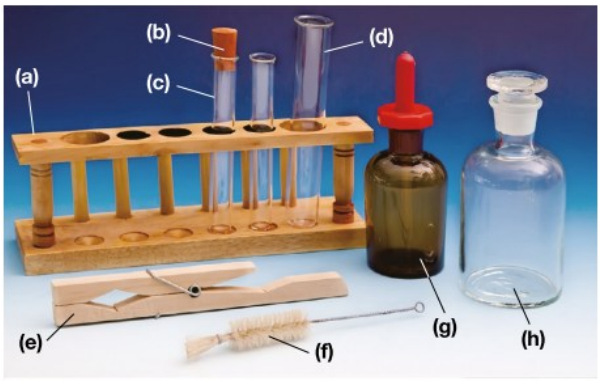
Intensive note (Topic 1: Planet Earth)

What is Chemistry

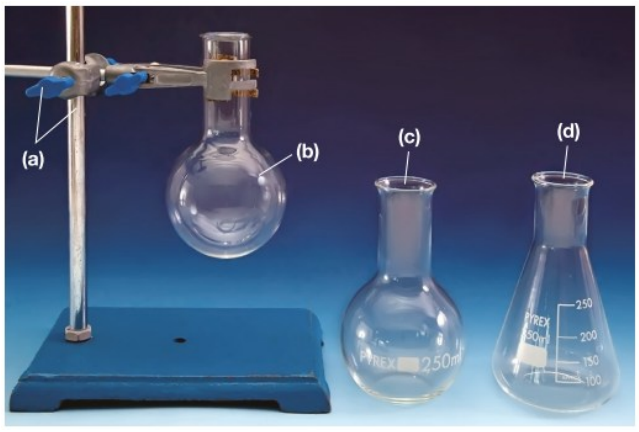
Chemistry is the study of substances, about their compositions, structures, properties and the interactions among them.

Common apparatus in the laboratory

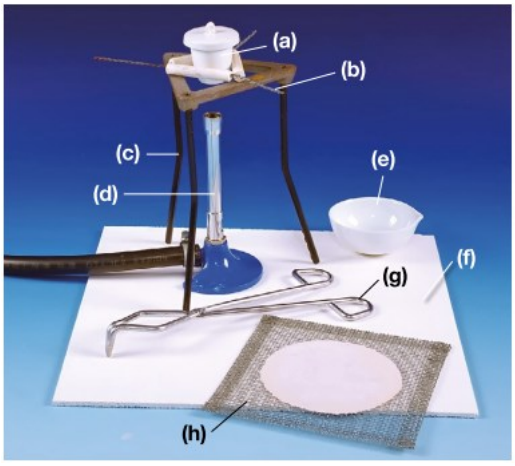


(a) Test tube rack
(b) Rubber stopper
(c) Test tube
(d) Boiling tube
(e) Test tube holder
(f) Test tube brush
(g) Dropping bottle
(h) Reagent bottle

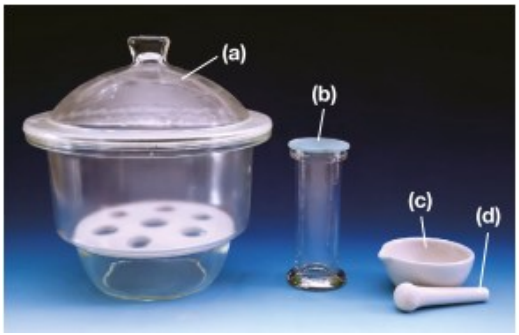
(a) Measuring cylinder
(b) Beaker
(c) Dropper
(d) Filter funnel
(e) Wash bottle
(f) Watch glass
(g) Thermometer
(h) Glass rod



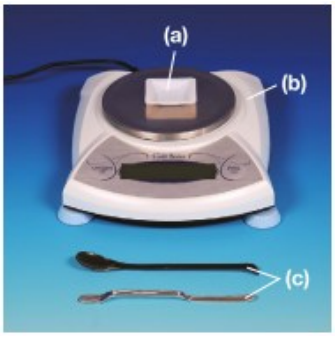
(a) Stand and clamp
(b) Round-bottomed flask
(c) Flat-bottomed flask
(d) Conical flask



(a) Crucible (with lid)
(b) Pipe-clay triangle
(c) Tripod
(d) Bunsen burner
(e) Evaporating dish
(f) Heat-resistant mat
(g) Crucible tongs
(h) Wire gauze

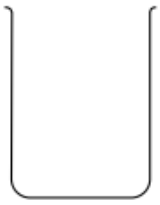
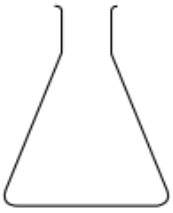
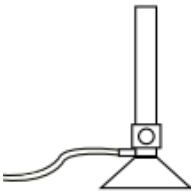


(a) Desiccator
(b) Gas jar
(c) Mortar
(d) Pestle



(a) Weighing dish
(b) Electronic balance
(c) Spatula

Vertical section diagrams of common laboratory apparatus

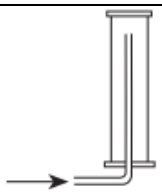
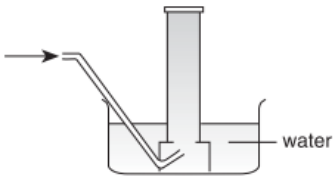
				
Test tube	**Beaker**	**Measuring cylinder**	**Filter funnel**	**Conical flask**
				
Round-bottomed flask	**Evaporating dish**	**Watch glass**	**Wire gauze**	**Bunsen burner**
				
Tripod	**Dropper**	**Glass rod**	**Thermometer**	**Crucible**

Hazard warning labels

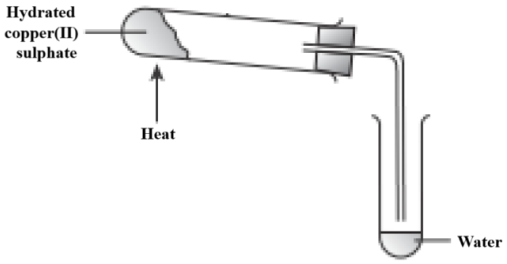
Advantages of microscale experiments

- Reduce the amount of chemicals used
- Reduce chemical wastes produced
- Save the cost of chemicals used
- Complete the experiment in a shorter period of time
- Minimize chemical hazards

Gas collection method

		
Downward delivery (For gases that are denser than air) Example: Carbon dioxide, chlorine	Upward delivery (For gases that are less dense than air) Example: Hydrogen, ammonia	Displacement of water (For gases that are insoluble in water) Example: Hydrogen, nitrogen

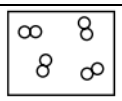
Other safety precautions



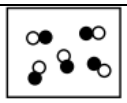
1. Remove the delivery tube before removing heating stop
   ➔ Prevent sucking back of cold water which may crack the hot boiling tube
2. The boiling tube should be slanted downward
   ➔ Prevent condensed water from flowing back which may crack the hot boiling tube

Classification of matters

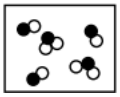
Mixture consists of two or more pure substances which have not chemically combined together
Element is a pure substance that cannot be broken down into anything simpler by chemical methods
Compound is a pure substance made up of two or more elements chemically combined together



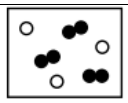
Pure element



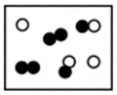
Pure compound



Mixture of compounds



Mixture of elements



Mixture of element and compound

Example: Constituent elements of some compounds

Compound	Constituent element
Water (H_2O)	Hydrogen (H) and oxygen (O)
Carbon dioxide (CO_2)	Carbon (C) and oxygen (O)
Sodium chloride (NaCl)	Sodium (Na) and chlorine (Cl)
Glucose ($C_6H_{12}O_6$)	Carbon (C), hydrogen (H) and oxygen (O)
Ammonia (NH_3)	Nitrogen (N) and hydrogen (H)
Sulphuric acid (H_2SO_4)	Hydrogen (H), sulphur (S) and oxygen (O)

*Percentage abundance by mass of elements in the **Earth's crust**: Oxygen > Silicon > Aluminium > Iron > Calcium

	Mixture	Compound
1. Composition by mass	Variable	Fixed
2. Changes in formation	No chemical reaction takes place. Usually no heat change.	Chemical reaction takes place. Heat change involved.
3. Melting / boiling point	Melts/boils over a wide range of temperature	Melts/boils at a definite temperature
4. Properties	Each constituents retains its own properties	Properties are different from those of its constituent elements
5. Separation method	Physical method (Based on different physical properties)	Chemical method

Example: Properties of iron, sulphur, iron/sulphur mixture and iron(II) sulphide

	Iron	Sulphur	Iron sulphur mixture	*Iron(II) sulphide
Appearance	Black solid	Yellow solid	Yellow + Black (grey) solid	Brown solid
Action of magnet	Attracted	Not attracted	Only iron is attracted	Not attracted
Adding into water	Sinks	Most sulphur sinks, a little sulphur floats	All iron and most sulphur sinks, little sulphur floats	Sinks
Adding into dilute hydrochloric acid	Give hydrogen gas	No reaction	Only iron reacts to give hydrogen gas	Gives toxic hydrogen sulphide gas with bad egg smell

* Iron(II) sulphide is formed by **heating iron with sulphur.**

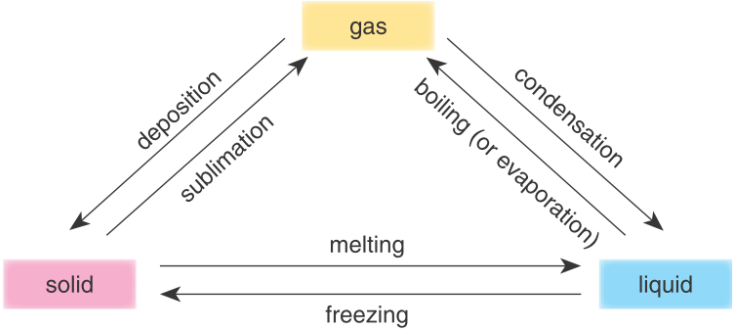
Properties of substances

Physical change is a change in which no new substances are produced.
Chemical change is a change in which one or more new substances are produced.
Physical properties are those properties that can be determined without the substance changing into another substance
Chemical properties are those properties that describe the ability of that substance to react with other substance(s).

Examples of physical properties:

- Appearance
- Odour
- Taste
- Hardness
- Density
- Solubility
- Melting point
- Boiling point
- Malleability
- Ductility
- Electrical conductivity
- Thermal conductivity

Change of states



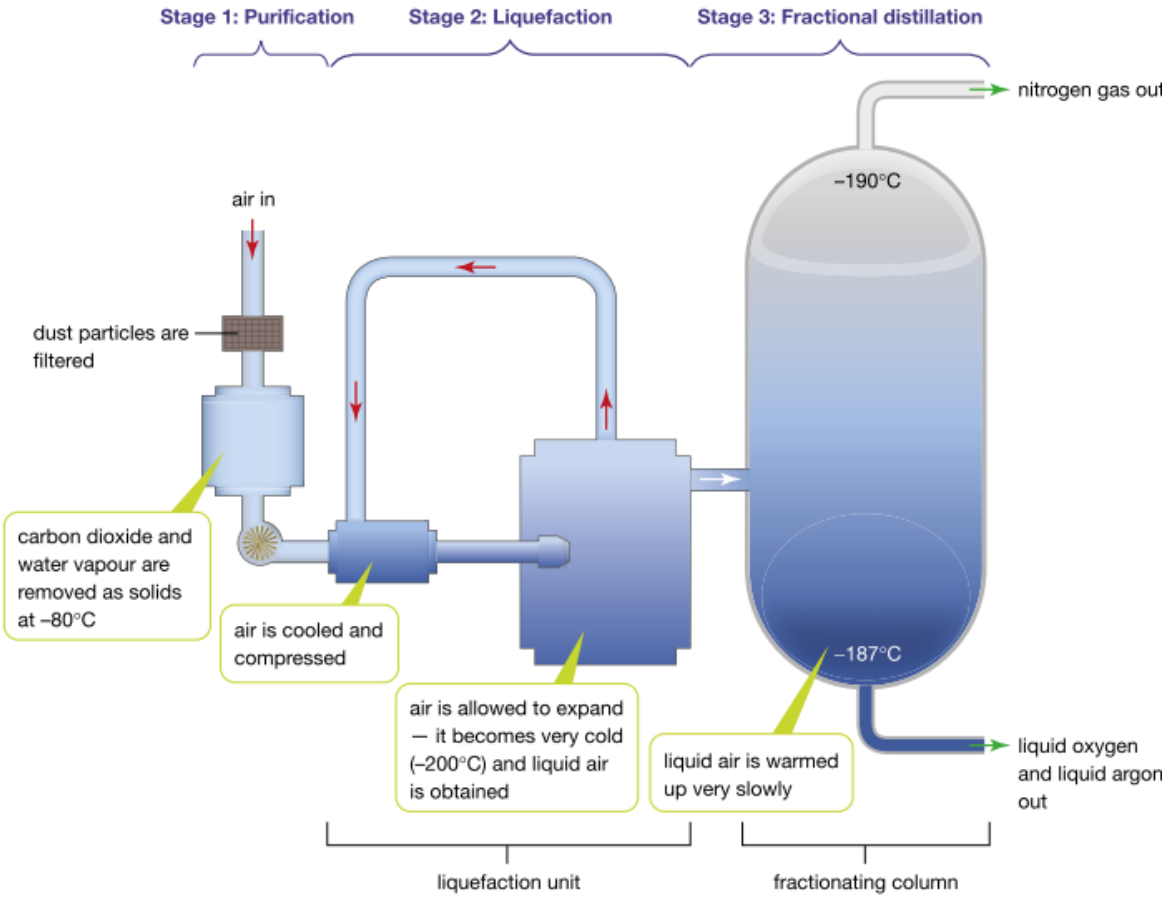
Composition of air

Nitrogen (78%), Oxygen (21%), Argon (0.9%), Carbon dioxide (0.03%)

Other gases (0.1%) include water vapor, Helium, Neon, Krypton, Xenon

Fractional distillation of liquid air

Air can be separated by fractional distillation because different gases have **different boiling points.**



Filtering water and carbon dioxide is necessary since they will block the pipes when they are solidified.

Uses of gas

Oxygen (b.p. = -183 ℃): Medical use (Patients with breathing difficulties), Burning of fuels, cutting/welding metals

Nitrogen (b.p. = -196 ℃): Food packaging, Refrigerant, Making ammonia (and fertilizer)

Argon (b.p. = -186 ℃): Filling light bulbs

Test of oxygen

It supports burning (NOT flammable), and it relights glowing splint

Hazard warning label on a cylinder containing oxygen: Oxidizing (NOT flammable)

Test of hydrogen

Hydrogen be tested by burning splint and it burns with 'pop' sound.

Note: The above test involves chemical change since new substance (water) is produced.

Solute, Solvent and Solution

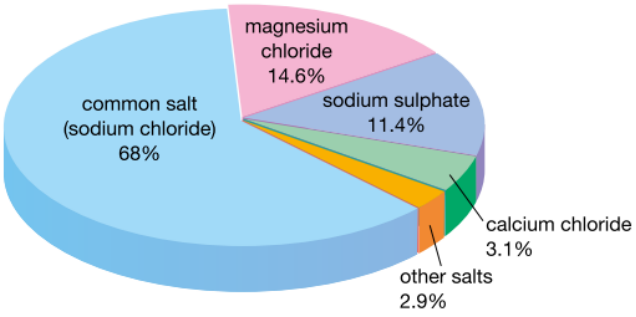
A solution is a mixture formed when one or more substances (the solute(s)) dissolves in another substance (the solvent).

Sea water is an example of solution

Solute: Salt (Mainly sodium chloride with magnesium chloride and sodium sulphate)

Solvent: Water

Solution: Salt solution



Solute + Solvent = Solution

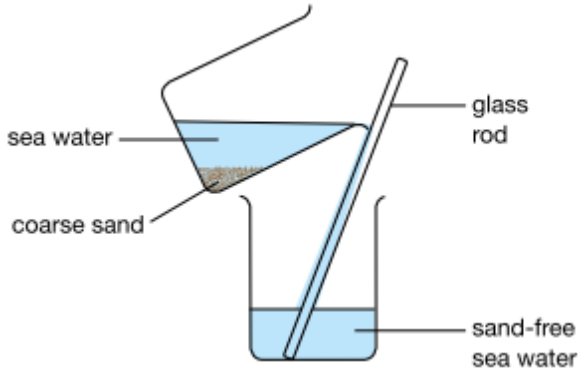
Dilute solution, concentrated solution and saturated solution

- **Dilute solution:** A solution which contains a relatively small amount of solute in a given amount of solvent.
- **Concentrated solution:** A solution which contains a relatively large amount of solute in a given amount of solvent.
- **Saturated solution**: A solution which the solvent has dissolved the maximum amount of solute it can at a specific temperature

* A saturated solution is not necessarily concentrated. Limewater, a saturated calcium hydroxide solution, is still a dilute solution.

Decantation

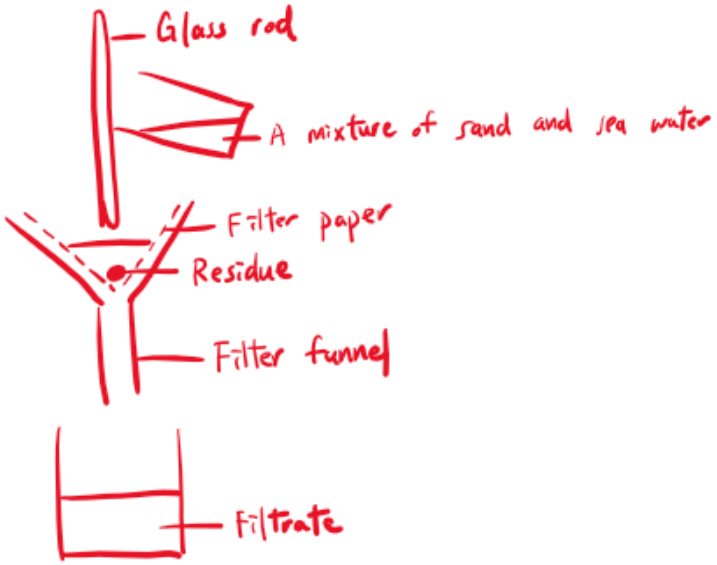
A quick but rough method of separating a dense insoluble solid from a liquid or solution.



The solid in the mixture is allowed to settle to the bottom of the beaker. The liquid on top is carefully decanted (poured off).

Filtration

Filtration can separate an insoluble solid (As residue) from a liquid or solution (As filtrate)

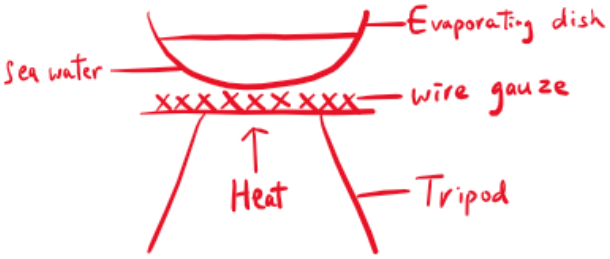


There are many tiny holes in filter paper. These holes allow very small particles (including water and dissolved substances) to pass through as **filtrate**. Insoluble substances remain on the filter paper as **residue.**

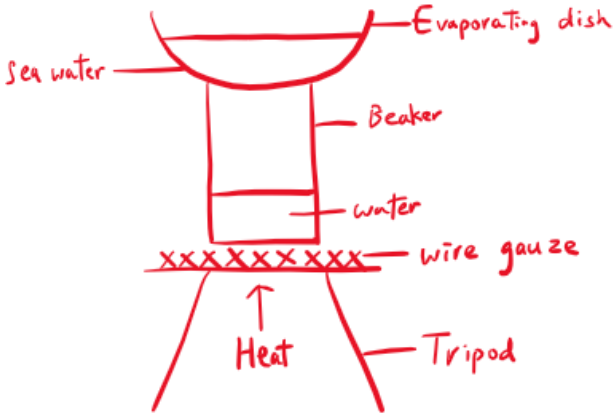
Evaporation

Evaporation is a method to obtain solute from a solution **quickly**.

In the evaporation of seawater, only water (solvent) will evaporate because it has a much lower boiling point.



Direct heating



Heating with a steam bath

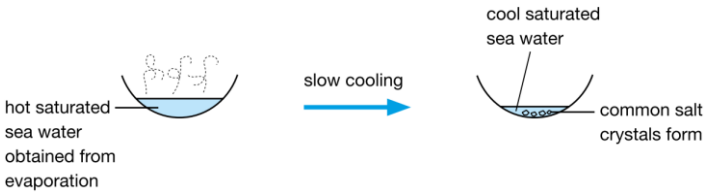
- The solute obtained is a mixture of salts, and it is a powder but NOT crystal.
- Evaporation often causes decomposition of crystals.
  (e.g. Hydrated copper(II) sulphate will be decomposed to anhydrous copper(II) sulphate)
- If the solvent to be evaporated burns easily, a steam bath rather than direct heating should be used.
- If the sea water is heated directly, it may splash out from the watch glass when the evaporation is near completion / the watch glass may crack.

Crystallization

Crystallization is another method to obtain soluble solute from a solution (as crystals).

Procedures of crystallization (Cooling a hot concentrated solution)

1. Sea water is heated to remove some of the water such that a saturated solution is obtained.
2. Cool the solution slowly by standing in air. Water will further evaporate and crystals will be formed.
3. Filter to obtain the crystals (As residue).
4. Wash the crystals with small amount of cold, distilled water and dry the crystals with filter paper.

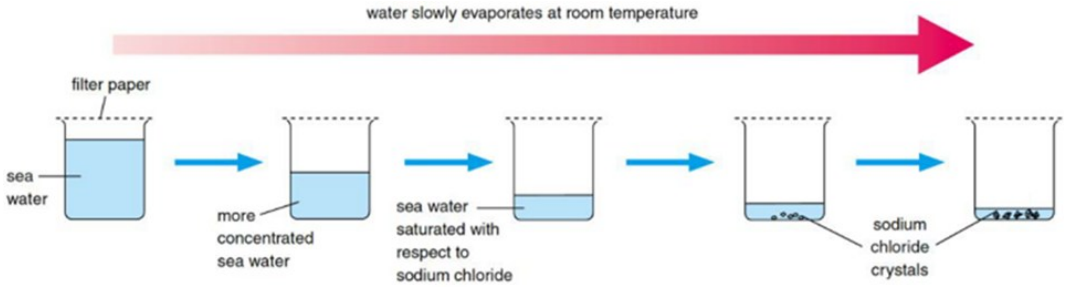


At 50°C: 100 cm^3 water + 54 g NaCl(aq)	At 25°C: 100 cm^3 water + 36 g NaCl(aq) + 18 g NaCl(s)
Solubility of NaCl in water at 50°C: 54 g / 100 cm^3 water	Solubility of NaCl in water at 25°C: 36 g / 100 cm^3 water

- To test whether a solution is saturated, we can dip a glass rod into the solution and take it out. If crystals are formed on it upon cooling, the solution is saturated
- When the temperature of the solution drops, the solubility will decrease. Sea water cannot hold all the dissolved solute and some of the salt crystals will be formed
- Crystals obtained by this method are **small crystals.** To obtain larger crystals, we can leave the solution at room temperature for a week.

Procedures of crystallization (Slow evaporation)

1. Sea water is allowed to evaporate slowly at room temperature and becomes saturated.
2. Further evaporation of water will cause salt crystals to separate out.
3. Filter to obtain the crystals (As residue)
4. Wash the crystals with small amount of cold, distilled water and dry the crystals with filter paper.



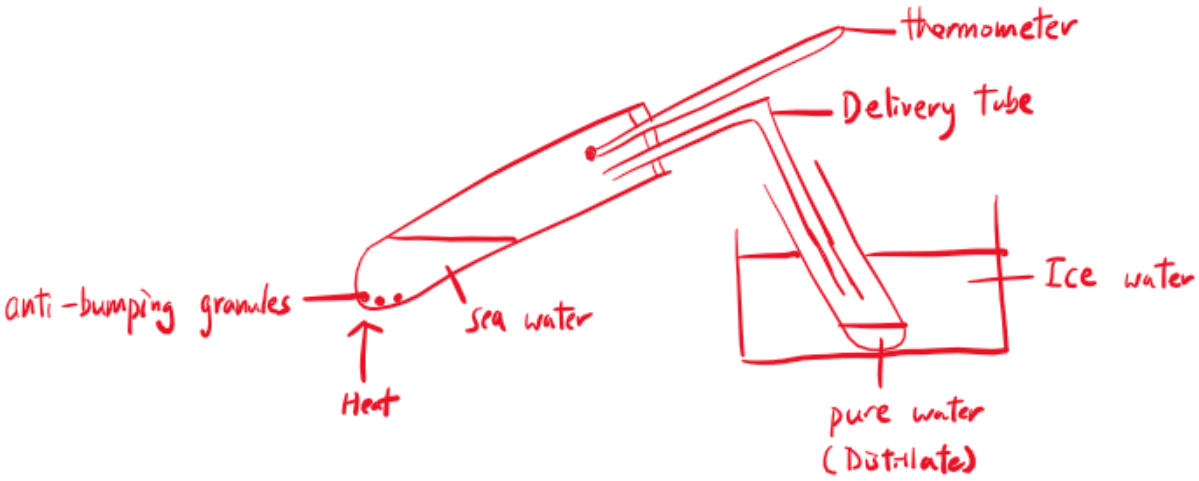
200 cm^3 water 36 g NaCl(aq)	150 cm^3 water 36 g NaCl(aq)	100 cm^3 water 36 g NaCl(aq)	50 cm^3 water 18 g NaCl(aq) 18 g NaCl(s)	25 cm^3 water 9 g NaCl(aq) 27 g NaCl(s)
Solubility of NaCl in water at 25°C is 36 g / 100 cm^3 water				

- Crystals obtained by this method are **large crystals.** Solute particles have sufficient time to arrange themselves regularly.
- Filter paper can avoid impurities falling off the solution. Water will evaporate during crystallization. Therefore the beaker should NOT be tightly covered by filter paper

Distillation

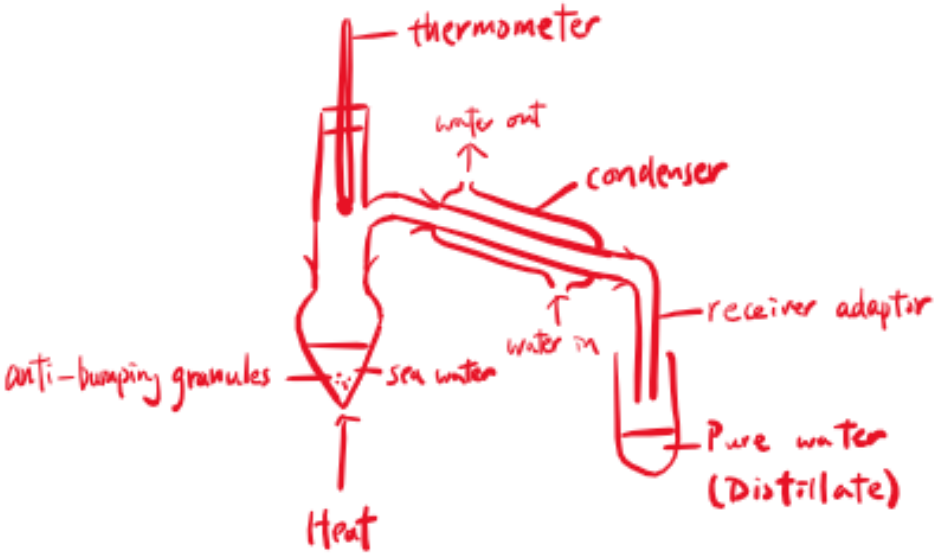
Distillation is a method to obtain pure water from sea water. (Obtain solvent from solution)

Distillation using simple apparatus:



- Anti-bumping granule provides smooth heating and prevents bumping of water.
- Thermometer can check the boiling point of the distillate which helps to check its identity.
- The solid left behind is **residue** while the water distilled out is **distillate**.
- The end of the delivery tube should be placed above the distillate and below the cooling agent. This can prevent sucking back of distillate and prevent water vapor escaping from the test tube.

Distillation using quick-fit apparatus:



- Cold running water is passed into the condenser from the lower opening and leaves from the upper opening. This provides a better cooling effect for the steam.
- Water boils at 100 °C and turns to water vapor. Salt does not boil since it has a much higher boiling point than water and it is left in the flask as residue. Hot water vapor condenses in the condenser and turns to water again.

Flame test

Compound of:	Potassium	Sodium	Calcium	Copper
Flame color	Lilac	Golden yellow	Brick-red	Bluish green

Procedures of flame test:

1. Dip a clean **platinum wire / nichrome wire** into concentrated hydrochloric acid.
2. Dip the wire into the sample.
3. Heat the wire strongly in a **non-luminous flame.** Observe the flame color.

Test for chloride

Silver nitrate test can be used to test the **presence of chloride ion.** If **white precipitate** (due to the formation of insoluble silver chloride) is produced, the sample should contain chloride ion.

Procedures of silver nitrate test:

1. Dissolve the sample completely by distilled water. (If the sample is already a solution, ignore this step)
2. Add **excess dilute nitric acid** into the solution to be tested.
3. Add **silver nitrate solution** into the acidified solution.
   (If white precipitate is produced, the sample should contain chloride ion)

- Dilute nitric acid can prevent the formation of other precipitates (e.g. silver carbonate) which are soluble in nitric acid.

Sodium chloride $\xrightarrow{\text{Silver nitrate}}$ **Silver chloride** (white precipitate) $\xrightarrow{\text{Nitric acid}}$ **No reaction** (White precipitate remains)

Sodium carbonate $\xrightarrow{\text{Silver nitrate}}$ **Silver carbonate** (white precipitate) $\xrightarrow{\text{Nitric acid}}$ **Sodium nitrate** (colorless solution)

Test of water

Method 1: Using anhydrous copper(II) sulphate.

If the sample contains water is added to anhydrous copper(II) sulphate, the **white solid will turn blue.**

Method 2: Using dry cobalt(II) chloride paper.

If the sample contains water is added to dry cobalt(II) chloride paper, the paper **will turn from blue to pink.**

- The above test CANNOT show whether a sample contains pure water. To test whether a sample contains pure water, we should carry out boiling point test. If a liquid boils at 100 ℃ (under room pressure), it should be pure water.

Electrolysis of sea water

In this process, sea water is decomposed by electricity.

Equation: Sea water → Hydrogen gas + Chlorine gas + Sodium hydroxide solution.

Note: Hydrogen and chlorine are collected in negative and positive electrodes respectively.

Products	Hydrogen	Chlorine	Sodium hydroxide
Uses	1. Make margarine 2. Make ammonia 3. As rocket fuel	1. Sterilizing swimming pool 2. Make PVC 3. Make chlorine bleach	1. Make soap 2. Make drain cleaner 3. Make chlorine bleach

Ores

Ore	Major element / compound	Metal extracted
Bauxite	Aluminium oxide (Al_2O_3)	Aluminium (Al)
Copper pyrite	Copper iron sulphide ($CuFeS_2$)	Copper (Cu)
Haematite	Iron(III) oxide (Fe_2O_3)	Iron (Fe)
Galena	Lead(II) sulphide (PbS)	Lead (Pb)
Rock salt	Sodium chloride (NaCl)	Sodium (Na)
Gold ore	Gold (Au)	Gold (Au)

Extraction of metals from their ores

1. Mechanical separation (e.g. panning)

- Gold can be extracted by panning
- This method involves physical change as no new substances are produced.

2. Heating the metal ore alone

- Silver and mercury (unreactive metals) can be extracted by heating their ores

Word equation: Silver oxide ➔ Silver + oxygen

- This method involves chemical change as new substances (silver and oxygen) are produced

3. Heating the metal ore with carbon

- Zinc, iron and lead (more reactive metals) can be extracted by heating their ores with carbon

Word equation: Lead(II) oxide + Carbon ➔ Lead + Carbon dioxide

- This method involves chemical change as new substances (lead and carbon dioxide) are produced

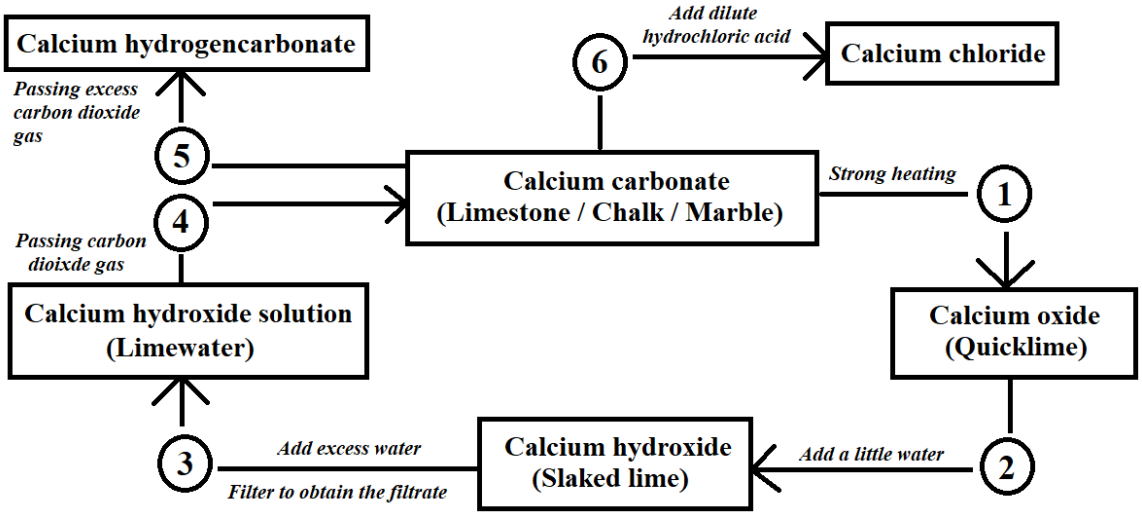
4. Electrolysis of molten metal ore

- Sodium, calcium and aluminium (most reactive metals) can be extracted by electrolysis of their molten ores.

Word equation: Aluminium oxide ➔ Aluminium + Oxygen

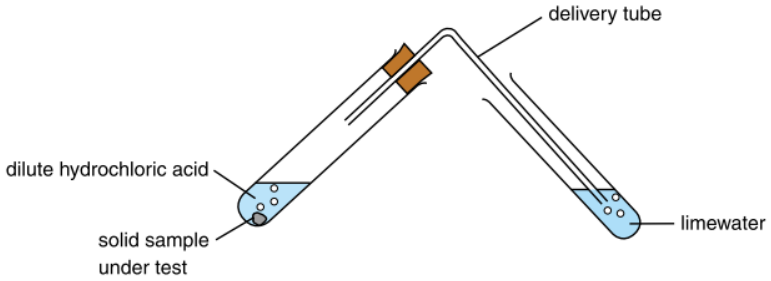
- This method involves chemical change as new substances (aluminium and oxygen) are produced

Lime cycle



	Word equation	Observation
1	Calcium carbonate → ***Calcium oxide*** + Carbon dioxide $CaCO_3(s)$ ➔ $CaO(s) + CO_2(g)$	Limestone breaks down into ***white powder***
2	Calcium oxide + Water → Calcium hydroxide $CaO(s) + H_2O(l)$ ➔ $Ca(OH)_2(s)$	Heat is given off
3	***Calcium hydroxide*** → Calcium hydroxide solution (* This is a physical change) $Ca(OH)_2(s)$ ➔ $Ca(OH)_2(aq)$	***White suspension*** is formed (Calcium hydroxide is slightly soluble in water)
4	Calcium hydroxide + Carbon dioxide → ***Calcium carbonate*** + Water $Ca(OH)_2(aq) + CO_2(g)$ ➔ $CaCO_3(s) + H_2O(l)$	Limewater turns ***milky***
5	Calcium carbonate + Water + Carbon dioxide → ***Calcium hydrogencarbonate*** $CaCO_3(s) + H_2O(l) + CO_2(g)$ ➔ $Ca(HCO_3)_2(aq)$	Milky solution turns ***colorless*** in excess carbon dioxide
6	Calcium carbonate + Hydrochloric acid → Calcium chloride + ***Carbon dioxide*** + Water $CaCO_3(s) + 2\ HCl(aq)$ ➔ $CaCl_2(aq) + CO_2(g) + H_2O(l)$	1. ***Colorless gas*** evolved 2. Calcium carbonate dissolves

Test for carbonate



To test the presence of carbonate, we can add **dilute hydrochloric acid** to the sample. If the sample contains carbonate, **colorless gas** will be produced which can **turn limewater from colorless to milky**.

Weathering of limestone

Rainwater is slightly acidic:

Carbon dioxide + water ➔ Carbonic acid

Carbonic acid reacts with calcium carbonate in limestone to form water-soluble calcium hydrogencarbonate

Calcium carbonate + carbonic acid ➔ calcium hydrogencarbonate