SC25-26: Qualitative analysis and materials

Sequence

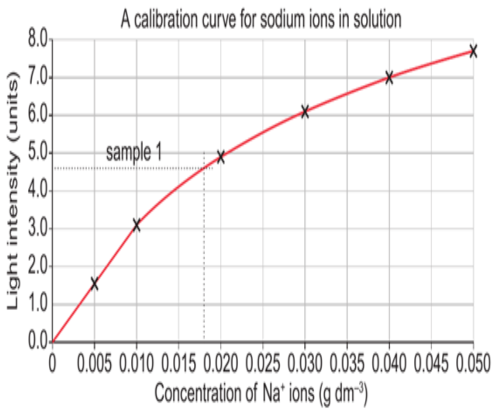
1. Flame tests and photometry
2. Tests for positive ions
3. Tests for negative ions
4. Core practical – Identifying ions
5. Choosing materials
6. Composite materials
7. Nanoparticles

1. Flame tests and photometry

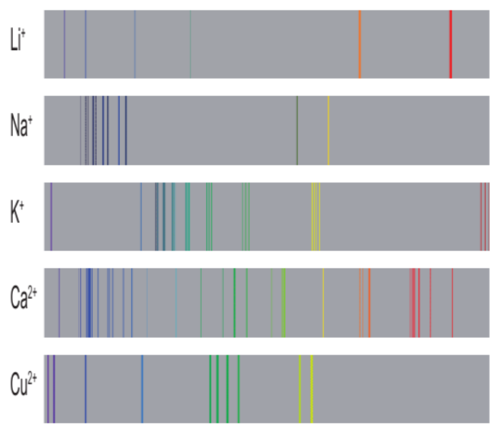
Flame test	Flame tests are used to identify metal cations in substances. To carry out a flame test: 1. Light a Bunsen burner and open the air hole to give a hot blue flame, 2. Clean the nichrome wire loop in hydrochloric acid, 3. Pick up a small sample of the test substance using a nichrome wire loop, 4. Hold the sample in the edge of the flame and observe the flame colour.
Nichrome wire	A nichrome wire is a nickel and chrome alloy, which has a high melting point, making it suitable for use in flame tests.
Cations	Positively charged ions, formed when atoms give away electrons.
Lithium – Li^+	Lithium ions produce a red flame during a flame test.
Sodium – Na^+	Sodium ions produce a yellow flame during a flame test.
Potassium – K^+	Potassium ions produce a lilac flame during a flame test.
Calcium – Ca^{2+}	Calcium ions produce a brick red flame during a flame test.
Copper – Cu^{2+}	Copper ions produce a blue-green flame during a flame test.

Flame photometry	Flame photometry uses machines to carry out a more sensitive and accurate version of a flame test.
Flame photometer	A machine used to identify metal ions in solution and to determine their concentration. This is done by measuring the light intensity of the flame colours produced by metal cations. This data is then used to determine the concentration by comparing the light intensity to a calibration curve produced using standard solutions.
Calibration curve	A graph used to determine the concentration of a substance in a sample.
Standard solution	A solution containing a known concentration of a substance.
Spectrum	Individual components of light arranged in order of wavelength or frequency.
Emission spectra	A set of wavelengths of light or electromagnetic radiation showing which wavelengths have been given out (emitted) by a substance.

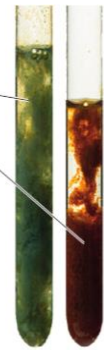
B Sodium ions produce a yellow flame test colour.



D a calibration curve from a flame photometer



E emission spectra for some metal ions



Metal ion	Symbol	Precipitate colour
iron(II)	Fe^{2+}	green
iron(III)	Fe^{3+}	brown
copper	Cu^{2+}	blue
calcium	Ca^{2+}	white
aluminium	Al^{3+}	white

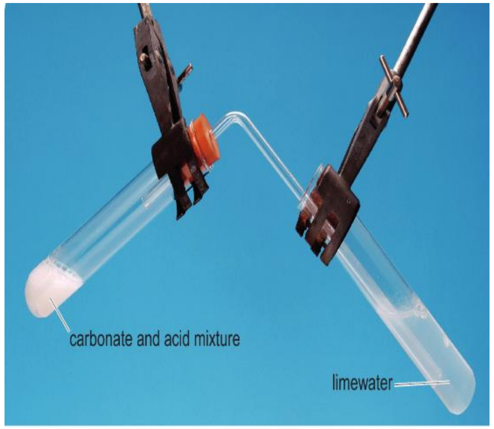
B metal hydroxide precipitate colours for different metal ions

2. Tests for positive ions

Precipitates	An insoluble substance that is formed when two soluble substances react together in solution.
Precipitation reactions	A reaction in which precipitates are formed.
Sodium hydroxide	One of few soluble metal hydroxides, which when added to other metal salts will form colourful insoluble hydroxide precipitates.
Iron (II) – Fe^{2+}	Iron (II) ions produces a green precipitate of Iron (II) hydroxide ($Fe(OH)_2$) $Fe^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Fe(OH)_{2\,(s)}$
Iron (III) – Fe^{3+}	Iron (III) ions produces a brown precipitate of Iron (III) hydroxide ($Fe(OH)_3$) $Fe^{3+}_{(aq)} + 3OH^-_{(aq)} \rightarrow Fe(OH)_{3\,(s)}$
Copper – Cu^{2+}	Copper ions produces a blue precipitate of copper hydroxide ($Cu(OH)_2$) $Cu^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Cu(OH)_{2\,(s)}$
Calcium – Ca^{2+}	Calcium ions produces a white precipitate of calcium hydroxide ($Ca(OH)_2$) which does not redissolve in excess sodium hydroxide. $Ca^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Ca(OH)_{2\,(s)}$
Aluminium – Al^{3+}	Aluminium ions produces a white precipitate of aluminium hydroxide ($Al(OH)_3$) which does redissolve in excess sodium hydroxide. $Al^{3+}_{(aq)} + 3OH^-_{(aq)} \rightarrow Al(OH)_{3\,(s)}$
Ammonium – NH_4^+	Ammonium ions do not produce a precipitate when excess sodium hydroxide is added. Once the sodium hydroxide is added the solution is heated and ammonia gas is produced. This ammonia will turn damp red litmus paper blue, confirming ammonium ions were present.

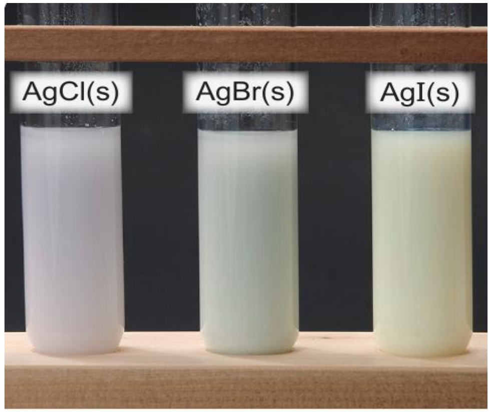
3. Tests for negative ions

Anions	Negatively charged ions, formed when atoms gain (steal!) electrons.
Carbonate – CO_3^{2-}	To test for carbonate ions add a dilute hydrochloric acid and look for bubbling caused by the production of carbon dioxide gas. $2H^+_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow CO_{2(g)} + H_2O_{(l)}$ To prove the gas produced is carbon dioxide you must bubble it through limewater, which will turn cloudy if CO_2 is present. $Ca(OH)_{2(aq)} + CO_{2(g)} \rightarrow CaCO_{3(g)} + H_2O_{(l)}$
Sulfate – SO_4^{2-}	To test for sulfate ions add dilute hydrochloric acid, to remove any carbonate ions and then add 5 drops of barium chloride and a white precipitate of barium sulfate should be formed if sulfate ions are present. $Ba^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4(s)}$
Halide ions	The ions formed by the group 7 elements, also called the halogens. To test for halide ions you should first add nitric acid, to remove carbonate ions and then add 5 drops of silver nitrate and observe the colour of the precipitate formed.
Chloride ions Cl^-	If chloride ions are present then a **white** precipitate of silver chloride will be formed when silver nitrate is added. $Ag^+_{(aq)} + Cl^-{}_{(aq)} \rightarrow AgCl_{(s)}$
Bromide ions Br^-	If bromide ions are present then a **cream** precipitate of silver bromide will be formed when silver nitrate is added. $Ag^+_{(aq)} + Br^-{}_{(aq)} \rightarrow AgBr_{(s)}$
Iodide ions I^-	If iodide ions are present then a **yellow** precipitate of silver iodide will be formed when silver nitrate is added. $Ag^+_{(aq)} + I^-{}_{(aq)} \rightarrow AgI_{(s)}$



B using limewater to confirm the results of a positive test for carbonate ions


C A white precipitate of barium sulfate forms in a positive test for sulfate ions.



E silver halide precipitates

4. Core practical – Identifying ions

Aim You will use laboratory tests to identify the cations and anions in some unknown salts. You can then work out the name of each salt.

Method

For all tests, wear eye protection and avoid skin contact with all the chemical substances.

Flame tests for metal cations

a. Light a Bunsen burner and open the air hot to give a hot blue flame,
b. Pick up a small sample of a solid salt using a clean nichrome wire and hold the sample in the flame,
c. Observe and record the colour of the flame.

Hydroxide precipitates tests for metal cations

a. Dissolve a little solid salt in a test tube using distilled water,
b. Add a few drops of dilute sodium hydroxide, one drop at a time,
c. Record the colour of the precipitate,
d. If a white precipitate forms, add excess dilute sodium hydroxide to see if it will disappear to leave a clear colourless solution.

Testing for ammonium ions

a. Add a few drops of sodium hydroxide to the salt solution and warm gently,
b. Remove from the heat and hold a piece of damp red litmus paper near the mouth of the test tube. Record what happens to its colour.

Testing for carbonate ions

a. Put a little of the solid salt in a test tube and add dilute hydrochloric acid,
b. Record any evidence of effervescence,
c. Bubble the gas through limewater, which will turn cloudy if CO_2 is present.

Testing for sulfate ions

a. Dissolve a little solid salt in a test tube of distilled water,
b. Add a few drops of dilute hydrochloric acid, then a few drops of barium chloride. Record whether a white precipitate is formed.

Testing for halide ions

a. Dissolve a little solid salt in a test tube of distilled water,
b. Add a few drops of dilute nitric acid, then a few drops of silver nitrate. Record the colour of any precipitate is formed.


A Analytical chemists work in many areas, including chemical and forensic analysis, quality control, medical drug development and toxicology.

Li^+	•		•	orange-red
Na^+	•		•	red
K^+	•		•	blue-green
Ca^{2+}	•		•	yellow
Cu^{2+}	•		•	lilac

Metal cation	Colour of metal hydroxide
aluminium, Al^{3+}	white
calcium, Ca^{2+}	white
copper, Cu^{2+}	
iron(II), Fe^{2+}	
iron(III), Fe^{3+}	

Halide ion	Colour of silver halide		
	white	yellow	cream
chloride, Cl^-			
bromide, Br^-			
iodide, I^-			

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Triple Science - Chemistry

SC25-26 Knowledge organiser

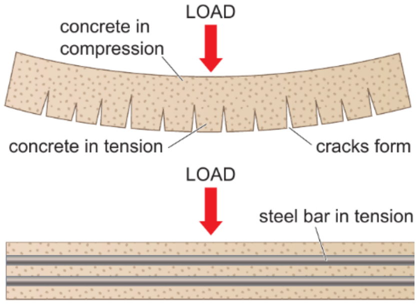
5. Choosing materials

Ceramics	A hard, durable, non-metallic material which is generally unaffected by heat e.g. china and glass
Glass	A solid produced by cooling molten substances. The atoms are joined to form a giant structure without crystals.
Transparent	A coloured or colourless material that light can travel through without scattering.
Opaque	A material that does not let light through. It is not possible to see through an opaque object.
Polymers	A long chained molecule made by joining many smaller molecules (monomers) together.
Monomers	A small molecule that can be joined with other molecules like itself to form a polymer.
Plasticisers	A substance added to a polymer during its manufacture to make the polymer softer and more flexible.
Metals	An element that is shiny when polished, conducts heat and electricity, is malleable and flexible and often has a high melting point.
Malleable	A substance that can be hammered or rolled into shape without shattering.
Alloys	A mixture of two or more metals, which results in improved properties such as lower density or improved strength.

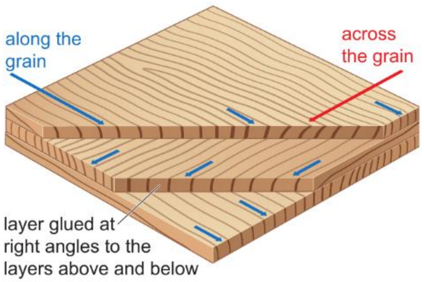
A Bathrooms contain many different materials, including glass and clay ceramics, polymers and metals.

6. Composite materials

Composite material	A mixture of two or more materials with contrasting properties, combined to produce a material with properties of both.
Reinforcement	In a composite material, it is the substance that binds the reinforcement material together.
Matrix	In a composite material, the substance that is bound together by the matrix material.
Tensile strength	A measure of how well a substance resists stretching.
Carbon fibre	A woven fabric of carbon fibres held in shape by a solid polymer resin.
Compressive strength	A measure of how well substances resist squashing.
Steel reinforced concrete	Concrete with steel bars running through it, which helps the concrete to resist cracking.
Laminates	Thin sheets of wood, each glued at right angles to the sheet below.



D Steel-reinforced concrete resists cracking much better than concrete alone.



E In plywood, the glue that sticks the layers together forms part of the composite material.

7. Nanoparticles

Bulk materials	A substance in the form of lumps or powders is described as being in bulk.
Nanoparticles	Piece of a material consisting of a few hundred atoms, and between 1nm and 100 nm in size.
Nanoparticulate materials	Substances that consist of nanoparticles.
Surface area	Calculated by multiplying the height x length x number of faces
Volume	Calculated by multiplying the height x length x depth
Surface area to volume ratios	The total amount of surface area of an object divided by its volume.
Uses of nanoparticles	Sunscreens which contain nanoparticles of titanium dioxide appear transparent whilst also still absorbing UV radiation. Stain resistant clothes treated with nanoparticulate materials stay clean because the nanoparticles catalyse the breakdown dirt. Glass treated with nanoparticles of titanium dioxide stay clean because the nanoparticles catalyse the breakdown dirt.
Risks of nanoparticles	The small size of nanoparticles allows them to be breathed in, or to pass through cell-surface membranes. Their large surface area to volume ratios may allow them to catalyse harmful reactions, or to carry toxic substances bound to their surfaces. The risks are difficult to determine because modern nanoparticulate materials have not been in use for long.

Worked example W1

A gold nanoparticle is 32 nm in diameter.

a Calculate its diameter in metres, m.

$1\,nm = 1 \times 10^{-9}\,m$

$32\,nm = 32 \times 10^{-9}\,m = 3.2 \times 10^{-8}\,m$

b The diameter of a gold atom is 0.28 nm. Estimate how many times larger the gold nanoparticle is compared to a gold atom.

Rounding each number to 1 significant figure gives 30 nm and 0.3 nm.

Number of times larger $\approx \frac{30}{0.3} = 100$

Worked example W2

A cube-shaped nanoparticle has sides of 20 nm.

a Calculate its total surface area.

surface area $= 6 \times 20 \times 20 = 2400\,nm^2$

b Calculate its volume.

volume $= 20 \times 20 \times 20 = 8000\,nm^3$

c Calculate its surface area to volume ratio.

surface area to volume ratio $= \frac{2400}{8000} = 0.3$

A cube-shaped nanoparticle has sides of 2 nm. Calculate its:

a total surface area

b volume

c surface area to volume ratio.