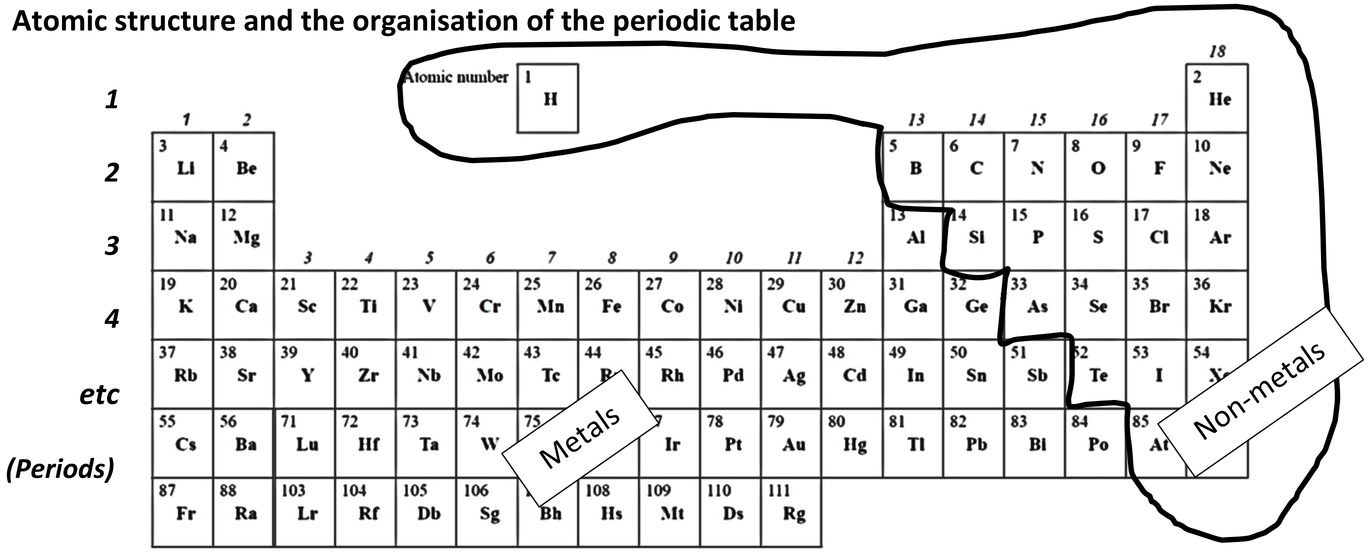
Atomic structure and the organisation of the periodic table



Groups ↓ and Periods → Watch out – period 1 only has H and He in it.

Group # 1 and 2 and 13-18 tell you the number of valence electrons an element has. Be in group 2 has 2 valence electrons; S in group 16 has 6 (16-10) electrons. He – group 18 – only has 2 of course as its atomic number is 2! Trend across a period → is elements go from metals (LHS and middle) to non-metals (RHS).

TRENDS

Down groups.

For metals reactivity INCREASES going down a group e.g. K > Na > Li. This is because there is only 1 electron in the valence shell that is easily lost and the elements get more reactive as that valence electron is further away from the nucleus in the bigger atoms. Similar trend for Group 2 where Ca > Mg.

For non-metals e.g. group 17 (the halogens) the opposite is true; reactivity DECREASES going down the group e.g. F > Cl > Br > I

BUT elements in a group, despite differences in reactivity, show similarities in their reactions as their valence electron arrangement is the same. E.g. since all the metals in group 1 have one valence electron, each reacts in a similar way with air and water etc, and each forms a 1^+ ion.

Demonstrate understanding of aspects of selected elements AS 90933

This achievement standard involves demonstrating understanding of atomic structure and the organisation of the periodic table, and the properties and uses of selected metals, non-metals, and non-metal compounds.

Electron configurations

Electron arrangement of first 20 elements (H to Ca); Electrons fill up 2, 8, 8 etc. up to Ca (2,8,8,2) e.g. Mg atomic # 12 is 2,8,2

Group # (or group # - 10) = # of valence electrons (for groups 1 & 2 and 13-18).

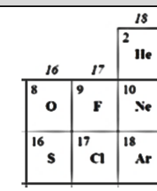
Example: Fluorine 2, 7 ; Chlorine 2, 8, 7

F, Cl, Br and I are all in Group 17 of the periodic table.

Because F and Cl both have 7 electrons in their valence shell, Br and I will also have 7 valence electrons.

See Science AS 90944 for more notes.

Group 18 – Noble gases (also known as inert gases)



He, Ne, Ar, Kr etc are all very unreactive; this is because they each have a full valence shell of 8 electrons (except He which has 2).

This is a stable arrangement; these elements do not combine /bond with other elements to make compounds.

Ions are charged particles formed when some atoms lose or gain electron(s) to achieve a full valence shell (the same electron configuration as the nearest noble gas) because this is a more stable arrangement. Non-metals gain electrons. E.g. F (2,7) will gain an electron to gain the electron arrangement of Ne (2,8), and become F^-. S (2,8,6) will gain 2 electrons to gain the electron arrangement of Ar (2,8,8) and become S^{2-}.

Metal atoms lose electrons to achieve the electron arrangement of the nearest noble gas. E.g. Na 2,8,1 will lose an electron to gain the electron arrangement of Ne (2,8), and becomes Na^+ because it now has one more positively charged proton than electrons. (11+ AND 10-)

PROPERTIES OF METALS – THEIR REACTIVITY AND THEIR USES

Properties are physical and chemical.
Physical properties may include – melting and boiling points (state), colour, lustre, hardness, ductility and malleability, electrical and thermal conductivity, density – and maybe tensile strength.

Chemical properties - corrosion resistant or not; may include reaction with oxygen, reactions with water and acids (HCl, H_2SO_4).

Metal activity series – provided in exam resource booklet.
Na Ca Mg Al Zn Fe Pb (H) Cu Ag
Na is more reactive than Ca, Ca more reactive than Mg etc.

General equations

- Metal + oxygen → metal oxide
- Metal + water → metal hydroxide* + hydrogen
- Metal + acid → metal salt + water

*or metal oxide e.g. Mg + steam

As you down the activity series all the reactions with air, water and acid get less vigorous or may not occur at all.
Ones to know:

React with O_2 – Na, Ca, Mg will burn in O_2; Al, Zn and Fe will if powdered; Pb and Cu tend to form oxide layers.

React with water – Na, Ca react vigorously. Freshly exposed Mg will bubble very very slowly. But Mg, Al, Zn and Fe will react with steam if powdered, with decreasing activity, Pb hardly reacts at all. Cu and Ag do NOT react.

Reaction with acid – Na and Ca – dangerously! Mg, Al, Zn, Fe, Pb with decreasing activity. Cu & Ag do NOT react with dilute HCl or H_2SO_4.

Some sample reactions and expected observations

Metal + oxygen
A silvery grey strip of magnesium ribbon reacts with the colourless gas oxygen by burning with a bright white light. White smoke is given off and a white ash remains after the reaction. The magnesium is reacting with oxygen to form the (ionic) compound magnesium oxide. $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

Metal + water
Lithium floats on water - gently fizzing, giving off H_2 gas until it disappears. Not much heat is produced, so Li does not melt. A colourless solution of LiOH is formed.
$2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$
Sodium is more reactive than lithium. Sodium also floats on the surface, but enough heat is given off to melt the sodium (Na has a lower m.pt than Li and the more vigorous reaction produces more heat) - it melts almost at once to form a small silvery ball that dashes around the surface, pushed by the H_2 gas being formed. A colourless solution of sodium hydroxide is formed. Sometimes the H_2 catches fire burning with a yellow-orange flame. (Colour due to contamination of H_2 flame with sodium compounds).
$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$
Calcium reacts vigorously with water to form a metal hydroxide and hydrogen gas. The water goes cloudy as sparingly soluble calcium hydroxide forms, and there is fizzing, which indicates a gas (hydrogen). $Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2 (aq) + H_2 (g)$
Magnesium does not generally react with cold water unless very clean.
$Mg(s) + 2H_2O(l) \rightarrow Mg(OH)_2(s) + H_2 (g)$
It will react in steam to produce white magnesium oxide and hydrogen gas.
$Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2 (g)$
Magnesium is not as reactive as calcium because it is further down the activity series / it does not lose its 2 valence electrons as easily as calcium.

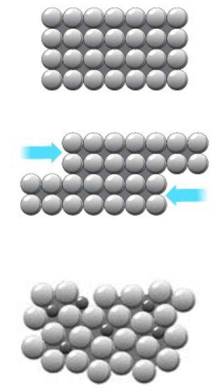
Metal + acid
Zinc, a reactive metal. Bubbles of gas are released. Metal disappears (may detect heat being released). $Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$
Iron reacts with dilute sulfuric acid relatively slowly. Some bubbles of gas are formed as hydrogen gas forms and the metal slowly disappears. However zinc is higher on the activity series than iron, so the zinc will react faster than the iron. $Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$
Lead, an unreactive metal. Small bubbles of gas appear on the surface of the metal. (It is unlikely that any heat will be detectable or that any of the metal will be seen to disappear, unless over a long period.) $Pb(s) + H_2SO_4(aq) \rightarrow PbSO_4(aq) + H_2(g)$

Physical properties of metals

Physical properties may include

- melting and boiling points (state),
- colour,
- lustre,
- hardness,
- ductility and malleability,
- electrical and thermal conductivity,
- density
- tensile strength.

ALLOYS



An alloy is a metal made by combining two or more elements (usually metals) to give improved properties such as greater strength or greater resistance to corrosion.

Atoms in a pure metal are perfectly aligned, but not in an alloy. The atoms can slide past each other relatively easily. This makes the metal malleable so it can be shaped without breaking. By alloying this metal, another element has been added and its atoms do not sit neatly within the metal structure. Atoms of differing sizes create an irregular arrangement. Now these atoms are not easily able to slide across each other so the metal is harder and it is not as easy to change its shape.

Uses of metals

Example:

Copper and aluminium are both good conductors of electricity and so are used for power cables and power lines. Both are ductile and easily drawn into wires.

Copper - Excellent electrical conductor, better than Al so more efficient in its energy transfer. Is dense (and so expensive support structures needed to be used in comparison to aluminium). Also corrosion resistant so will not react with household substances and cause any problems.

Has higher melting point than aluminium, so is less likely to melt and cause damage in household wiring.

Aluminium

Its low density makes it the first choice for long distance power lines because it is cheaper to build structures to hold up power lines. Not such a good electrical conductor than copper which means it will not be as efficient in its energy transfer.

Aluminium is corrosion-resistant due to oxide layer that is formed because of aluminium's reactivity with oxygen in the air so it will withstand the conditions of the outside.

Examples of alloys

Surgical steel is used because as an alloy; it has a mixture of elements in it that give it desired characteristics. E.g. Body piercing jewellery needs to be sterile, shiny, malleable and unreactive. Corrosion resistance is important so that the jewellery doesn't corrode / react in someone's nose / mouth / belly button area and remains something that is easily sterilised / cleaned.

Cr in the alloy provides a shiny appearance (lustre) and provides scratch and corrosion resistance. **Ni** provides a smooth finish and corrosion resistance. **Mo** provides extra hardness and corrosion resistance to the alloy.

Steel / iron is malleable as are other metals so it can be shaped into jewellery but with the Mo and Ni, it will not break due to high tensile strength. Although iron has lustre, nickel and chromium provide a shininess and high lustre in the alloy so that the jewellery remains shiny and looks good (aesthetically pleasing).

Sterling silver

Silver is an attractive metal - lustrous white and malleable - can be turned into jewellery or other precious objects. Silver is quite unreactive, so will not readily react with oxygen in the air, water, food or beverages, making it useful to use in jewellery or other precious objects.

Sterling silver is an alloy made up of mostly silver (92.5%) and some copper (7.5%). Silver has a high melting point (962°C) but is not very hard.

Advantages of sterling silver over pure silver: Alloy is stronger / harder because the copper atoms are smaller than the silver ones so the atoms don't move across each easily as the atoms in pure silver metal can, making sterling silver stronger / harder than pure silver.

Disadvantages of sterling silver over pure silver: Alloy is more brittle and / or more difficult to shape / bend than the pure metal because the atoms in an alloy can't move across each other as easily as those in a pure metal. (Less malleable and ductile than pure silver.)

Since copper is more reactive than silver, by adding it to silver as an alloy it will make the alloy less resistant to corrosion than the pure metal. (The copper will oxidise more readily).