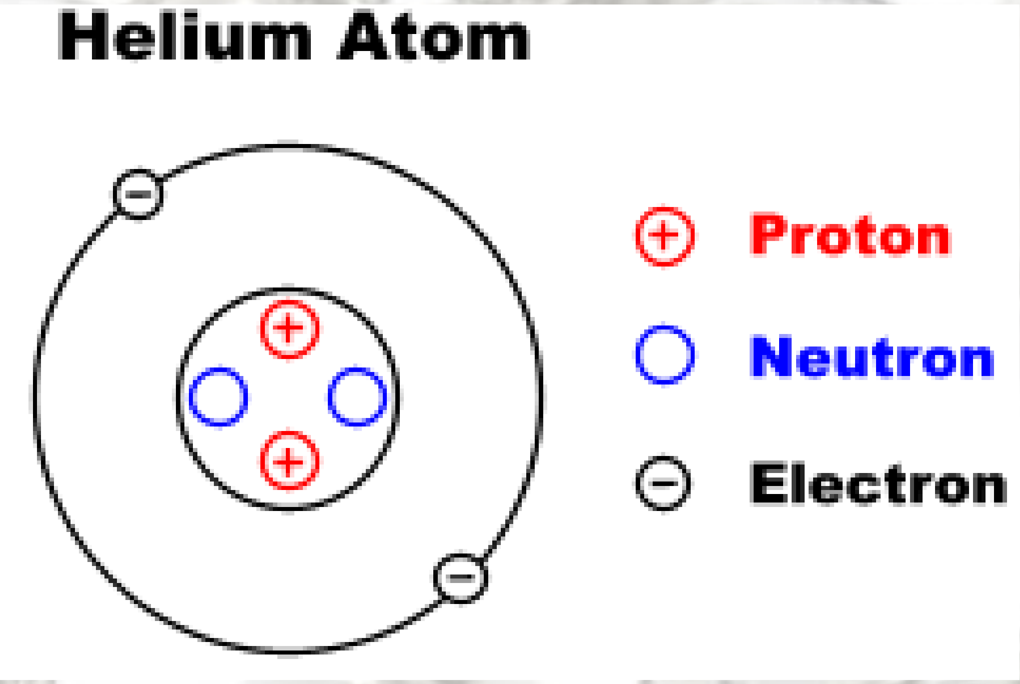
All you need to know about Additional Science

Chapters in this unit

- 1. Structures and bonding
- 2. Structures and properties
- 3. How much?
- 4. Rates of reaction
- 5. Energy and reactions
- 6. Electrolysis
- 7. Acids, alkalis and salts

1.1 Atomic structure



Type of sub-atomic particle	Relative charge	Mass
Proton	+1	1
Neutron	0	1
Electron	-1	Negligible

1.1 Atomic structure

Columns = groups
Group number = number of electrons in outer shell

Rows = periods
Row number = number of shells

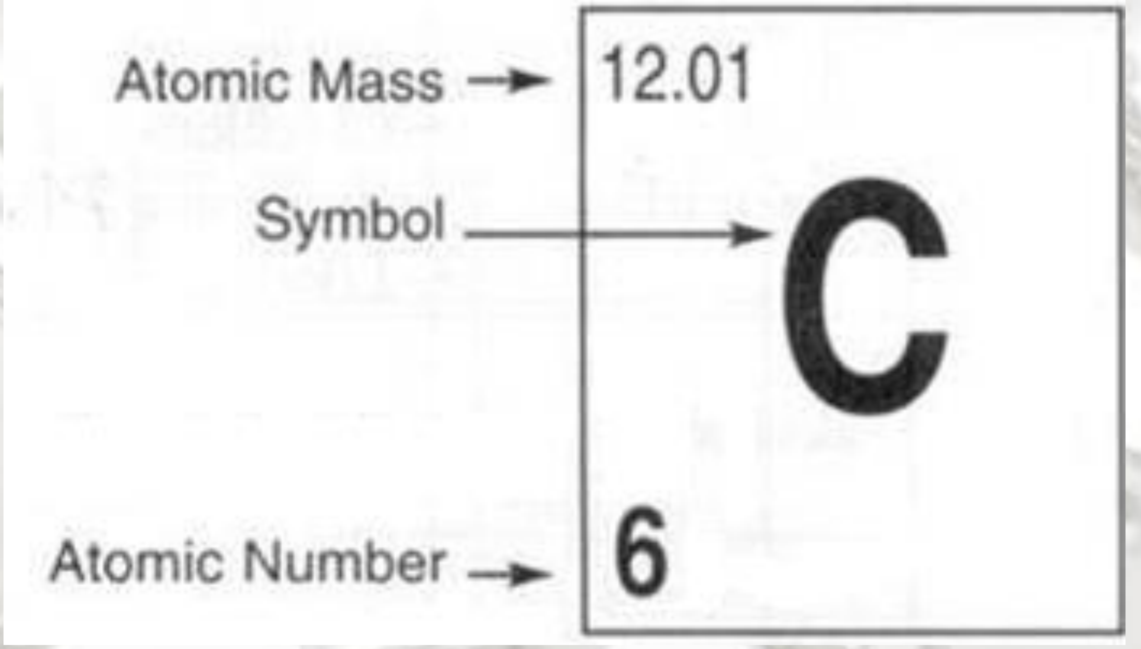
hydrogen 1 H 1.0079																		helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122												boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305												aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 * *	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]				

*Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
* *Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

1.1 Atomic structure

Atomic number:

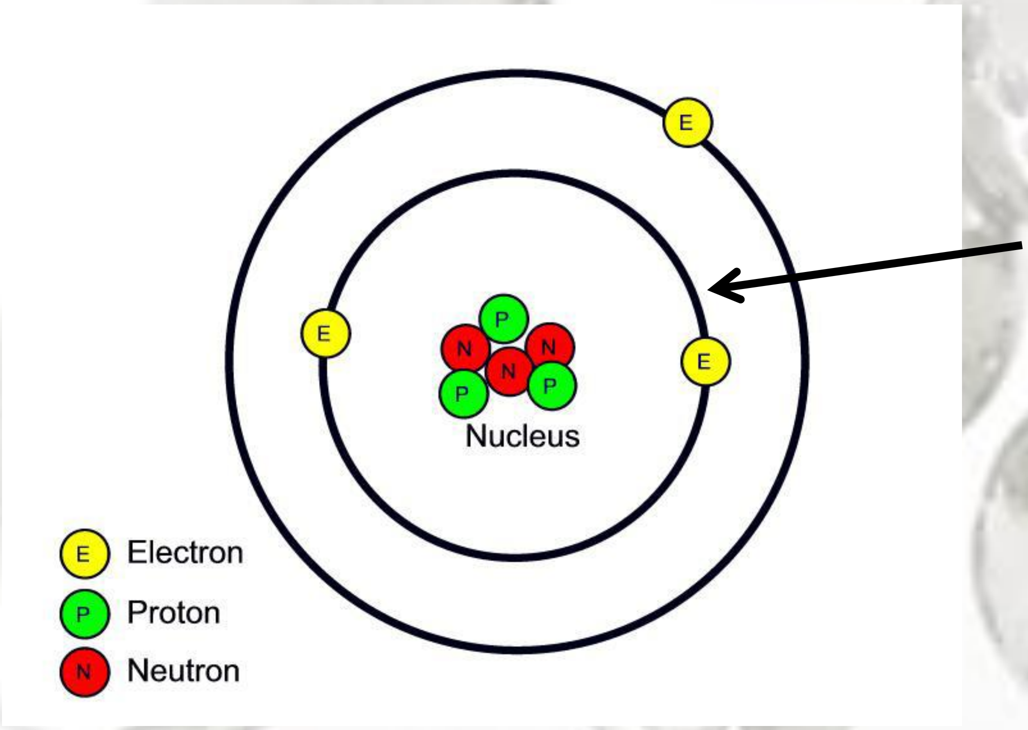
The number of protons in an atom



Mass number:

The number of protons and neutrons in an atom

1.2 Electronic arrangement

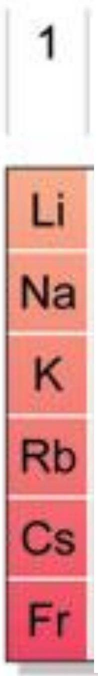


Each shell =
different energy level

Shell nearest nucleus =
lowest energy level

Energy needed to
overcome attractive
forces between
protons and electrons

1.2 Electronic arrangement



<u>Group 1 metals (aka alkali metals)</u>

- Have 1 electron in outer most shell
- Soft metals, easily cut
- Reacts with water and oxygen
- Reactivity increases down the group
- Low melting and boiling points

1.2 Electronic arrangement

<u>Group 0/8 metals (aka noble gases)</u>

- Have 2/8 electrons in outer most shell
- Very stable gases, no reaction

1.2 Electronic arrangements

No.	Element	Shell			
		1	2	3	4
1	Hydrogen	1			
2	Helium	2			
3	Lithium	2	1		
4	Berylium	2	2		
5	Boron	2	3		
6	Carbon	2	4		
7	Nitrogen	2	5		
8	Oxygen	2	6		
9	Fluorine	2	7		
10	Neon	2	8		

No.	Element	Shell			
		1	2	3	4
11	Sodium	2	8	1	
12	Magnesium	2	8	2	
13	Aluminium	2	8	3	
14	Silicon	2	8	4	
15	Phosphorus	2	8	5	
16	Sulphur	2	8	6	
17	Chlorine	2	8	7	
18	Argon	2	8	8	
19	Potassium	2	8	8	1
20	Calcium	2	8	8	2

1.3 Chemical bonding

- Mixture

The combined substances do not change

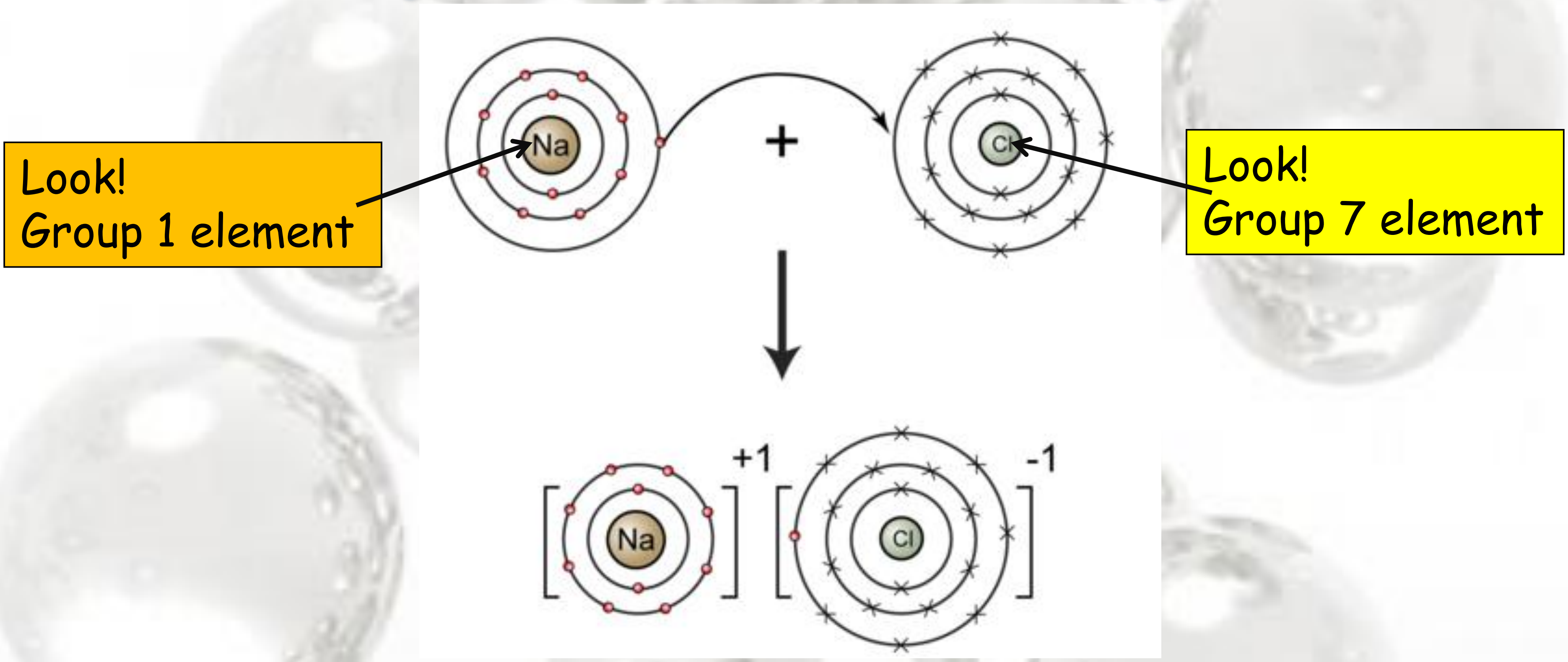
Easy to separate

- Compound

Chemical reaction takes place

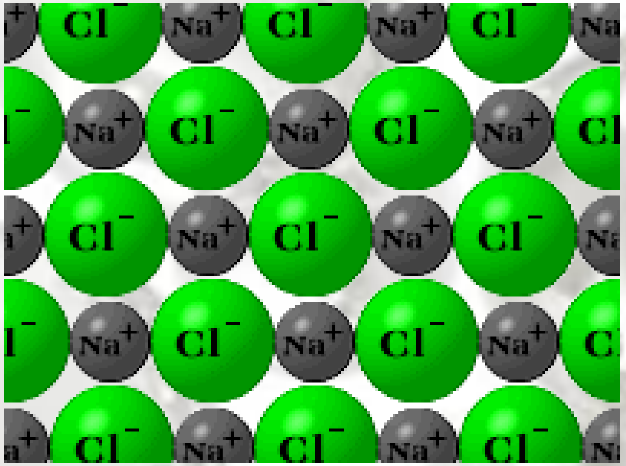
Bonds form between atoms

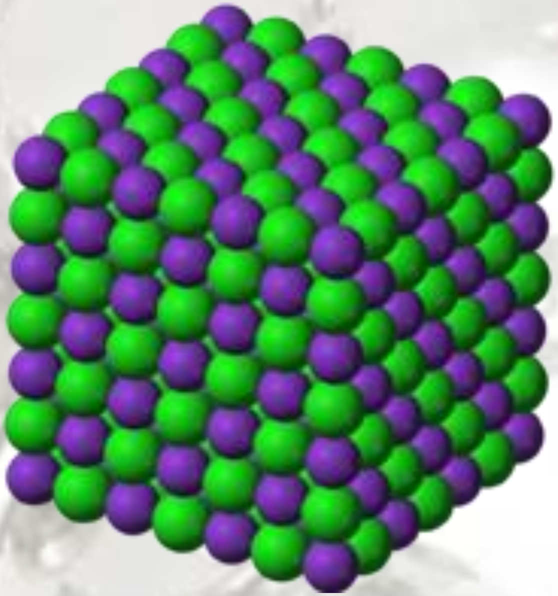
1.4 Ionic bonding (metal + non-metal)



Very strong forces of attraction between positive and negative ions = ionic bond

1.4 Ionic bonding (metal + non-metal)

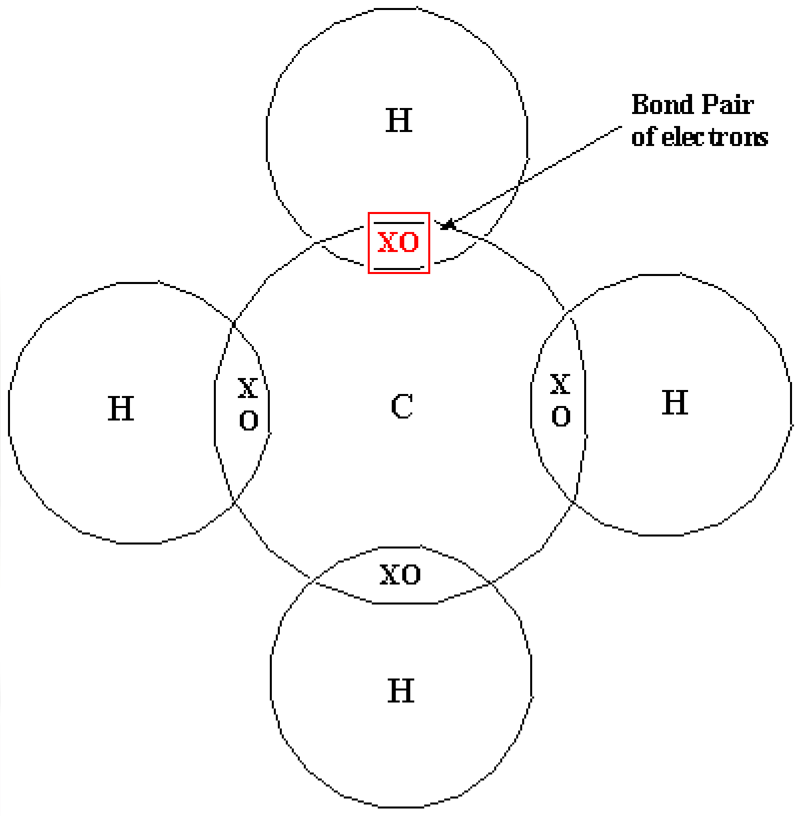




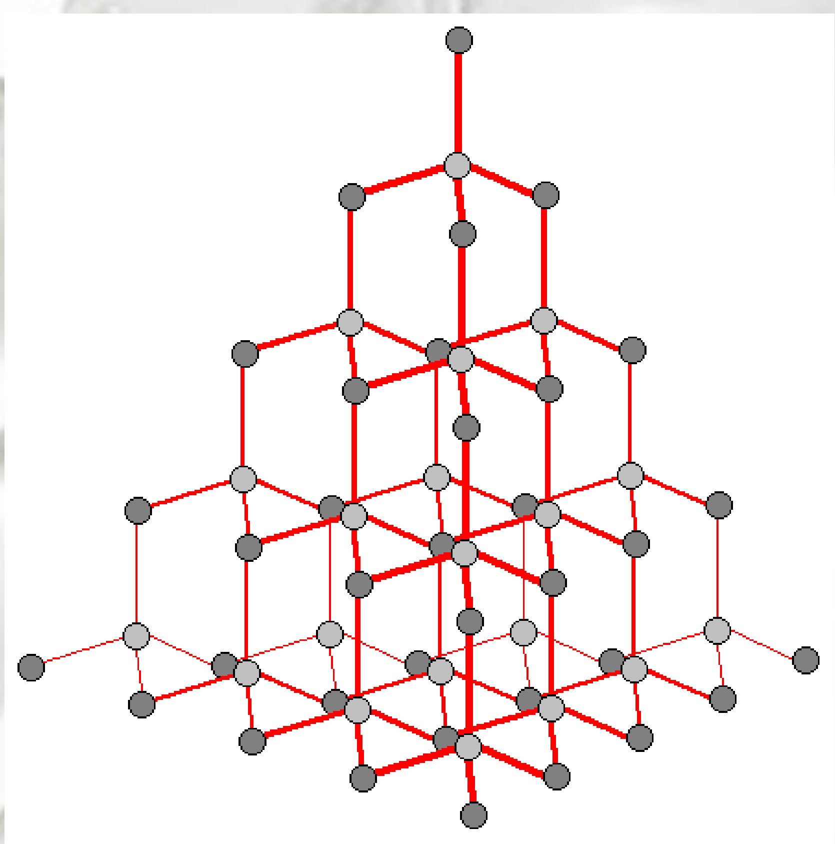
Ionic bonds form a giant lattice structure

1.5 Covalent bonding (non-metal + non-metal)

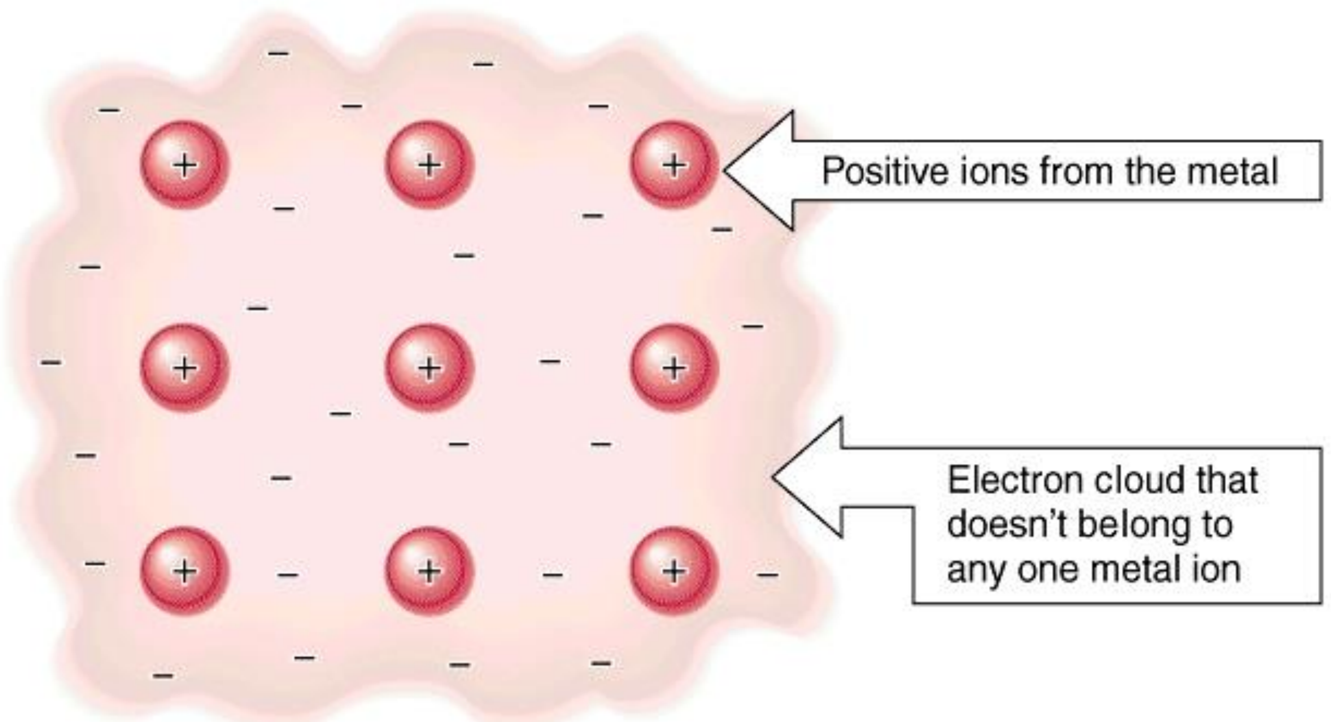
Simple molecules



Giant structures



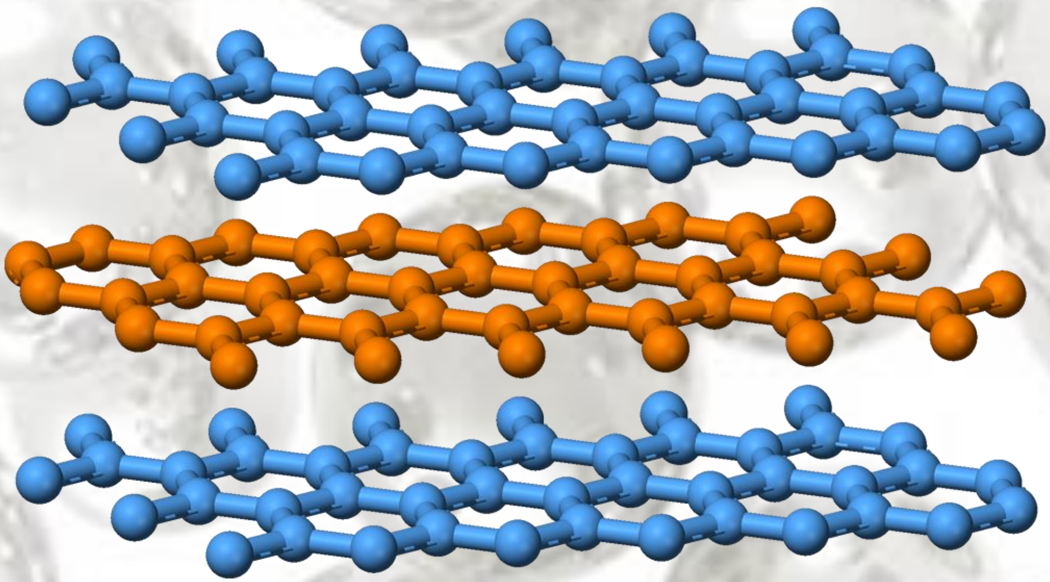
1.6 Bonding in metals



2.1 - 2.4 Properties

	Ionic	Simple (covalent)	Giant (covalent)	Metallic
Melting point	↑ (Strong electrostatic forces)	↓ (Strong covalent bonds, weak intermolecular forces)	↑ (Strong covalent bonds)	
Boiling point	↑	↓	↑	
Electrical/ heat conductor	Yes, when molten or in solution (aq) as allows ions to move	No, due to no overall charge	No – diamond Yes – graphite due to delocalised electrons	Yes, due to delocalised electrons

2.3 Graphite



Layers of graphite slip off and leave a mark on paper

The free e^- from each C atom can move in between the layers, making graphite a good conductor of electricity

2.4 Metal

- Pure metals are made up of layers of one type of atoms
- These slide easily over one another and therefore metals can be bent and shaped

2.5 Nanoscience

- Structures are:

  1-100 nm in size or

  a few hundred atoms

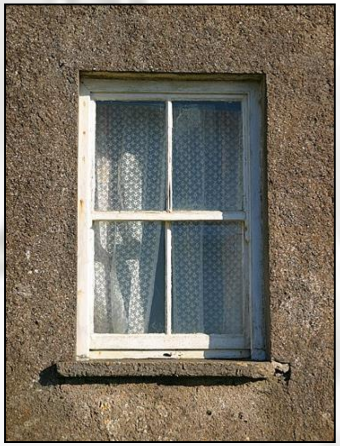
- Show different properties to same materials in bulk

- Have high surface area to volume ratio

2.5 Nanoscience

- <u>Titanium oxide on windows</u>

  Titanium oxide reacts with sunshine, which breaks down dirt



- <u>Silver and socks</u>

  Silver nanoparticles in socks can prevent the fabric from smelling

3.1 Mass numbers

Mass number –
atomic number
= number of neutrons

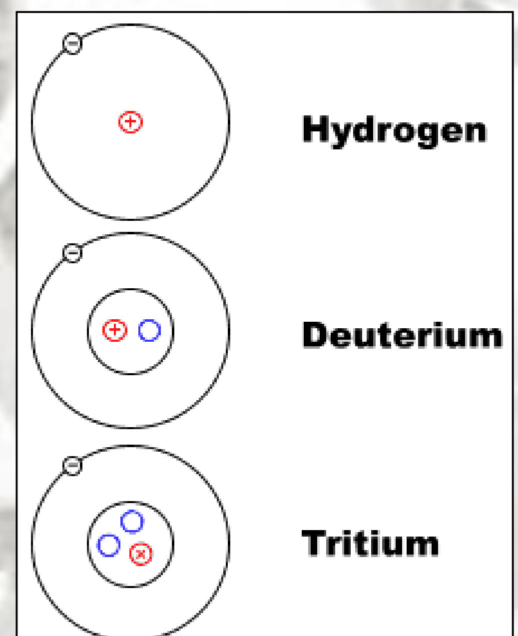
E.g. Sodium

23 – 11 = 12

$$^{23}_{11}Na$$

<u>Isotopes</u>

- Same number of protons
- Different number of neutrons



3.2 Masses of atoms and moles

Relative atomic masses (A_r)

Mass of atom compared to ^{12}C

e.g. Na = 23, Cl = 35.5

Relative formula masses (M_r)

Mass of a compound found by adding A_r of each element

e.g. NaCl = 23 + 35.5 = 58.5

Moles

- A mole of any substance always contains same number of particles

- Relative atomic mass in grams

- Relative formula mass in grams

3.3 Percentages and formulae

Percentage mass

$$\% = \frac{\text{mass of element}}{\text{total mass of compound}}$$

Percentage composition / empirical formula

	Al	Cl
Mass	9	35.5
Ar	27	35.5
Moles	(9/27) = 0.33	(35.5/35.5) = 1
Simplest ratio (divide by smallest number of moles)	(0.33 / 0.33) = 1	(1 / 0.33) = 3
Formula	$AlCl_3$	

3.4 Balancing equations

$$H_2 + O_2 \rightarrow H_2O$$

Elements (Right-hand side)	Elements (Left-hand side)
H =	H =
O =	O =

3.4 Reacting masses

$$2NaOH + Cl_2 \rightarrow NaOCl + NaCl + H_2O$$

If we have a solution containing 100 g of sodium hydroxide, how much chlorine gas should we pass through the solution to make bleach? Too much, and some chlorine will be wasted, too little and not all of the sodium hydroxide will react.

3.4 Reacting masses

$2NaOH + Cl_2 \rightarrow NaOCl + NaCl + H_2O$

100 g ?

	2NaOH	Cl_2
A_r / M_r	80	71
Ratio	(80/80) = 1 1 x 100 = 100	(71/80) = 0.8875 0.8875 x 100 = 88.75
Mass	100 g	88.75 g

3.5 Percentage yield

Very few chemical reactions have a yield of 100% because:

- Reaction is reversible
- Some reactants produce unexpected products
- Some products are left behind in apparatus
- Reactants may not be completely pure
- More than one product is produced and it may be difficult to separate the product we want

3.5 Percentage yield

Percentage yield

$$\% \text{ yield} = \frac{\text{amount of product produced (g)}}{\text{max. amount of product possible (g)}} \times 100\%$$

3.5 Atom economy

The amount of the starting materials that end up as useful products is called the atom economy

$$\%\ \text{atom economy} = \frac{M_r \text{ of useful product}}{M_r \text{ of all products}} \times 100\%$$

3.6 Reversible reactions

$$A + B \rightleftharpoons C + D$$

$\rightleftharpoons$ = reversible reaction

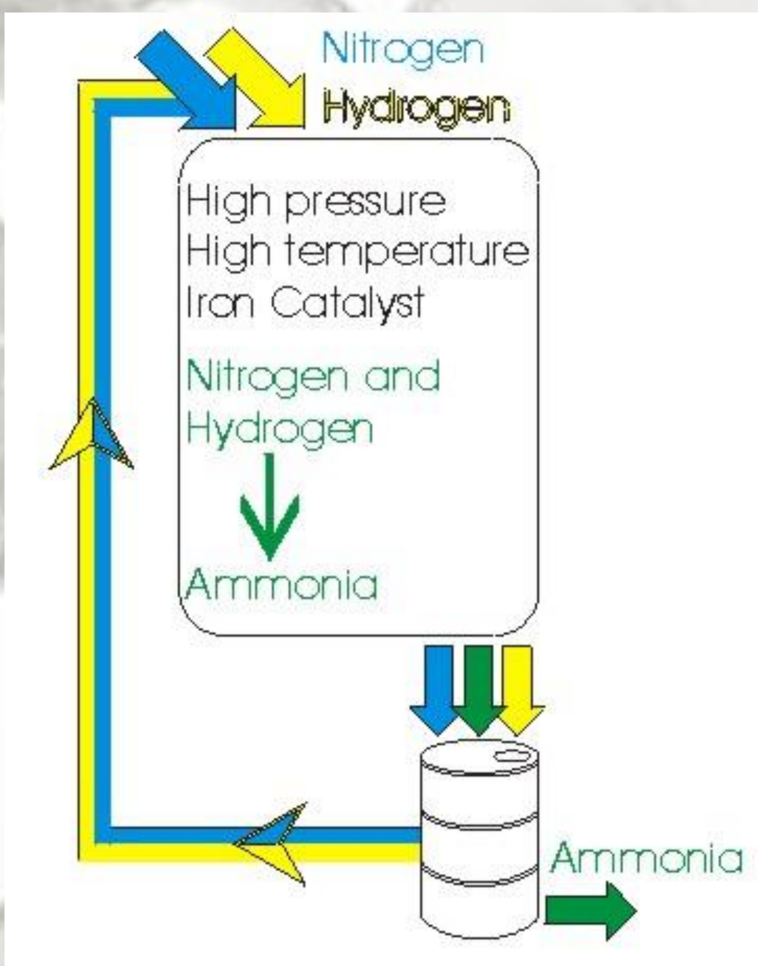
e.g. iodine monochloride and chlorine gas:

$$ICl + Cl_2 \rightleftharpoons ICl_3$$

- increasing Cl_2 increases ICl_3
- decreasing Cl_2 decreases ICl_3

3.7 Haber process

- Fritz Haber invented the Haber process
- *A way of turning nitrogen in the air into ammonia*



$$N_2 + 3H_2 \underset{200\ atm}{\overset{450^oC}{\rightleftharpoons}} 2NH_3$$

4.2 Collision theory

<u>Collision theory</u>

Chemical reactions only occur when reacting particles collide with each other with sufficient energy. The minimum amount of energy is called the activation energy

Rate of reaction increases if:

- temperature increases
- concentration or pressure increases
- surface area increases
- catalyst used

4.2 Surface area

Why?

The inside of a large piece of solid is not in contact with the solution it is reacting with, so it cannot react

How?

Chop up solid reactant into smaller pieces or crush into a powder

4.3 Temperature

Why?

At lower temperatures, particles will collide:

a) less often

b) with less energy

How?

Put more energy into reaction

Increasing the temperature by 10^{o}C will double the rate of reaction

4.4 Concentration

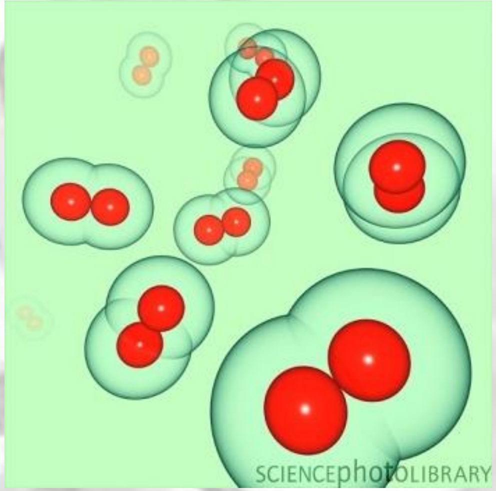
Why?

Concentration is a measure of how many particles are in a solution. Units = mol/dm^3

The lower the concentration, the fewer reacting particles, the fewer successful collisions

How?

Add more reactant to the same volume of solution



4.4 Pressure

Why?

Pressure is used to describe particles in gases

The lower the pressure, the fewer successful collisions

How?

Decrease the volume or
Increase the temperature

4.5 Catalysts

Why?

Expensive to increase temperature or pressure

Do not get used up in reaction and can be reused

How?

Catalysts are made from transition metals, e.g. iron, nickel, platinum

Provide surface area for reacting particles to come together and lower activation energy

5.1 Energy changes

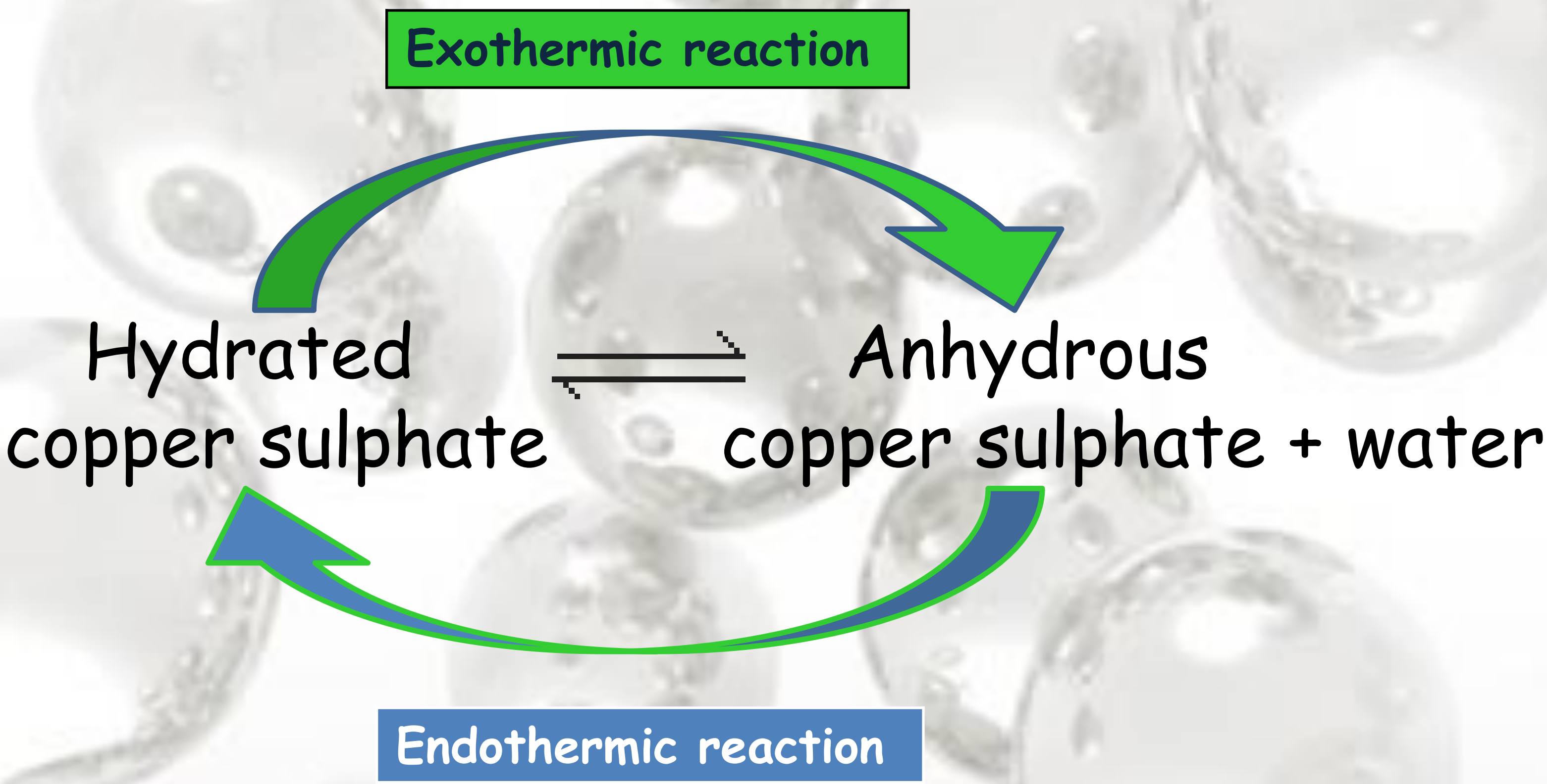
<u>Exothermic reaction</u>, e.g. respiration

- Energy 'exits' reaction – heats surroundings
- Thermometer readings rises

<u>Endothermic reaction</u>, e.g. photosynthesis

- Energy 'enters' reaction – cools surroundings
- Thermometer readings fall

5.2 Energy and reversible reactions



5.3 Haber process (again!)

Exothermic reaction	↑ temperature, ↓ products	↓ temperature, ↑ products

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

Endothermic reaction	↑ temperature, ↑ products	↓ temperature, ↓ products

5.3 Haber process (again!)

Smaller vol. of gas produced	↑ pressure, ↑ products	↓ pressure, ↓ products

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

Larger vol. of gas produced	↑ pressure, ↓ products	↓ pressure, ↑ products

5.3 Haber process (again!)

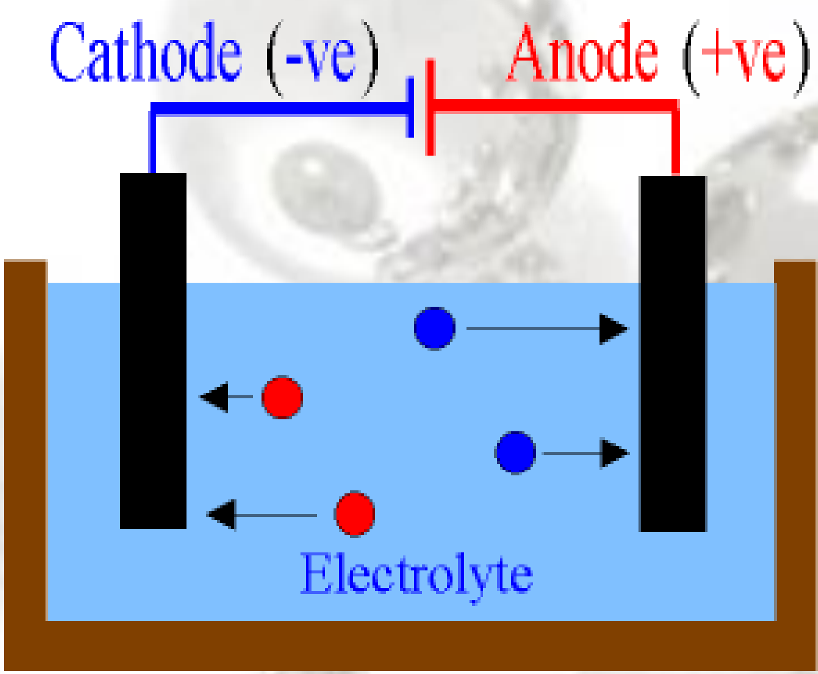
Temperature:
- Forward reaction is exothermic, so low temperature is preferred
- But this makes reaction slow
- Compromise by using 450^{o}C

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

Pressure:
- The higher the better
- High pressure is dangerous!
- Compromise by using 200-350 atm

Catalyst:
- Iron
- Speeds up both sides of reaction

6.1 Electrolysis



Electrolysis: splitting up using electricity

Ionic substance

- molten (l)
- dissolved (aq)

Non-metal ion

Metal ion

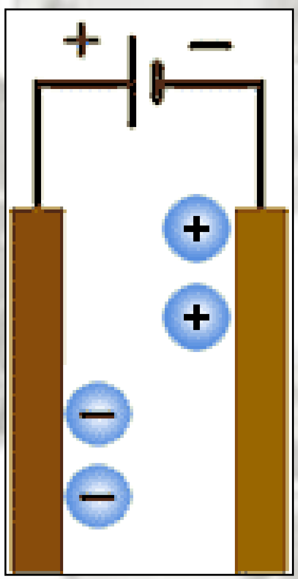
6.2 Changes at the electrodes

Solutions

Water contains the ions:

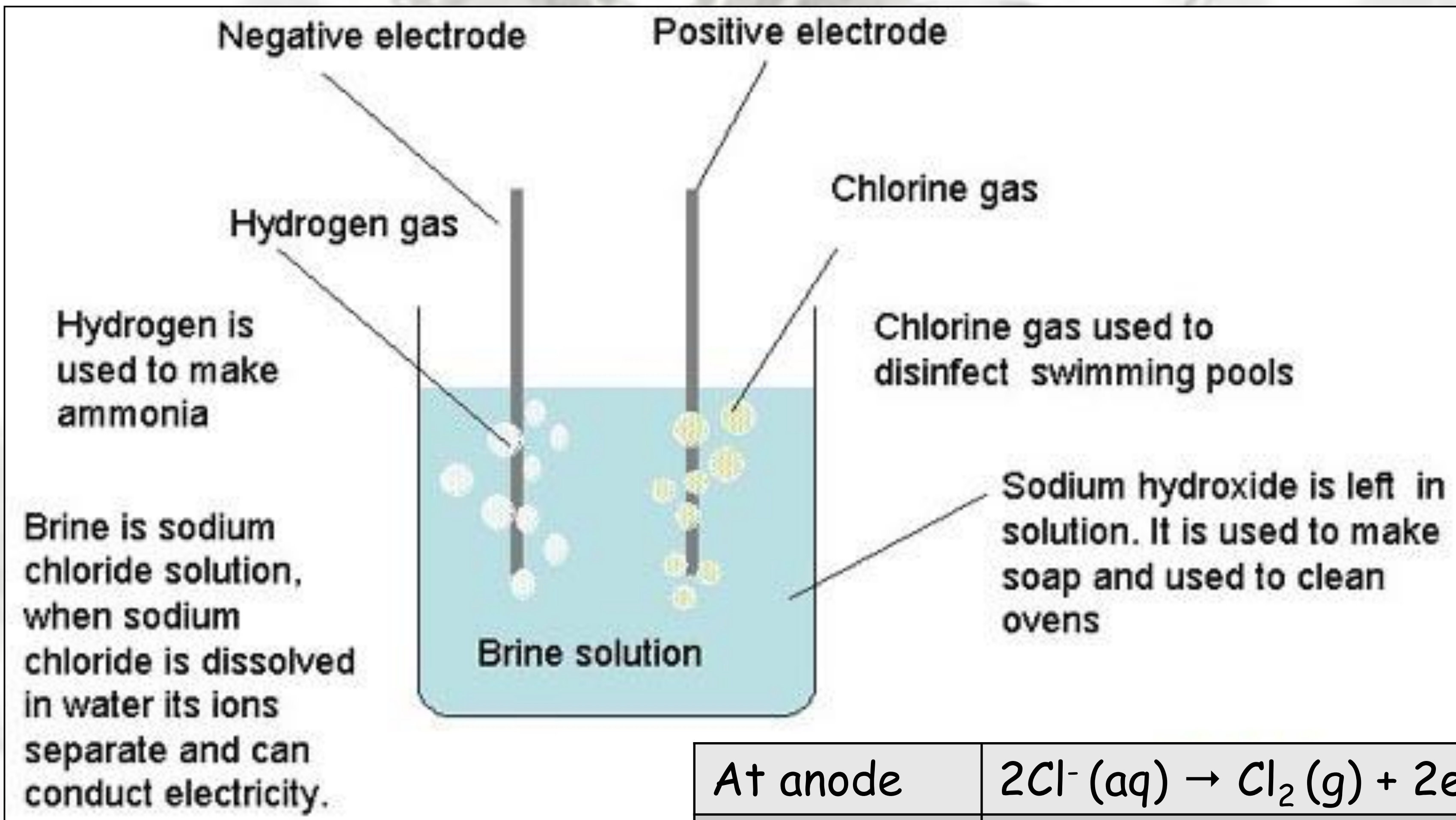
H^+ and O^{2-}

The less reactive element will be given off at electrode



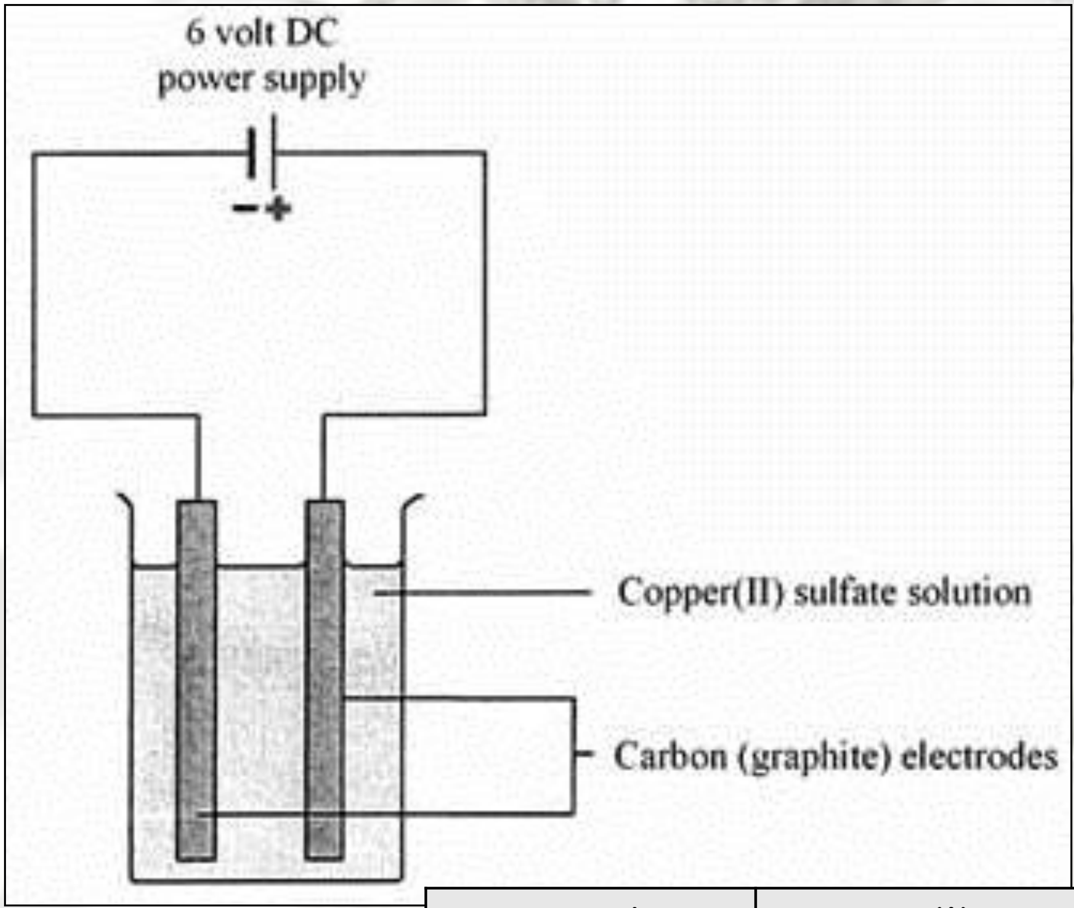
	Oxidation is loss	Reduction is gain
	OIL	RIG
Molten (PbBr)	$2Br^- \rightarrow Br_2 + 2e^-$	$Pb^{2+} + 2e^- \rightarrow Pb$
Solution (KBr)	$2Br^- \rightarrow Br_2 + 2e^-$	$2H^+ + 2e^- \rightarrow H_2$

6.3 Electrolysing brine



At anode	$2Cl^{-}(aq) \rightarrow Cl_2(g) + 2e^{-}$
At cathode	$2H^{+}(aq) + 2e^{-} \rightarrow H_2(g)$
In solution	Na^{+} and OH^{-}

6.4 Purifying copper



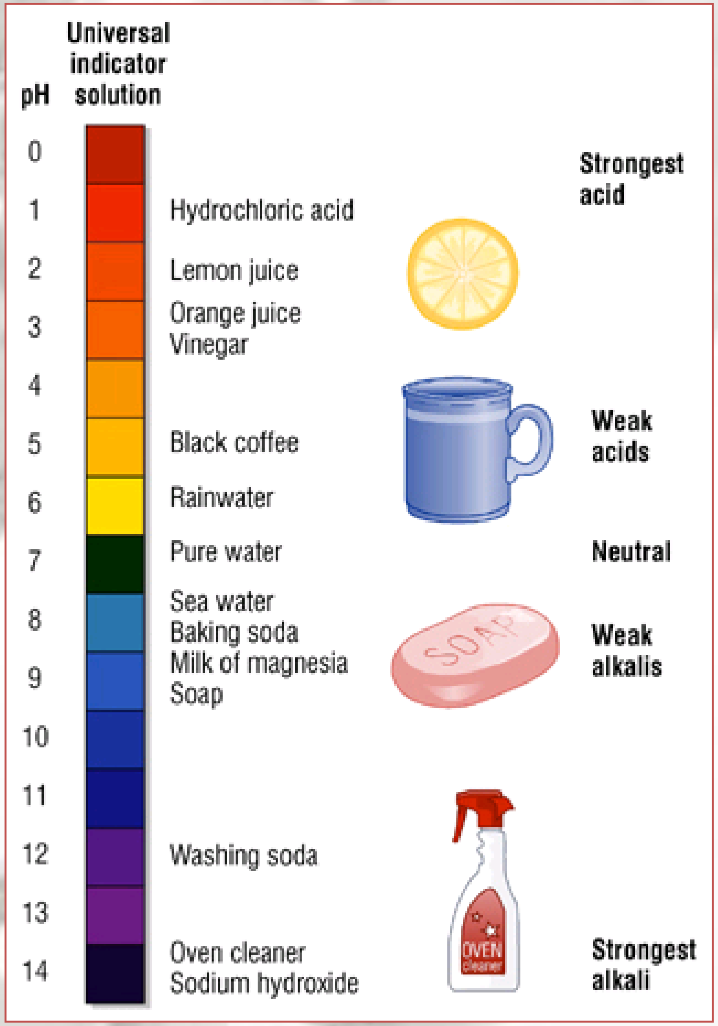
At anode	$2H_2O\,(l) \rightarrow 4H^+\,(aq) + O_2\,(g) + 2e^-$
At cathode	$Cu^{2+}\,(aq) + 2e^- \rightarrow Cu\,(s)$

7.1 Acids and alkalis

Acids = H^+ ions

Alkalis = OH^- ions

Alkalis = soluble bases



7.2 + 7.3 Salts

Acid	Formula	Salt	Example
Hydrochloric	HCl	Chloride	Sodium chloride
Sulphuric	H_2SO_4	Sulphate	Copper sulphate
Nitric	HNO_3	Nitrate	Potassium nitrate

7.2 + 7.3 Salts – metals, bases and alkalis

Metals:

Metal(s) + acid(aq) → salt(aq) + hydrogen(g)

Bases: Acid(aq) + base(aq) → salt(aq) + water(l)

Alkalis: Acid(aq) + alkali(aq) → salt(aq) + water(l)

Ionic equation (neutralisation): $H^+ + OH^- \rightarrow H_2O$

7.3 Salts – solutions

Solutions:

solution(aq) + solution(aq) → precipitate(s) + solution(aq)

Solid precipitate is filtered off and dried