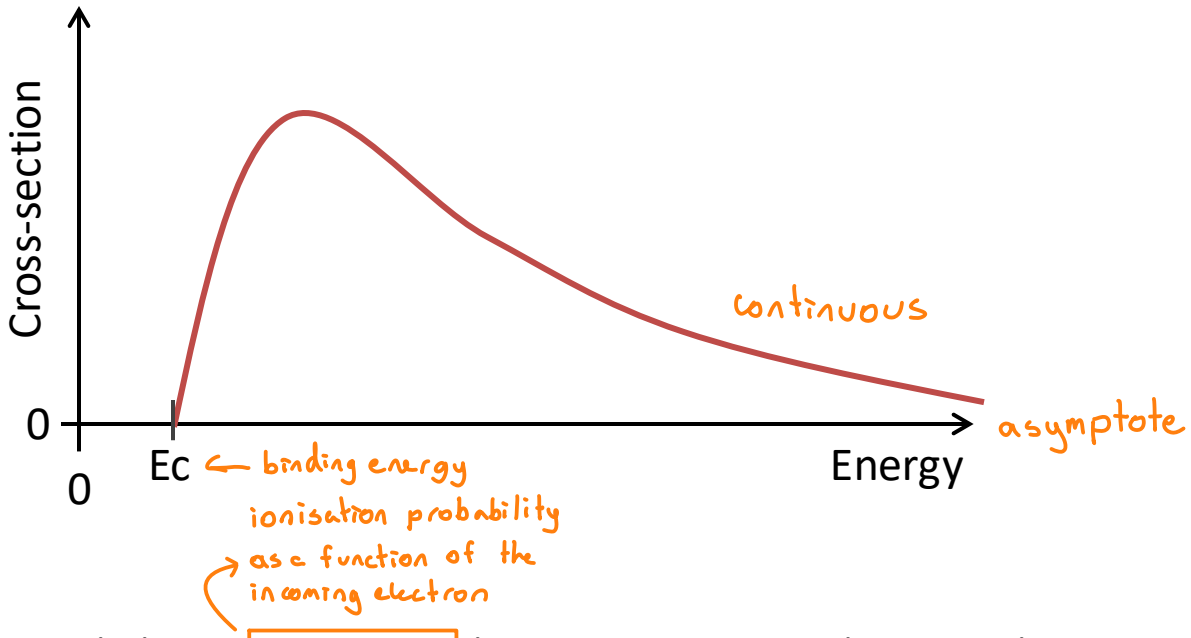
Which statement is true?

outter shell electron is knocked out instead of the outter

a) Ea is equal to the energy of Auger electrons emitted from lanthanum atoms.
b) Ea is equal to Ex.
c) Ea greater than Ex.
d) Ea is smaller than Ex.

x-ray energy must be smaller than the active energy

Cross-sections



The graph shows a cross-section that pertains to x-ray analysis in an electron microscope. Which statement is true?

a) A cross-section can not equal to zero below the energy Ec. This is physically impossible and hence this plot must be incorrect. → if its less it can have less which is not allowed, it will go to zero (bc that would mean it is between orbitals)

b) The units of a cross-section are the same as the units of probability (i.e., it is unitless). → has unit of area

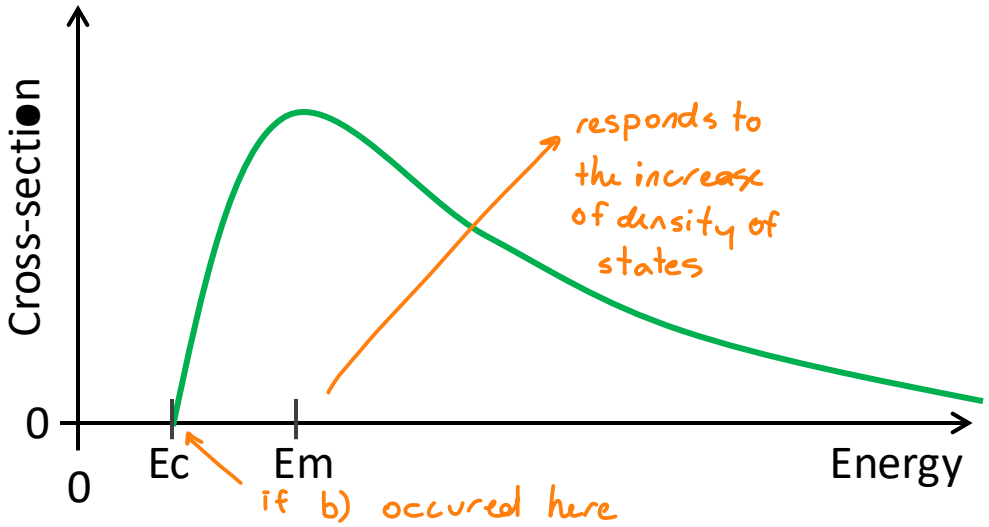
c) This is a cross-section for an electron relaxation transition that gives rise to x-ray emission.

d) This is a cross-section for ionisation of an atom by an electron. → measuring the probability of ionisation of electron

e) The quantity on the horizontal axis is the energy of the emitted x-ray.

can't make sense of this process

Scattering cross-section



The graph shows a cross-section plotted as a function of electron energy. The general shape of this curve is typical of some electron collision processes (i.e., as the energy increases from zero, the cross section is zero up to Ec, then increases up to a maximum at Em and then decreases at energies greater than Em). What is the quantity Ec?

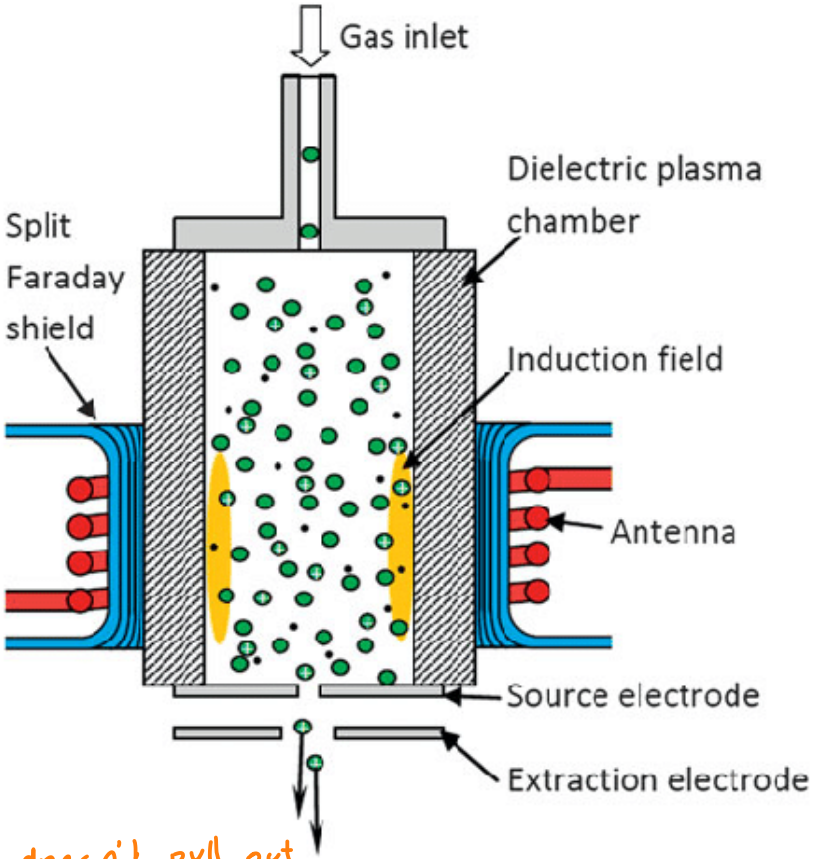
a) Binding energy of a particle involved in the collision.

~~b)~~ Kinetic energy of a particle involved in the collision. → technically not wrong

~~c)~~ Ec is not a real quantity. This plot doesn't make sense because a cross-section must be a non-zero value at all energies greater than zero.

Plasma ion source

Consider this schematic illustration of a plasma ion source. Which statement is true?



Strange?

technically true but reason is wrong
- spread of energy due to collisions (high temp)
- RF oscillating so range of energies → energy spread

doesn't pull out electrons bc it is negative / repels

a) Chromatic aberrations are high because the "extraction electrode" shown in the figure extracts both (i) positive ions and (ii) electrons from the source.

b) The energy spread of the ions is affected by the temperature of the plasma.

c) Plasma sources are used to generate Ga+ ion beams. This is done by injecting Ga vapor into the source via the "gas inlet" shown in the figure.

could be done but would block the apparatus

BP is over 2000°C but MP is room temp

Sample test question: Ion beam lens

The operator of a focused ion beam (FIB) microscope increases the magnitude of the voltage applied to a 3 electrode electrostatic Einzel lens. This causes the FIB image to become blurred. Which one of these actions can be used to re-focus the image?

more intense of the field the cross-over (focal point) is higher (shifts closer)

a) Decrease the working distance.
b) Increase the ion beam scan speed.
c) Decrease the ion beam scan speed.
d) Increase the working distance.
e) Decrease the ion beam energy.

nothing to do with this

you can decrease the WD or increase the ion beam energy so A is correct

Sample question: Ion beam column

Consider this schematic of an ion beam column. Why does the focal length (f) of a perfect, symmetric condenser lens affect the spatial resolution of the image?

refers to objective lens, not condenser lens

a) Because a perfect condenser lens is designed to control the location of the focal plane below the pole piece.

b) Because f alters the fraction of ions transmitted through the current-limiting aperture.

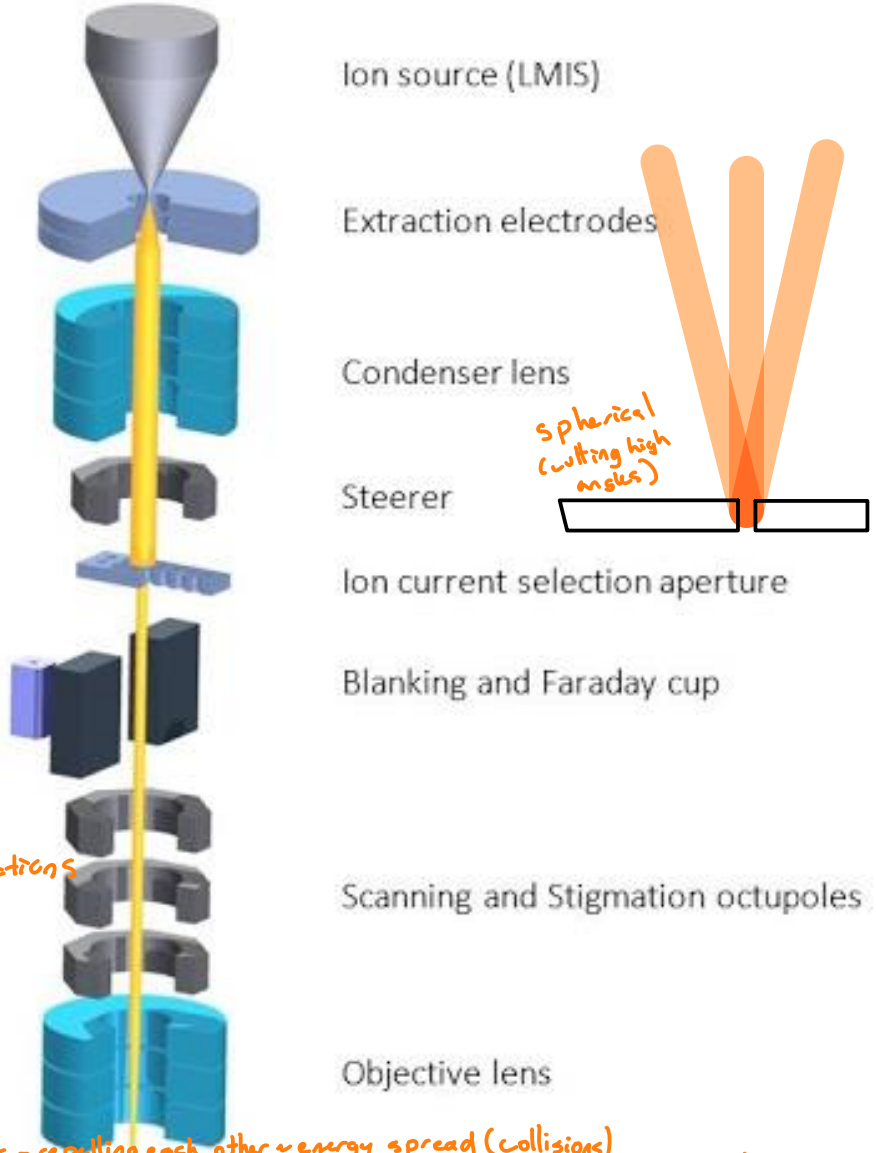
focuses the beam current
↳ current determines the spot size

c) Because a perfect condenser lens is designed to increase the energy distribution of the ions.

no, don't change

d) Because a perfect condenser lens is designed to decrease the energy distribution of the ions.

not the function of the condenser lens



it affects the abberations

↳ chromatic - repelling each other → energy spread (collisions)
↳ spherical - filters out the higher angles (angular distribution is reduced)
↳ diffraction - when apperture is too small (wavelength front)

Ion-solid interactions

Consider a piece of single crystal silicon (Si) irradiated by a focused argon (Ar+) ion beam. The ions generate crystal damage (i.e., defects) in the Si. The defect generation rate can be expressed as a "density per unit time", denoted by the symbol D, in units of [defects per nm^3 per second].

Which of the following statements is true?

→ silly answer — increase will go deeper

a) Increasing the ion beam energy (and keeping all else fixed) will reduce the ion penetration range in the Si sample.

b) Changing the ion beam species from Ar+ to Xe+ (and keeping all else fixed) will reduce D because the penetration range of Xe+ is lower than that of Ar+. penetration range is lower (Xe is lower) but D will increase

c) Changing the ion beam species from Ar+ to He+ (and keeping all else fixed) will reduce D because the penetration range of He+ is lower than that of Ar+. → this part is wrong

d) Changing the ion beam species from Ar+ to Xe+ (and keeping all else fixed) will increase D because Xe+ ions are heavier than Ar+ ions.