MSJChem
Tutorials for IB Chemistry

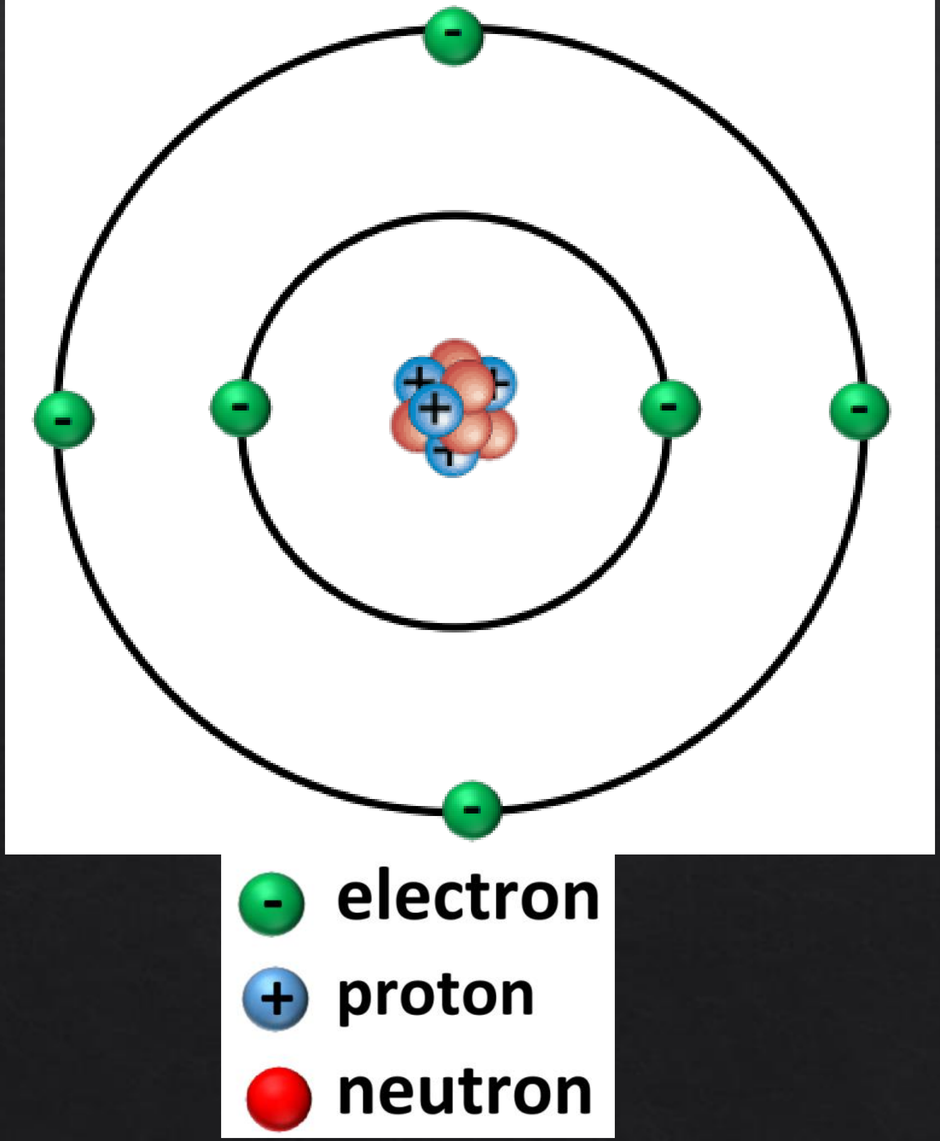
Structure 1.2

MSJChem

Tutorials for IB Chemistry

Atomic structure

Atomic structure



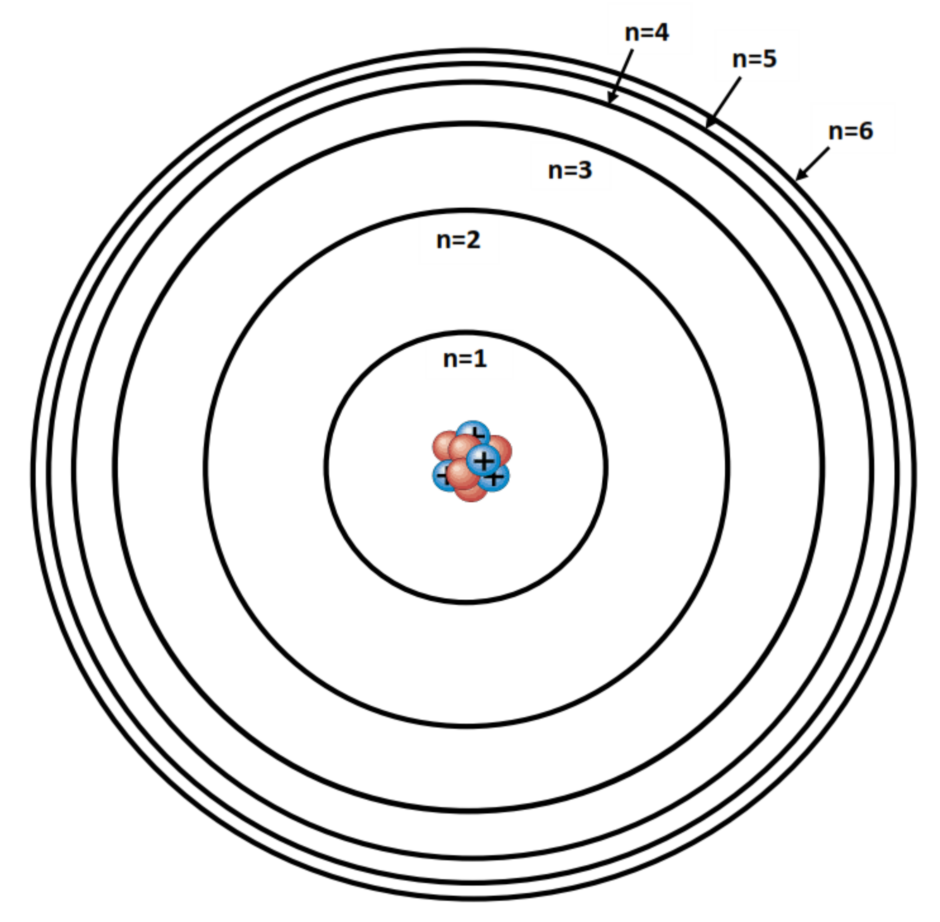
Protons and neutrons (nucleons) are located in the nucleus of the atom.

Electrons are located in energy levels surrounding the nucleus.

Sub-atomic particle	Relative charge	Relative mass
proton	+1	1
neutron	no charge	1
electron	-1	1/2000

Principal energy levels

Principal energy levels (n) in an atom



Electrons are located in principal energy levels (main energy levels).

The first main energy level (n=1) has the lowest energy and energy increases as the value of n increases.

Each main energy level can hold a maximum of $2n^2$ electrons.

n=2 (2×2^2) = 8 electrons

n=3 (2×3^2) = 18 electrons

Sub-levels in the atom

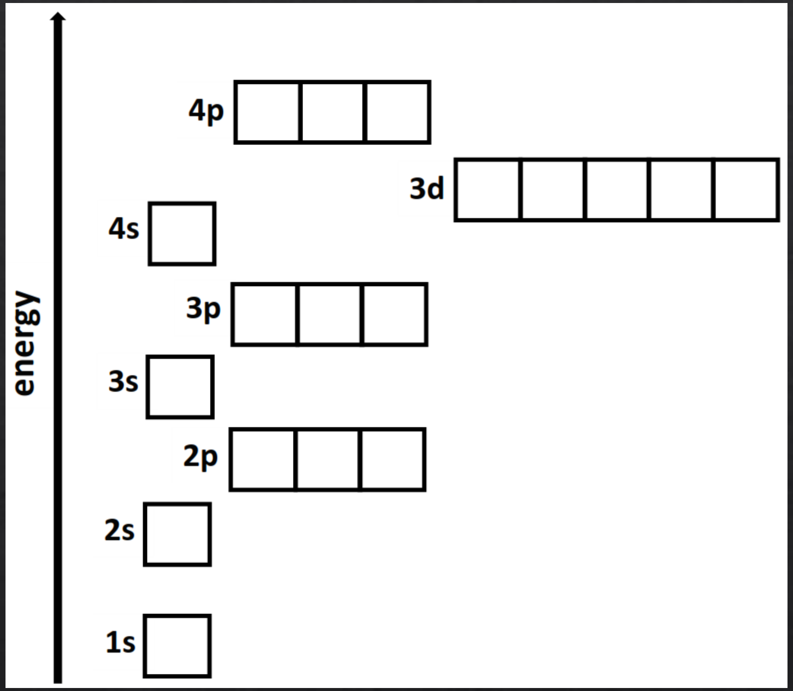
Each main energy level is split into sub-levels.

n=1 has 1 sub-level (1s)

n=2 has 2 sub-levels (2s, 2p)

n=3 has 3 sub-levels (3s, 3p, 3d)

n=4 has 4 sub-levels (4s, 4p, 4d, 4f)



Within a main energy level, the order of energy is:

s < p < d < f

MSJChem
Tutorials for IB Chemistry

Sub-levels in the atom

Principal energy level (*n*)	Sub-levels	Number of electrons in sub-level	Number of electrons in main energy level
1	1s	2	2
2	2s 2p	2 6	8
3	3s 3p 3d	2 6 10	18
4	4s 4p 4d 4f	2 6 10 14	32

Sub-levels in the atom

Main energy level, *n*	Sub-levels	Number of orbitals	Number of electrons
1	1s	1	2
2	2s, 2p	4	8
3	3s, 3p, 3d	9	18
4	4s, 4p, 4d, 4f	16	32

MSJChem
Tutorials for IB Chemistry

Atomic number and mass number

Atomic number and mass number

The atomic number (*Z*) is the number of protons in the nucleus of an atom.

The mass number (*A*) is the total number of protons and neutrons (nucleons) in the nucleus of an atom.

Atomic number	3
Element	Li
Relative atomic mass	6.94

MSJChem
Tutorials for IB Chemistry

Atomic number and mass number

$$^{A}_{Z}\mathrm{X}$$

X is the symbol of the element
A is the mass number
Z is the atomic number

$$^{12}_{6}\mathrm{C} \quad ^{35}_{17}\mathrm{Cl} \quad ^{54}_{26}\mathrm{Fe}$$

MSJChem
Tutorials for IB Chemistry

Atomic number and mass number

$^{12}_{6}C$ $^{35}_{17}Cl$ $^{54}_{26}Fe$

6 protons	17 protons	26 protons
6 neutrons	18 neutrons	28 neutrons
6 electrons	17 electrons	26 electrons

MSJChem
Tutorials for IB Chemistry

Atomic number and mass number

$$^{40}_{20}Ca^{2+} \qquad ^{81}_{35}Br^{-}$$

20 protons
20 neutrons
18 electrons

35 protons
46 neutrons
36 electrons

Atomic number and mass number

Which is correct for ${}^{31}_{15}P^{3-}$?

	Protons	Neutrons	Electrons
A	15	16	15
B	16	15	18
C	15	16	18
D	15	16	12

MSJChem
Tutorials for IB Chemistry

Isotopes

Isotopes

Isotopes are atoms that have the same atomic number but a different mass number (they have the same number of protons but a different number of neutrons).

$${}^{12}_{6}C \quad {}^{13}_{6}C \quad {}^{14}_{6}C$$

Isotopes

$$^{12}_{6}C \qquad ^{13}_{6}C \qquad ^{14}_{6}C$$

6 protons	6 protons	6 protons
6 neutrons	7 neutrons	8 neutrons
6 electrons	6 electrons	6 electrons

MSJChem
Tutorials for IB Chemistry

Isotopes

$^{1}_{1}H$ $^{2}_{1}H$ $^{3}_{1}H$

1 proton
0 neutrons
1 electron

1 proton
1 neutron
1 electron

1 proton
2 neutrons
1 electron

Isotopes

The relative abundance of an isotope is the percentage of atoms with a specific mass number in a naturally occurring sample of the element.

Isotope	Relative abundance (%)
$^{24}_{12}Mg$	78.99
$^{25}_{12}Mg$	10.00
$^{26}_{12}Mg$	11.01

MSJChem
Tutorials for IB Chemistry

Isotopes

Isotope	Boiling point (K)	Melting point (K)	Density (g cm^{-3})
$^{1}_{1}H$	20.4	14.0	0.09
$^{2}_{1}H$	23.7	18.7	0.18
$^{3}_{1}H$	25.0	20.6	0.27

Isotopes

Chemical properties are related to the number of electrons in an atom - isotopes have the same number of electrons, therefore they have identical chemical properties.

Isotopes have different numbers of neutrons, therefore their masses are different.

Isotopes have different physical properties such as density and boiling point.

To summarise, isotopes have identical chemical properties but different physical properties.

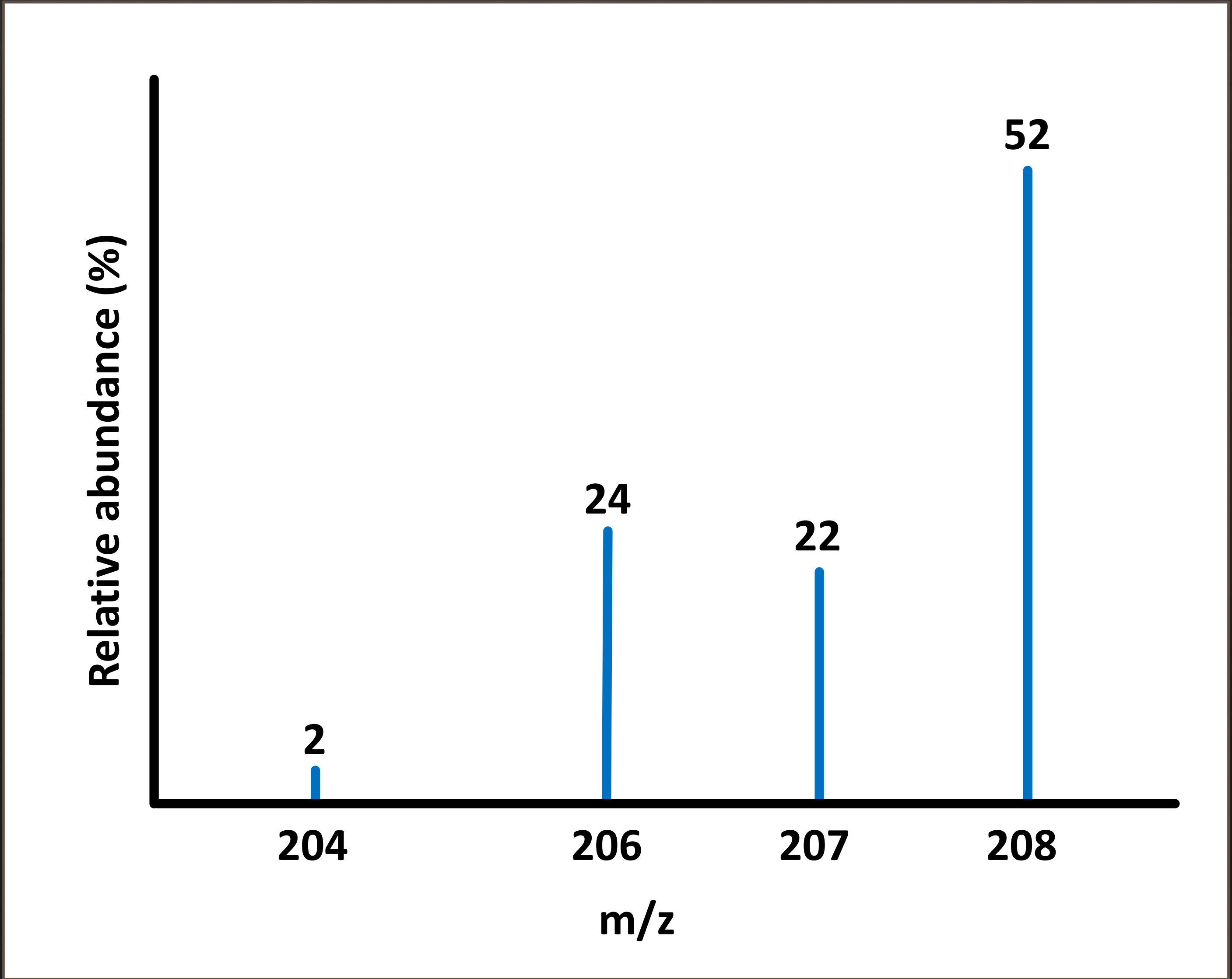
MSJChem
Tutorials for IB Chemistry

Calculating relative atomic mass (A_r)

MSJChem
Tutorials for IB Chemistry

Relative atomic mass (A_r)

Mass spectrum of lead (Pb)



Isotope	Relative abundance (%)
^{204}Pb	2.00
^{206}Pb	24.00
^{207}Pb	22.00
^{208}Pb	52.00

Relative atomic mass (A_r)

Isotope	Relative abundance (%)
^{204}Pb	2.00
^{206}Pb	24.00
^{207}Pb	22.00
^{208}Pb	52.00

$$A_r = \frac{(204\times 2.00)+(206\times 24.00)+(207\times 22.00)+(208\times 52.00)}{100} = 207.20$$

Relative atomic mass (A_r)

Isotope	Relative abundance (%)
^{54}Fe	5.95
^{56}Fe	91.88
^{57}Fe	2.17

$$A_r = \frac{(54\times5.95)+(56\times91.88)+(57\times2.17)}{100} = 55.90$$

Relative atomic mass (A_r)

Bromine (A_r = 79.90) has two isotopes, ^{79}Br and ^{81}Br. Calculate the relative abundance of each isotope.

$$79.90 = \frac{81(x) + 79(100 - x)}{100}$$

$$7990 = 81x + 7900 - 79x$$

$$x = 45 \quad {}^{81}\mathrm{Br} = 45\% \quad {}^{79}\mathrm{Br} = 55\%$$

Relative atomic mass (A_r)

Europium (A_r = 151.96) has two isotopes, ^{151}Eu and ^{153}Eu. Calculate the percentage abundance of each isotope.

$$151.96 = \frac{153(x) + 151(100 - x)}{100}$$

$$15196 = 153x + 15100 - 151x$$

$$x = 48 \quad ^{153}\mathrm{Eu} = 48\% \quad ^{151}\mathrm{Eu} = 52\%$$