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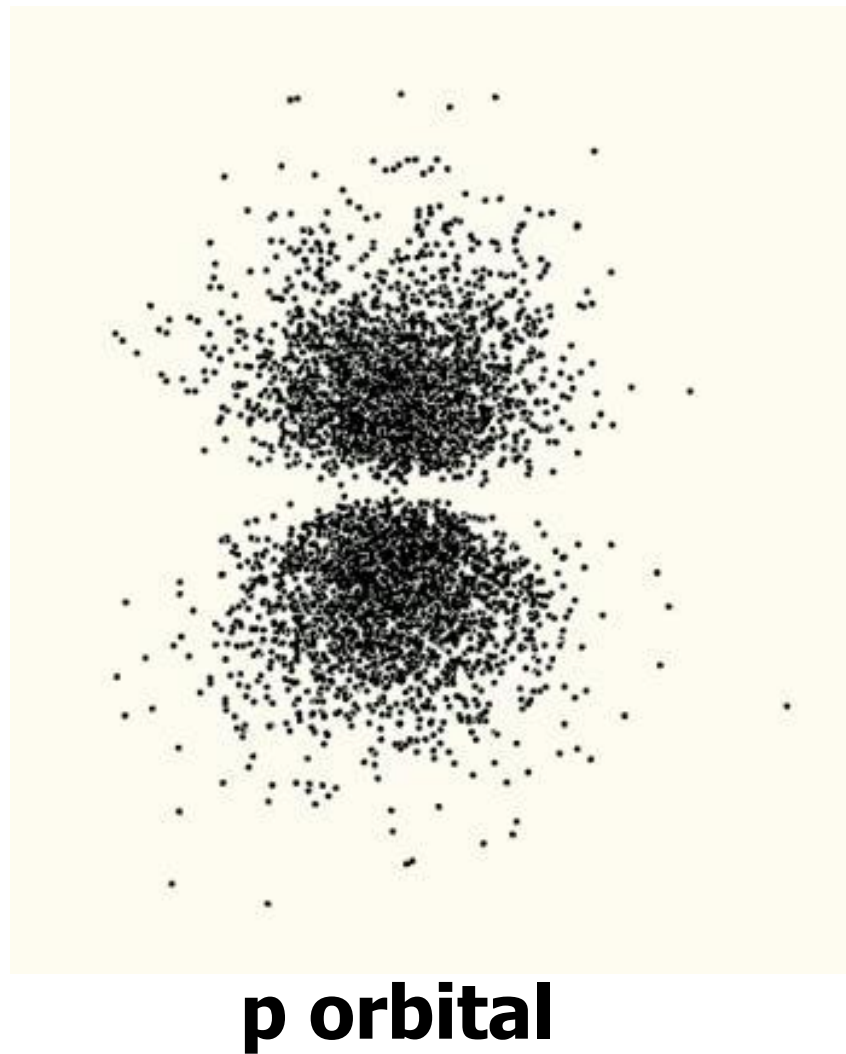
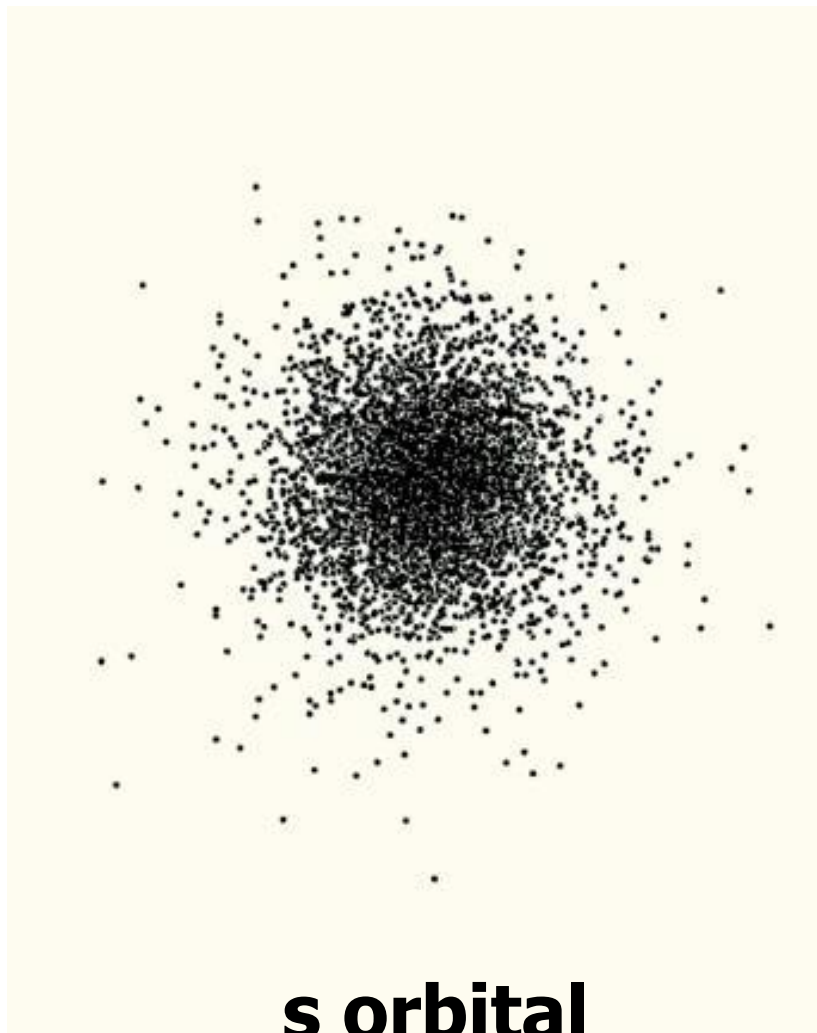
# ELECTRON ARRANGEMENT

# Shells, sub-shells & orbitals

- Electrons are arranged in electrons shells (energy levels).
- The shells have sub-shells (sub-levels).
- Each shell/sub-shell is made up of electron orbitals which can each hold 2 electrons.

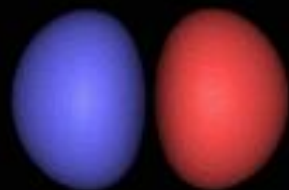
# Orbitals

- Each sub-level consists of electron orbitals (region of space in which the electron spends most of its time).
- Each orbital can hold 2 electrons with opposite spins (one electron spins clockwise and one anticlockwise).
- Orbitals are regions of space that electrons are most likely to be in.

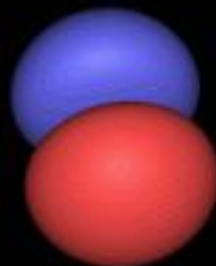




s



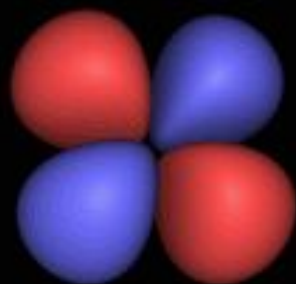
$p_x$



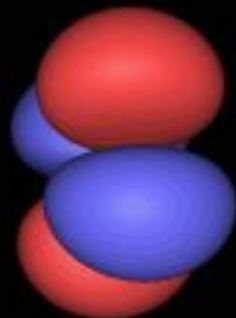
$p_y$



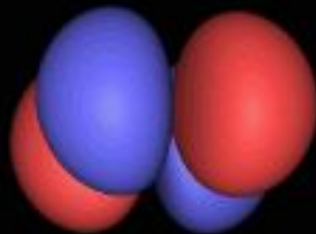
$p_z$



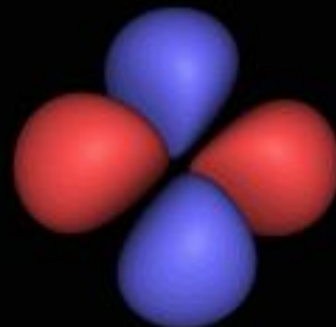
$d_{xy}$



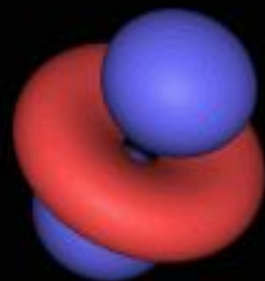
$d_{xz}$



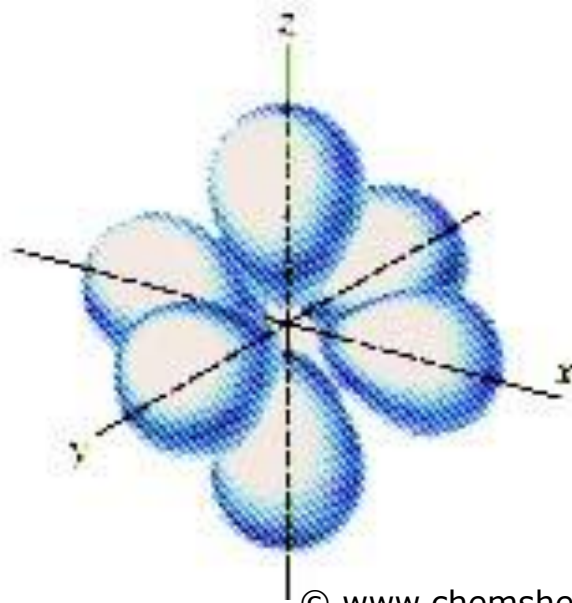
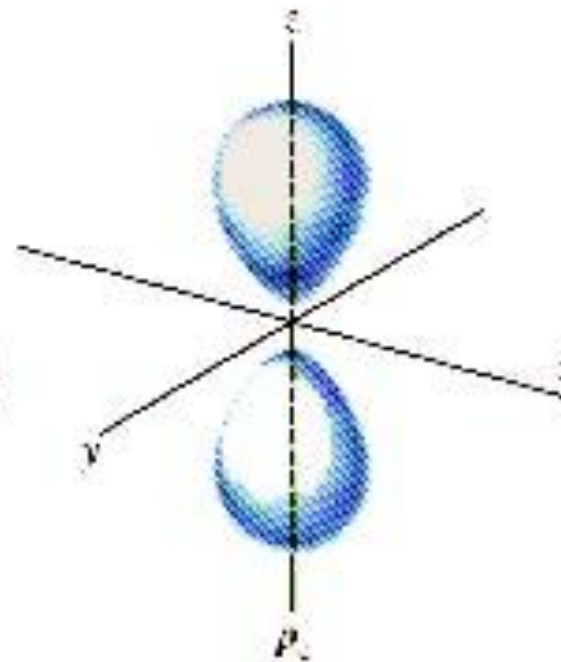
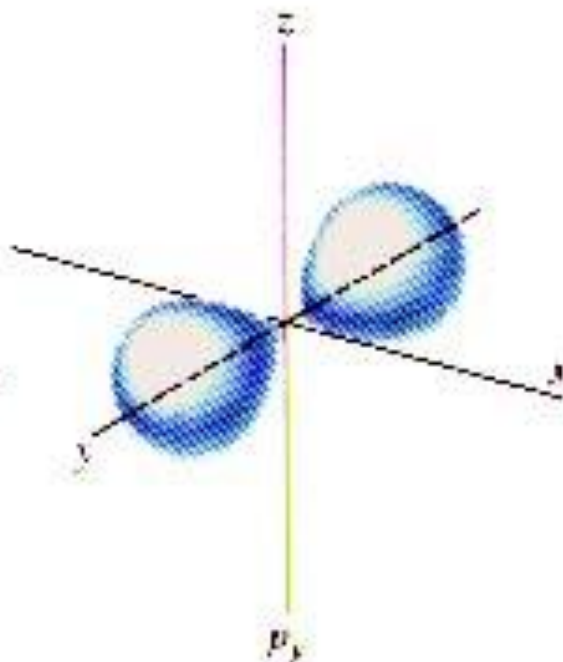
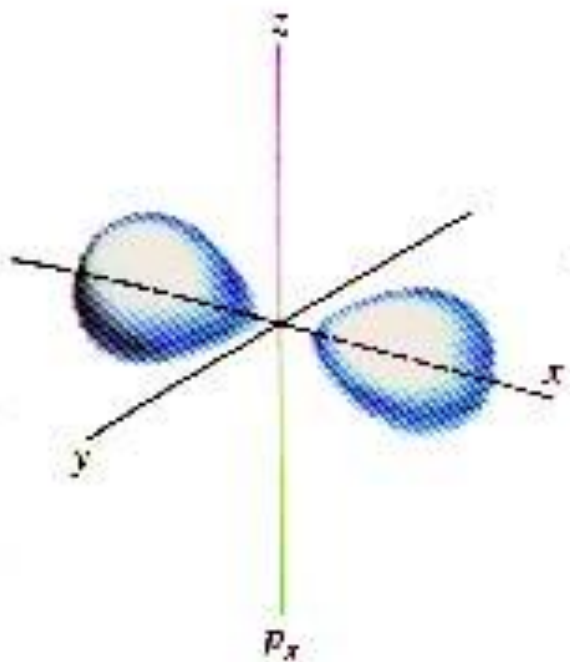
$d_{yz}$



$d_{x^2 - y^2}$

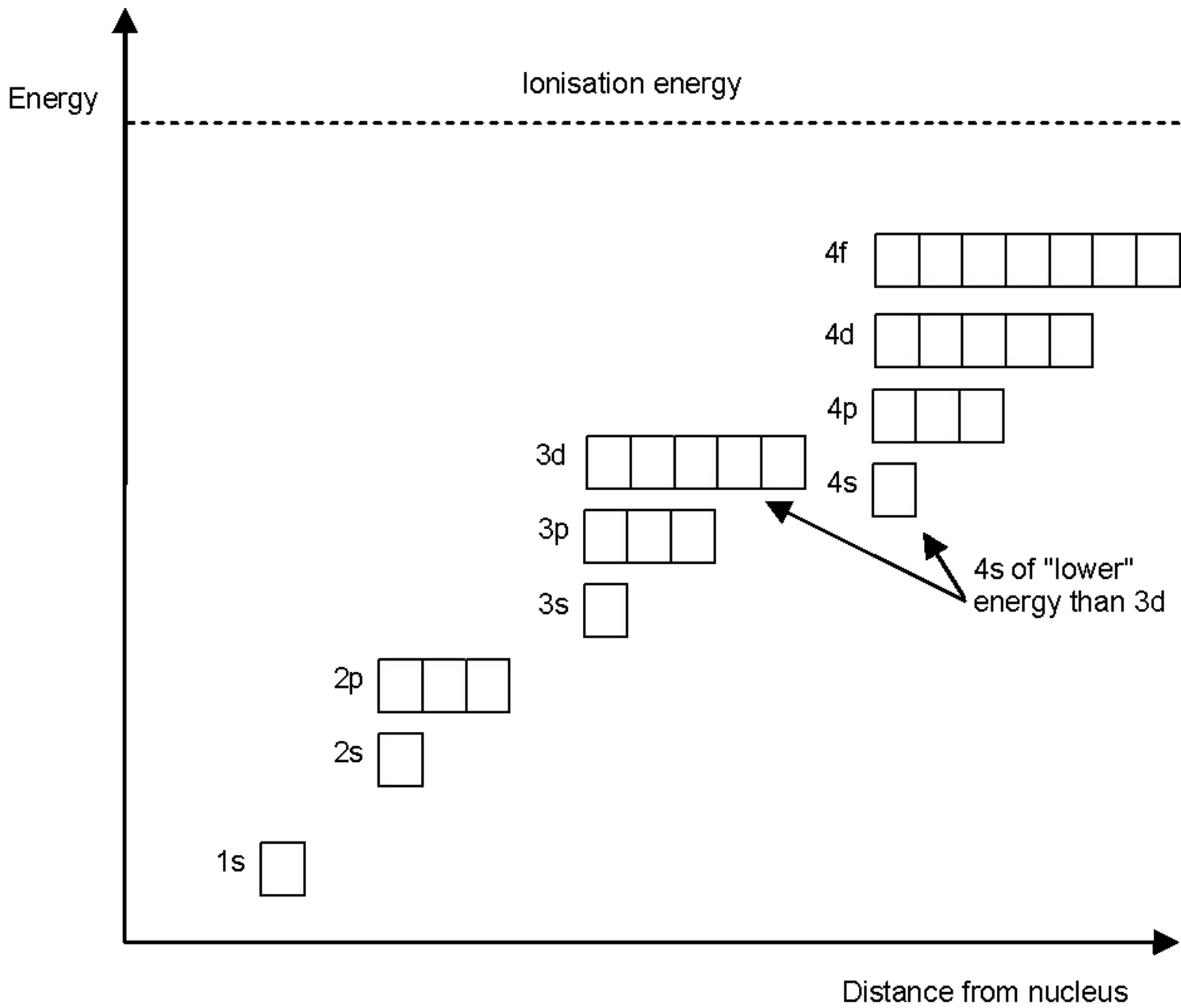


$d_{z^2}$



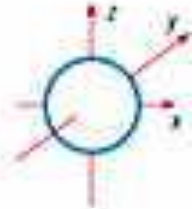
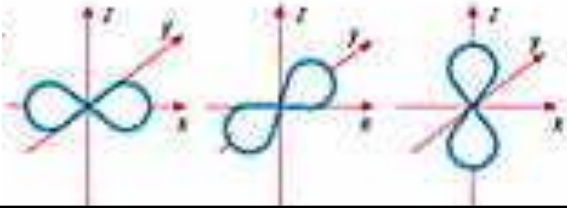
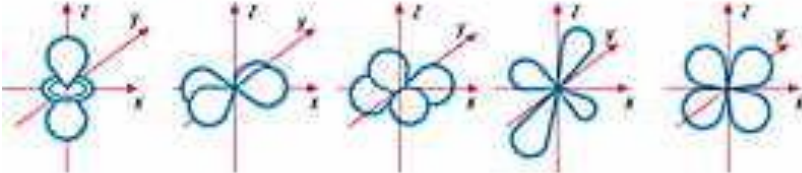
# The Orbitron


<http://winter.group.shef.ac.uk/orbitron/AOs/1s/index.html>





# Orbitals

Sub-level	Number of orbitals in sub-level	Shape (no need to learn)	Maximum number of electrons in sub-level
s	1		2
p	3		6
d	5		10
f	7	Even more complicated!	14

A black t-shirt with white text. The text is centered on the chest and reads "You're in my 1s friendship orbital." in a clean, sans-serif font. The t-shirt is shown from the chest up, with the person's arms visible on the sides.

You're in my 1s  
friendship orbital.

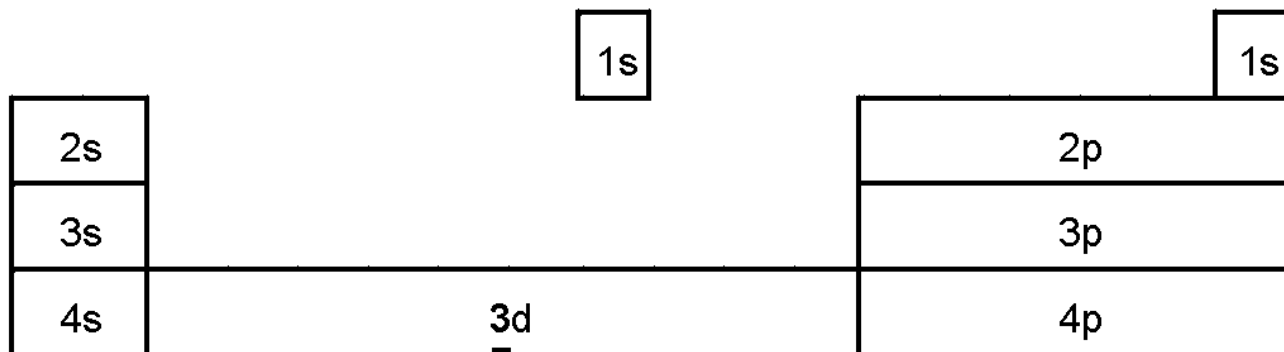
other T-shirts  
are available!!

# Aufbau Principle

Electrons enter the lowest energy orbital available.

This diagram helps you to work out the order in which orbitals fill:  
1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, .....

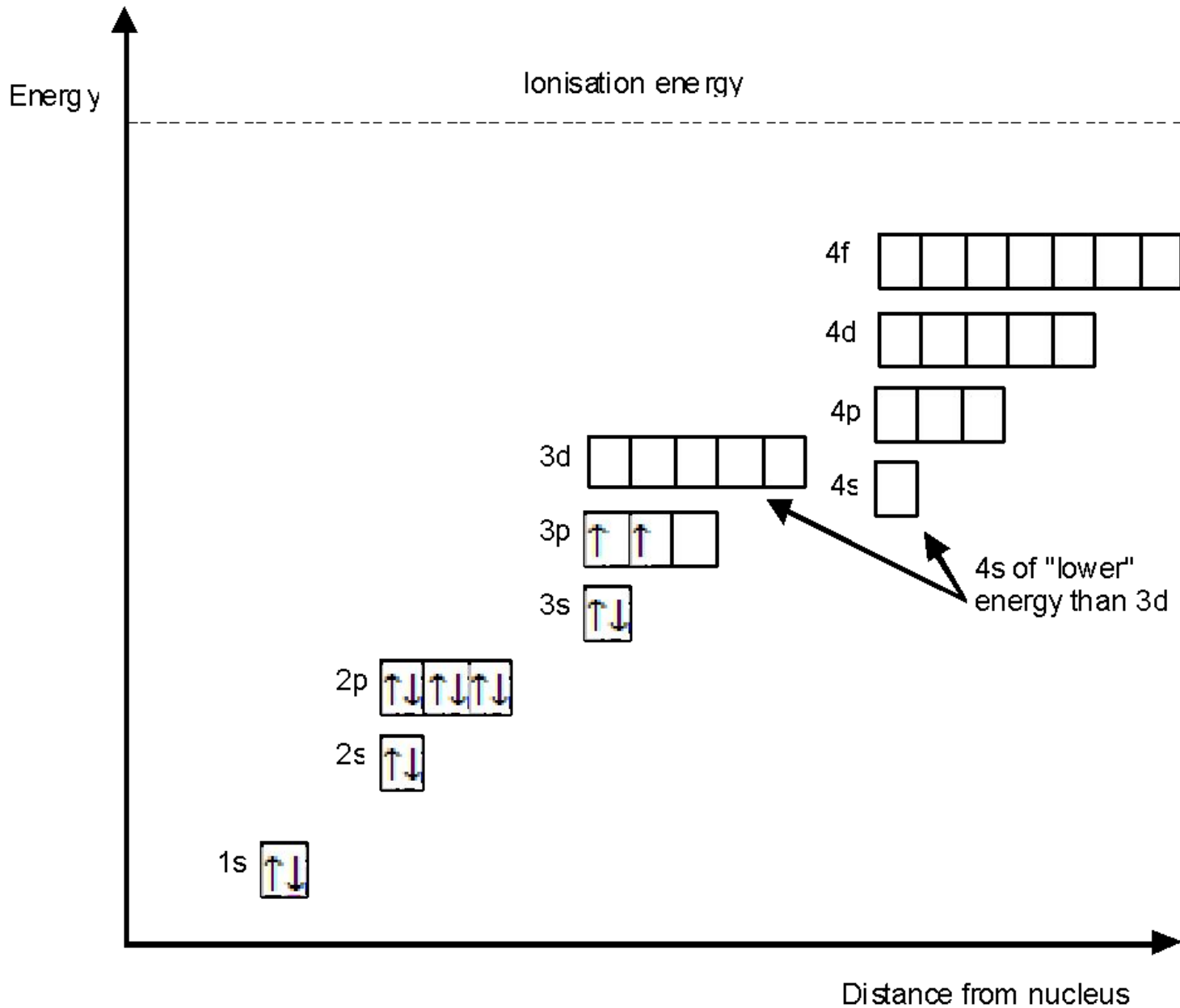
However, it can be easier to read across the periodic table, but remember that the first transition metal row is 3d:



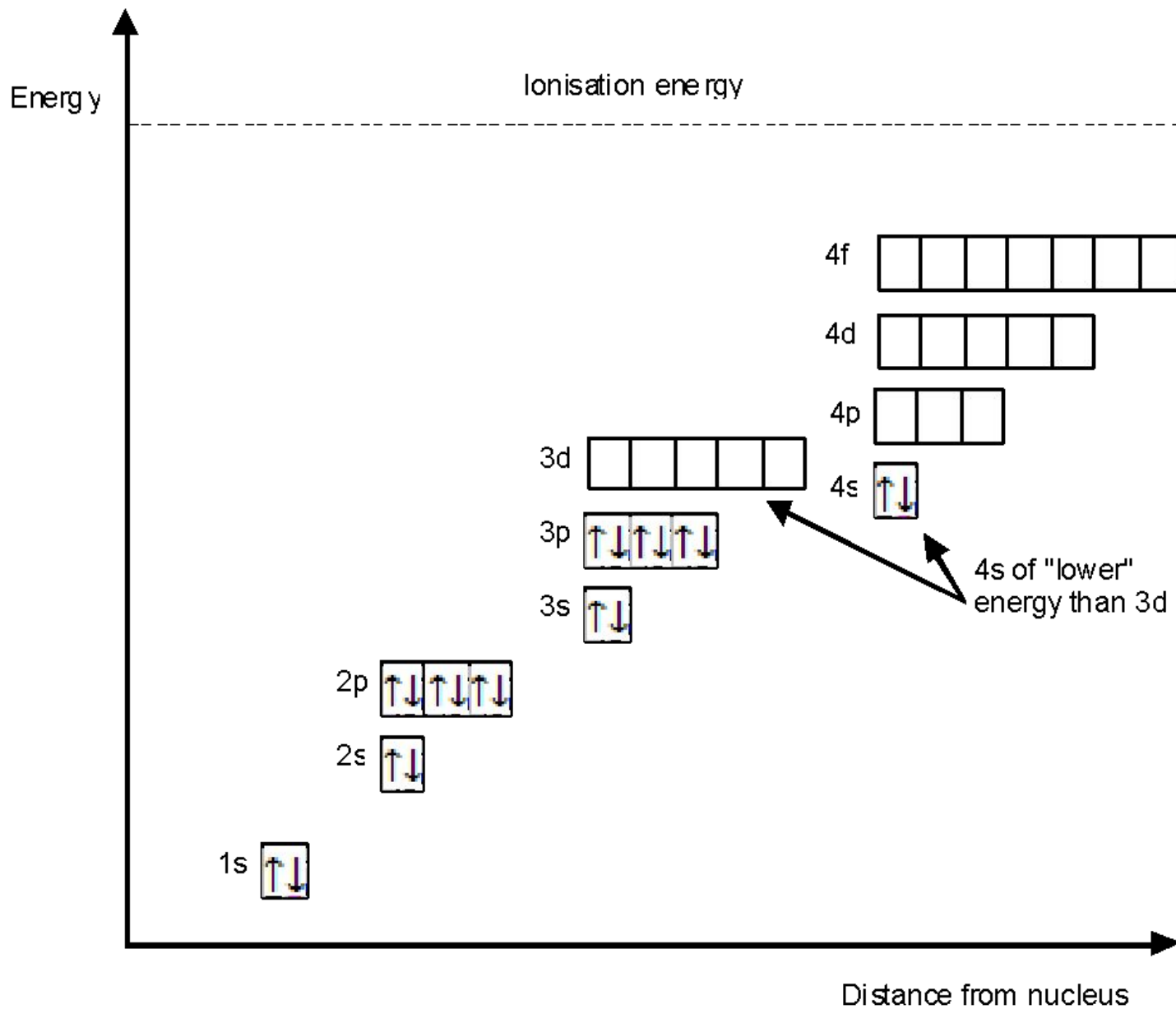
# Hund's Rule

Electrons prefer to occupy orbitals on their own, and only pair up when no empty orbitals of the same energy are available .

e.g. silicon 14 e<sup>-</sup> 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>2</sup> 3p<sup>2</sup>



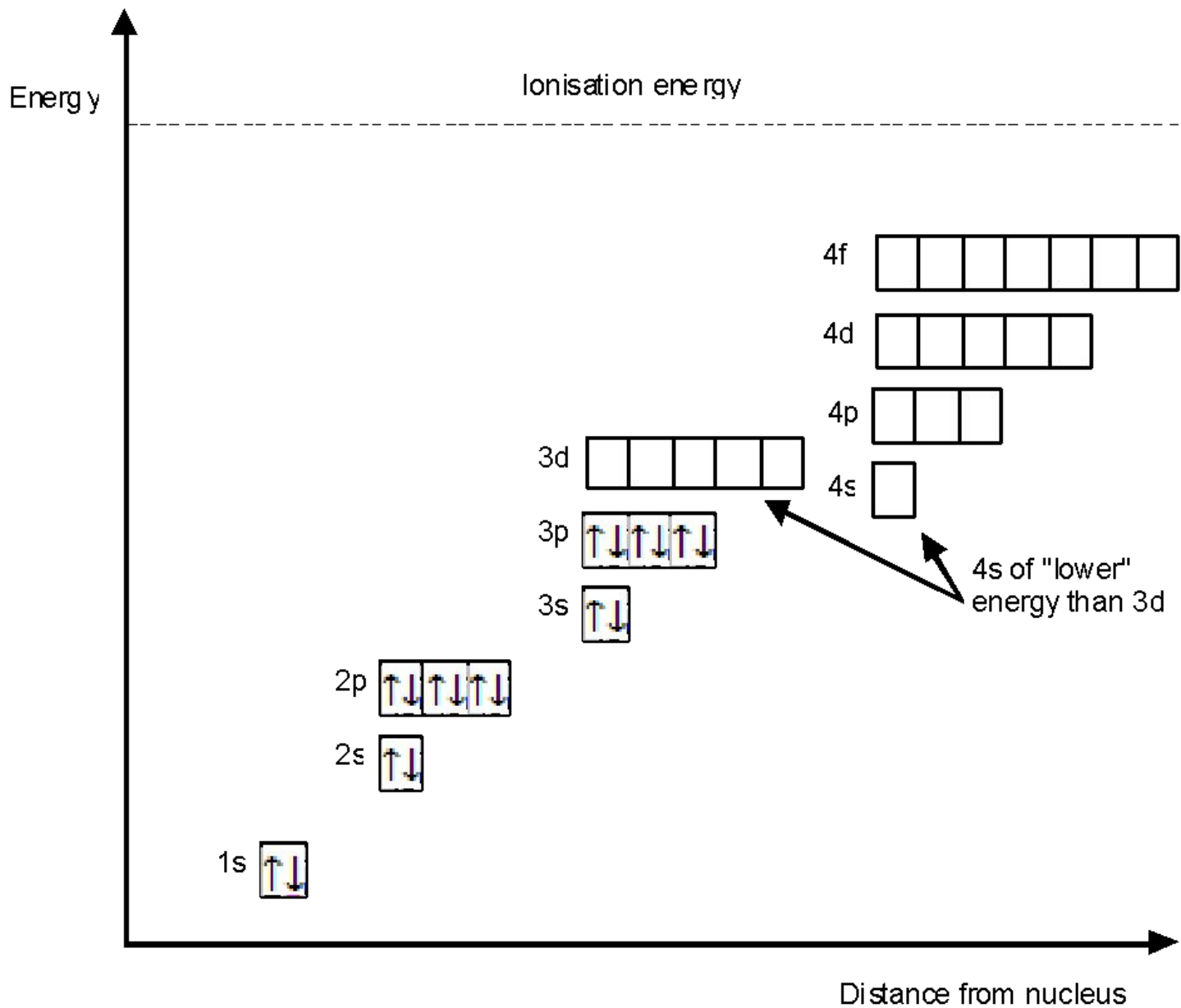
e.g. calcium  $20 e^-$   $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$



# Ions

- The highest energy electrons are lost when an ion is formed.
- Note that 4s electrons are lost before 3d (as once 4s and 3d are occupied, 4s moves above 3d).

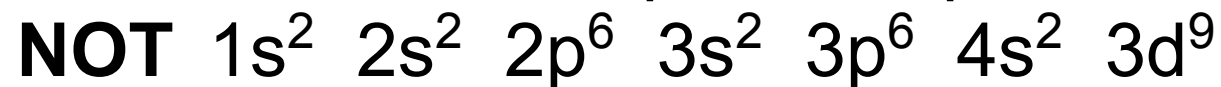
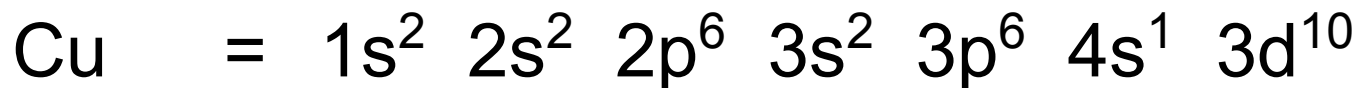
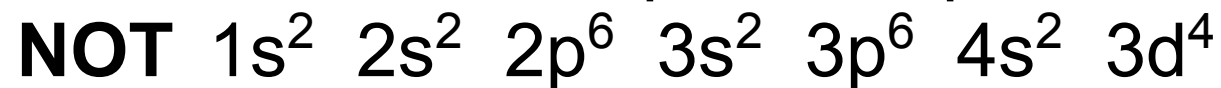
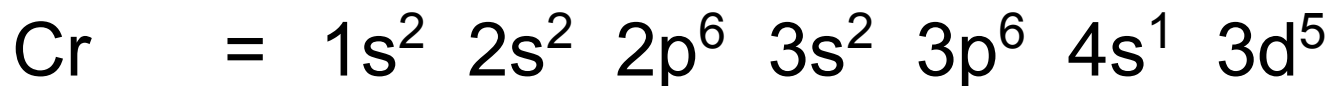
e.g.  $\text{Ca}^{2+}$  18  $e^-$   $1s^2 2s^2 2p^6 3s^2 3p^6$





# Cu & Cr

- Cu and Cr do not have the expected electron structure.

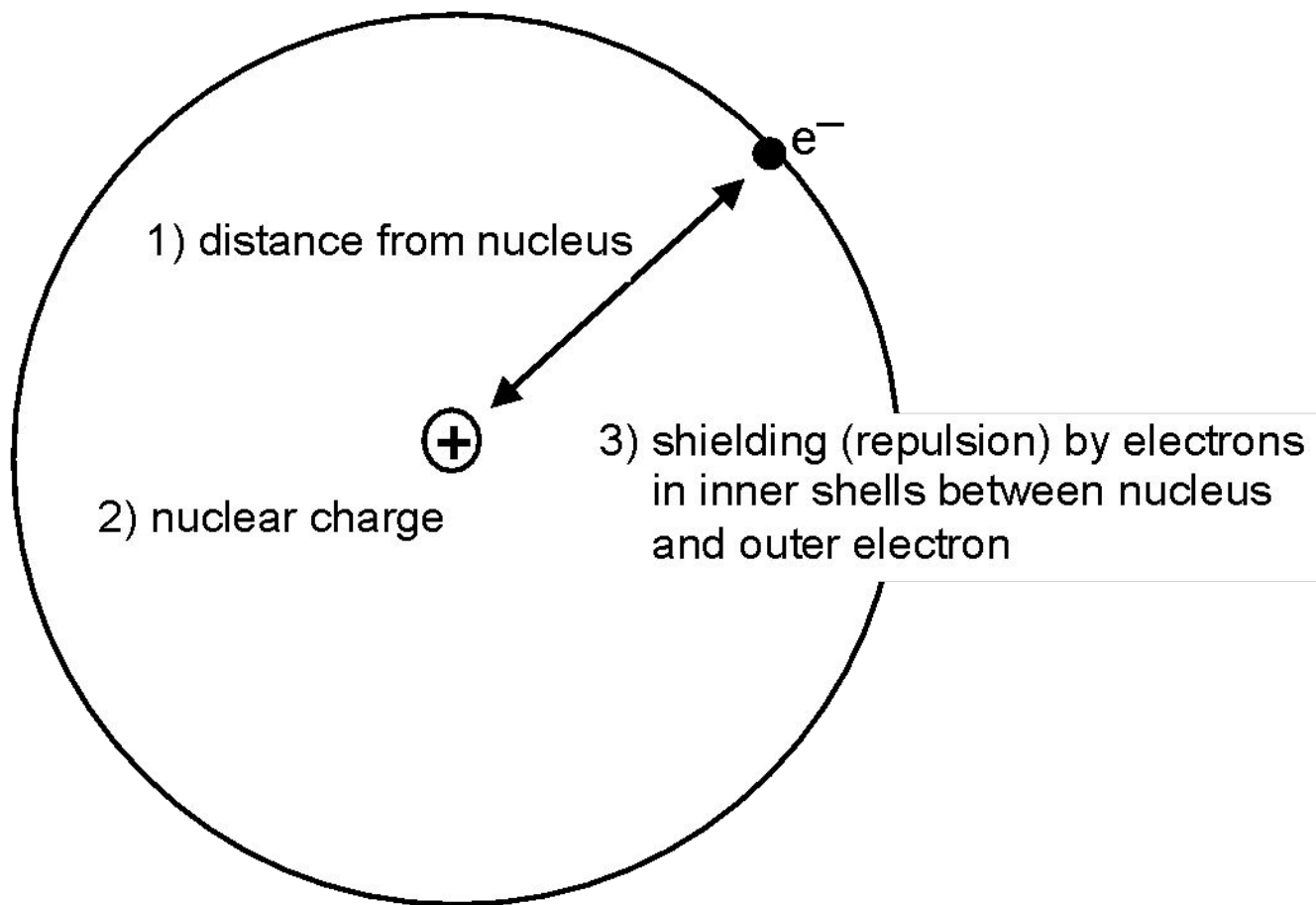


# Ionisation Energy

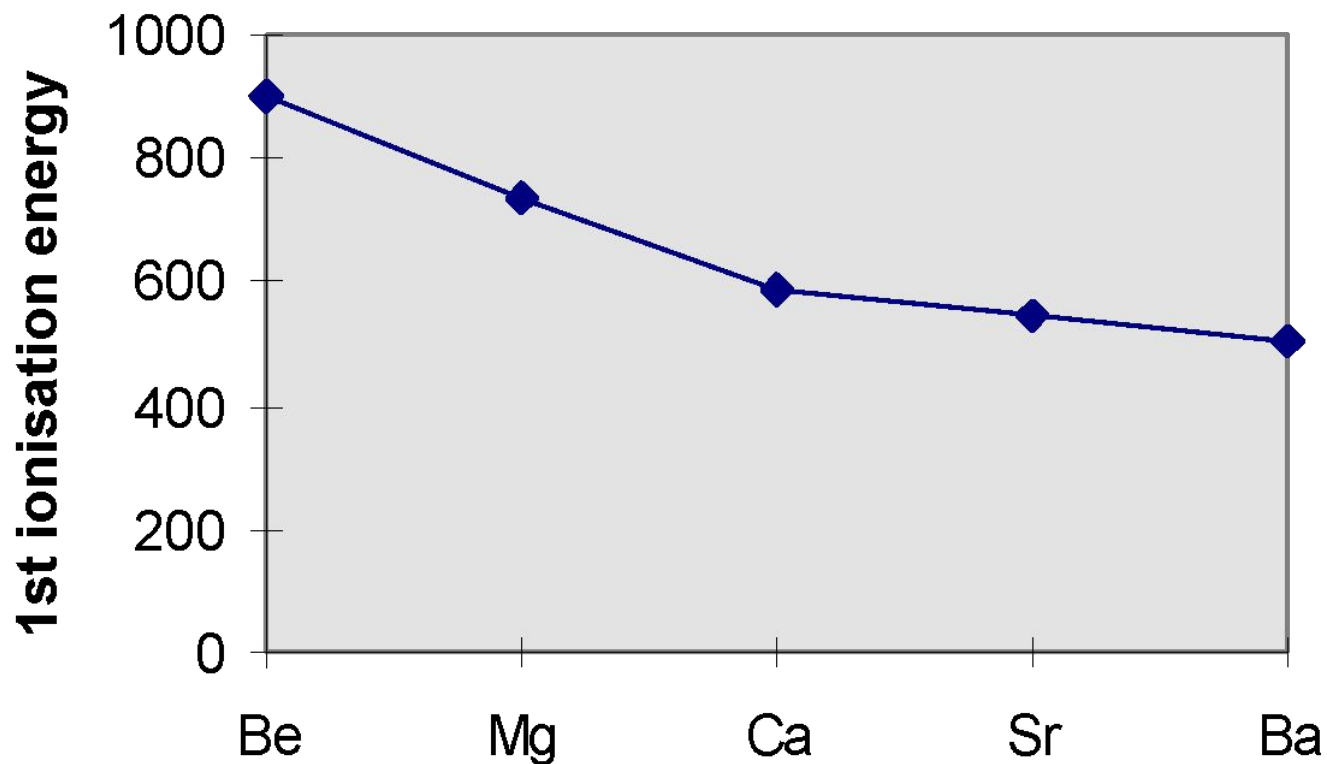
- Evidence for how the electrons are arranged in atoms comes from ionisation energies.
- 1st ionisation energy = energy required to remove one electron from each atom in a mole of gaseous atoms producing one mole of 1+ gaseous ions.
- Note that 2nd ionisation energy is the energy required to remove the second electron (not both electrons).



# Ionisation Energy



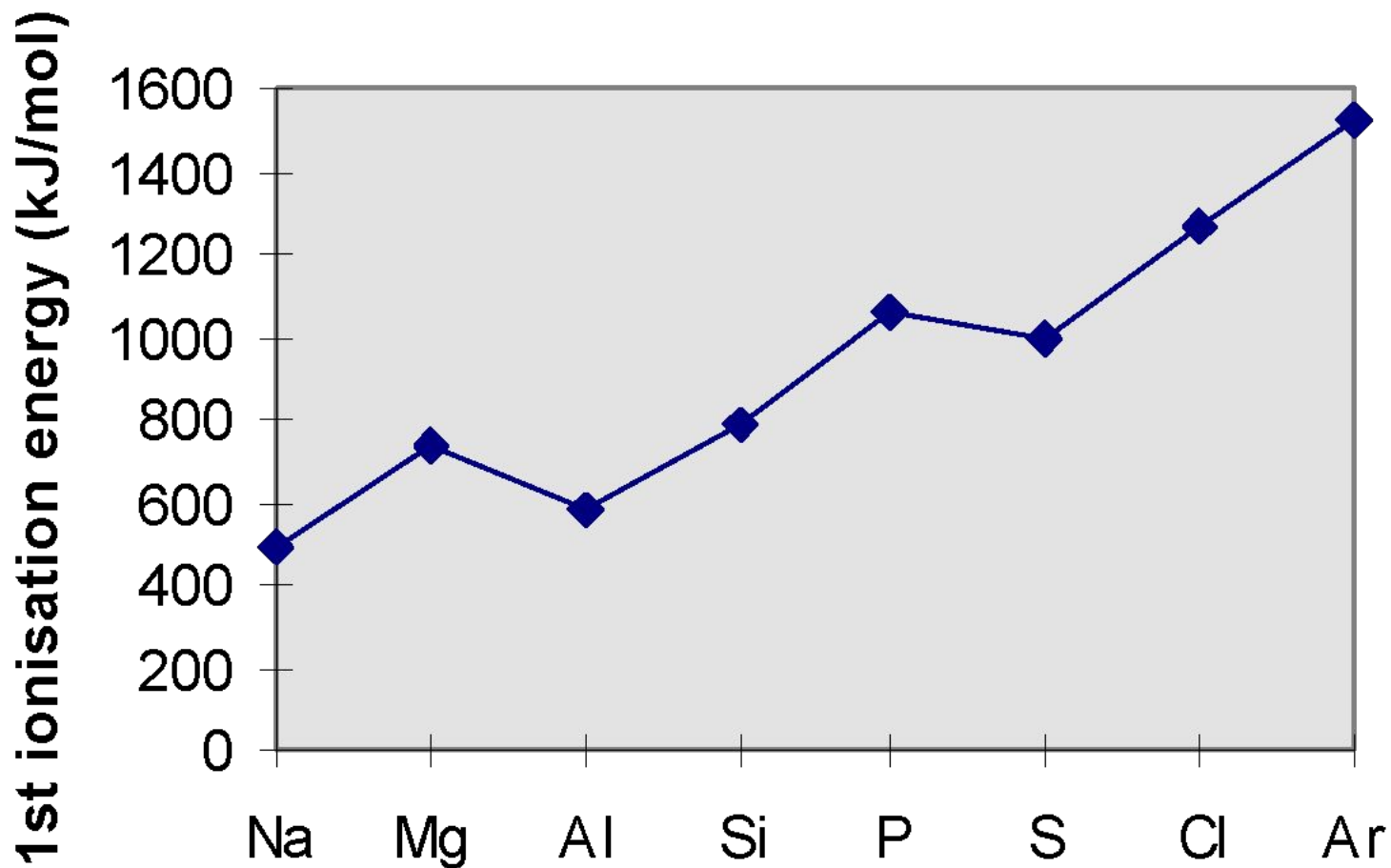
# 1st ionisation energy (down group)



# 1st ionisation energy (down group)

- Atoms get bigger
- More shielding
- Therefore weaker attraction from nucleus to electron in outer shell

# 1st ionisation energy (across period)



# 1st ionisation energy (across period)

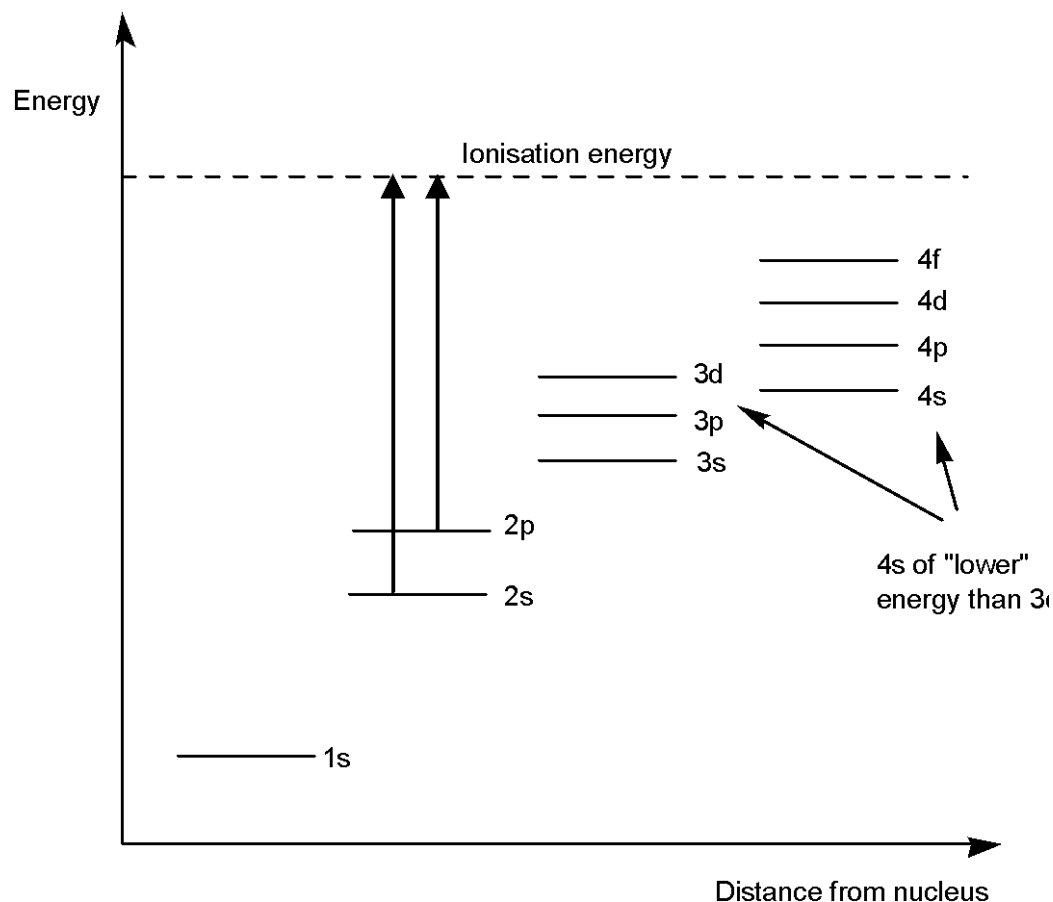
## General trend

- Increased nuclear charge (i.e. more protons)
- Atoms get smaller
- Therefore stronger attraction from nucleus to electron in outer shell

# 1st ionisation energy (across period)

## Group 2 → 3

- Electron lost from Group 3 element is from p orbital, while that lost from Group 2 element is from s orbital.
- p orbital is higher energy than s orbital, so easier to lose electron.





# 1st ionisation energy (across period)

## Group 5 → 6

- Group 6 element loses electron from orbital with 2 electrons ( $p^4$ )

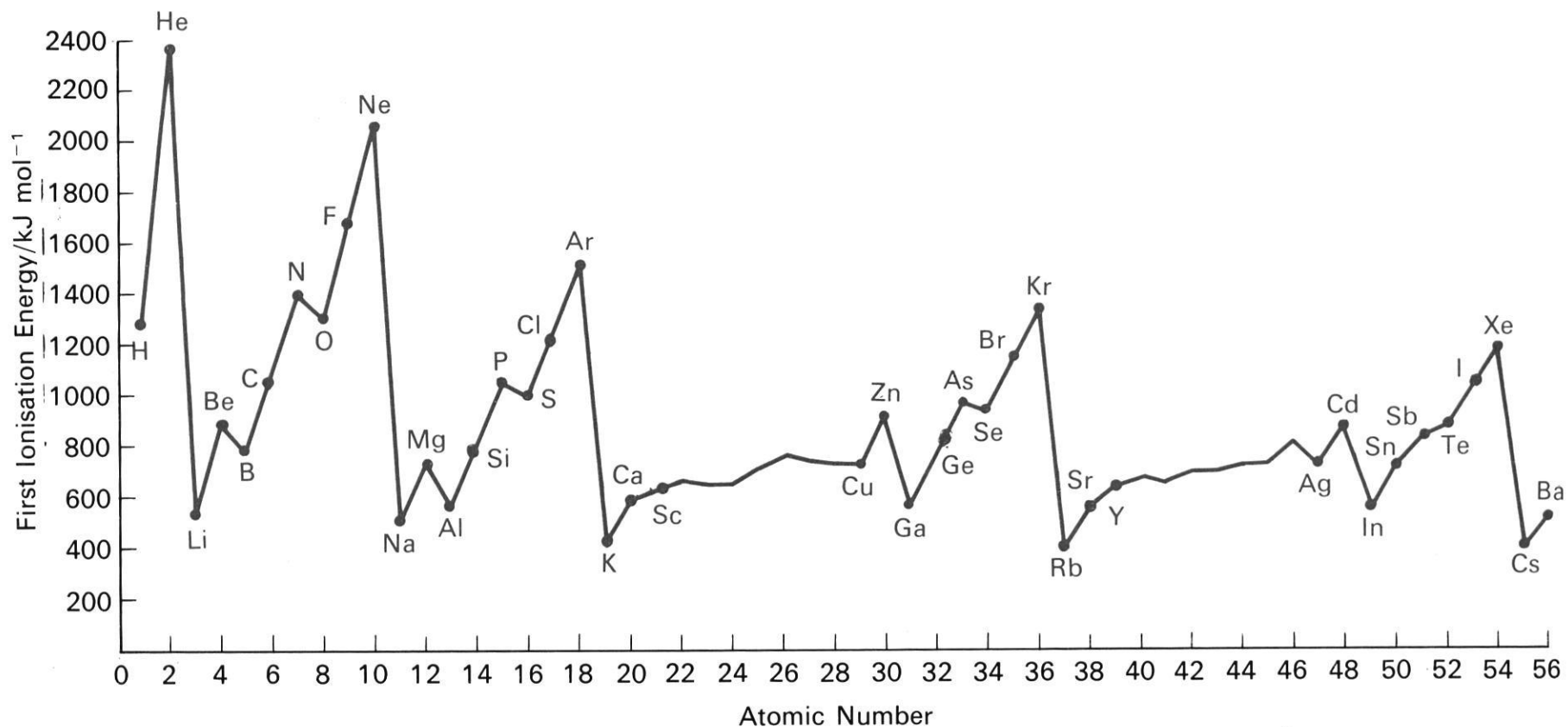


- Group 5 element loses electron from orbital with 1 electrons ( $p^3$ )

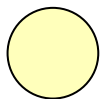


- Extra electron-electron repulsions make it easier to lose electron from  $p^4$  than  $p^3$ .

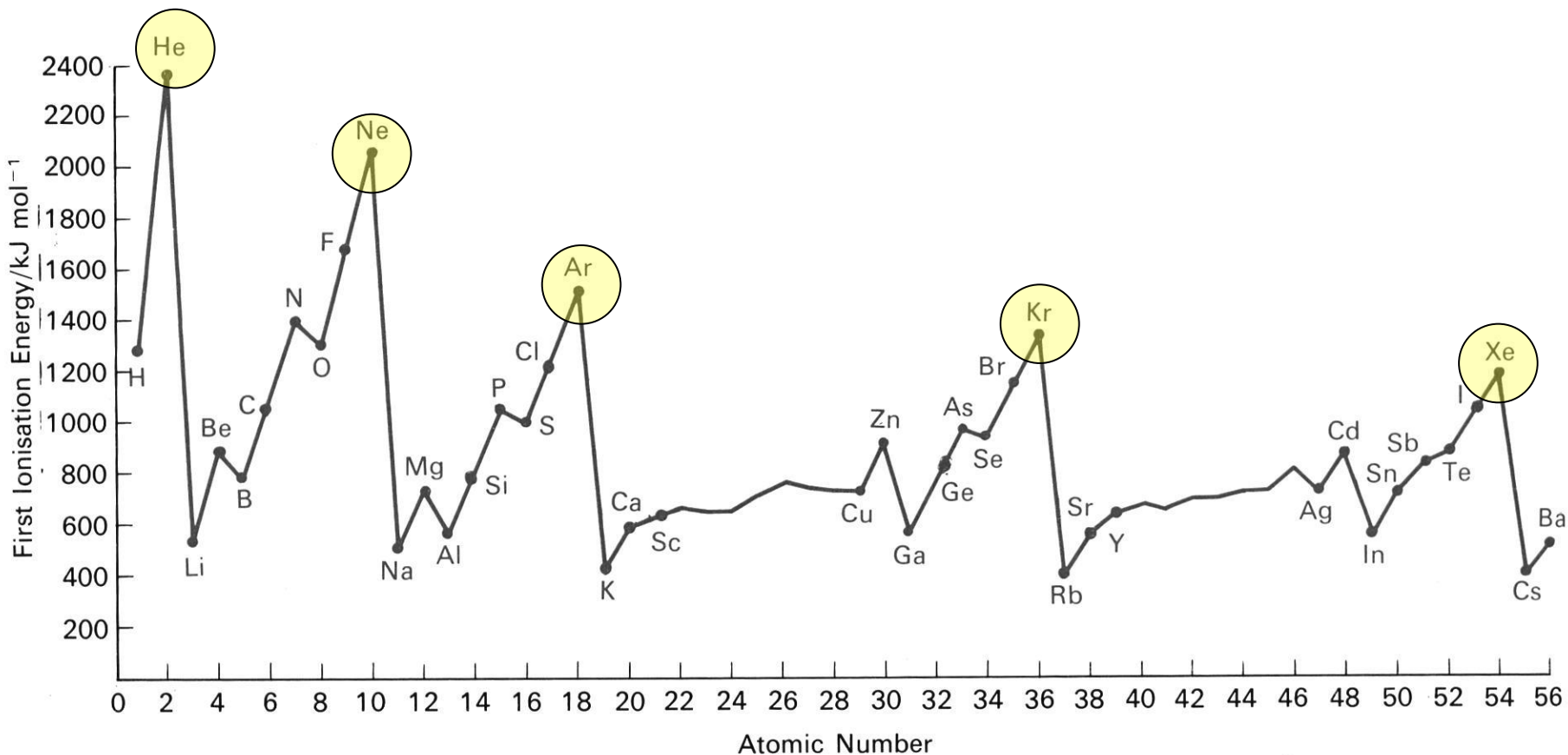
# 1st ionisation energy



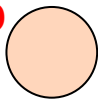
down a group  
(group 0)



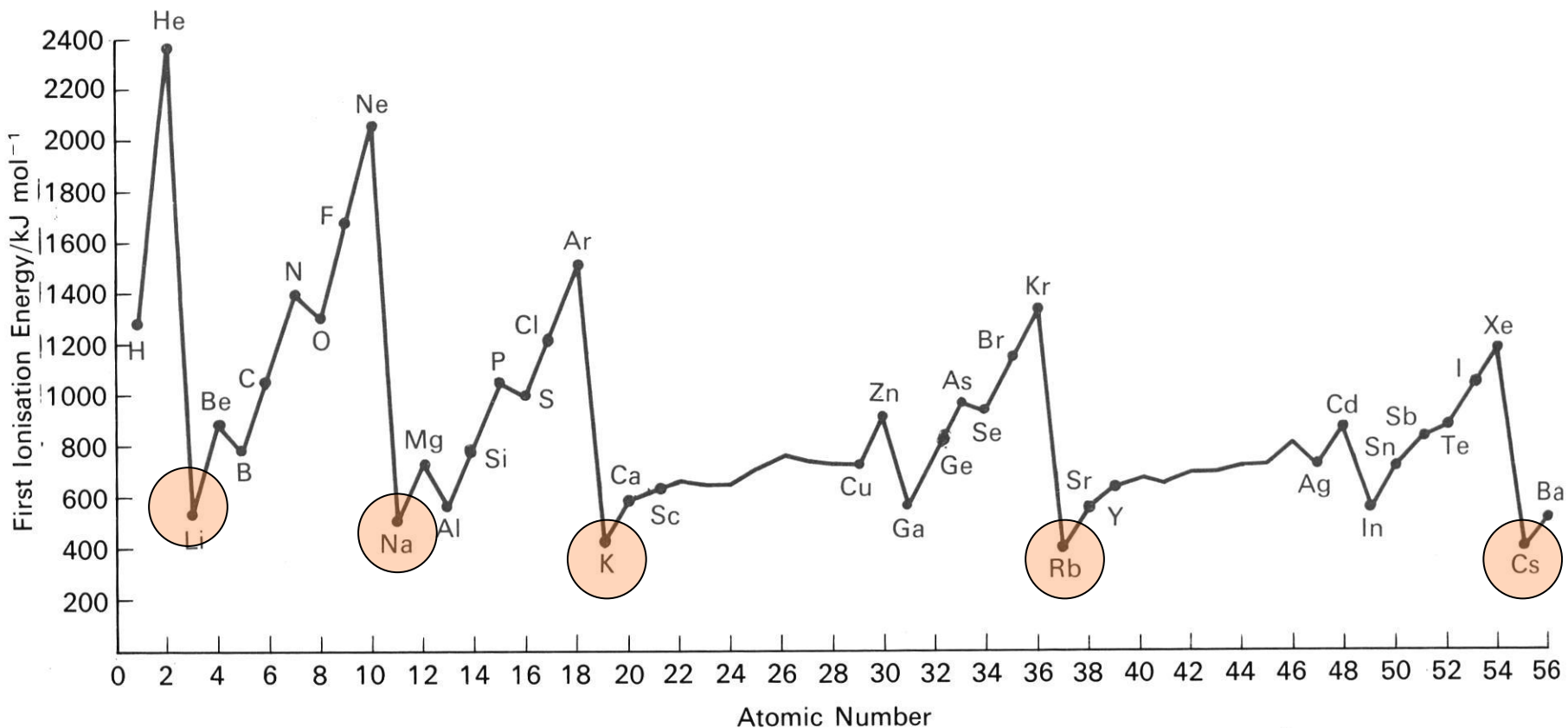
# 1st ionisation energy



down a group  
(group 1)



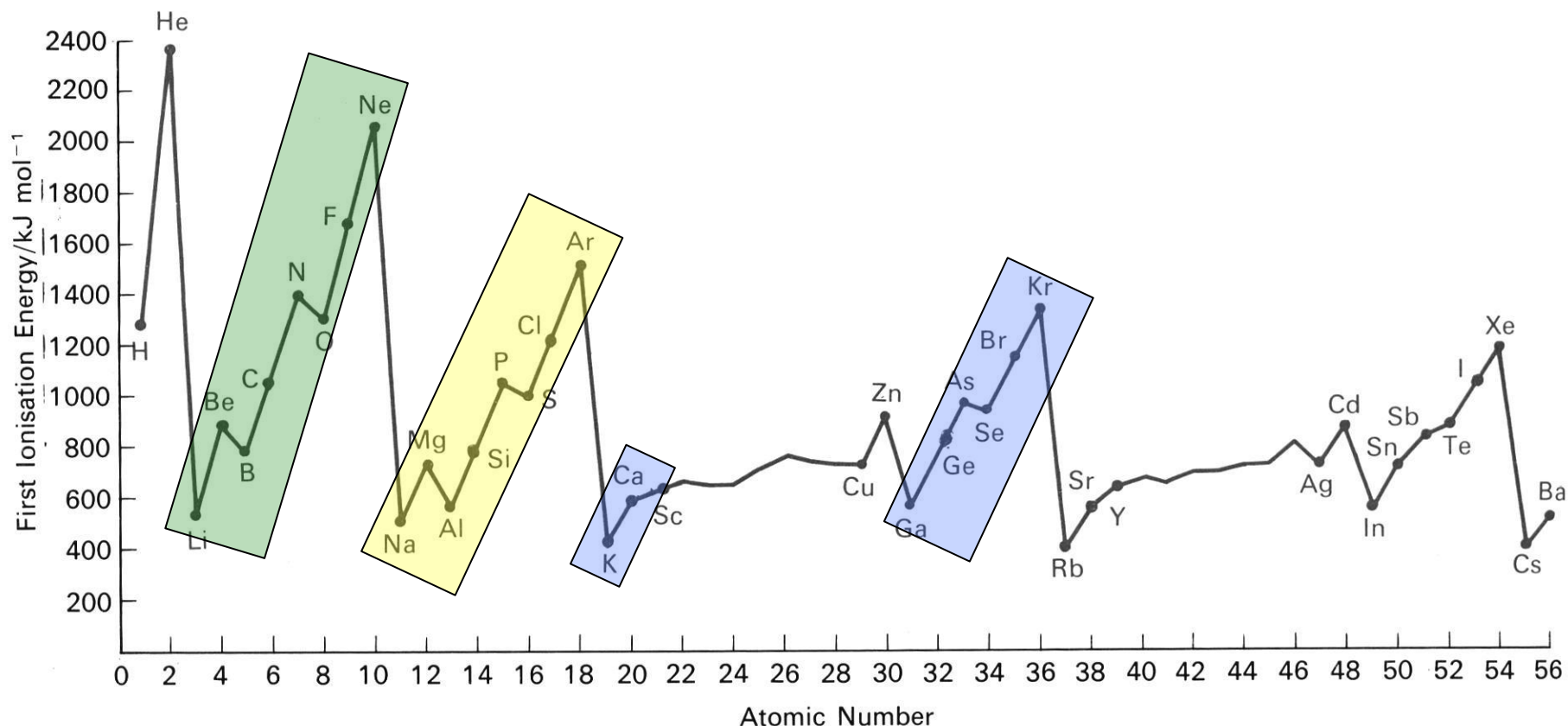
# 1st ionisation energy



# Across a period

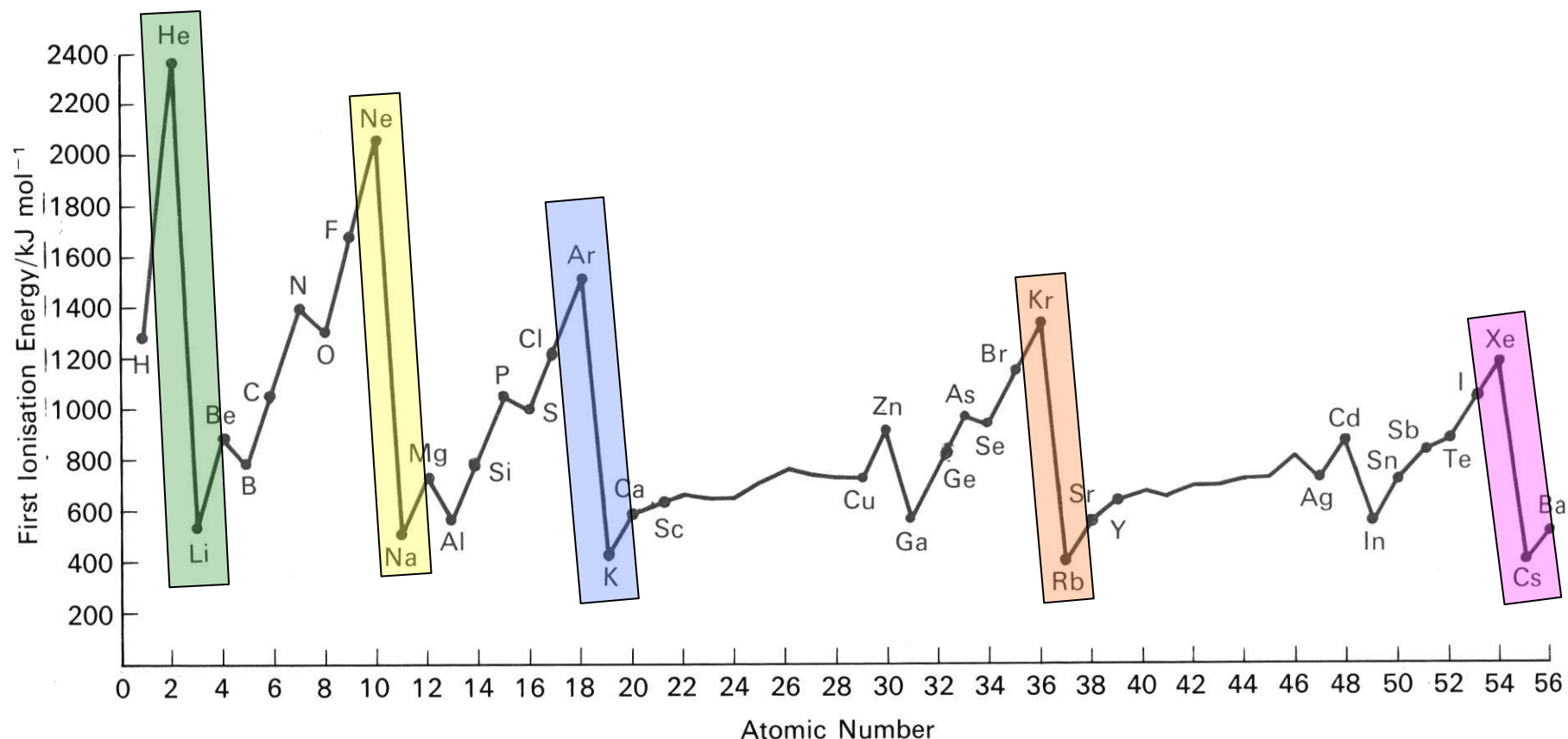
## 1st ionisation energy

period 2
period 3
period 4



**End of period**

# 1st ionisation energy



# Successive ionisation energies (K)

