MSJChem
Tutorials for IB Chemistry

Topic 12
Atomic structure HL

MSJChem

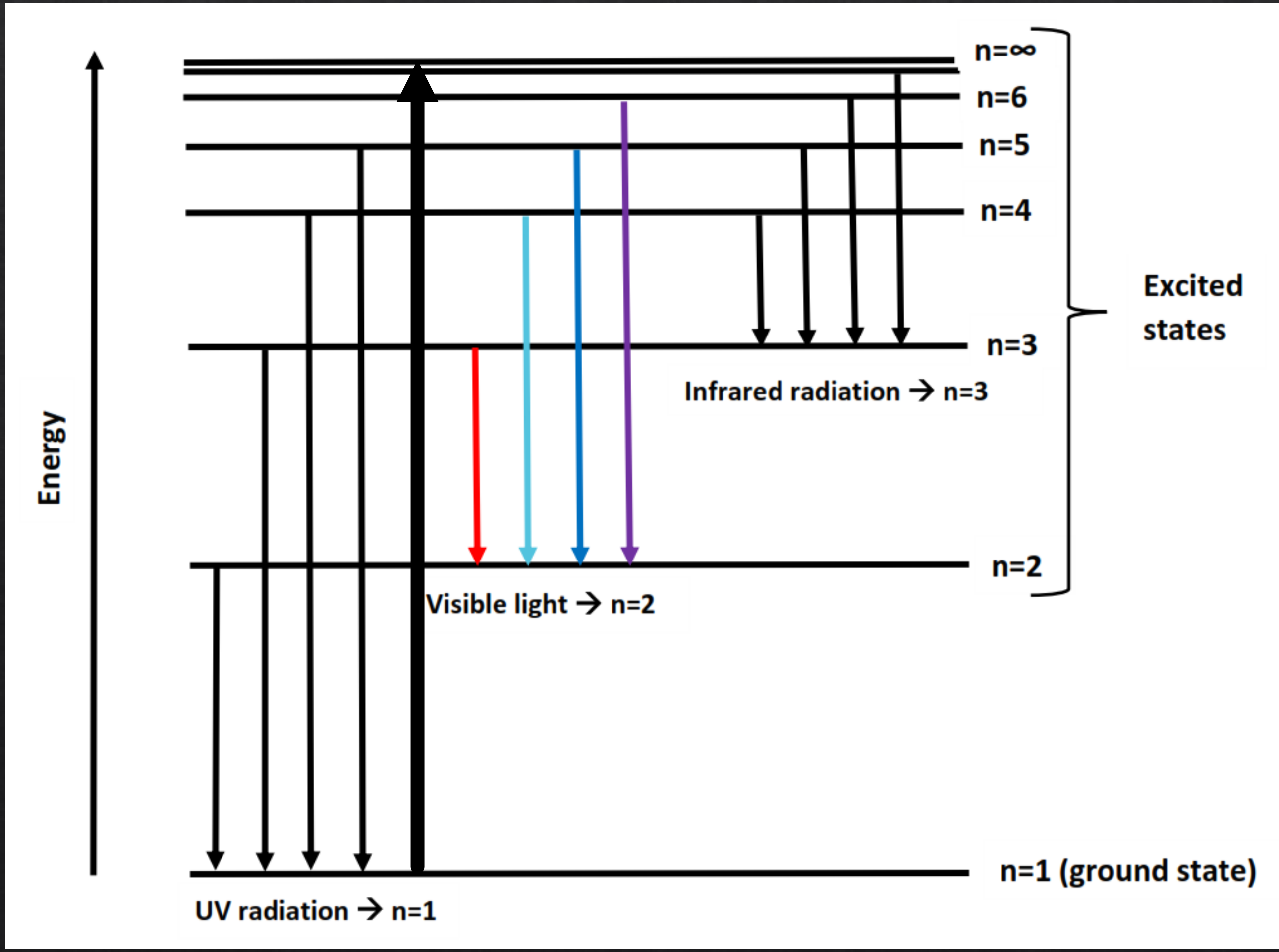
Tutorials for IB Chemistry

Calculating ionisation energy

MSJChem
Tutorials for IB Chemistry

Ionisation energy

The ionisation energy of an atom can be calculated using the frequency (or wavelength) of the convergence limit.



The convergence limit is the frequency at which the spectral lines converge.

The ionisation energy corresponds to the energy required for the electron transition from $n=1$ to $n=\infty$.

Ionisation energy

The convergence limit for the hydrogen atom has a wavelength of 9.15×10^{-8} m. Calculate the ionisation energy (in kJ mol^{-1}).

$$E = h\nu$$

$$c = \nu\lambda$$

E – energy (J)

h – Planck's constant (6.63×10^{-34} J·s)

ν – frequency (s^{-1})

λ – wavelength (m)

c – speed of light (3.00×10^{8} m s^{-1})

Ionisation energy

The convergence limit for the hydrogen atom has a wavelength of 9.15×10^{-8} m. Calculate the ionisation energy (in kJ mol^{-1}).

$$c = \nu\lambda$$

$$3.00 \times 10^{8} = \nu \times 9.15 \times 10^{-8}$$

$$\nu = 3.00 \times 10^{8} / 9.15 \times 10^{-8}$$

$$\nu = 3.28 \times 10^{15}\ s^{-1}$$

Ionisation energy

$$E = h\nu$$

$$E = 6.63 \times 10^{-34} \times 3.28 \times 10^{15}\ \mathrm{s^{-1}}$$

$$E = 2.17 \times 10^{-18}\ \mathrm{J/atom}$$

For one mol of H atoms:

$$E = 2.17 \times 10^{-18} \times 6.02 \times 10^{23}$$

$$E = 1306340\ \mathrm{J\ mol^{-1}} = 1310\ \mathrm{kJ\ mol^{-1}}$$

Ionisation energy

The convergence limit for the sodium atom has a frequency of 1.24×10^{15} s^{-1}. Calculate the ionisation energy (in kJ mol^{-1}).

$$E = hv$$

$$E = 6.63 \times 10^{-34} \times 1.24 \times 10^{15}$$

$$E = 8.22 \times 10^{-19} \text{ J/atom}$$

For one mol of Na atoms:

$$E = 8.22 \times 10^{-19} \times 6.02 \times 10^{23}$$

$$E = 494844 \text{ J mol}^{-1} = 495 \text{ kJ mol}^{-1}$$

MSJChem

Tutorials for IB Chemistry

Successive ionisation energies

MSJChem
Tutorials for IB Chemistry

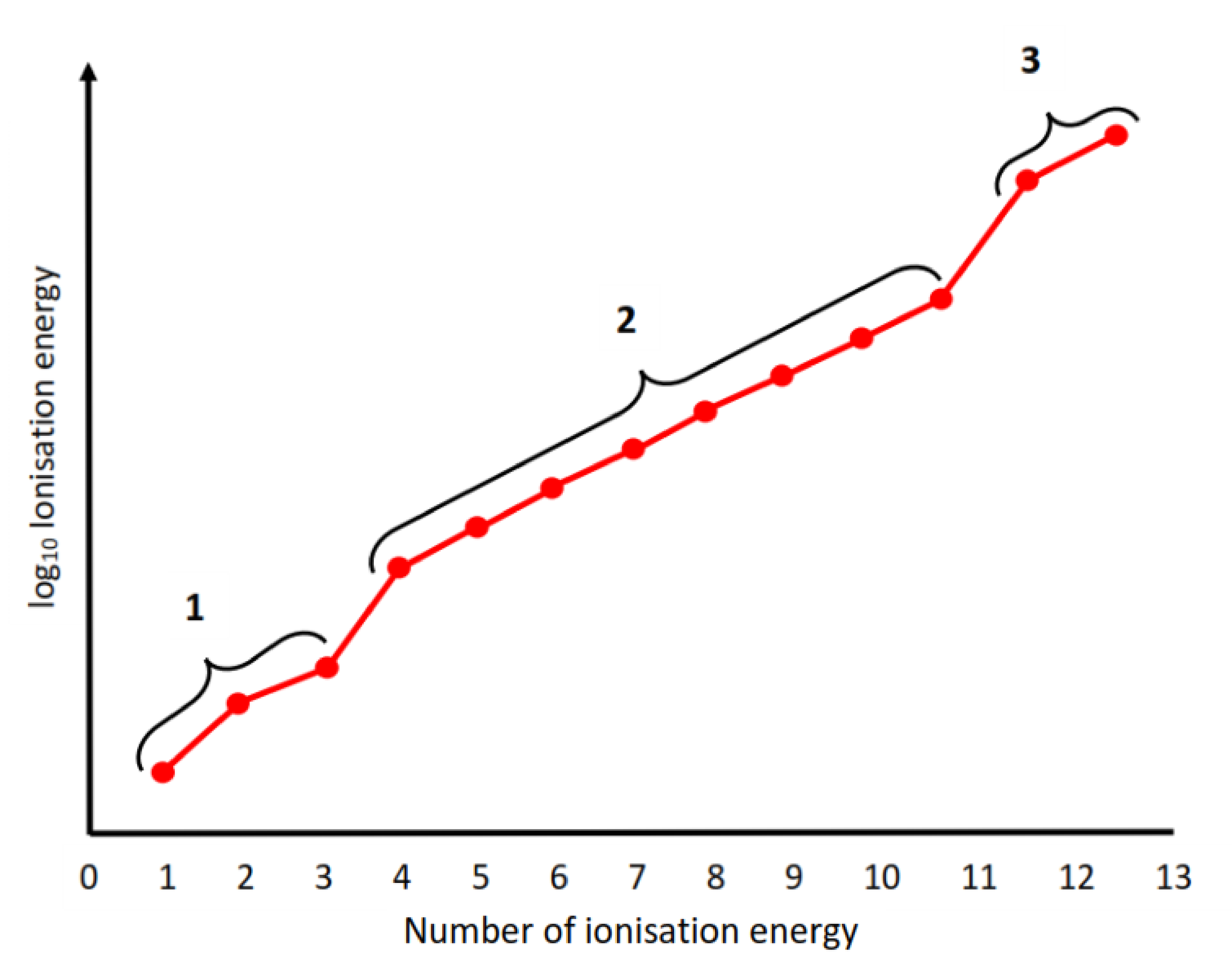
Ionisation energies

Values for the successive ionisation energies for an unknown element are given in the table below.

First IE (kJ mol^{-1})	Second IE (kJ mol^{-1})	Third IE (kJ mol^{-1})	Fourth IE (kJ mol^{-1})
420	3600	4400	5900

There is a large increase in IE between the first and second IE values therefore the element is found in group one of the periodic table.

Ionisation energies

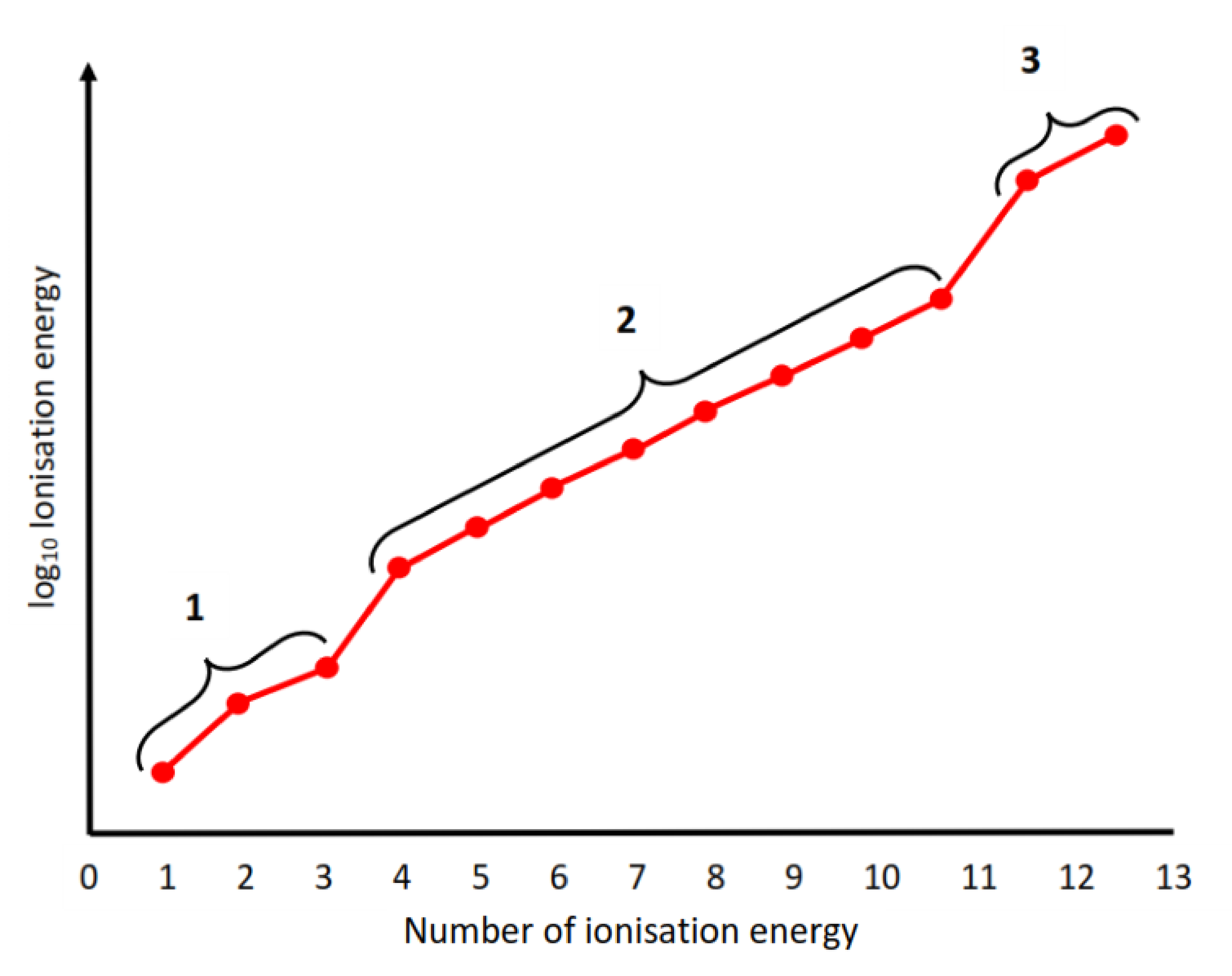


$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

These electrons are removed from the energy level furthest from the nucleus (n=3). Electrons in the outer energy level require less energy to remove due to the weaker electrostatic attraction from the nucleus.

MSJChem
Tutorials for IB Chemistry

Ionisation energies

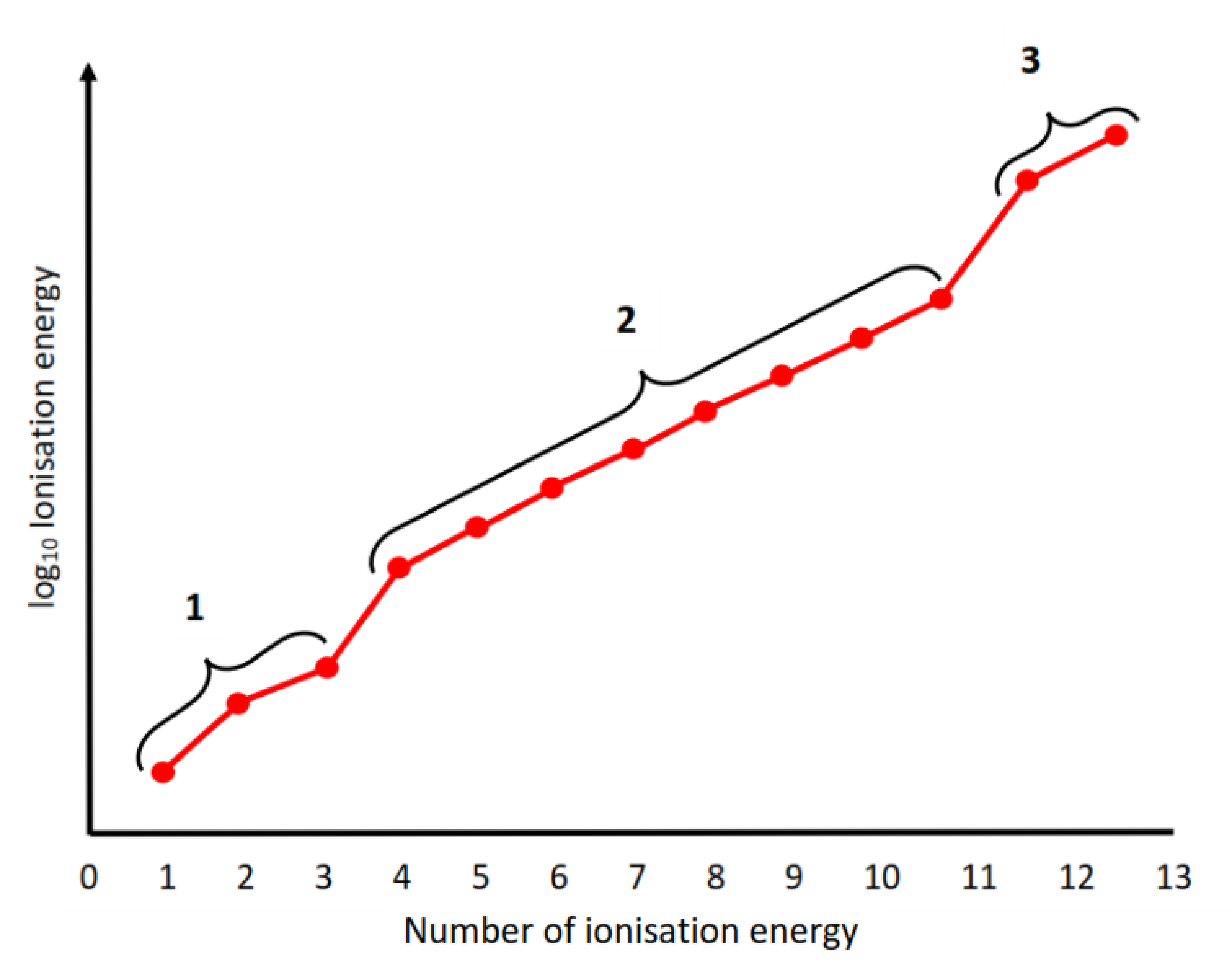


$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

These electrons are removed from the second main energy level (n=2).

The jump between the 3rd and 4th ionisation energies is evidence of the existence of energy levels within the atom.

Ionisation energies



$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

These electrons are being removed from the energy level closest to the nucleus (n=1).

Electrons in the inner energy level require the most energy to remove because of the strong electrostatic attraction from the nucleus.