Periodicity and periodic table

- A **Period is a horizontal row of elements** with a variety of properties, changing from very metallic elements on the left to non-metallic elements on the right. A period starts when the next electron goes into the next available main energy level or shell (Group 1 alkali Metals). The period ends when the main energy level is full (Group 0 or 8 Noble Gases).
- **All the elements on the same period use the same number of principal electron shells**, and this equals the period number (e.g. sodium's electron arrangement 2,8,1, the first element in Period 3).
- The first element in a period is when the next electron goes into the next available electron shell or energy level (i.e. 1 electron in the outer shell, after H it is the Group 1 Alkali Metals like sodium 2.8.1).
- **The last element in a period is when the outer shell is full** (The Group 0 Noble Gases e.g. argon 2.8.8). The next electron for the next element goes into the next highest level (shell) available, and so starts the next period.
- So **in terms of electrons** ....
    - **Period 1** is elements 1-2, H (1) to He (2)
    - **Period 2** is elements 3-8, Li (2,1) to Ne (2,8)
    - **Period 3** is elements 11-18, Na (2.8.1) to Ar (2.8.8)
    - **Period 4** is elements 19-36, starts with K (2,8,8,1) and Ca (2,8,8,2) and finishes with the Noble Gas Kr (2,8,18,8).
    - Note that the number of shells containing electrons is equal to the period number.
- The similarities (e.g. same Group) or differences (e.g. across a period) of the properties of the elements can be explained by the electronic structure of the atoms.
- From Period 4 onwards the length of a period significantly increases because it includes horizontal series of similar metals with their own characteristic physical and chemical properties e.g. **The 1st Transition Metals Series** Fe, Cr, Cu etc.)
- More than **three-quarters** of the **109 known elements** are **metals** (elements **naturally occur up to uranium 92, 93-109 are 'man-made' elements** from the experiments of nuclear physicists.
    - This work will continues as heavier and heavier elements are likely to be made in nuclear reactions. They will be all metals and radioactive. BUT one theory suggests that 'super-heavy' elements of about atomic number 150? may be in a nuclear stability region and would prove most interesting to study. Chemists are trying to predict their properties now!, so it may have started with Mendeleev but it ain't finished yet!
- **Only about 19 are definitely are non-metal** but **about 7 more are semi-metals of mixed physical and chemical character**.
- **The metals in the periodic table are mainly found in the left hand columns (Groups 1 and 2) and in the central blocks of the transition elements**.
- There is a 'rough' diagonal division between the two principal types of element zig-zagging from B-Al in group 3 to Te-Po in Group 6.
- The elements in this 'band' are sometimes referred to as '**semi-metals**' or '**metalloids**' because of **their 'mixture' of metallic and non-metallic physical or chemical character** e.g. the semi-conductor silicon in group 4.

- **There trends to be gradual changes in physical and chemical properties down a group** e.g.
    - Down Group 1 (Alkali Metals) and Group 2 the metals get more reactive.
    - Down Group 7 (Halogens) the non-metals get less reactive, their colour gets darker, their melting/boiling points increase.
    - Down Group 4 you start with a definite non-metal carbon, and end up at the bottom with a the definite metal lead, so there are quite significant changes in both physical and chemical character.
- **There trends to be major changes in physical and chemical properties across a period** e.g.
    - Period 2 starts with a solid low melting reactive metal lithium, in the middle there are the high melting and rather unreactive non-metals boron and carbon, next to the end is the very highly reactive non-metal gas fluorine, and the period finishes with the very unreactive gas neon. Very complicated pattern!
    - Period 4 starts with a solid low melting very reactive metal rubidium, after calcium there are ten transition metals with a wide variety of chemistry, followed by the metallic gallium, semi-metal germanium and more non-metallic arsenic/selenium, next to the end is the very reactive non-metal liquid bromine, and the period finishes with the very unreactive gas krypton. Even more complicated pattern!
    - From left to right across a period the bonding in chlorides or oxides changes from ionic (with metals e.g. Na^+Cl^-, $(Na^+)_2O^{2-}$) to covalent (with non-metals e.g. ClF, SO_2).
    - From left to right across a period the oxides change from alkaline/basic (with metals e.g. Na_2O) to acidic (with non-metals e.g. SO_2).
    - **Note on electron arrangements**:
        - Except for boron, **most non-metals** have at least four electrons in the out shell.
        - Except for the noble gases, the more electrons in the outer shell the more non-metallic and the more reactive the element. The **most reactive non-metals only need to share/gain one or two electrons**.
        - The **most reactive metals** only have 1 or 2 electrons in the outer shell which tend to be easily lost to form the metal ion in reaction.
        - The most reactive metals have a low number of outer valency shell electrons (<= 3).
        - The very reactive non-metals have 5 to 7 outer valency shell electrons.
        - Elements in the 'middle' of the Periodic Table e.g. Group 4 with 4 outer electrons, show mixed chemical character and are not very reactive elements.
        - The Noble Gas elements have full, very stable, outer valency shells.
- The **valency**, or, **combining power of an element** is **related to the elements position in the Periodic Table**.
    - **For Groups 1 to 8(0), the group number gives the maximum valency possible and equals the number of outer electrons** (well, nearly always!).
    - For many compounds, this rule works fine: e.g. for chlorine valency 1 and oxygen valency 2, **you can deduce the following formulae for valencies of 1 to 7 across the period for Group 1 to 7 compounds** (at least up to a point!)
        - **chlorides**: NaCl, $MgCl_2$, $AlCl_3$, $SiCl_4$, PCl_5, SCl_6, then Cl itself and Ar can't combine with other elements.

        - **oxides**: Na_2O, MgO, Al_2O_3, SiO_2, P_2O_5, SO_3, Cl_2O_7 and Ar can't combine with other elements.
    - **BUT** things are not so simple
        - **Na to Si no problem!** great! In fact, apart from N, O, F (which have valency restrictions NOT for GCSE though!) you can usually make a reasonable prediction of the maximum valency compound for all of the elements in Groups 1 to 7.
        - However there are lots of other compounds where the element's valency is less than its group number, and there are other complications too! tough! never a dull academic moment in chemistry!?!?!?
        - e.g. in Group 4, C forms CO (nasty!), Pb forms $PbCl_2$ which is much more stable than $PbCl_4$ etc. etc. !
        - and all these exist: P_2O_5 is really a P_4O_{10} molecule and there is also P_2O_3 (which is actually a P_4O_6 molecule), S_2Cl_2, SCl_4, SO_2, Cl_2O, ClO_2, Cl_2O_3, Cl_2O_5 ....
        - **YET THERE IS GOOD NEWS TOO!**, Xenon forms XeF_8 and XO_4 using its maximum valency of 8! and that got somebody a Nobel Prize in Chemistry! (and in scrabble too?)

Typical Properties of Metallic Elements

Physical properties of metals

- **Usually high melting points and boiling points** so all solid bar one (exceptions like mercury the only liquid metal at room temperature and the **Alkali Metals** [have untypical low melting points).
- **Often very good conductors of heat and electricity**. This is due to the mobility of the free moving electrons in the structure of a metal.
- **Most have a high density** (exceptions like the Alkali Metals have untypical low densities, the first three Li, Na and K float on water before the 'fizzing'!).
- **Their appearance is always 'shiny'** (usually silvery, except for copper and gold)
- **Usually quite strong materials** (exceptions like the Alkali Metals which are atypically very soft, and metals like lead are relatively soft too)
- **They are easily beaten into shape (malleable) or drawn into wire (ductile)** of varying strength, from very weak sodium to very strong iron).
- **Solids sonorous, they ring or resonate to produce a note when struck**.

Chemical Properties of metals

- **They tend to form basic oxides that react with acids to form salts** (if the oxide is soluble in water it forms an alkali of pH > 7, universal indicator blue or violet).
- **Most metals react with acids to form a salt and hydrogen. (see metal reactions: reactivity and metal-acid reactions/equations [1] and [2] with answers).**
- **Metals readily form positive ions** in compounds by losing electrons e.g.
    - sodium Na - e^- => $\mathbf{Na^+}$, magnesium Mg - $2e^-$ => $\mathbf{Mg^{2+}}$ or aluminium Al - $3e^-$ => $\mathbf{Al^{3+}}$
- Their **oxides** and **chlorides** are usually **ionic** in terms of chemical bonding. (at least at GCSE level, but there are plenty of exceptions at Advanced level!) e.g.
    - magnesium oxide, MgO or $\mathbf{Mg^{2+}O^{2-}}$, sodium oxide Na_2O or $\mathbf{(Na^+)_2O^{2-}}$,

- and aluminium oxide Al_2O_3 or $(Al^{3+})_2(O^{2-})_3$

Reactivity of Metals Notes ... Metal Extraction Notes

Typical Properties of Non-metallic Elements

Physical properties of non-metals

- **They usually have low melting points and boiling points and so can be gases, liquids or solids** (exceptions like **silicon, and carbon** as diamond or graphite, see GCSE notes).
- **Usually poor conductors of heat and electricity** (exceptions like carbon in the form of graphite).
- **NOn-metals generally have a low density.**
- **The appearance can be quite varied but tend to be dull if solid.**
- **Often weak materials e.g. soft or brittle solids** (exceptions like silicon, and carbon as diamond, which are very hard and strong)
- **When solid they are not easily beaten into shape or drawn into wire, the solids tend to be too brittle.**
- **Solid non-metals are not usually sonorous, e.g. they do not usually resonate or ring with sound,** like when a piece of metal is struck.

Chemical properties of non-metals

- **They form acidic oxides when burned in air or oxygen, these react with alkalis to form salts, if soluble in water they form acid solutions of pH <7, universal indicator yellow-orange-red**
- **They do not usually react with acids** e.g. to produce a salt and hydrogen like most metals do.
- Non-metals **readily form positive ions** in compounds by losing electrons e.g.
  - sodium Na - e^- => $\mathbf{Na^+}$, magnesium Mg - $2e^-$ => $\mathbf{Mg^{2+}}$ or aluminium Al - $3e^-$ => $\mathbf{Al^{3+}}$
- The **oxides** and **chlorides,** when **combined with other non-metals** are always **covalent** in terms of chemical bonding.
  - e.g. water $\mathbf{H_2O_{(l)}}$, methane $\mathbf{CH_{4(g)}}$, sulphur dioxide $\mathbf{SO_{2(g)}}$ and hydrogen chloride $\mathbf{HCl_{(g)}}$
- The **oxides** and **chlorides,** when **combined with metals** tend to be **ionic** in terms of chemical bonding e.g.
  - sodium chloride, NaCl or $\mathbf{Na^+Cl^-}$, magnesium chloride $MgCl_2$ or $\mathbf{Mg^{2+}(Cl^-)_2}$,
    - and magnesium oxide, MgO or $\mathbf{Mg^{2+}O^{2-}}$