Topic 1 – Atomic structure and the periodic table

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1.1 A simple model of the atom, symbols, relative atomic mass, electronic charge and isotopes

1.1.1 Atoms, elements and compounds

Atom – smallest part of an element that can exist

Element

- Substance made of 1 type of atom
- Cannot be broken down chemically into simpler substance

Compound

- 2 or more elements chemically bonded in fixed properties
- Form / separate by chemical reactions

Molecules – collection of 2 or more atoms chemically bonded by covalent bonds

1.1.2 Mixtures

Mixture

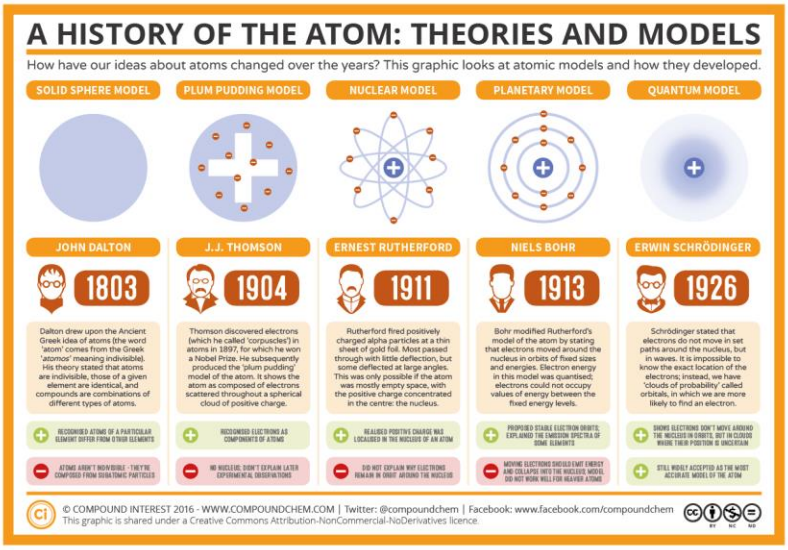
- 2 or more elements / compounds not chemically bonded tgt
- Separated by physical processes
    - Not involved chemical reactions
    - No new substances made

Separation techniques

Simple distillation	• Separates a liquid from a solution	1. Heat mixture until it boils & evaporates into water vapour 2. Water vapour rises up & passes through condenser 3. As condenser is cold, water vapour condenses back to water, which is collected in the flask
Fractional distillation	• Separates 2 liquids with similar boiling pt & are miscible	1. Heat mixture 2. Liquid with lower melting pt evapourates into vapour 3. Vapour rises up & passes through fractionating column 4. Vapour condenses back to water, which is collected in the flask 5. Liquid with higher melting pt start evapourate 6. Crude oil is heated & vaporised as it enters fractional distillation column 7. Shorter chain lengths have weaker intermolecular forces & lower boiling pt 8. This means they will condense at top of column where it's cooler 9. Longer chain lengths have stronger intermolecular forces & higher boiling pt 10. This means they will condense at bottom of column where it's hotter 11. This is due to different chains length of hydrocarbons having different boiling pt so they can be separated & tapped off at different levels as fractions

Filtration	• Separates an insoluble solid from a liquid	1. Pour solid and liquid mixture in filter funnel which contains filter papers 2. Liquid goes through filer paper but solid does not
Crystallisation	• Separate soluble solid from solution	1. Pour acid into beaker 2. Gently heat acid with Bunsen Burner till almost boiling 3. Add base to acid one spatula at a time & stir at the same time till base is in excess 4. Filter excess base using filter paper & funnel 5. Pour solution into evaporating basin 6. Heat gently over beaker of boiling water till half of solution remains 7. Leave to cool and crystallise 8. Pat dry using filter paper
Chromatography	• Separate mixtures & give info to help identify substance	1. Draw a pencil line on the paper. 2. Place ink on the baseline in a dot. 3. Place the paper into the beaker which has water in it. Make sure the baseline is above water level, so dye doesn't dissolve in water. 4. Hang paper over edge of beaker to keep it right. 5. Put a lid on. 6. Wait for solvent to go up paper near the top. 7. Remove paper & let it dry. 8. Draw circles around spots.

1.1.3 The development of the model of the atom



1. **John Dalton** – tiny hard sphere & indivisible
2. **JJ Tomson** – **'Plum Puddy Model'**

   Experiment
   - Apply high voltages to gases at low pressure on beams of particles

   Results
   - Attract on +ve charge
   - Show atom contains -ve charged particles (electrons)

- -ve charged e^- embedded in a cloud of +ve charge → atom is neutral

3. **Rutherford – 'Alpha Particle Scattering Experiment'**

Experiment

- Fired +ve alpha particle beams on extremely thin gold foil

Results

a) Straight through → most atom is empty spaced
b) Slightly deflected → nucleus is +ve charged
c) Deflected by >90° → nucleus is +ve charged

- +ve nucleus concentrate mass of atom at centre of atom
- -ve e^- exist in cloud around nucleus

4. **Neil Bohr – 'Nuclear Model'**

Experiment

- Notice light given out when atoms were heated only had specific amount of energy

Results

- e- orbit nucleus in specific energy levels at specific distances with nothing in between

5. **James Chadwick** – proved neutrons existed in nucleus in 1932

1.1.4 Relative electrical charges of subatomic particles
1.1.5 Size and mass of atoms

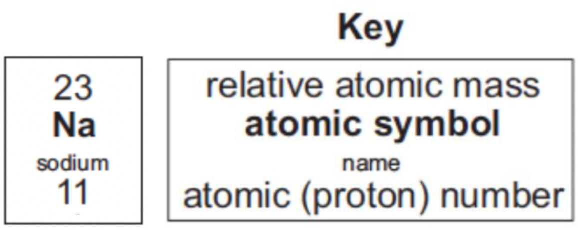
Name of particle	Relative mass	Electric charge
Proton	1	+1
Neutron	1	0
Electron	0 or $\frac{1}{1836}$	-1

Why doesn't an atom have charge?

- Relative electrical charge
  - Electrons: -1, protons :+1
- No of electrons = no of protons

Atom radius = 0.1nm (1×10^{-10}m)
Nucleus radius = $\frac{1}{10000}$ of an atom (1×10^{-14}m)

Formulae
No of neutrons = mass no – atomic no = 23-11 = 12
Atomic no = no of protons = 11
Mass no = protons + neutrons



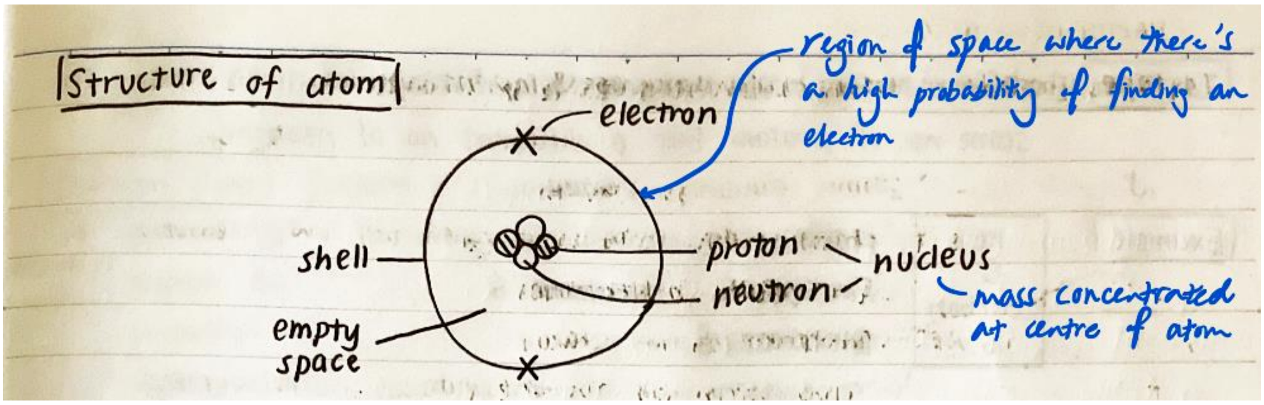
1.1.6 Relative atomic mass

$$Relative\ atomic\ mass = \frac{sum\ of\ (isotope\ adundance \times\ isotope\ mass\ no)}{100\ (total\ no\ at\ atoms)}$$

High relative atom mass

- Less waste products
- Less pollutants

1.1.7 Electronic structure



Explain why fluorine and chlorine are in the same group of the period table. Give the electronic structures of fluorine and chlorine in your explanation. (2)

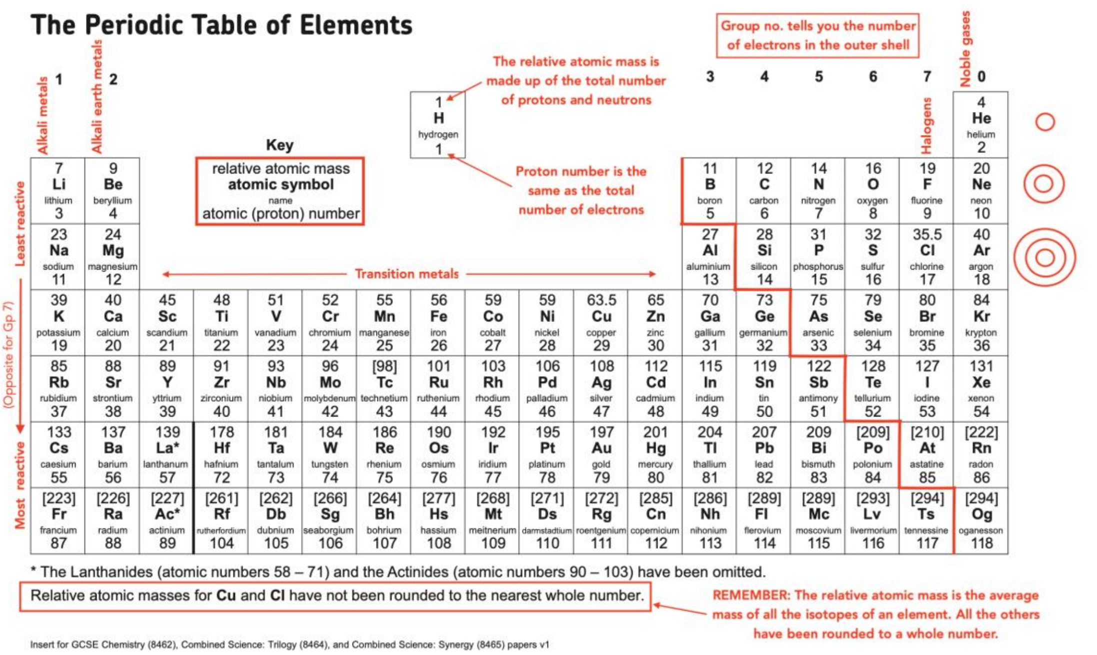
- Isotope is different forms of the same element, which have the same no of protons but different no of neutrons
- The electronic structure of fluorine is 2,7 and chlorine is 2,8,7
- F & Cl both has 7e- in outer shell

Explain why $^{12}_{6}C$ and $^{14}_{6}C$ are isotopes of carbon. You should refer to the numbers of sub-atomic particles in the nucleus of each isotope. (3)

- Isotope is different forms of the same element, which have the same no of protons but different no of neutrons
- They both have 6 protons
- 12C has 6 neutrons, 14C has 8 protons

1.2 The periodic table

1.2.1 The periodic table



Arrangement – order of increasing atomic no

- Elements with similar properties are in **columns**, aka **groups**

Why is the table called periodic table?

- Similar properties occur at regular intervals

Why are the elements in the same group?

- Same no of e- on outer shell
- Similar chemical & physical properties

1.2.2 Development of the periodic table

1. **Antoine Lavoisier** – has compounds

2. **John Newlands**
   - Arranged strictly in octaves by atomic weights (but no chemical properties)
   - Realised every 8th element reacts in similar way – 'Law of octaves'

3. **Dimitri Mendeleev**
   - Arranged in order of atomic mass but changed some order base on atomic weight
     - Isotopes proved correct
   - Left gaps for elements that he though hadn't been discovered

   Why Mendeleev left gaps?
   - For undiscovered elements so elements with similar properties can be placed tgt / pattern fit
   - Predicted properties of missing elements

   Later on, elements discovered properties matches predictions

4. **Modern** – organized in atomic no

1.2.3 Metals and non-metals

Properties

Metals (+ve ions)	Non-metals (-ve ions)
• High melting points • High density • Conduct electricity • Shinny, malleable, sonorous	• Low melting points • Low density • Electrical insulator • Dull, brittle

1.2.4 Group 0 (Noble gases)

Properties

- Non-metal
- Colorless gases, low melting point, low density, not flammable

Why are elements in group 0 unreactive & don't form molecules easily? (1)

- Have full & stable outer shell

Why does the boiling point increase down the group? (3)

- ↑ no of shell / size of atom
- Intermolecular force between atom become stronger
- Need more energy to overcome force

1.2.5 Group 1 (Alkali metals)

- Metals
- Soft, low melting point, less dense (so top 3 elements float on water)
- +1 ion → lose e- → form ionic compound
    - White solids, dissolve in water, form colourless solutions

Reaction with oxygen

Metal$_{(s)}$ + oxygen$_{(g)}$ → metal oxide$_{(s)}$

Metal	Equation	Flame colour
Lithium	Lithium + oxygen → lithium oxide $4Li + O_2 \rightarrow 2Li_2O$	Crimson red
Sodium	Sodium + oxygen → sodium oxide $4Na + O_2 \rightarrow 2Na_2O$	Yellow
Potassium	Potassium + oxygen → potassium oxide $4K + O_2 \rightarrow 2K_2O$	Lilac

Reaction with chloride

- Exothermic reaction
- Form ionic salt

Metal$_{(s)}$ + chlorine$_{(g)}$ → metal chloride$_{(s)}$

Metal	Equation
Lithium	Lithium + chlorine → lithium chloride $2Li + Cl_2 \rightarrow 2LiCl$
Sodium	Sodium + chlorine → sodium chloride $2Na + Cl_2 \rightarrow 2NaCl$

Potassium	Potassium + chlorine → potassium chloride $2K + Cl_2 \rightarrow 2KCl$

Reaction with water

Metal$_{(s)}$ + water$_{(l)}$ → metal hydroxide$_{(aq)}$ + hydrogen$_{(g)}$

Metal	Equation	Observation
Lithium	Lithium + water → lithium hydroxide + hydrogen $2Li + 2H_2O \rightarrow 2LiOH + H_2$	• Move around on surface • Fizzes steadily • Slowly becomes small till it disappears
Sodium	Sodium + water → sodium hydroxide + hydrogen $2Na + 2H_2O \rightarrow 2NaOH + H_2$	• Move around on surface • Melts to form a ball • Fizzes rapidly • Quickly becomes small till it disappears
Potassium	Potassium + water → potassium hydroxide + hydrogen $2K + 2H_2O \rightarrow 2KOH + H_2$	• Move around on surface • Quickly melts to form a ball • Fizzes & burin violently with sparks & lilac flame • Disappears rapidly

Why does the reactivity increase down the group? (4)

- ↑ no of shell
- ↑ electron shielding
- ↓ attraction between +ve nucleus & -ve outer e-
- Outer e- requires less energy to remove
- Atom is more reactive

1.2.6 Group 7 (Halogens)

- Non-metals
- Consist of diatomic molecules (2 elements chemically combined using covalent bond)
- -1 ion → gain e- → fill outer shell → stable
- Form molecular compounds with non-metallic elements
- Low melting point → coz weak force between molecules
- Density, melting point increases down the group

Why does the reactivity decrease down the group? (4)

- ↑ no of shell
- ↑ size → e- further from nucleus
- ↑ electron shielding
- ↓ attraction between +ve nucleus & -ve outer e-
- ↓ energy to attract e- to form -ve ion
- e- easily gained
- Atom is less reactive

Halogen	Appearance & state at room temp	Colour in water

Fluorine	Yellow gas	-
Chlorine	Pale yellow – green gas	Pale green
Bromine	Red – brown liquid	Orange
Iodine	Purple – black solid	Brown

Displacement reaction

- More reactive displace less reactive elements
- F > Cl > Br > I
- **More reactive(s) + compound(aq) → less reactive(s) + compound(aq)**

	KI	KBr	KCl
Cl_2	Orange $2KI + Cl_2 \rightarrow 2KCl + I_2$ $2I^- + Cl_2 \rightarrow 2Cl^- + I_2$	Pale yellow $2KBr + Cl_2 \rightarrow 2KCl + I_2$ $2Br^- + Cl_2 \rightarrow 2Cl^- + I_2$	×
Br_2	Yellow orange $2KI + Br_2 \rightarrow 2KCl + I_2$ $2I^- + Br_2 \rightarrow 2Cl^- + I_2$	×	Displaced (no reaction)
I_2	×	Displaced (no reaction)	Displaced (no reaction)

1.3 Properties of transition metals (chemistry only)

1.3.1 Comparison with Group 1 elements

What are the physical differences between group 1 & transition elements? (3)

Group 1	Transition metals
• Low melting point • Low density • Soft	• High melting point • High density • Strong, hard

What are the chemical differences between group 1 & transition elements? (3)

Group 1	Transition metals
• Very reactive • Not used as catalysts • Form colourless / white compound • Only form +1 ions	• Low reactivity • Used as catalysts • Form coloured compound • Ions with different charges

1.3.2 Typical properties (transition metals)

Properties

- High melting point, high density, strong, hard
- Low reactivity, used as catalysts, form coloured compound, ions with different charges

Uses as catalysts

- **Manganese (IV) oxide** increases decomposition of hydrogen peroxide to oxygen & water

- $2H_2O_2 \rightarrow 2H_2O + O_2$
- **Iron** for Haber process makes ammonia
  - $N_2 + 3H_2 \rightleftharpoons 2NH_3$
- **Nickel** for manufacture of margarine

Others - Ions

Ions – a charged particle produced by loss / gain of mass

Positive ions

Name	Formula
Hydrogen	H^+
Sodium	Na^+
Silver	Ag^+
Potassium	K^+
Lithium	Li^+
Ammonium	NH_4^+
Barium	Ba^{2+}
Calcium	Ca^{2+}
Copper(II)	Cu^{2+}
Magnesium	Mg^{2+}
Zinc	Zn^{2+}
Lead	Pb^{2+}
Iron(II)	Fe^{2+}
Iron(III)	Fe^{3+}
Aluminium	Al^{3+}

Negative ions

Name	Formula
Chloride	Cl^-
Bromide	Br^-
Fluoride	F^-
Iodide	I^-
Hydroxide	OH^-
Nitrate	NO_3^-
Oxide	O^{2-}
Sulfide	S^{2-}
Sulfate	SO_4^{2-}
Carbonate	CO_3^{2-}