

## Electron configuration

- The period number of an element is the highest shell number
- The group number of an element is the sum of all electrons in the outer shell
- The letter of the outermost (highest energy) subshell defines the block it is placed in (so helium is part of the s block even though in the periodic table it is over near the p block)

Electron subshells are filled in order of increasing energy: (s holds 2, p holds 6, d holds 10)

————— increasing energy —————>  
 $1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s$

Exceptions: Cu ( $4s^1 3d^{10}$ ) and Cr ( $4s^1 3d^5$ )

**Ions:** For main group ions, simply write out the electron configuration for that number of electrons. For transition metals, remove electrons from the 4s subshell first.

**Memorise, for the first 38 elements, which are metals, non-metals and metalloids.**

Zinc, tin, lead, aluminium and beryllium are metalloids (as far as oxide forming behaviour is concerned). Elements to the left and down from these are metals, elements to the right and up are non-metals.

**Memorise the following names for parts of the table:**

- alkali metals (Group I)
- alkaline earth metals (Group II)
- halogens (Group VII)
- noble gases (Group VIII)

## The Octet Rule

Periods 1 and 2 conform to the "Octet Rule": they are stable when their outer shell is 'complete', i.e. their electron configuration matches a noble gas.

Period 3 elements from groups V to VII don't have to follow the Octet Rule, they can have more than 8 outer shell electrons (first 3s and 3p are filled to 8, then extra electrons occupy 3d). This is called expansion of the octet.

**Charge of the monatomic ions:**

- *Group I:* always 1+. Note that hydrogen is not considered a member of group 1.
- *Group II:* always 2+.
- *Group III:* usually 3+.
- *Group IV:* usually 2+ or 4+ (depending on whether the outer  $s^2 p^2$  is lost or just the outer  $p^2$ )  
carbon is an exception, forming only 'carbide ion' with a 4- charge.
- *Group V:* 3-
- *Group VI:* 2-
- *Group VII:* 1-

**Electronegativities** (arrow indicates increasing electronegativity)

hydrogen 1 H																	helium 2 He	
lithium 3 Li	beryllium 4 Be											boron 5 B	carbon 6 C	nitrogen 7 N	oxygen 8 O	fluorine 9 F	neon 10 Ne	
sodium 11 Na	magnesium 12 Mg											aluminum 13 Al	silicon 14 Si	phosphorus 15 P	sulfur 16 S	chlorine 17 Cl	argon 18 Ar	
potassium 19 K	calcium 20 Ca	scandium 21 Sc	titanium 22 Ti	vanadium 23 V	chromium 24 Cr	manganese 25 Mn	iron 26 Fe	cobalt 27 Co	nickel 28 Ni	copper 29 Cu	zinc 30 Zn	gallium 31 Ga	germanium 32 Ge	arsenic 33 As	selecnium 34 Se	bromine 35 Br	krypton 36 Kr	
rubidium 37 Rb	strontium 38 Sr	yttrium 39 Y	zirconium 40 Zr	niobium 41 Nb	molybdenum 42 Mo	technetium 43 Tc	ruthenium 44 Ru	rhodium 45 Rh	palladium 46 Pd	silver 47 Ag	cadmium 48 Cd	indium 49 In	tin 50 Sn	antimony 51 Sb	tellurium 52 Te	iodine 53 I	xenon 54 Xe	
cesium 55 Cs	barium 56 Ba	lanthanum 57-70 * * * * *	hafnium 71 Hf	tantalum 72 Ta	tungsten 73 W	rhenium 74 Re	osmium 75 Os	iridium 76 Ir	platinum 77 Pt	gold 78 Au	mercury 79 Hg	thallium 80 Tl	lead 81 Pb	bismuth 82 Bi	polonium 83 Po	astatine 84 At	radon 85 Rn	
francium 87 Fr	radium 88 Ra	actinide series 89-102 * * * * *	actinide series 103-118 * * * * *	actinide series 119-132 * * * * *	actinide series 133-146 * * * * *	actinide series 147-160 * * * * *	actinide series 161-174 * * * * *	actinide series 175-188 * * * * *	actinide series 189-202 * * * * *	actinide series 203-216 * * * * *	actinide series 217-230 * * * * *	actinide series 231-244 * * * * *	actinide series 245-258 * * * * *	actinide series 259-272 * * * * *	actinide series 273-286 * * * * *	actinide series 287-300 * * * * *	actinide series 301-314 * * * * *	actinide series 315-328 * * * * *
* Lanthanide series		lanthanum 57 La	cerium 58 Ce	praseodymium 59 Pr	neodymium 60 Nd	promethium 61 Pm	samarium 62 Sm	europlum 63 Eu	gadolinium 64 Gd	terbium 65 Tb	dysprosium 66 Dy	holmium 67 Ho	erbium 68 Er	thulium 69 Tm	ytterbium 70 Yb			
** Actinide series		actinium 89 Ac	thorium 90 Th	protactinium 91 Pa	uranium 92 U	neptunium 93 Np	plutonium 94 Pu	americium 95 Am	curium 96 Cm	berkelium 97 Bk	californium 98 Cf	esbium 99 Es	fermium 100 Fm	mendelevium 101 Md	nobelium 102 No			

Metals: low electronegativity

Metalloids: intermediate electronegativity

Non-metals: high electronegativity

**Oxidation number (oxidation state) rules, in order:**

- All elemental state atoms are zero
- Hydrogen is usually +1 (in compounds) except as a metal hydride, where it is -1
- Oxygen is usually -2 (in compounds) except in hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) where it is -1
- Monatomic ions have oxidation number equal to their charge
- The sum of the oxidation numbers in a compound equals zero
- The sum of the oxidation numbers in a polyatomic ion equals the charge on the ion

Note: Oxidation numbers are always written sign then number (e.g. +1), whereas charges are written number then sign (e.g. 1+).

**Covalent bonding**

A covalent bond is formed by the sharing of valence electrons between two atoms. The shared electrons orbit both atoms and are considered in each atom's valence shell. By this sharing of electrons atoms can each increase the number of electrons they have and become more stable.

Covalence is the number of electrons shared during covalent bonding to make the atom stable.

Notice the relationship between the likely covalences and the number of electrons in the subshells.

- **Group I:** does not form covalent bonds
- **Group II:** does not form covalent bonds
- **Group III:** 3 (boron only)
- **Group IV:** 2 or 4 (except the metals)
- **Group V:** 3 or 5 (depending on whether the outer s<sup>2</sup>p<sup>3</sup> is shared or just the outer p<sup>3</sup>)
- **Group VI:** 2, 4 or 6 (two of the outer p<sup>4</sup>, all the outer p<sup>4</sup>, or all of the outer s<sup>2</sup>p<sup>4</sup>)  
 Note: oxygen never exhibits covalence of 4 or 6
- **Group VII:** 1, 3, 5 or 7 (one, three or all of the p<sup>5</sup>, or all seven of the s<sup>2</sup>p<sup>5</sup>)  
 Note: fluorine never exhibits covalence of 3,5 or 7

The magnitudes of the likely oxidation states are equal to the covalences.

**Acidic, Basic and Amphoteric Oxides**

Oxides (compounds of an element with oxygen) can be classified as acidic, basic or amphoteric:

- *Acidic*
  - React with hydroxide ions to produce oxyanions (negatively charged ions consisting of the element and oxygen) and water.
  - React with water (if soluble in water) to form oxyacids (acids consisting of the element, hydrogen and oxygen).
  - Oxides of non-metals are acidic.
  
- *Basic*
  - React with acids (or hydrogen ions) to produce positively charged metal ions and water molecules.
  - React with water (if soluble in water) to form metal ions and hydroxide ions.
  - Oxides of metals are basic.
  
- *Amphoteric (can behave either as acidic or basic)*
  - React with hydroxide ions to produce oxyanions (negatively charged ions consisting of the element and oxygen) and water.
  - React with acids (or hydrogen ions) to produce positively charged metal ions and water molecules.
  - Do *not* react with water.
  - Oxides of metalloids (zinc, tin, lead, aluminium and beryllium) are amphoteric.

**Memorise the acidic oxides below (and their corresponding oxyanions)**

Any other oxides required can be determined simply from standard formula balancing.

The left is the oxide, the right is the oxyanion formed by that particular oxide.

C	N	O
CO CO <sub>2</sub>	NO NO <sub>2</sub>	-
-	NO <sub>2</sub> <sup>-</sup> + NO <sub>3</sub> <sup>-</sup>	-
Si	P	S
SiO <sub>2</sub>	P <sub>4</sub> O <sub>10</sub>	SO <sub>2</sub> SO <sub>3</sub>
SiO <sub>3</sub> <sup>2-</sup>	PO <sub>4</sub> <sup>3-</sup>	SO <sub>3</sub> <sup>2-</sup> SO <sub>4</sub> <sup>2-</sup>

Note: Silicon oxide is not soluble in water (even though it is an acidic oxide)

**To write metallic and basic oxides:** balance the formula according to standard oxidation number rules.

**To construct the oxyanion formed by an amphoteric oxide:** attach just enough oxides to a single metal atom to give the molecule a negative charge.

The oxidation state of the metal or metalloid is maintained.

You may notice that most of the oxyanions of acidic oxides could be constructed this way too.