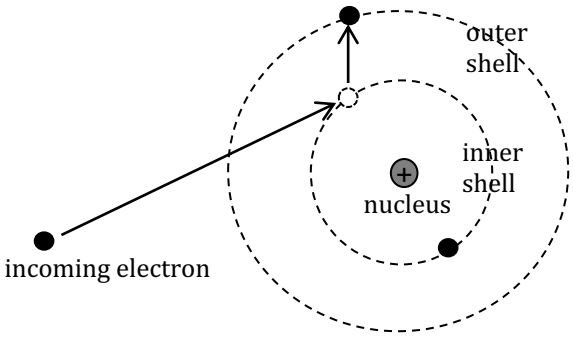
2.9 Collisions of electrons with atoms

When electrons collide with atoms, the electrons in the atoms can be excited (they move to a higher energy level) or they can be removed completely from the atom, causing it to become ionised.

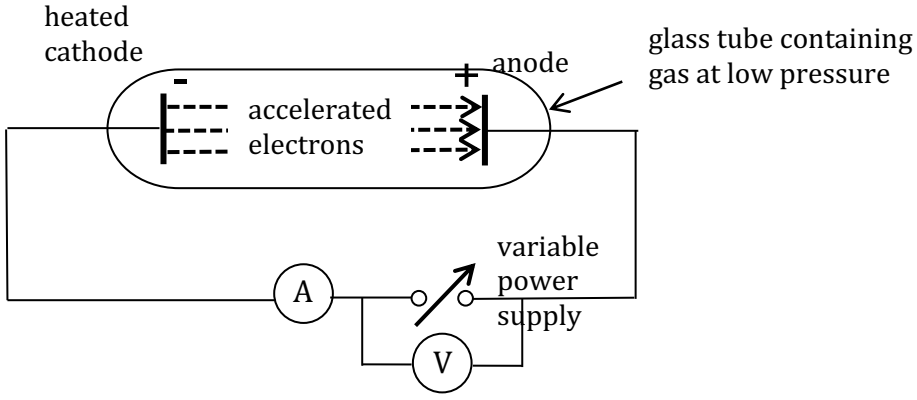
videos

Excitation



In the diagram above, the incoming electron collides with an electron in an inner shell (low energy level), giving it energy to lift it to an outer shell (higher energy level). This process is called excitation. The energy required to lift the electron from a lower energy level to a higher energy level is called the excitation energy. An exact amount of energy is required to do this.

We can measure the excitation energies of atoms in a gas using the following method:



Electrons are accelerated by applying a potential difference between a heated cathode and an anode. Electrons are attracted to the positive anode and pick up kinetic energy as they speed up. Some electrons will collide with gas atoms on the way. If they have exactly the right amount of kinetic energy to excite electrons from a lower energy level to a higher energy level, their energy will be lost and some will not arrive at the anode. This will be registered as a drop in current in the external circuit. The potential difference can be adjusted to give the electrons more or less energy.

The kinetic energy given to an electron is given as:

$$E_k = eV$$

where e is the charge on an electron (1.6 x 10^{-19}C) and V is the potential through which the electron is accelerated

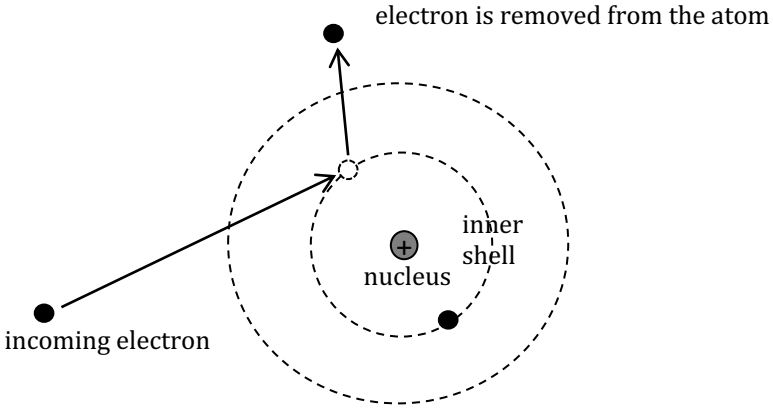
The kinetic energy lost by an accelerated electron, during collision, is transferred to the electrons in the atom. Therefore, their excitation energy is just the kinetic energy of the accelerated electrons:

$$E_{excitation} = E_k = eV$$

where V is the potential difference when there is a sudden decrease in current

(1) When mercury gas fills the tube, two dips in current are observed for potential differences of 3.06V and 3.56V. What are the excitations energies for these?

Ionisation



In this case the incoming electron collides with an electron in the inner shell, transferring enough energy to eject the electron completely from the atom. The atom loses the electron gaining a net positive charge – it has become ionised. The energy required to ionise an atom is called the ionisation energy. It can be measured with the same equipment as shown above. The potential difference is adjusted until a sudden increase in current is observed in the external circuit.

(2) Why do you think there is a sudden increase in current?

The ionisation energy can be calculated, as before, using the formula:

$$E_{ionisation} = eV$$

where V is the potential difference when there is a sudden increase in current.

The electron-volt

The electron-volt (eV) is a convenient unit of energy to use when dealing with very small energies.

As we have seen, the kinetic energy gained by an electron accelerated through a potential difference V is given by:

$$E_k = eV$$

where e is the charge on an electron (1.6×10^{-19}C)

The electron-volt is defined as the kinetic energy gained by an electron accelerated through 1 volt:

1 electron-volt = 1eV= 1.6×10^{-19}J

(3) What would the following be in electron-volts? 3×10^{-20}J, 4.2×10^{-18}J

(4) What would the following be in joules? 34.2eV, 4×10^{19}eV