

1. The four quantum numbers needed to define the energy state of an atom are:
- the principal quantum number, n . This can have integer, non-zero values and describes the size and energy of the orbital.
 - the angular momentum quantum number, l . For each value of n , l takes every value from 0 to $(n - 1)$. It describes the shape of the orbital. For historic reasons, orbitals with $l = 0$ are called s -orbitals, orbitals with $l = 1$ are called p -orbitals and orbitals with $l = 2$ are called d -orbitals.
 - the magnetic quantum number, m_l . For each value of l , m_l takes every value from $-l$ to $+l$. It describes the orientation of the orbital.
 - the spin quantum number, m_s . For an electron, $m_s = +\frac{1}{2}$ or $-\frac{1}{2}$. It describes the spin of the electron.

2. The rows of the Periodic Table correspond to different values of n .

The lowest value of n is 1. For $n = 1$, l can only be equal to 0. For $l = 0$, m_l can only be 0. As m_s can take two values ($+\frac{1}{2}$ and $-\frac{1}{2}$), there are two elements only in the first row: H and He.

The next value of n is 2. For $n = 2$, l can be equal to 0 or 1. Because there are two values, the $n = 2$ shell is made up of two subshells.

- For $l = 0$, m_l can again only be zero and as m_s can take two values, there are two elements in the first subshell (Li and Be).
- For $l = 1$, m_l can take three values: -1, 0 and +1. For each of these, m_s can take two values so that there are six elements in the second subshell (B, C, N, O, F and Ne).

As n increases, these subshells form blocks of elements. Those with the outer electrons having $l = 0$ are called s -block elements. Those with the outer electrons having $l = 1$ are called the p -block elements.

For $n = 3$, l can be 0, 1 and 2 and this leads to a new subshell and ultimately to a new block of elements called the d -block elements.

- 3.

	Na	$1s^2 2s^2 2p^6 3s^1$	
(a)	S	$1s^2 2s^2 2p^6 3s^2 3p^4$	or [Ne] $3s^2 3p^4$
(b)	Br ⁻	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6$	or [Ar] $5s^2 4d^{10} 4p^6$
(c)	Ca ²⁺	$1s^2 2s^2 2p^6 3s^2 3p^6$	or [Ar]

4. (a) O $1s^2 2s^2 2p^4$
 O^- $1s^2 2s^2 2p^5$
- (b) Mg $1s^2 2s^2 2p^6 3s^2$
 Mg^{2+} $1s^2 2s^2 2p^6$
- (c) Zn $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$
 Zn^{2+} $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$
- (d) Fe $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$
 Fe^{3+} $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$

5. **Atomic and ionic radii increase down groups as the n -shell increases. They decrease across periods as the nuclear charge increases. Positive charge decreases the radius due to lower e^-/e^- repulsion whereas negative charge increases the radius due to higher e^-/e^- repulsion.**

6. (a) P, As, Sb **Radii increases down the group: $\underline{P} < As < Sb$.**
- (b) S, Cl, K **Radii decrease across each period so $Cl < S$. K is in the next period so is the largest.**

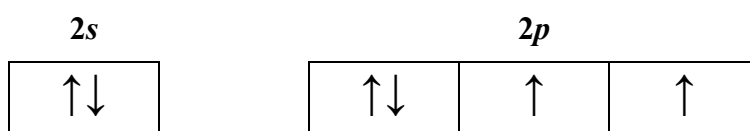
Overall, the radii increases in the order $\underline{Cl} < S < K$

- (c) O^+ , O, O^- , O^{2-} **Positive charge contracts the atom and negative charge expands the atom.**

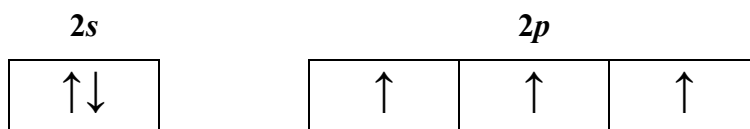
Overall, the radii increase in the order $\underline{O^+} < O < O^- < O^{2-}$

- (d) Pd, Ni, Pt **Radii increase down the group: $\underline{Ni} < Pd < Pt$**

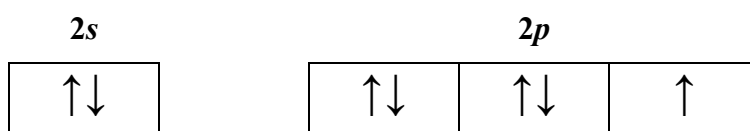
7. (a) O $1s^2 2s^2 2p^4$ or $[He] 2s^2 2p^4$. Two unpaired electrons:



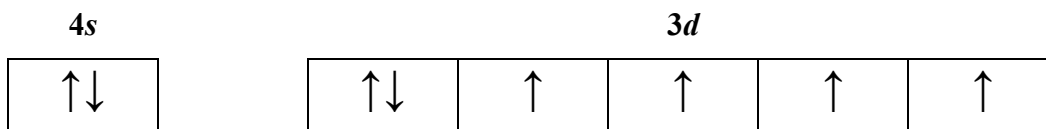
- (b) O^+ $1s^2 2s^2 2p^4$ or $[He] 2s^2 2p^3$. Three unpaired electrons:



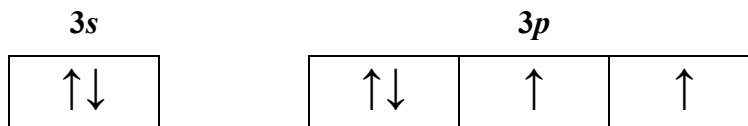
- (c) O^- $1s^2 2s^2 2p^5$ or $[He] 2s^2 2p^5$. One unpaired electron:



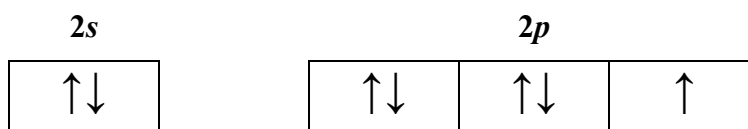
(d) Fe $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$ or [Ar] $4s^2 3d^6$. Four unpaired electrons:



(e) S $1s^2 2s^2 2p^6 3s^2 3p^4$ or [Ne] $3s^2 3p^4$. Two unpaired electrons:



(f) F $1s^2 2s^2 2p^5$ or [He] $2s^2 2p^5$. One unpaired electron:



7. (a) nitrous acid HNO_2
 (b) nitric acid HNO_3
 (c) sulfurous acid H_2SO_3
 (d) sulfuric acid H_2SO_4
 (e) sodium hydrogenphosphate Na_2HPO_4

(“Hydrogenphosphate” corresponds to HPO_4^{2-} so the compound must have two Na^+ ions. “Dihydrogenphosphate” is H_2PO_4^- so sodium dihydrogenphosphate is NaH_2PO_4).

8. (a) $3\text{PO}_4^{3-}(\text{aq}) + 5\text{Ca}^{2+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow \text{Ca}_5(\text{PO}_4)_3(\text{OH})(\text{s}) + \text{H}_3\text{O}^+(\text{aq})$
 (b) The number of moles (n) is related to the concentration (c) and the volume (V):

$$n = c \times V$$

As each mole of Na_3PO_4 contains one mole of PO_4^{3-} , 200 mL of a 0.090 M solution contains:

$$\text{number of moles of } \text{PO}_4^{3-} = 0.090 \text{ mol L}^{-1} \times \frac{200}{1000} \text{ L} = 0.018 \text{ mol}$$

As each mole of CaCl_2 contains one mole of Ca^{2+} , 400 mL of a 0.10 M solution contains:

$$\text{number of moles of } \text{Ca}^{2+} = 0.10 \text{ mol L}^{-1} \times \frac{400}{1000} \text{ L} = 0.040 \text{ mol}$$

From the chemical equation, each mole of $\text{Ca}_5(\text{PO}_4)_3(\text{OH})$ requires 3 moles of $\text{PO}_4^{3-}(\text{aq})$ and 5 moles of $\text{Ca}^{2+}(\text{aq})$.

To use all of the PO_4^{3-} present would require $\frac{5}{3} \times 0.018 \text{ mol} = 0.030 \text{ mol}$ of Ca^{2+} .

There is more than enough Ca^{2+} present to do this.

To use all of the Ca^{2+} present would require $\frac{3}{5} \times 0.040 \text{ mol} = 0.024 \text{ mol}$ of PO_4^{3-} .

There is not enough PO_4^{3-} present to do this and so the amount of PO_4^{3-} determines the possible yield. Unreacted $\text{Ca}^{2+}(\text{aq})$ will be left.

From the chemical equation, one mole of hydroxyapatite is made from every three moles of PO_4^{3-} . As 0.018 mol is available:

$$\text{maximum possible yield of hydroxyapatite} = \frac{1}{3} \times 0.018 \text{ mol} = 0.0060 \text{ mol}$$

- (c) As the chloride ions do not take part in the reaction, the number of moles of Cl^- (aq) remaining in solution is equal to the number of moles present in 400 mL of a 0.10 M solution of calcium chloride. As each mole of CaCl_2 yields two moles of Cl^- ions,

$$\text{number of moles of } \text{Cl}^- = 2 \times c \times V = 2 \times 0.10 \text{ mol L}^{-1} \times \frac{400}{1000} \text{ L} = 0.080 \text{ mol}$$

After the two solutions are mixed, the total volume is $200 + 400 = 600 \text{ mL}$. The concentration is thus:

$$\text{concentration of } \text{Cl}^- = \frac{n}{V} = \frac{0.080 \text{ mol}}{\left(\frac{600}{1000}\right)\text{L}} = \frac{n}{V} = \frac{0.080}{(600/1000)} = 0.13 \text{ M}$$