ELECTRONIC CONFIGURATIONS

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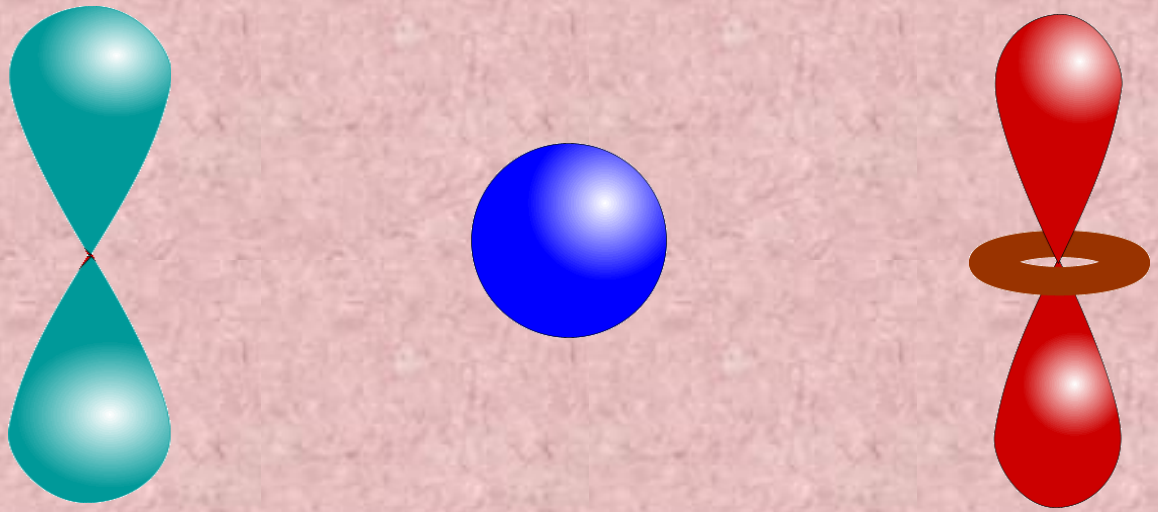
CONTENTS

- The Bohr Atom
- Levels and sub-levels
- Rules and principles
- Orbitals
- Rules for filling orbitals.
- The Aufbau principle
- Electronic configurations of elements 1 to 36
- Electronic configurations of ions

ELECTRONIC CONFIGURATIONS

Before you start it would be helpful to…

- Know that electrons can be found outside the nucleus in energy levels (shells)
- Know the electronic configurations of the first 20 elements in 2,8,1 notation



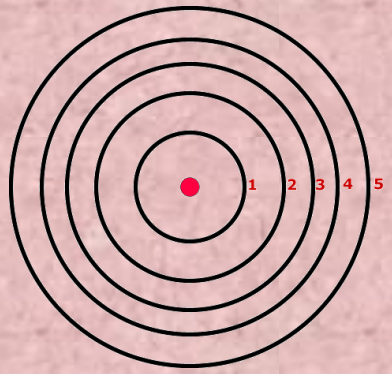
THE BOHR ATOM

Ideas about the structure of the atom have changed over the years. The Bohr theory thought of it as a small nucleus of protons and neutrons surrounded by circulating electrons.

Each shell or energy level could hold a maximum number of electrons.

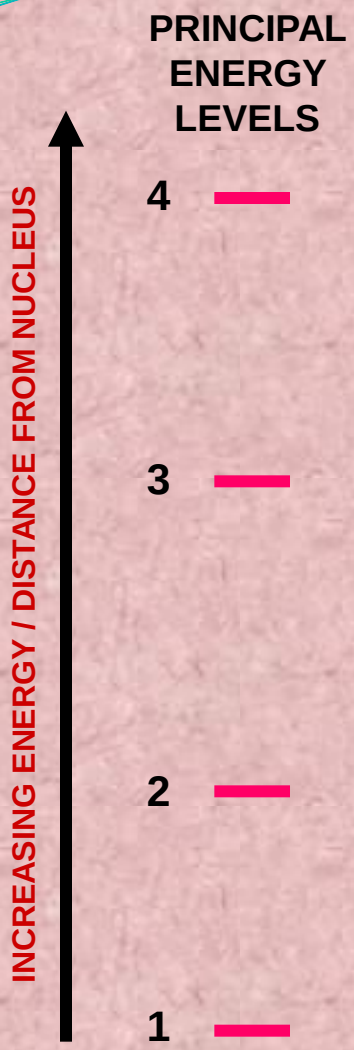
The energy of levels became greater as they got further from the nucleus and electrons filled energy levels in order.

The theory couldn't explain certain aspects of chemistry.



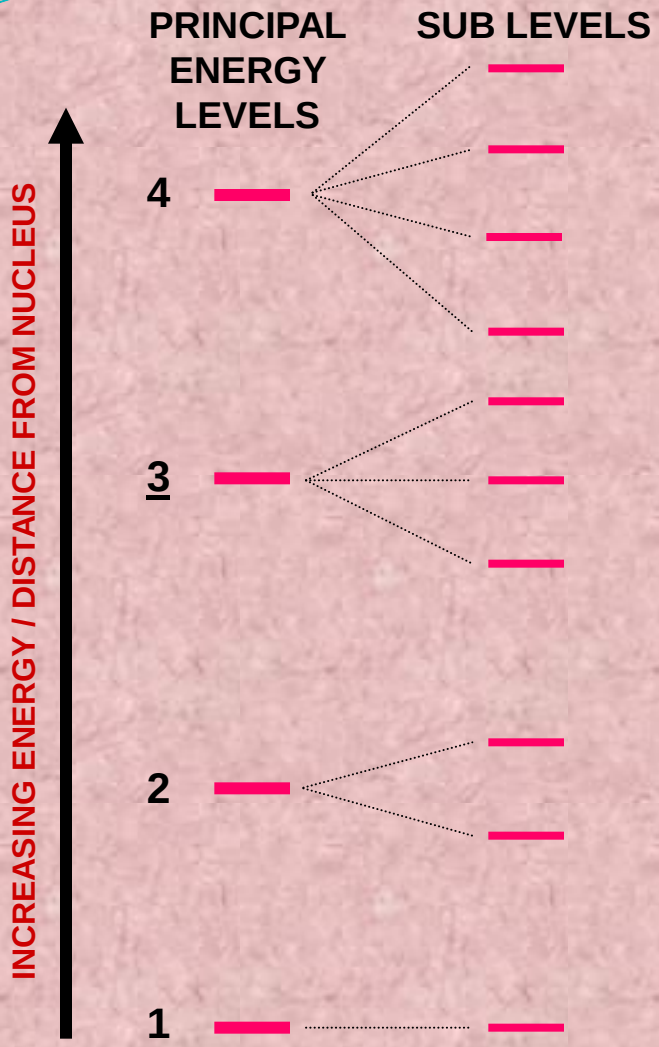
Maximum electrons per shell	
1st shell	2
2nd shell	8
3rd shell	18
4th shell	32
5th shell	50

LEVELS AND SUB-LEVELS



The **energy gap between successive levels got increasingly smaller as the levels got further from the nucleus**. The importance of this is discussed later.

LEVELS AND SUB-LEVELS



A study of Ionisation Energies and the periodic properties of elements suggested that the **main energy levels were split into sub levels**.

Level 1 was split into 1 sub level

Level 2 was split into 2 sub levels

Level 3 was split into 3 sub levels

Level 4 was split into 4 sub levels

CONTENTS

RULES AND PRINCIPLES

HEISENBERG'S UNCERTAINTY PRINCIPLE

"You cannot determine the position and momentum of an electron at the same time."

This means that you cannot say *exactly* where an electron is.

THE AUFBAU PRINCIPLE

"Electrons enter the lowest available energy level."

PAULI'S EXCLUSION PRINCIPLE

"No two electrons can have the same four quantum numbers."

Two electrons can go in each orbital, providing they are of opposite spin.

HUND'S RULE OF MAXIMUM MULTIPLICITY

"When in orbitals of equal energy, electrons will try to remain unpaired."

Placing two electrons in one orbital means that, as they are both negatively charged, there will be some electrostatic repulsion between them. Placing each electron in a separate orbital reduces the repulsion and the system is more stable. It can be described as the "SITTING ON A BUS RULE"!

ORBITALS

An orbital is... **a region in space where one is likely to find an electron.**

Orbitals **can hold up to two electrons as long as they have opposite spin**; this is known as PAULI'S EXCLUSION PRINCIPAL.

Orbitals have different shapes...

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Orbitals have different shapes...

ORBITAL	SHAPE	OCCURRENCE
s	**spherical**	**one in every principal level**
p	**dumb-bell**	**three in levels from 2 upwards**
d	**various**	**five in levels from 3 upwards**
f	**various**	**seven in levels from 4 upwards**

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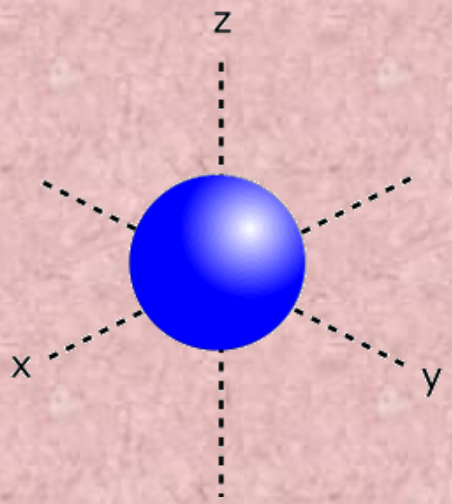
An orbital is a 3-dimensional statistical shape showing where one is most likely to find an electron. Because, according to Heisenberg, you cannot say exactly where an electron is you are only able to say where it might be found.

DO NOT CONFUSE AN ORBITAL WITH AN ORBIT

SHAPES OF ORBITALS

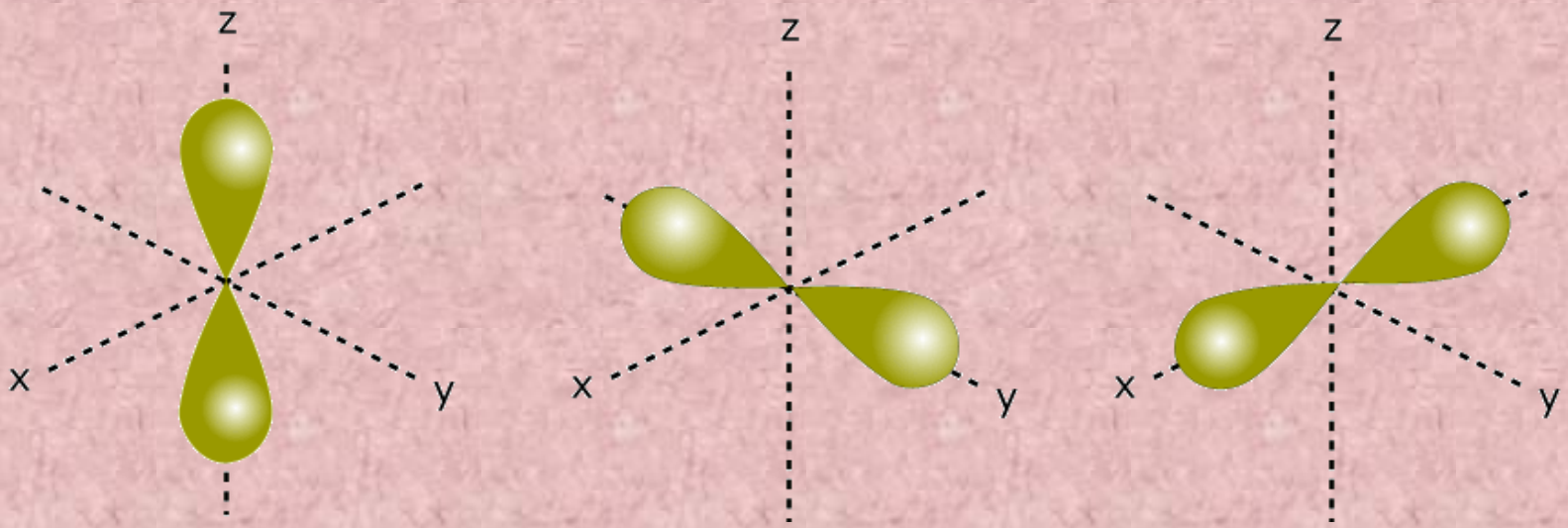
s orbitals



- spherical
- one occurs in every principal energy level

SHAPES OF ORBITALS

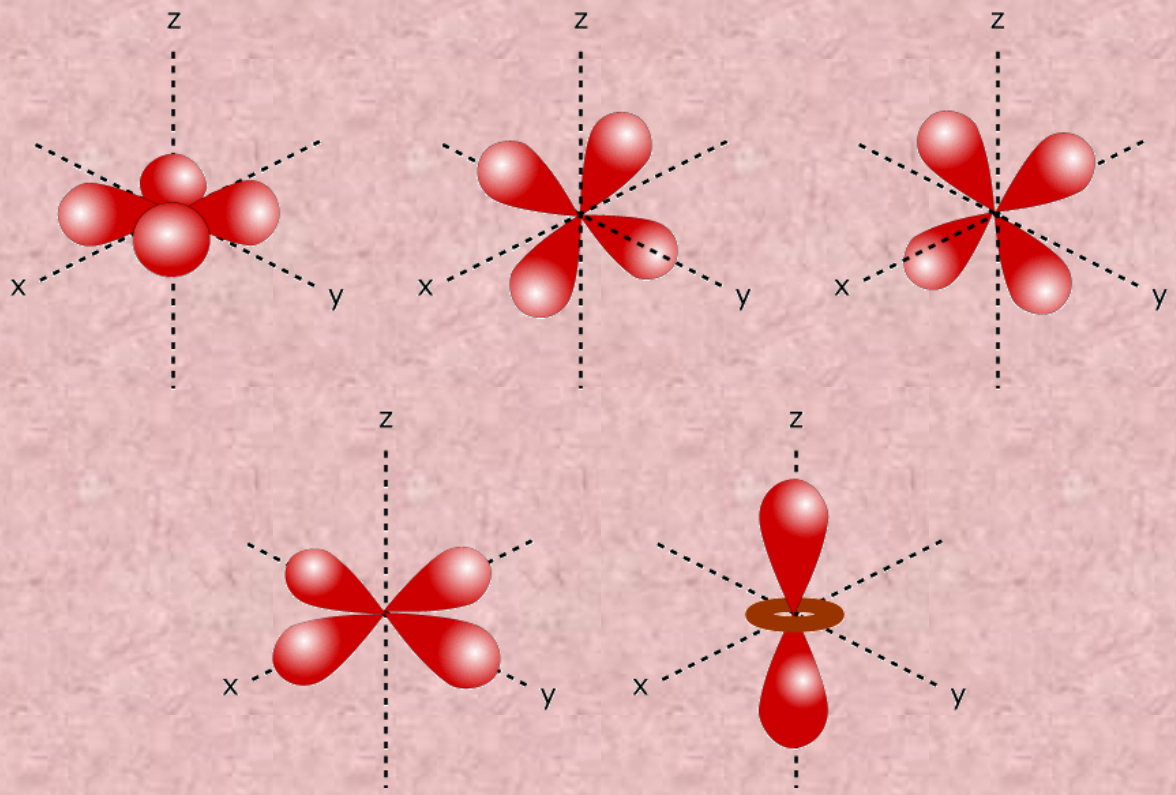
p orbitals



- dumb-bell shaped
- three occur in energy levels except the first

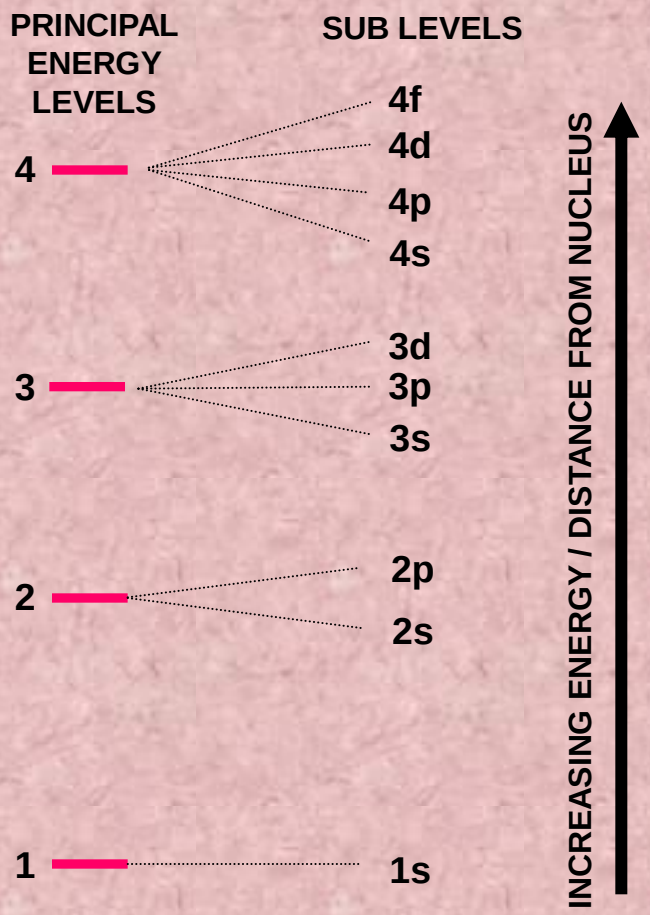
SHAPES OF ORBITALS

d orbitals



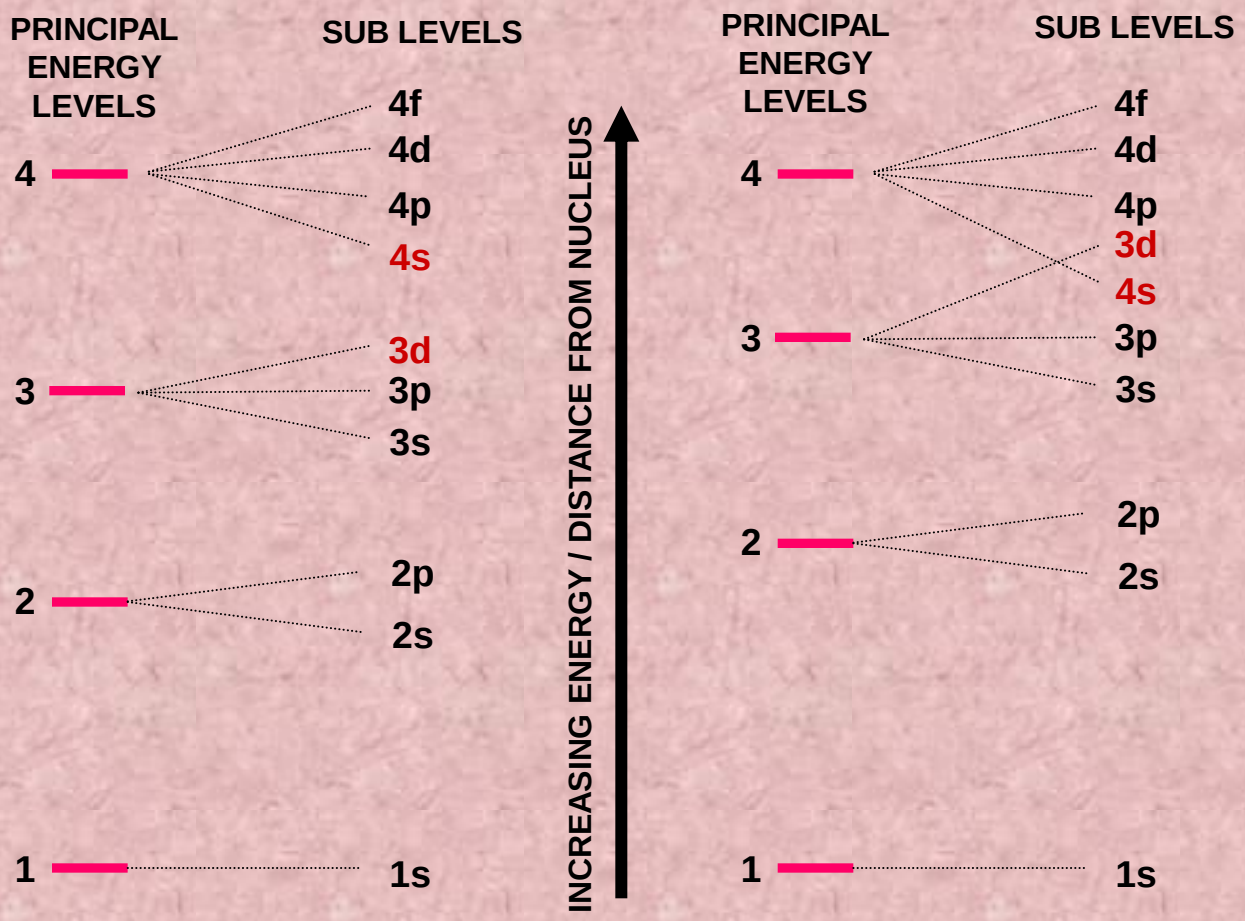
- various shapes
- five occur in energy levels except the first and second

ORDER OF FILLING ORBITALS



Orbitals are not filled in numerical order because the principal energy levels get closer together as you get further from the nucleus. This results in overlap of sub levels. The first example occurs when the 4s orbital is filled before the 3d orbitals.

ORDER OF FILLING ORBITALS



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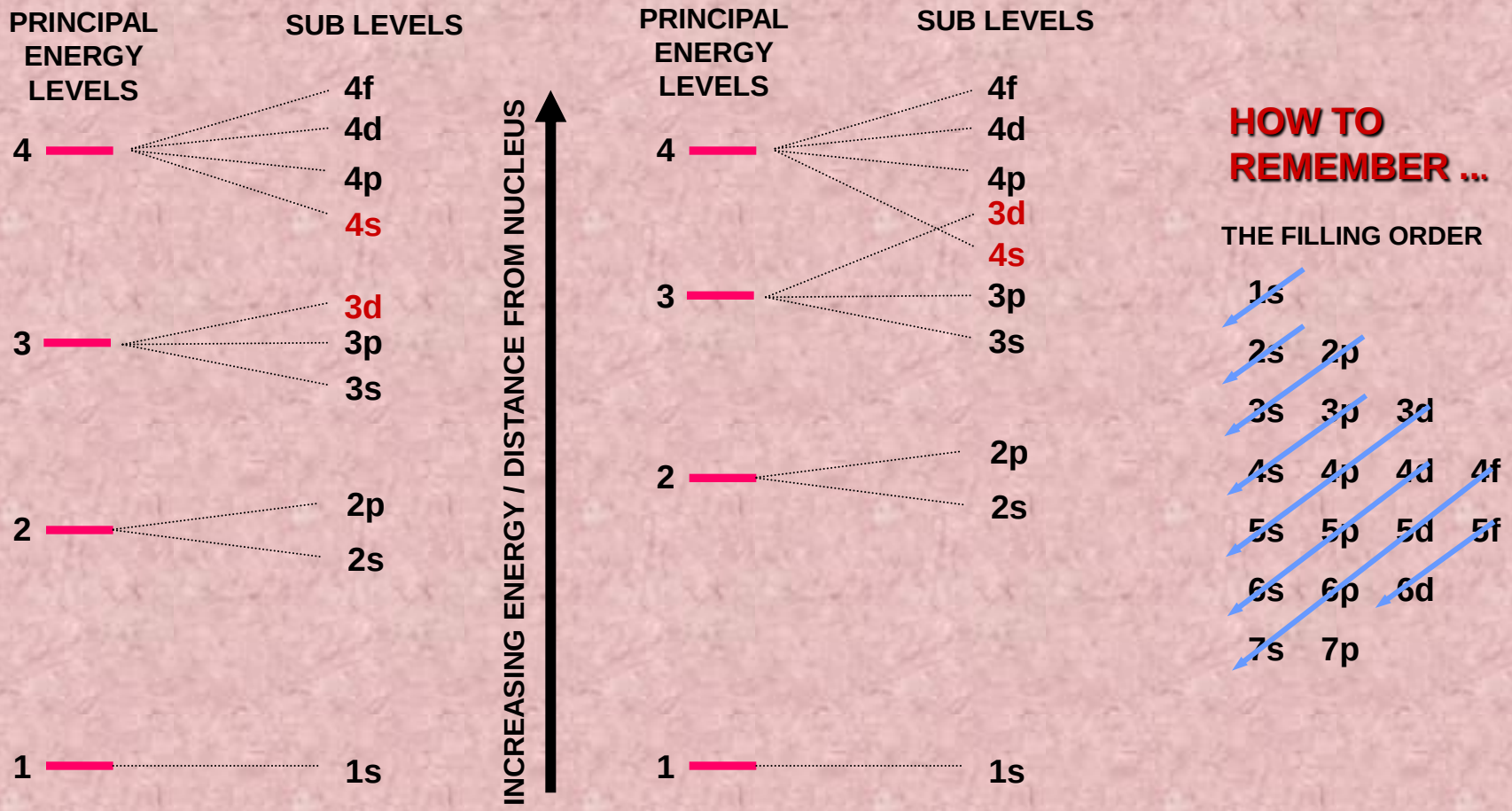

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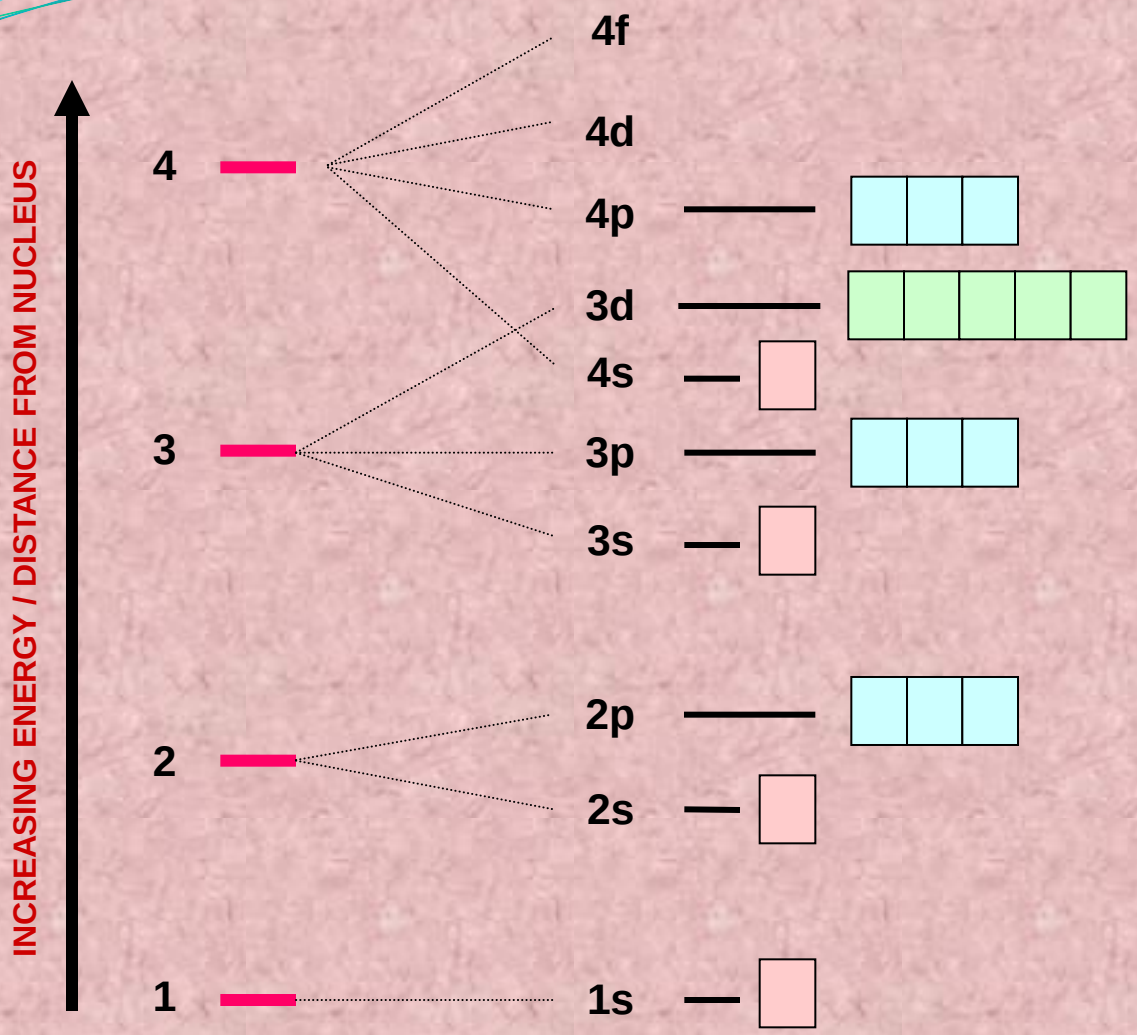
THE 'AUFBAU' PRINCIPAL



This states that…

"ELECTRONS ENTER THE LOWEST AVAILABLE ENERGY LEVEL"

The following sequence will show the 'building up' of the electronic structures of the first 36 elements in the periodic table.

Electrons are shown as half headed arrows and can spin in one of two directions

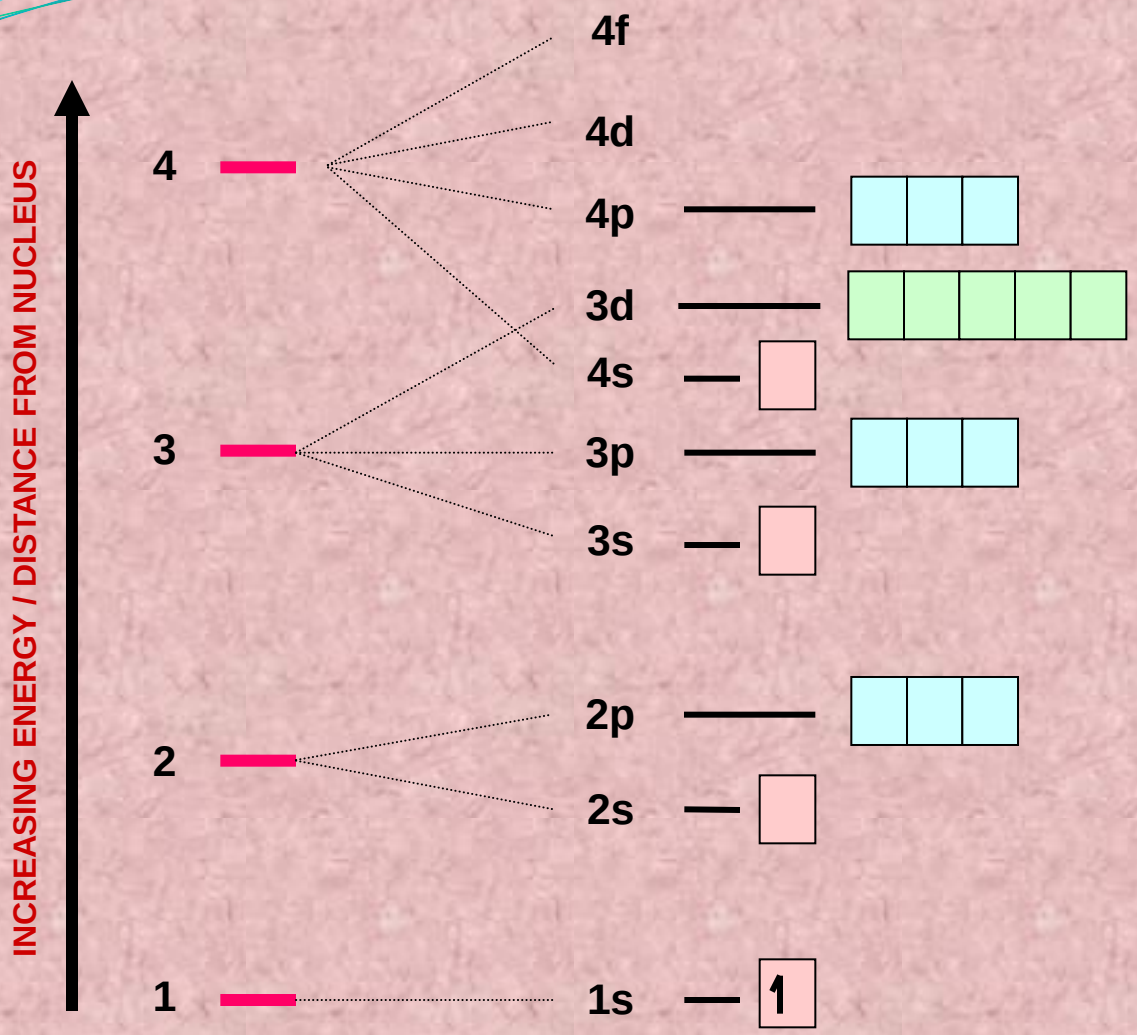
↿ or ⇂

s orbitals

p orbitals

d orbitals

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



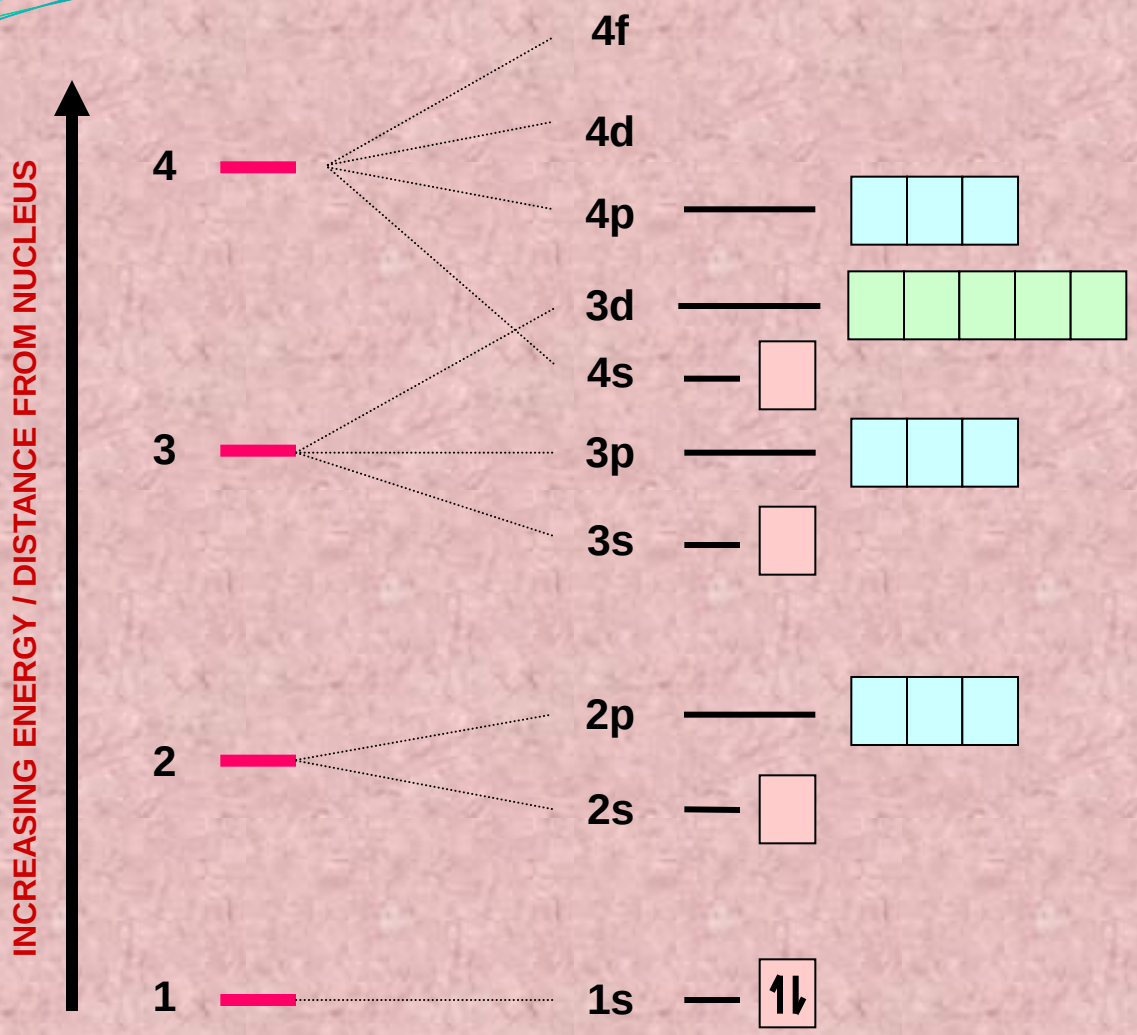
HYDROGEN

$1s^1$

Hydrogen atoms have one electron. This goes into a vacant orbital in the lowest available energy level.

'Aufbau' Principle

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



HELIUM

$1s^2$

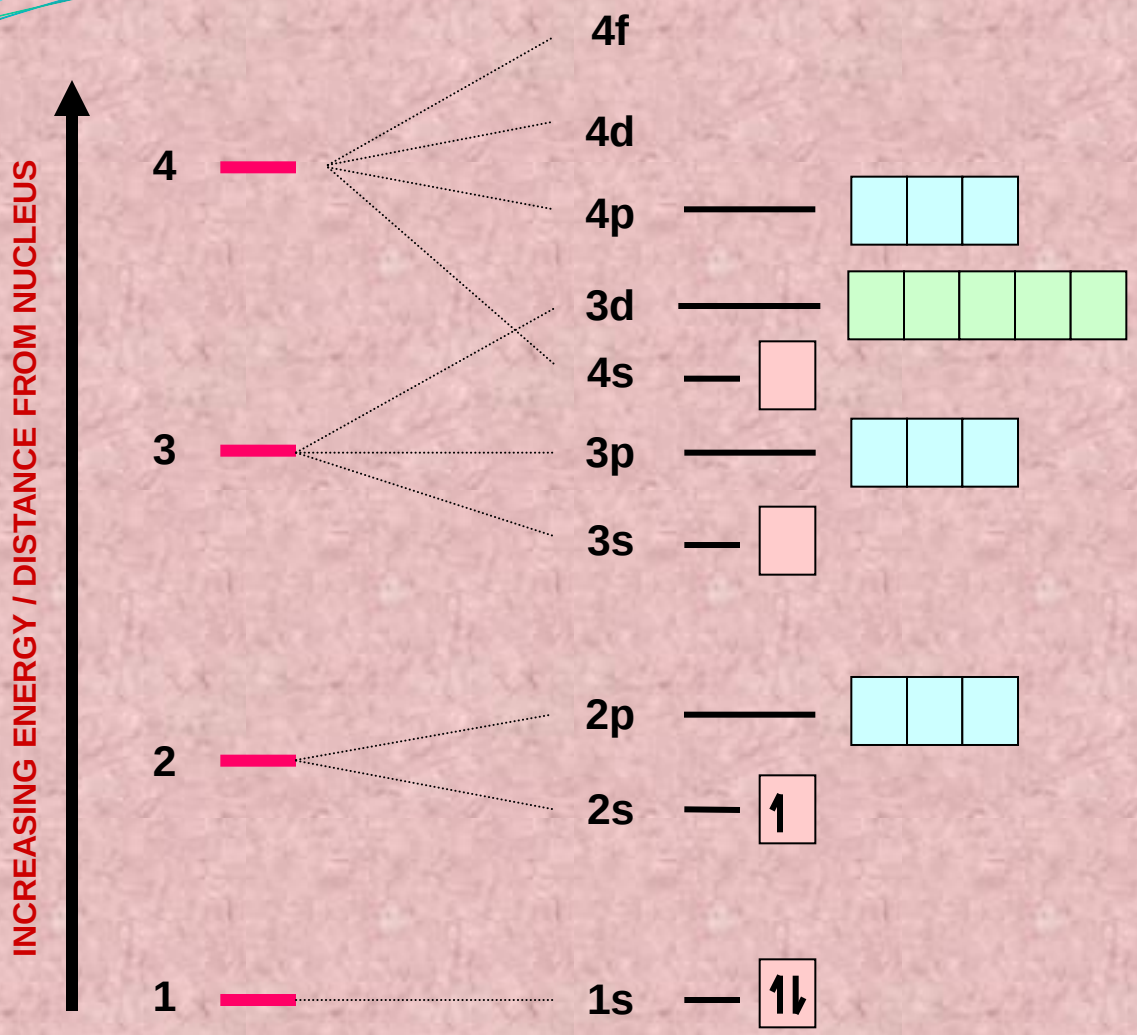
Every orbital can contain 2 electrons, provided the electrons are spinning in opposite directions. This is based on...

PAULI'S EXCLUSION PRINCIPLE

The two electrons in a helium atom can both go in the 1s orbital.

'Aufbau' Principle

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



LITHIUM

$1s^2\ 2s^1$

1s orbitals can hold a maximum of two electrons so the third electron in a lithium atom must go into the next available orbital of higher energy. This will be further from the nucleus in the second principal energy level.

The second principal level has two types of orbital (s and p). An s orbital is lower in energy than a p.

'Aufbau' Principle

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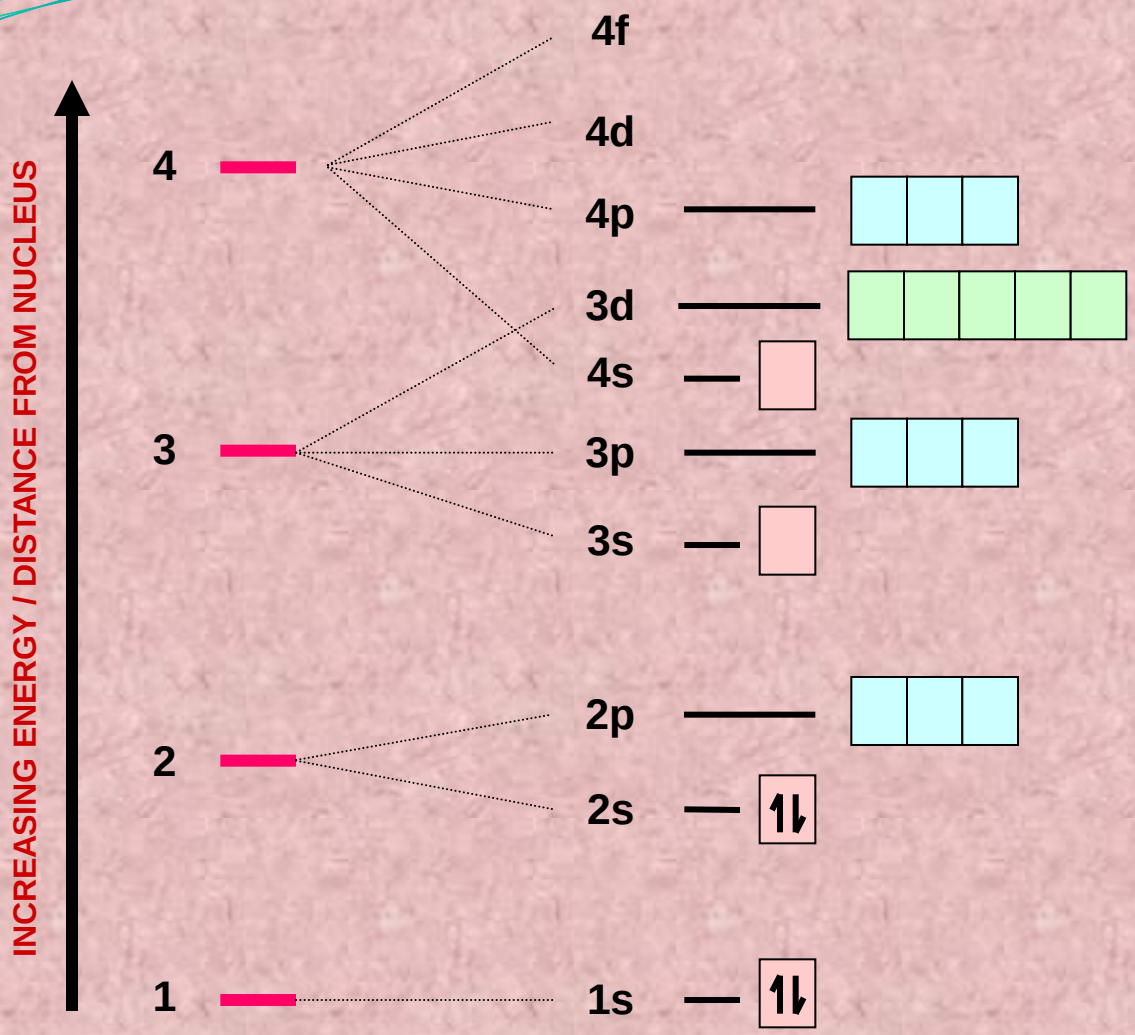


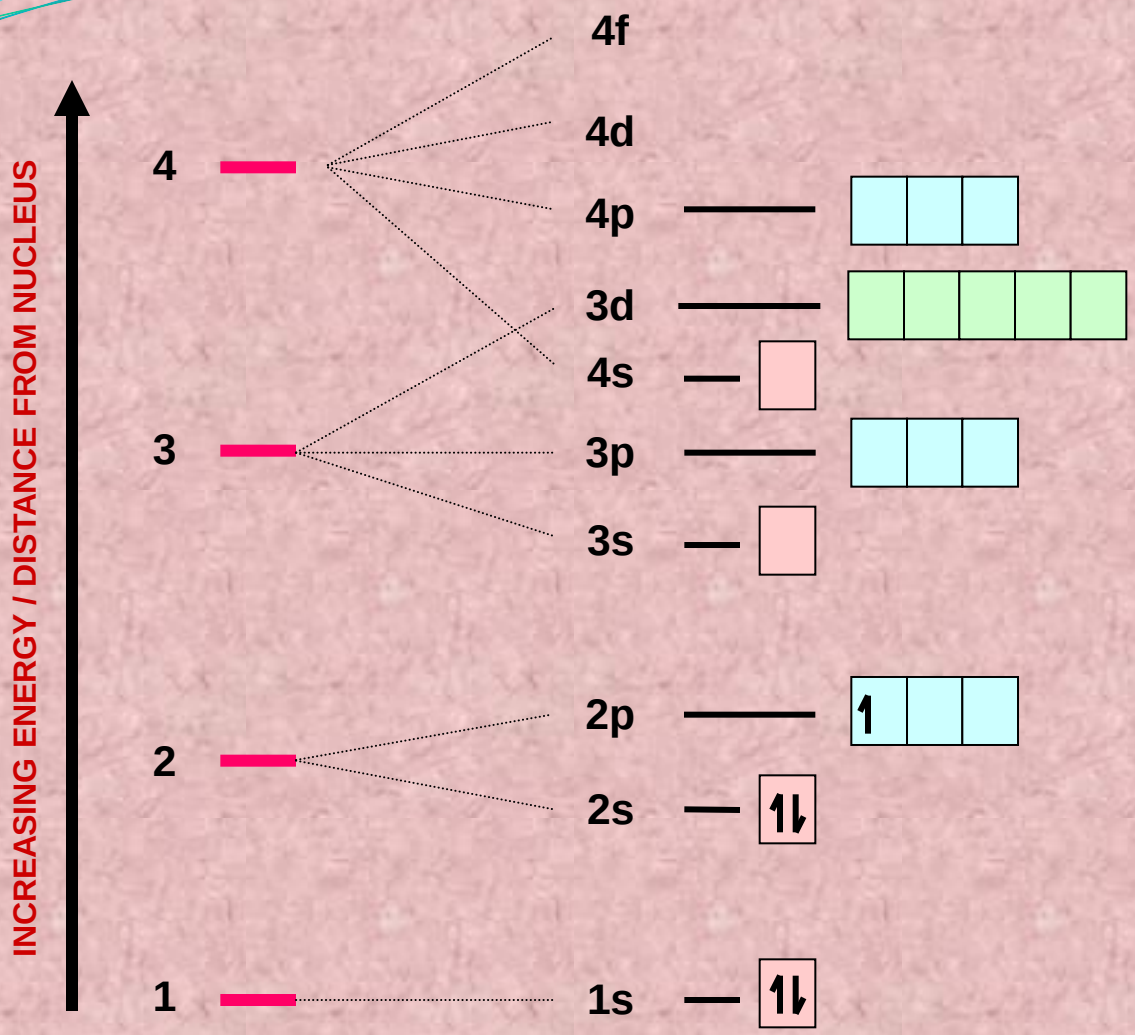
BERYLLIUM

$1s^2\ 2s^2$

Beryllium atoms have four electrons so the fourth electron pairs up in the 2s orbital. The 2s sub level is now full.

'Aufbau' Principle

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



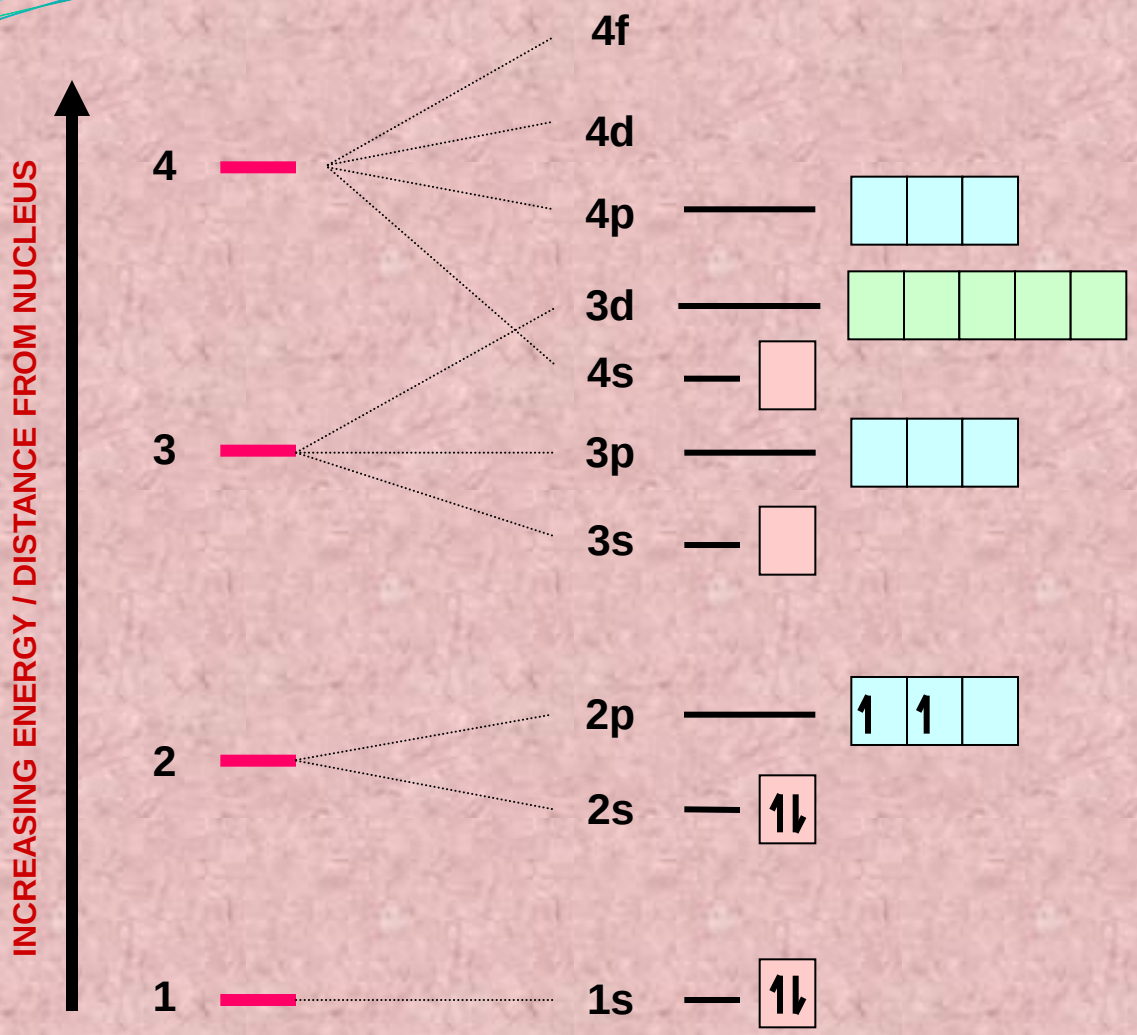
BORON

$1s^2\ 2s^2\ 2p^1$

As the 2s sub level is now full, the fifth electron goes into one of the three p orbitals in the 2p sub level. The 2p orbitals are slightly higher in energy than the 2s orbital.

'Aufbau' Principle

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



CARBON

$1s^2\ 2s^2\ 2p^2$

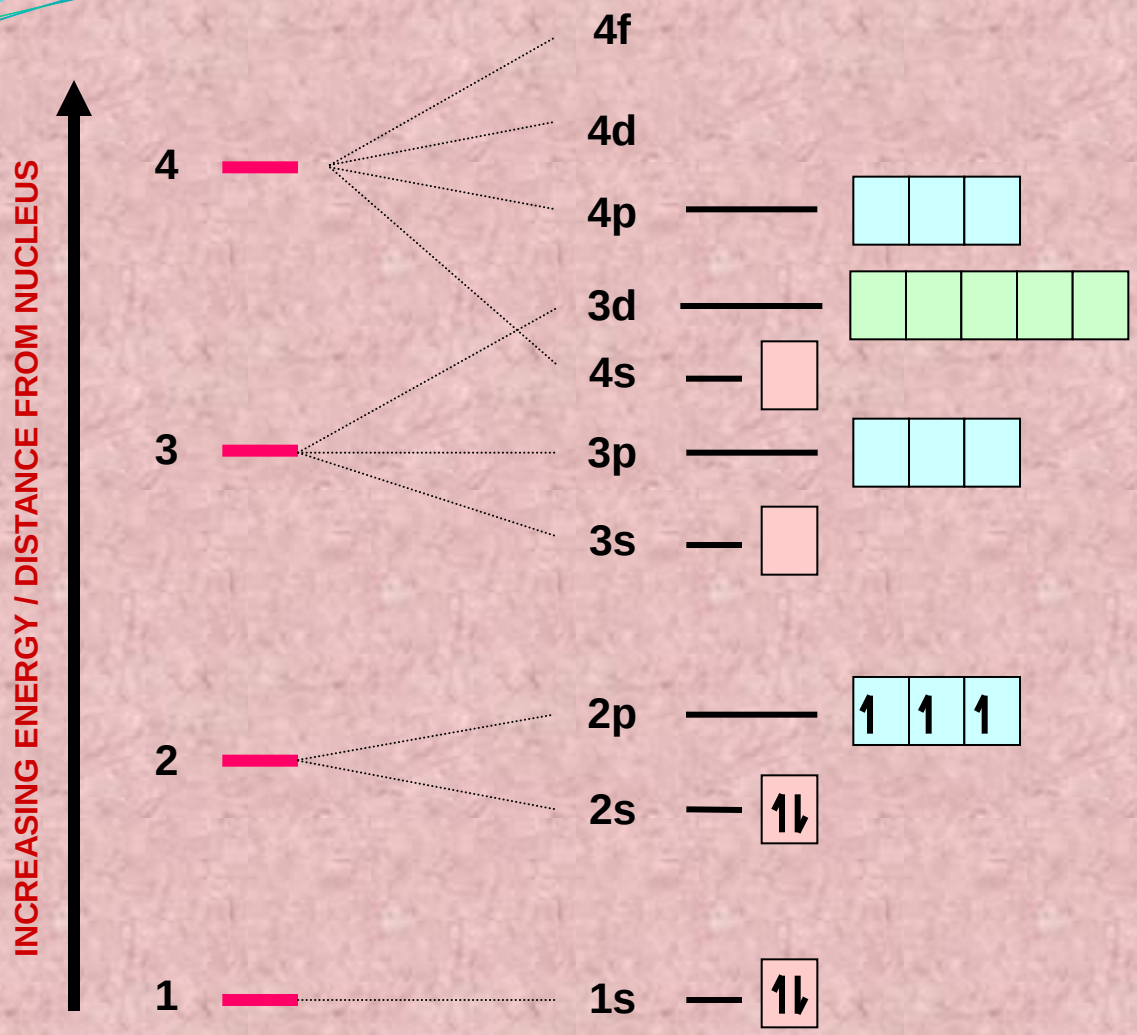
The next electron in doesn't pair up with the one already there. This would give rise to repulsion between the similarly charged species. Instead, it goes into another p orbital which means less repulsion, lower energy and more stability.

HUND'S RULE

OF

MAXIMUM MULTIPLICITY

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



NITROGEN

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

Following Hund's Rule, the next electron will not pair up so goes into a vacant p orbital. All three electrons are now unpaired. This gives less repulsion, lower energy and therefore more stability.

HUND'S RULE

OF

MAXIMUM MULTIPLICITY

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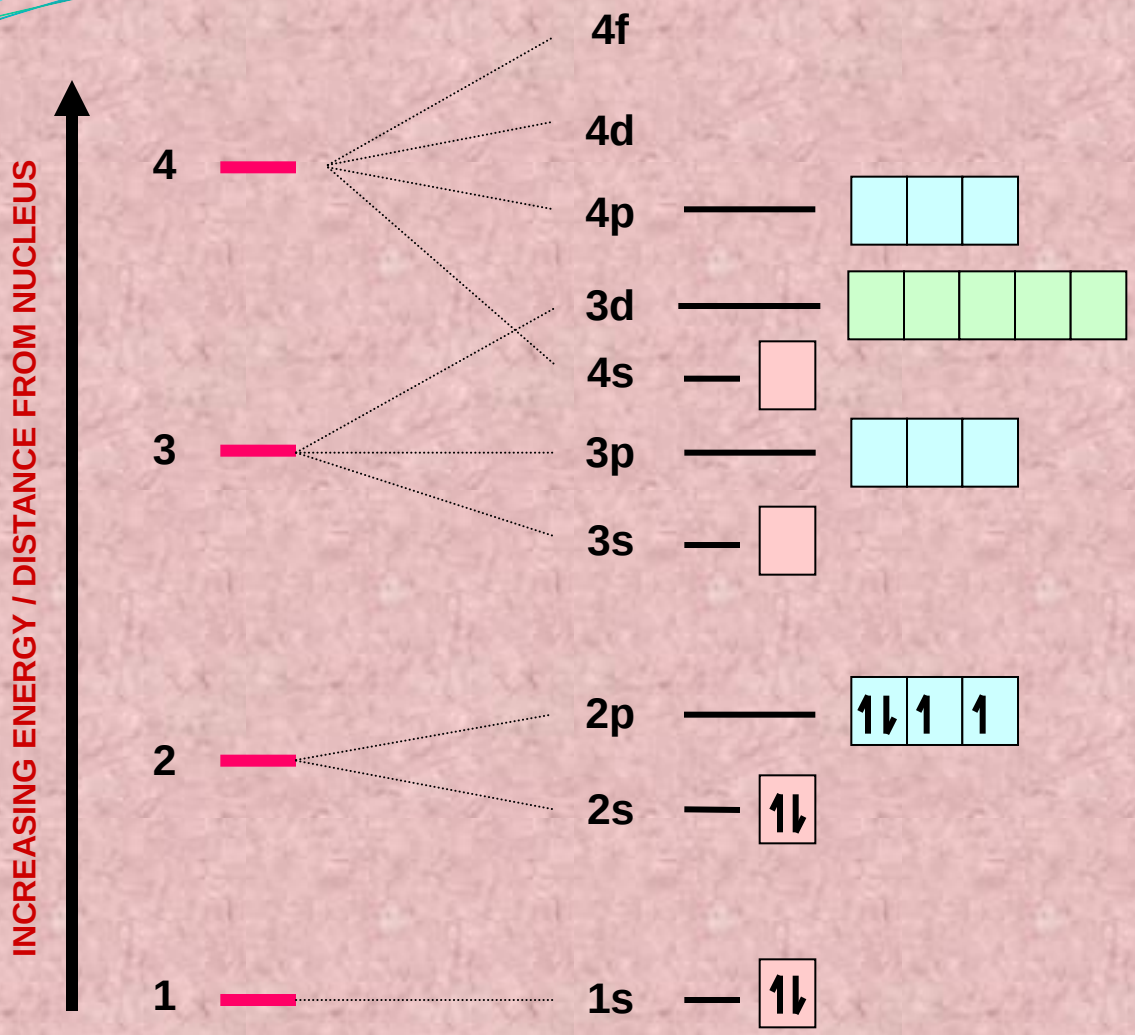


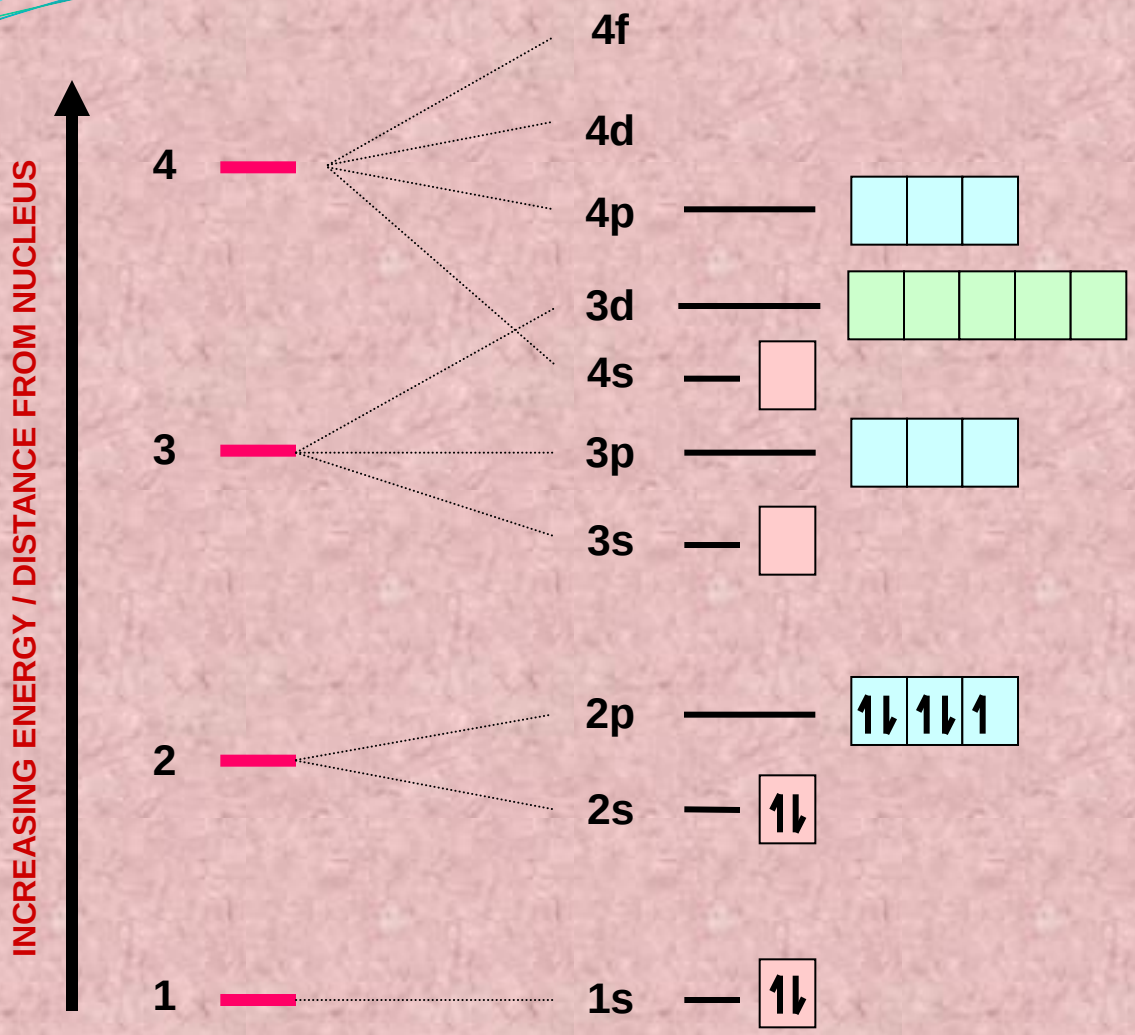
OXYGEN

$1s^2\ 2s^2\ 2p^4$

With all three orbitals half-filled, the eighth electron in an oxygen atom must now pair up with one of the electrons already there.

'Aufbau' Principle

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS

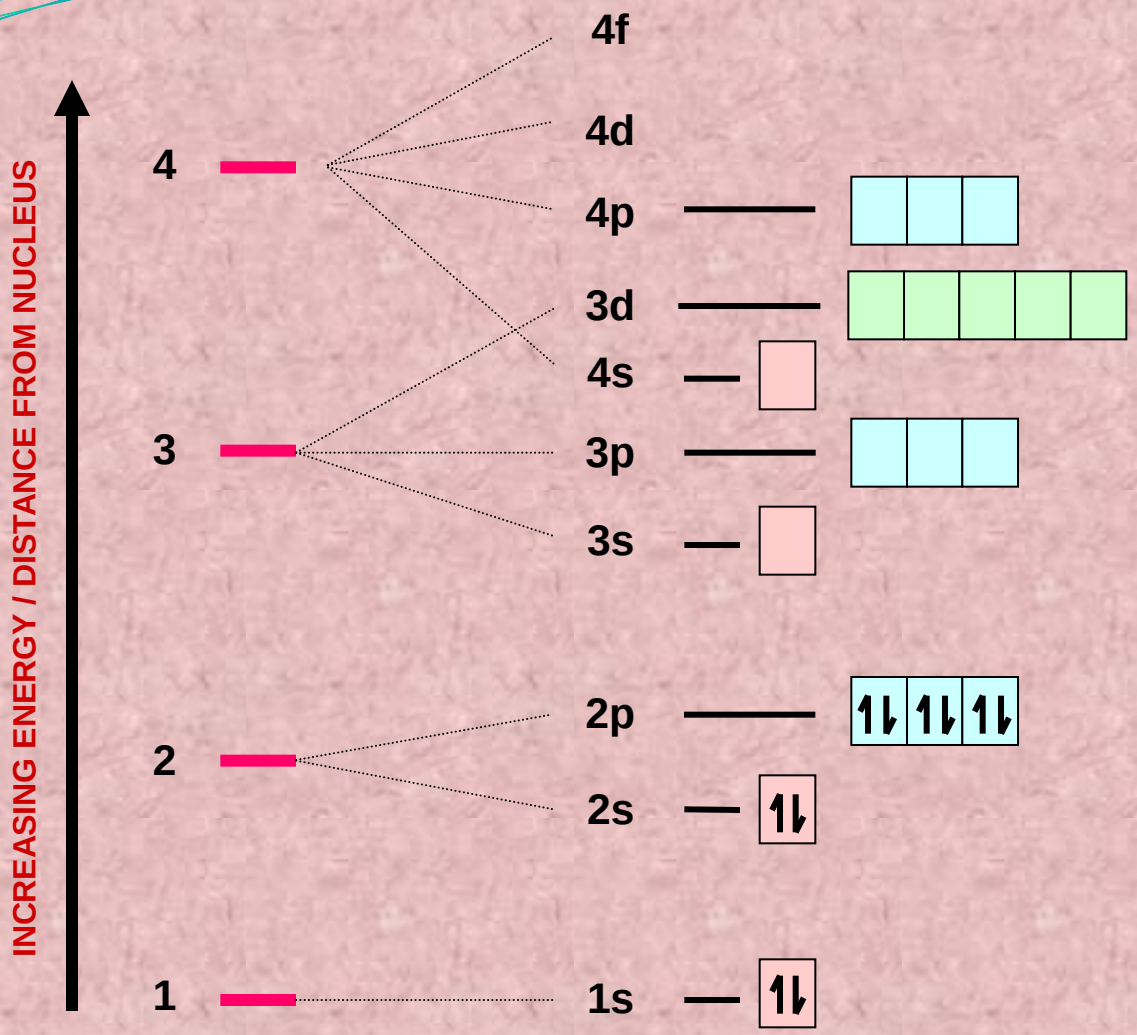


FLUORINE

$1s^2\ 2s^2\ 2p^5$

The electrons continue to pair up with those in the half-filled orbitals.

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



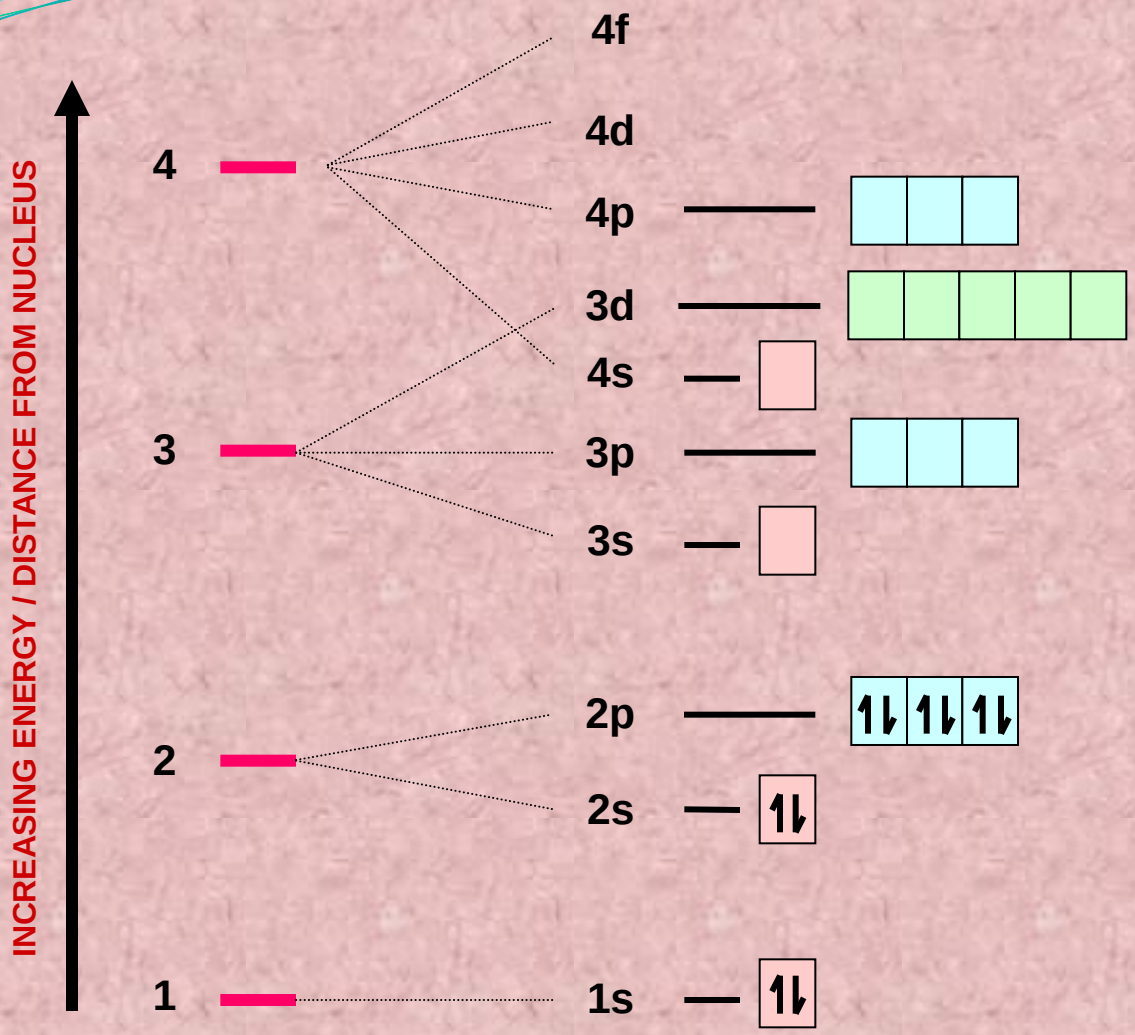
NEON

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

The electrons continue to pair up with those in the half-filled orbitals. The 2p orbitals are now completely filled and so is the second principal energy level.

In the older system of describing electronic configurations, this would have been written as 2,8.

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



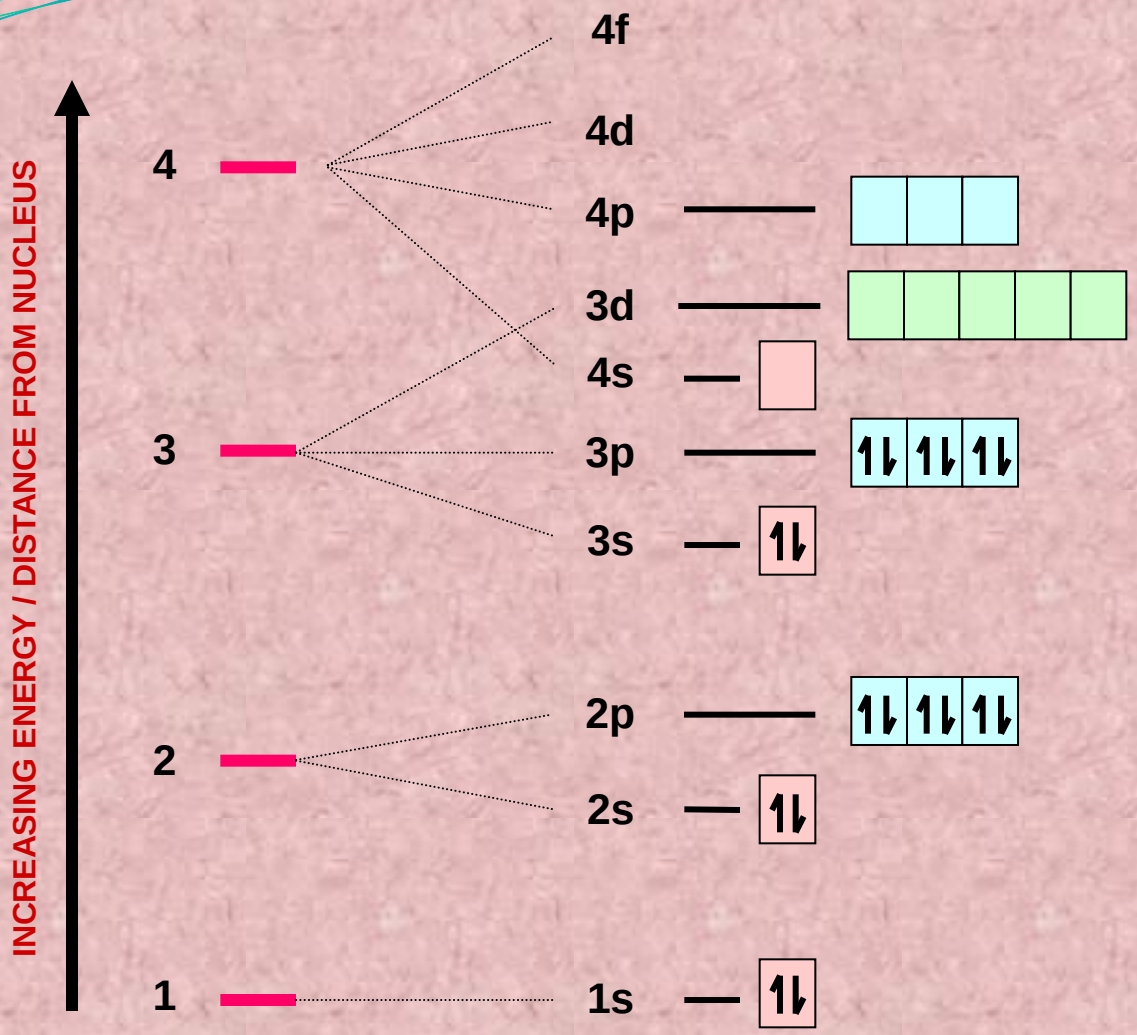
SODIUM - ARGON

With the second principal energy level full, the next electrons must go into the next highest level. The third principal energy level contains three types of orbital; s, p and d.

The 3s and 3p orbitals are filled in exactly the same way as those in the 2s and 2p sub levels.

'Aufbau' Principle

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS

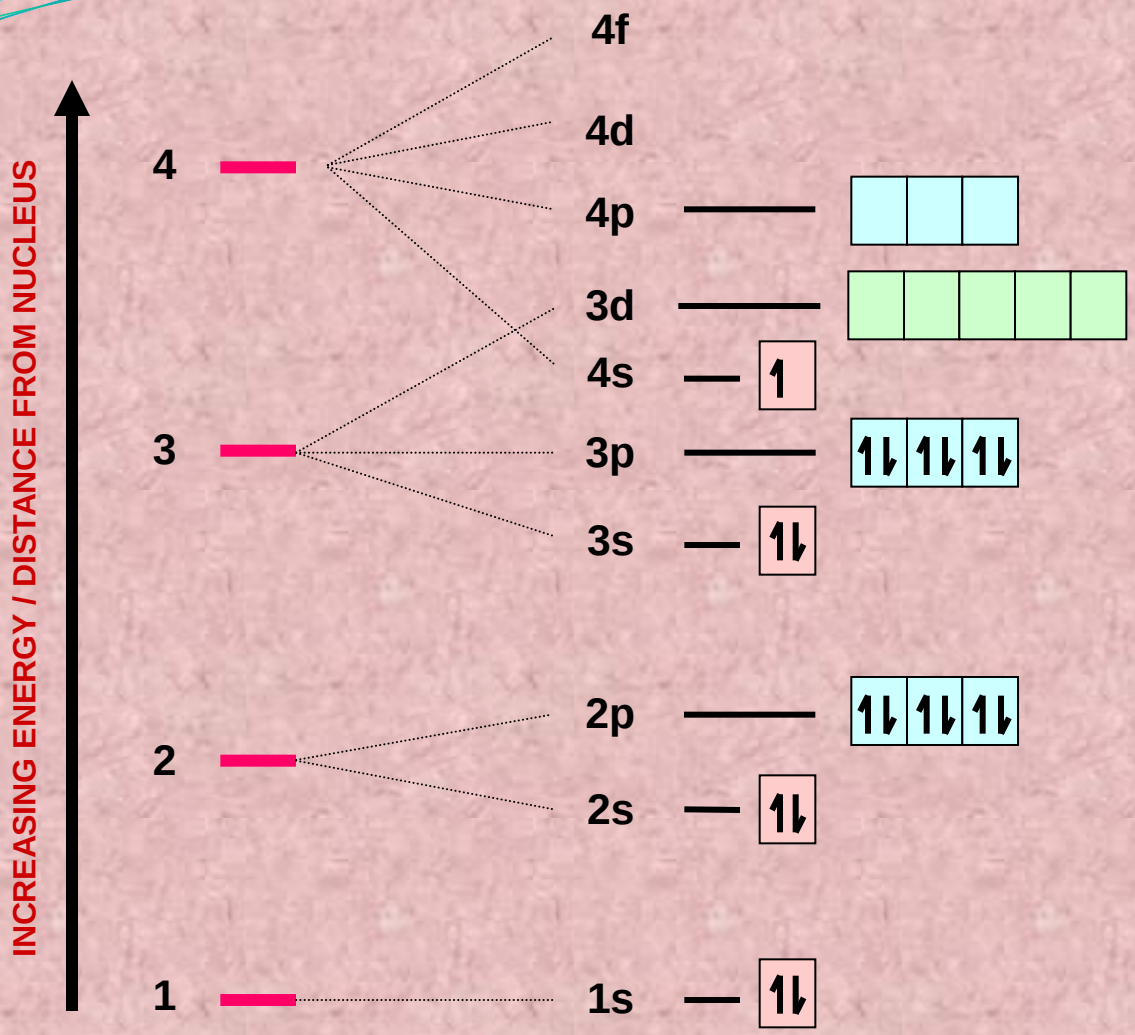


SODIUM - ARGON

Na	$1s^2\ 2s^2\ 2p^6\ 3s^1$
Mg	$1s^2\ 2s^2\ 2p^6\ 3s^2$
Al	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$
Si	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$
P	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$
S	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$
Cl	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$
Ar	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

Remember that the 3p configurations follow Hund's Rule with the electrons remaining unpaired to give more stability.

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



POTASSIUM

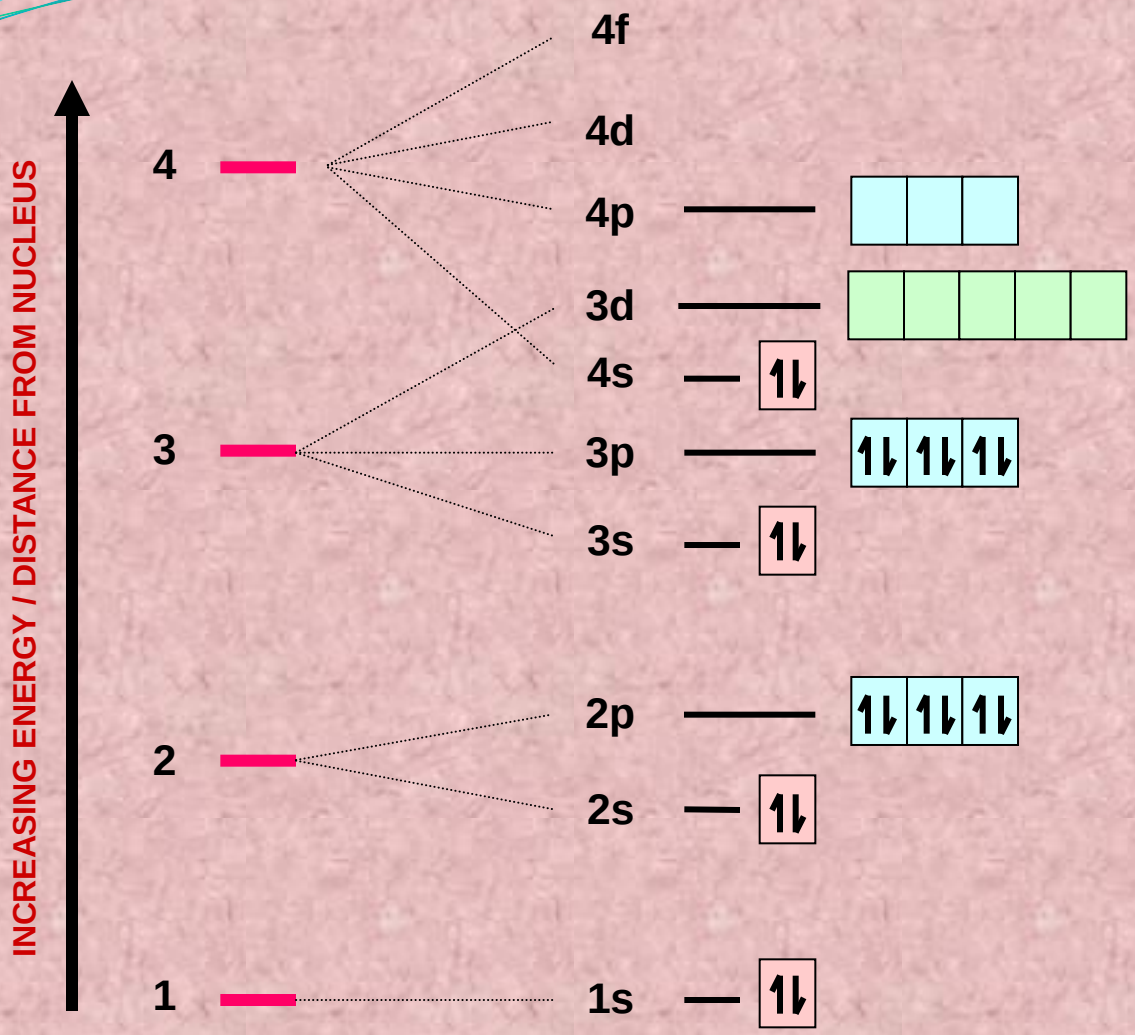
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$

In numerical terms one would expect the 3d orbitals to be filled next.

However, because the principal energy levels get closer together as you go further from the nucleus coupled with the splitting into sub energy levels, the 4s orbital is of a LOWER ENERGY than the 3d orbitals so gets filled first.

'Aufbau' Principle

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



CALCIUM

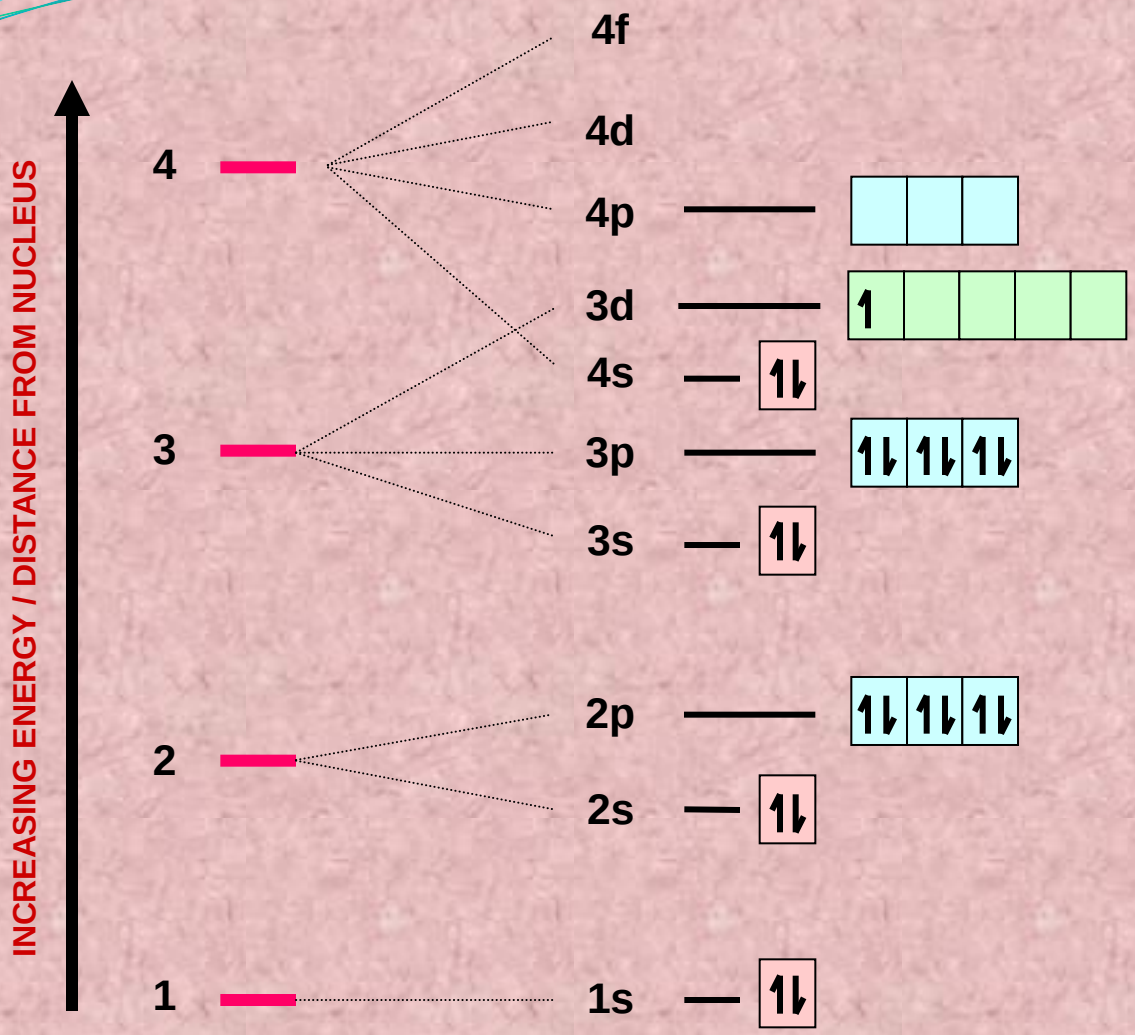
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

As expected, the next electron pairs up to complete a filled 4s orbital.

This explanation, using sub levels fits in with the position of potassium and calcium in the Periodic Table. All elements with an $-s^1$ electronic configuration are in Group I and all with an $-s^2$ configuration are in Group II.

'Aufbau' Principle

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



SCANDIUM

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^1$

With the lower energy 4s orbital filled, the next electrons can now fill the 3d orbitals. There are five d orbitals. They are filled according to Hund's Rule -

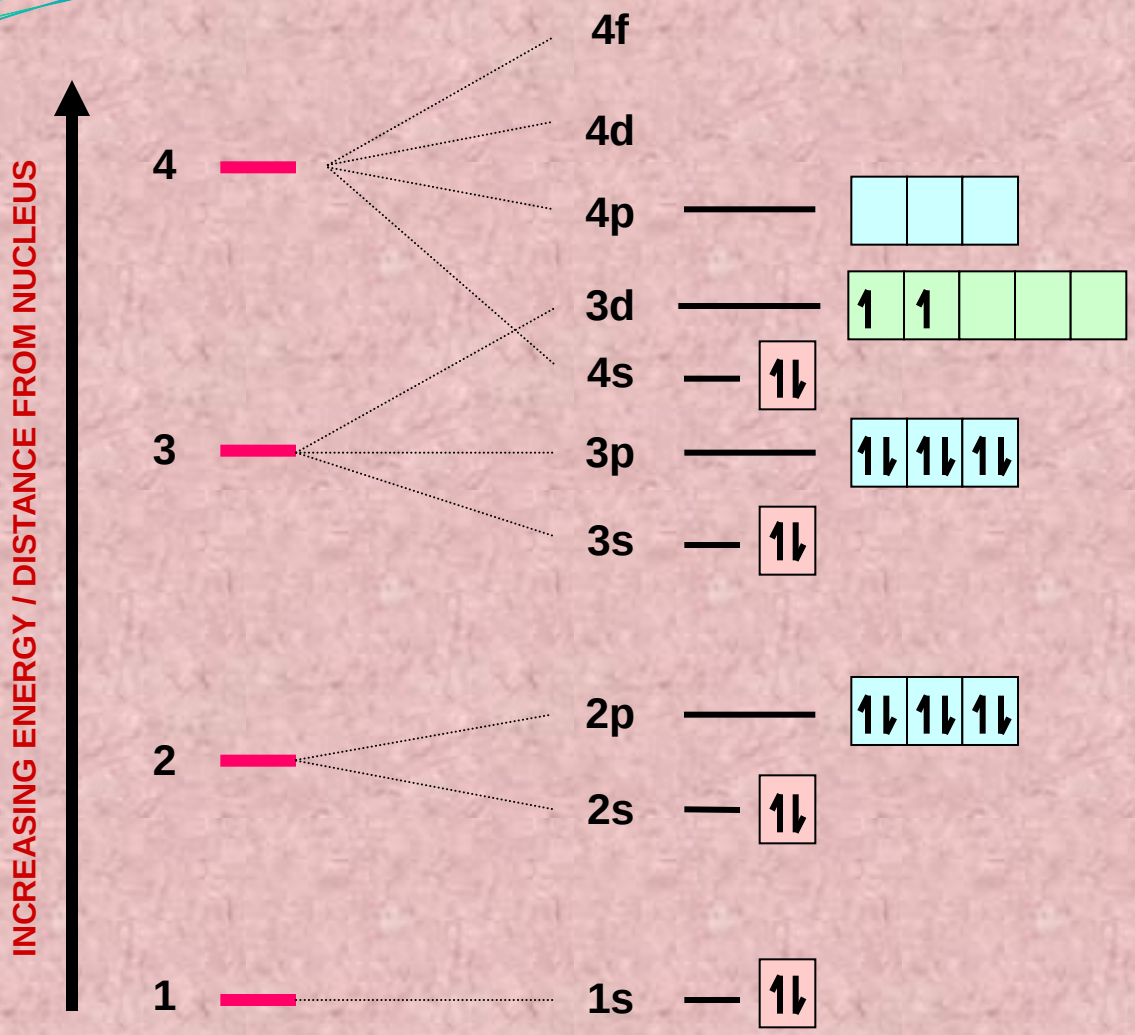
BUT WATCH OUT FOR TWO SPECIAL CASES.

HUND'S RULE

OF

MAXIMUM MULTIPLICITY

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



TITANIUM

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^2$

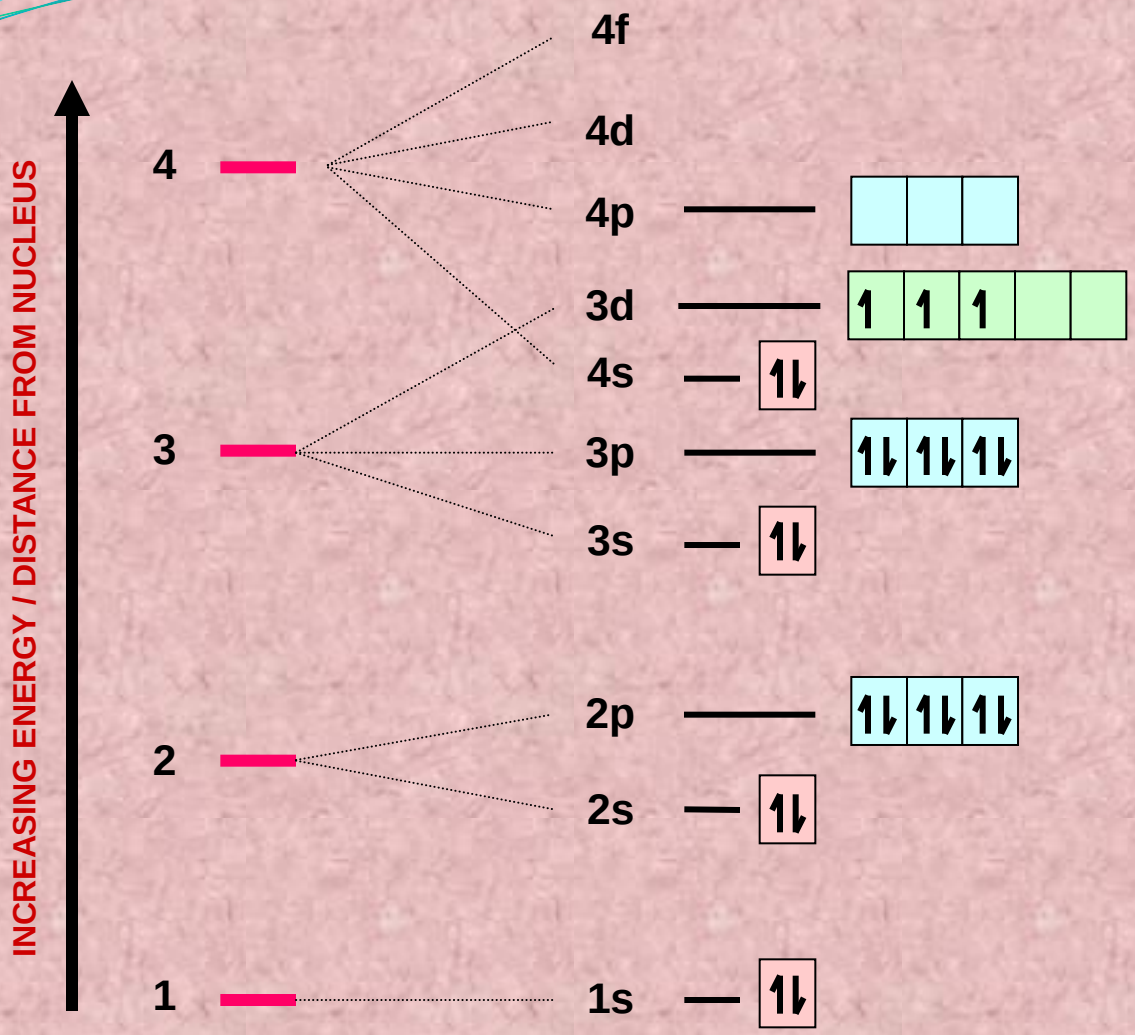
The 3d orbitals are filled according to Hund's rule so the next electron doesn't pair up but goes into an empty orbital in the same sub level.

HUND'S RULE

OF

MAXIMUM MULTIPLICITY

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



VANADIUM

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^3$

The 3d orbitals are filled according to Hund's rule so the next electron doesn't pair up but goes into an empty orbital in the same sub level.

HUND'S RULE

OF

MAXIMUM MULTIPLICITY

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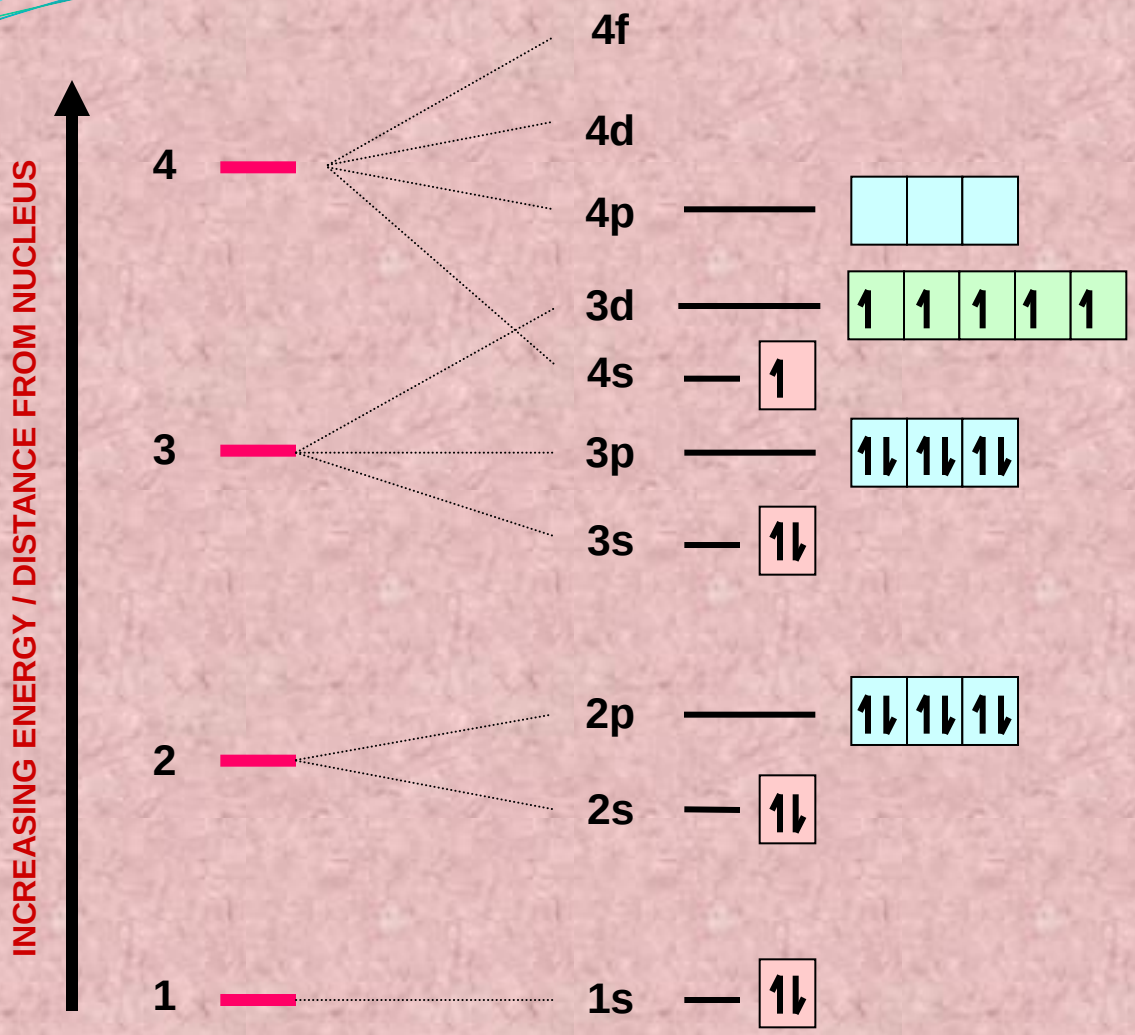


CHROMIUM

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5$

One would expect the configuration of chromium atoms to end in $4s^2\ 3d^4$.

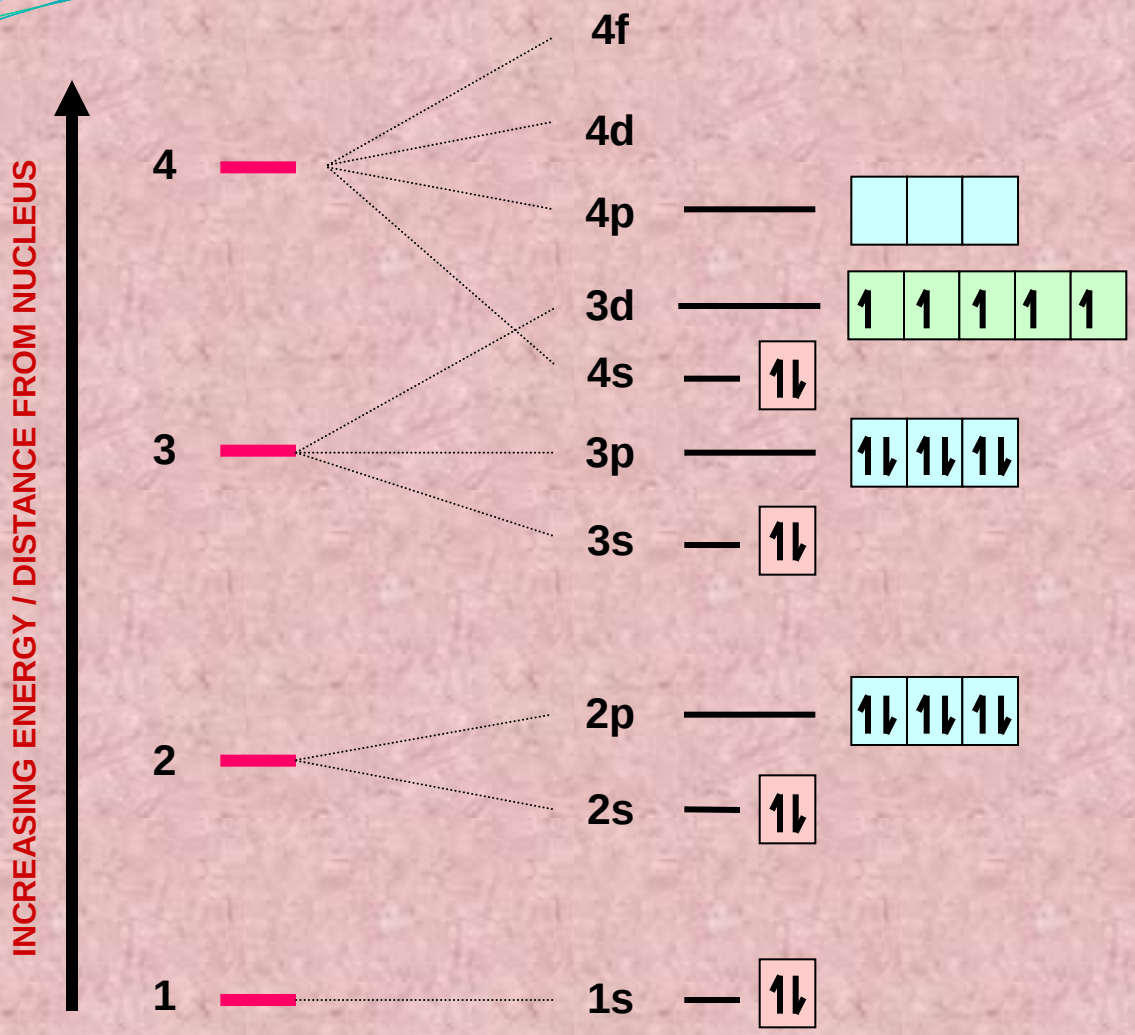
To achieve a more stable arrangement of lower energy, one of the 4s electrons is promoted into the 3d to give six unpaired electrons with lower repulsion.

HUND'S RULE

OF

MAXIMUM MULTIPLICITY

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



MANGANESE

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^5$

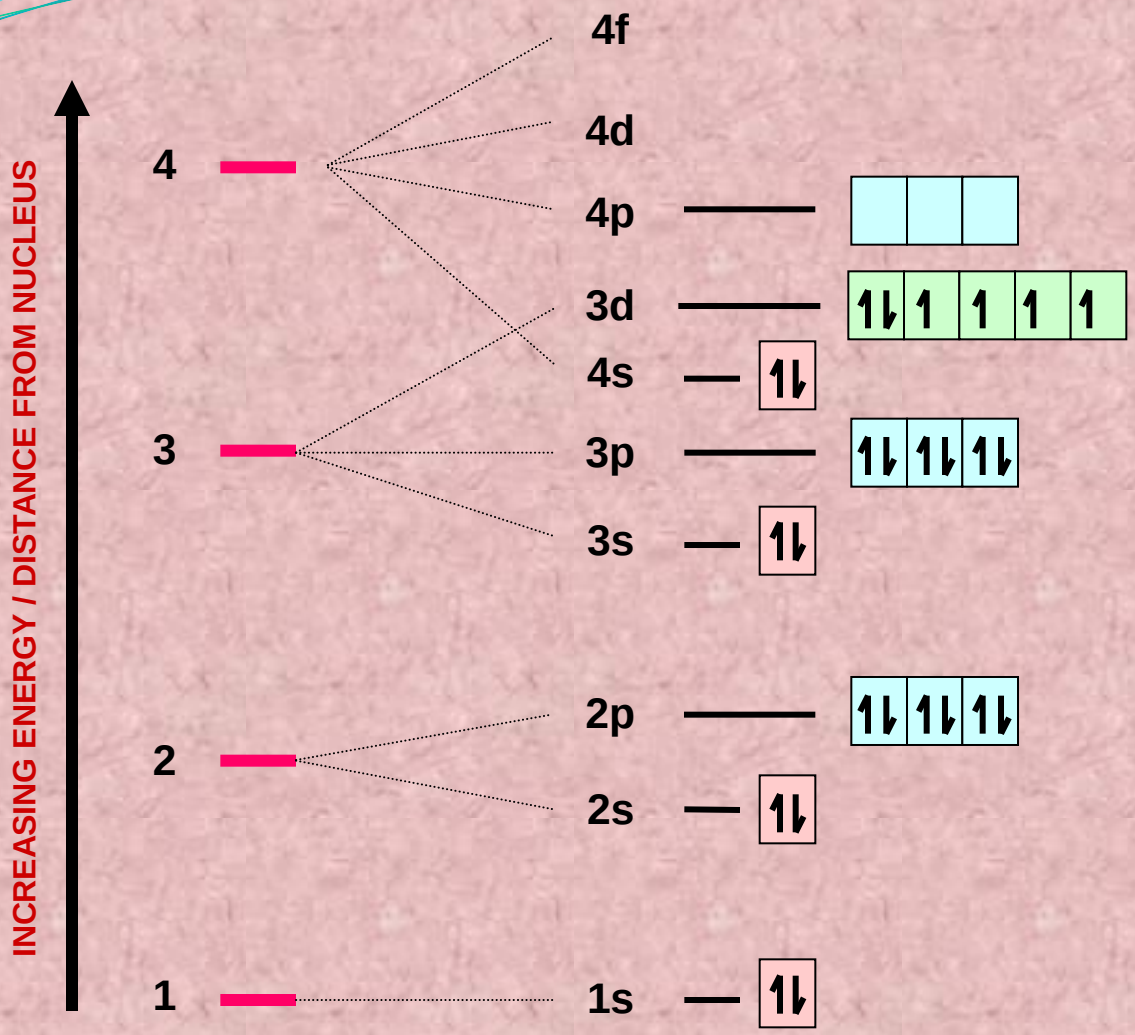
The new electron goes into the 4s to restore its filled state.

HUND'S RULE

OF

MAXIMUM MULTIPLICITY

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



IRON

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^6$

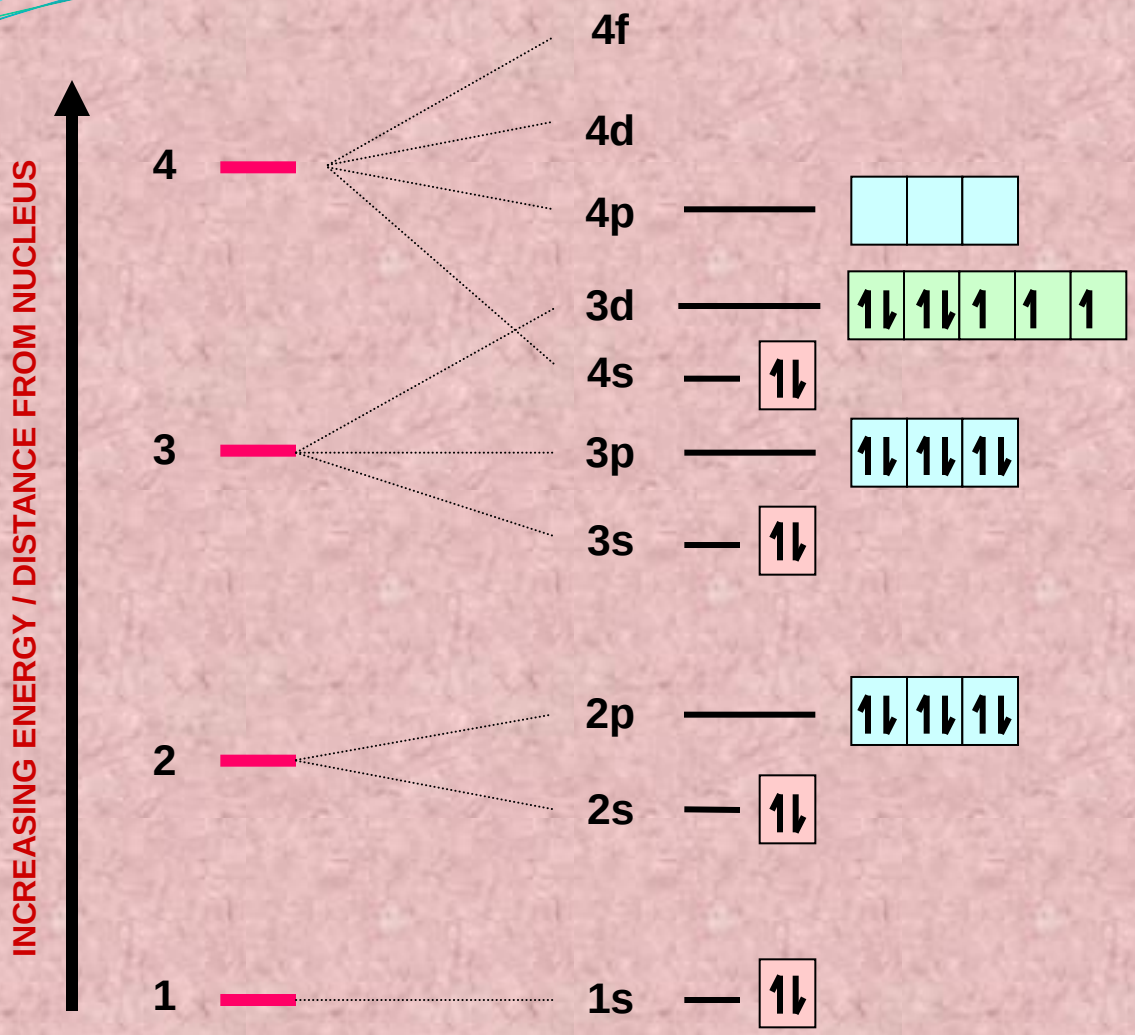
Orbitals are filled according to Hund's Rule. They continue to pair up.

HUND'S RULE

OF

MAXIMUM MULTIPLICITY

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



COBALT

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^7$

Orbitals are filled according to Hund's Rule. They continue to pair up.

HUND'S RULE

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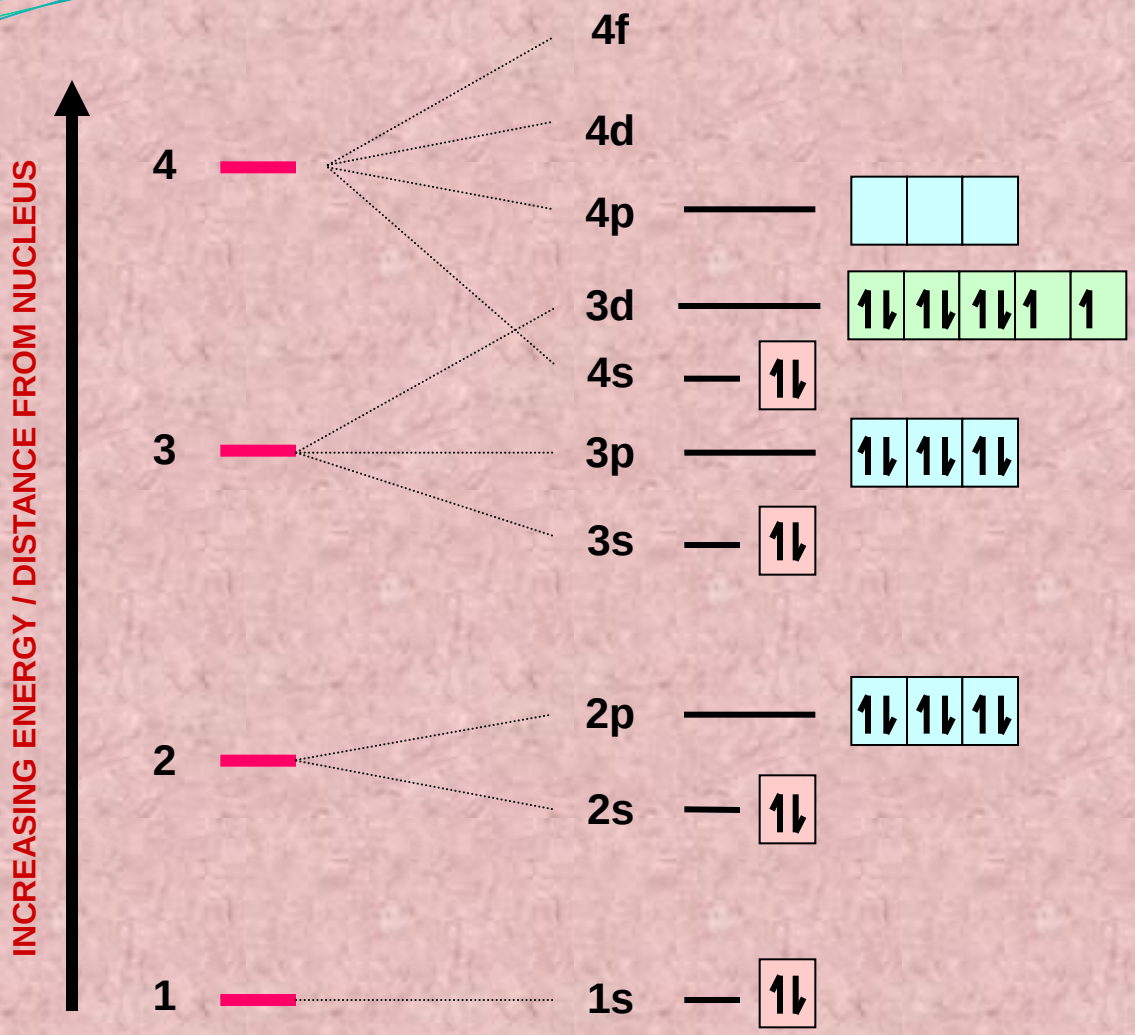
THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



NICKEL

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^8$

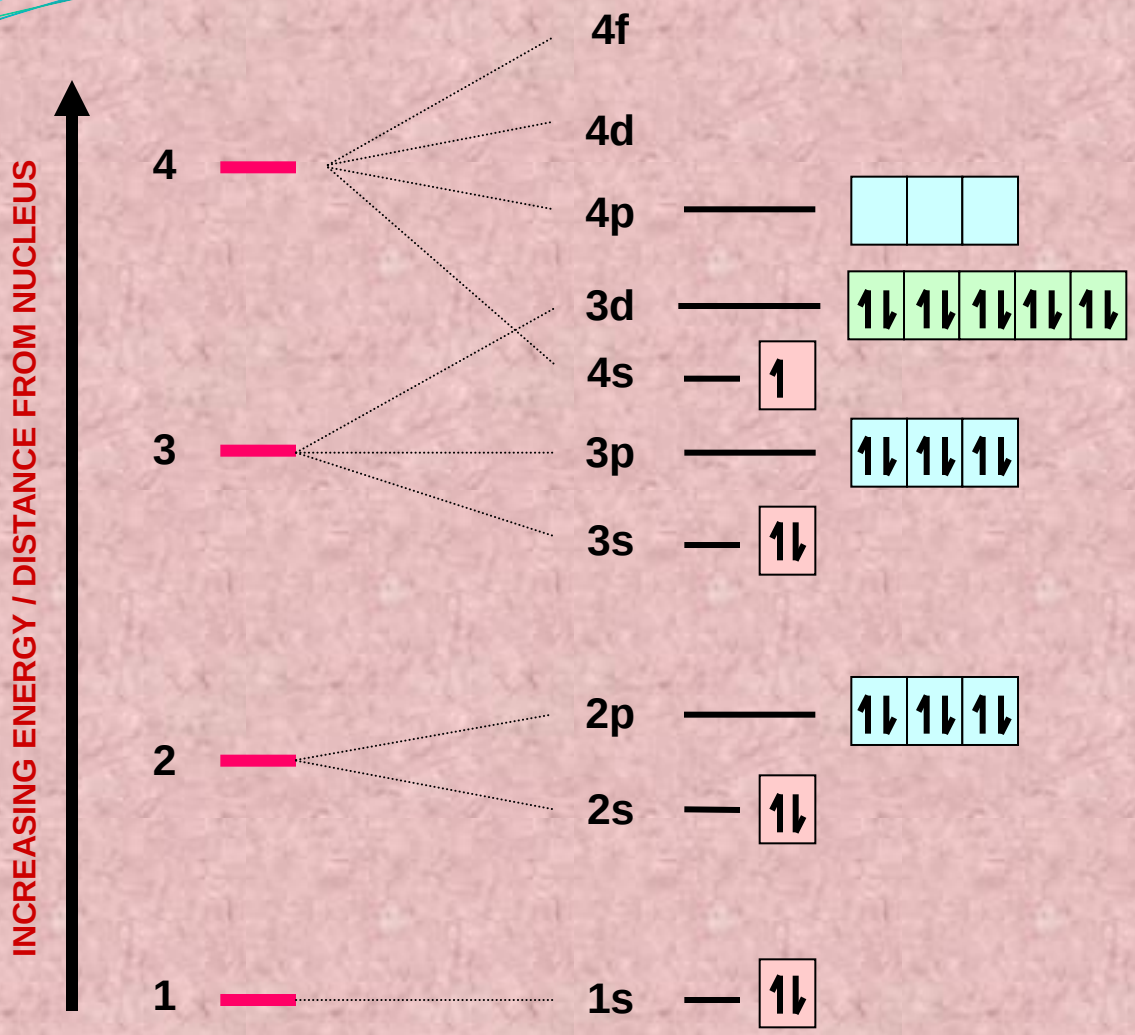
Orbitals are filled according to Hund's Rule. They continue to pair up.

HUND'S RULE

OF

MAXIMUM MULTIPLICITY

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



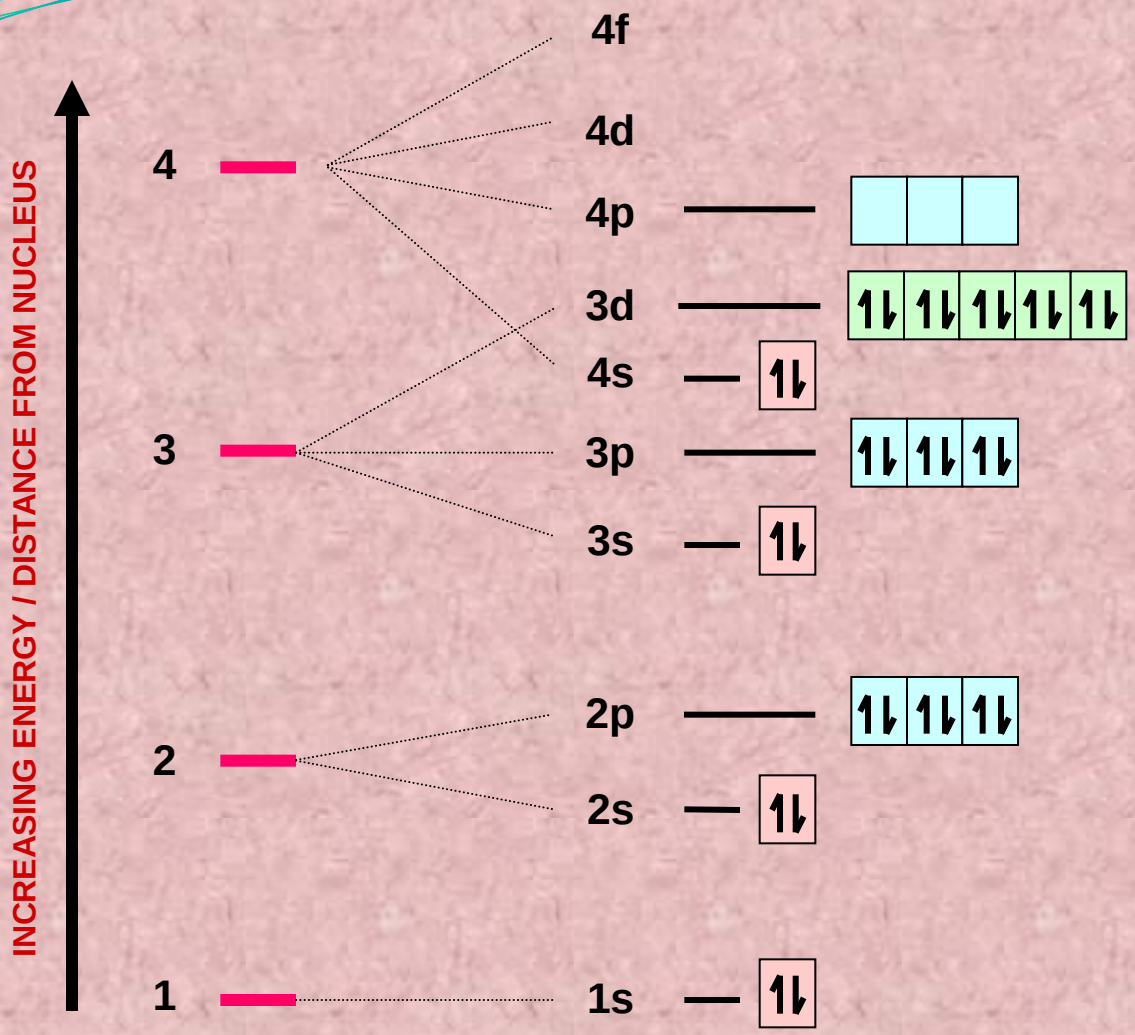
COPPER

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^{10}$

One would expect the configuration of chromium atoms to end in $4s^2\ 3d^9$.

To achieve a more stable arrangement of lower energy, one of the 4s electrons is promoted into the 3d.

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS

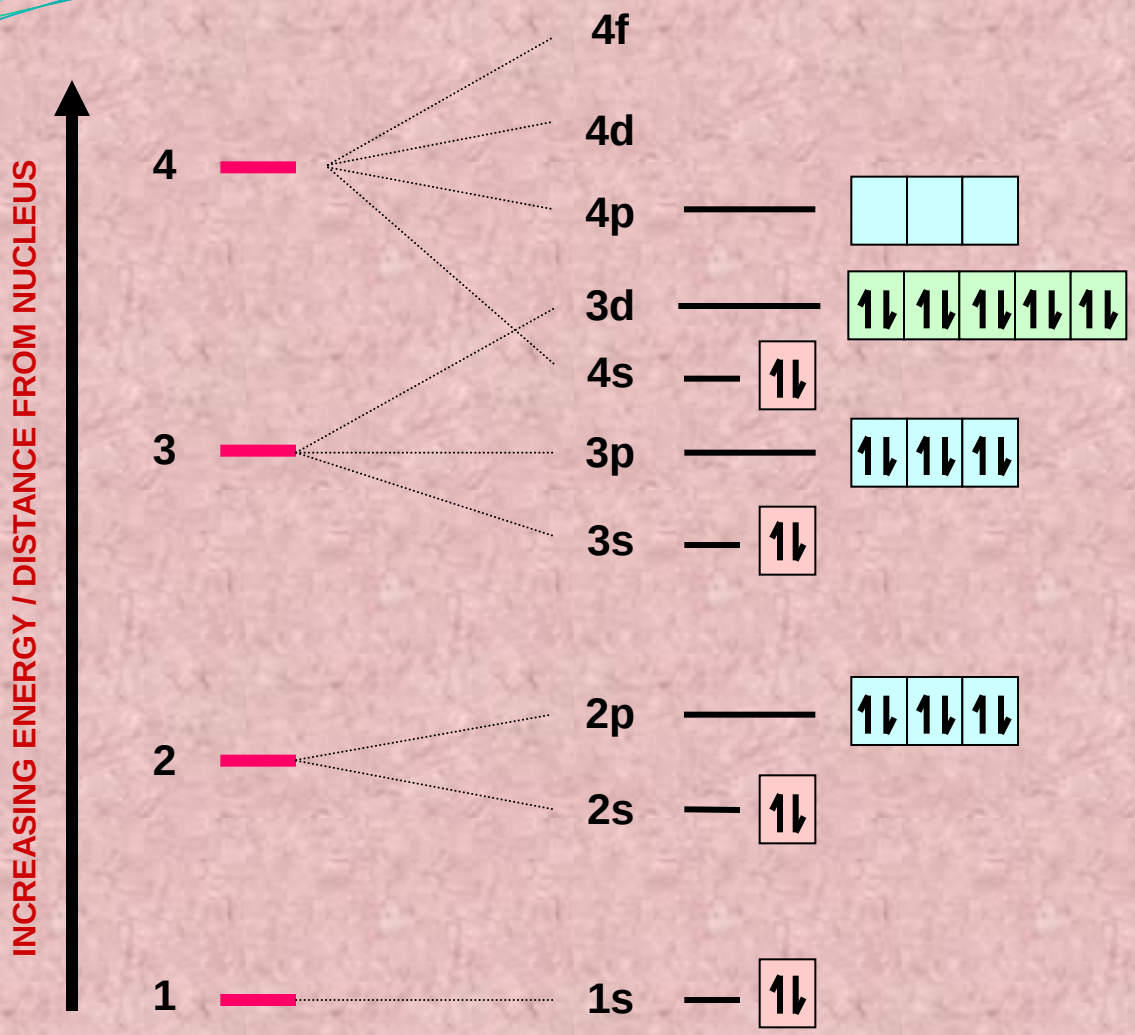


ZINC

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}$

The electron goes into the 4s to restore its filled state and complete the 3d and 4s orbital filling.

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



GALLIUM - KRYPTON

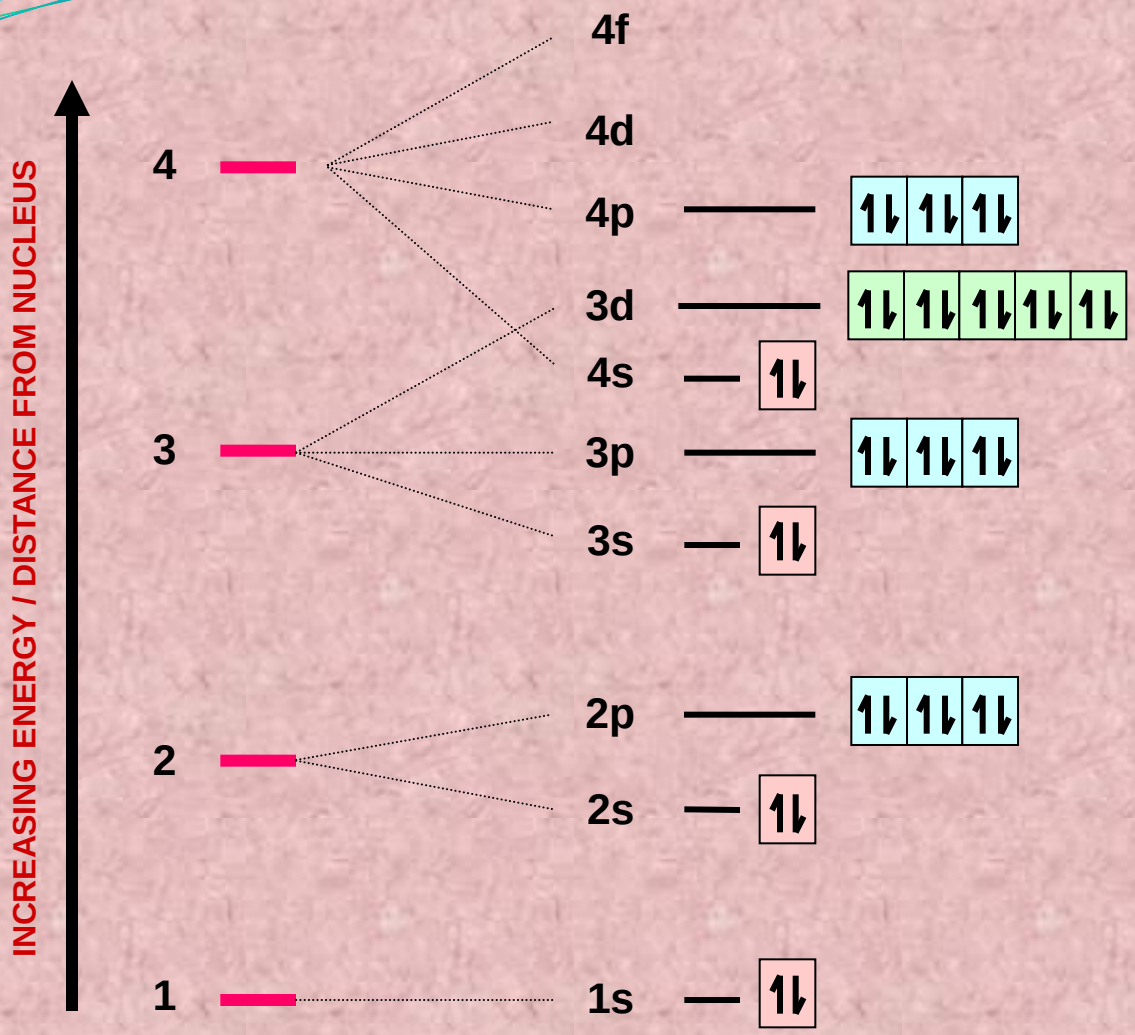
The 4p orbitals are filled in exactly the same way as those in the 2p and 3p sub levels.

HUND'S RULE

OF

MAXIMUM MULTIPLICITY

THE ELECTRONIC CONFIGURATIONS OF THE FIRST 36 ELEMENTS



GALLIUM - KRYPTON

Prefix with…

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}$

Ga - $4p^1$

Ge - $4p^2$

As - $4p^3$

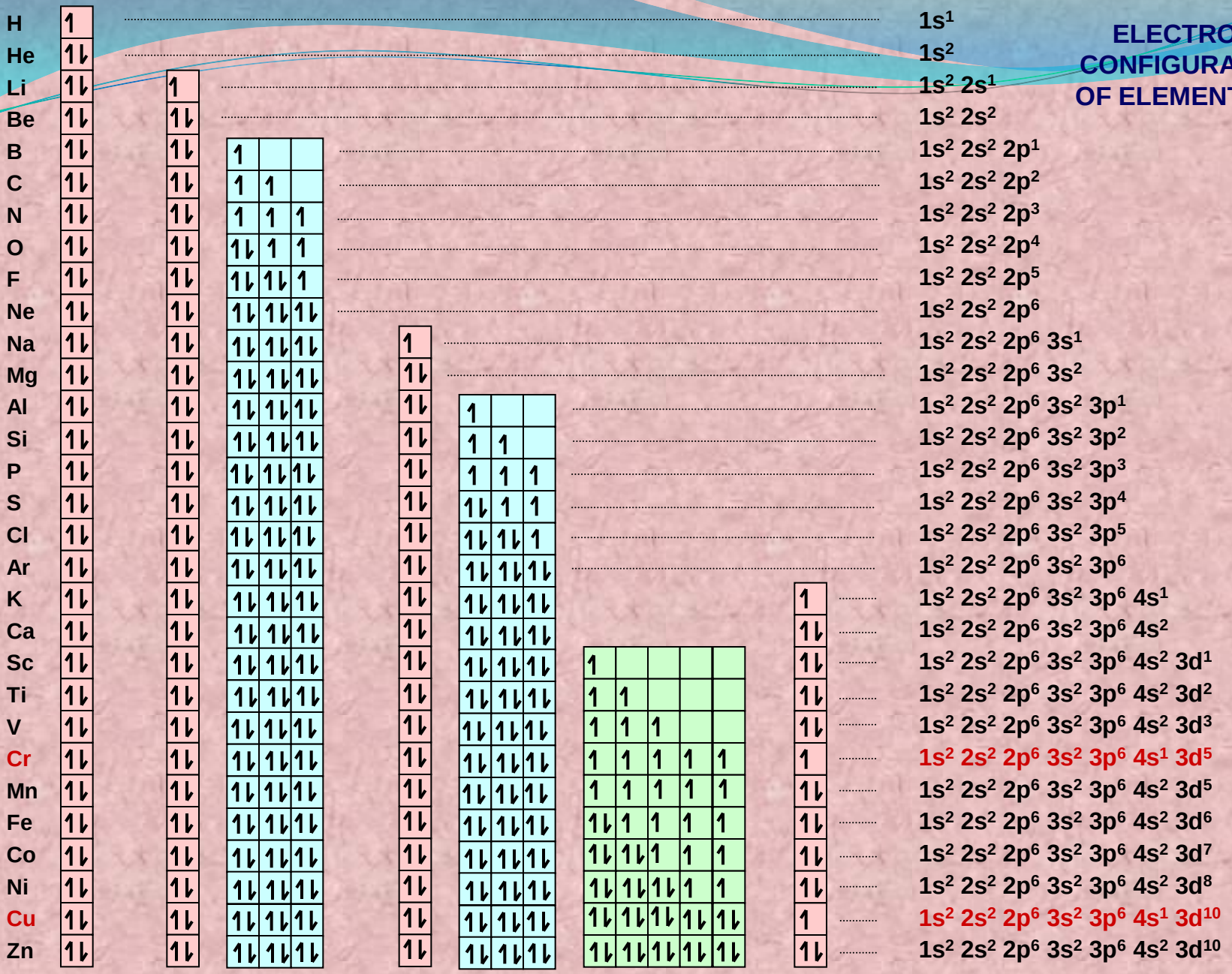
Se - $4p^4$

Br - $4p^5$

Kr - $4p^6$

Remember that the 4p configurations follow Hund's Rule with the electrons remaining unpaired to give more stability.

ELECTRONIC CONFIGURATIONS OF ELEMENTS 1-30



ELECTRONIC CONFIGURATIONS

THE END