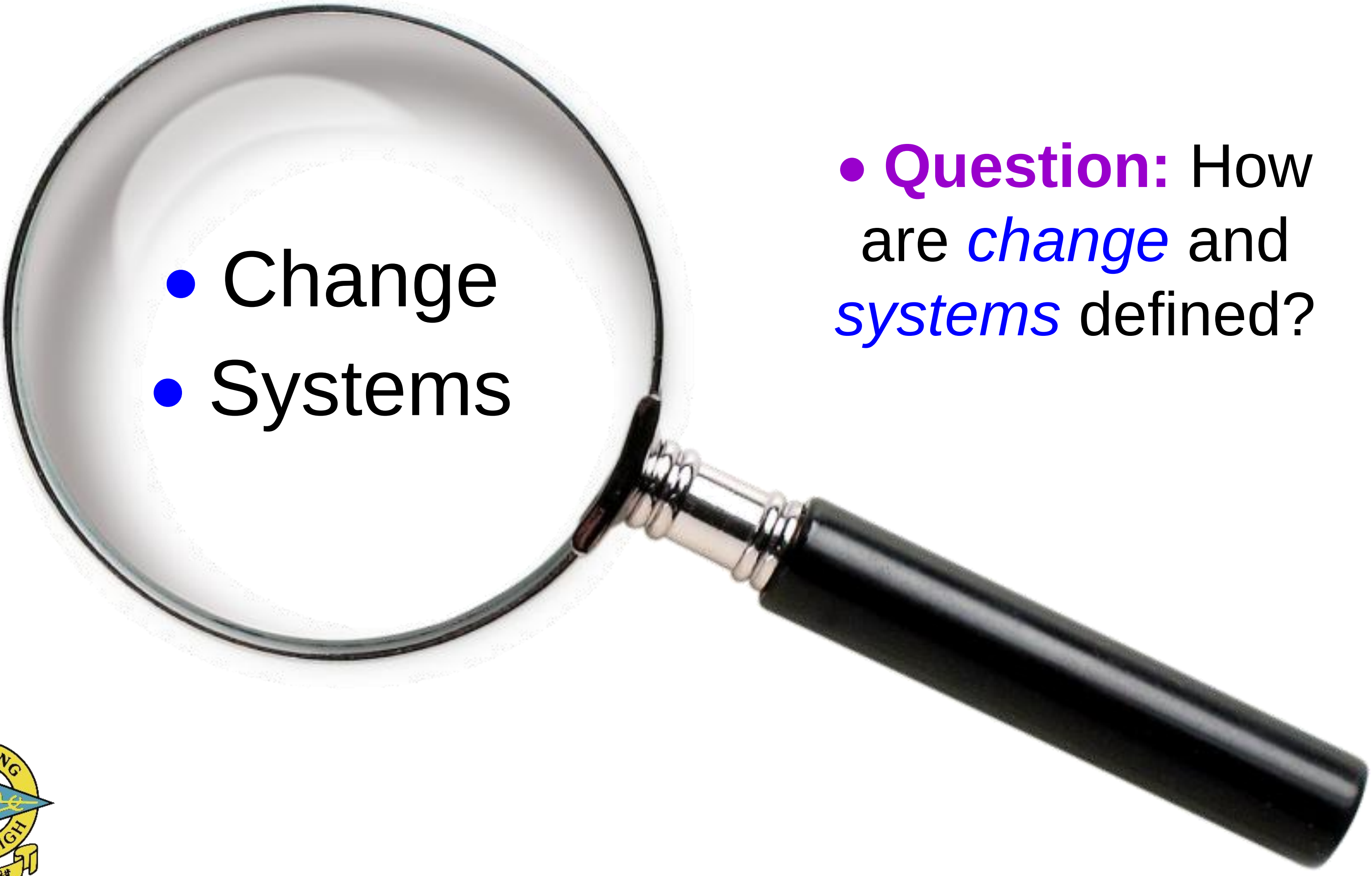

Separation
Techniques

Separation Techniques – Change & Systems

Conceptual Lenses



- Change
- Systems

- **Question:** How are *change* and *systems* defined?

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- **Answer:** Change

Change is inevitable. Change occurs as things become different over time. Change can be positive (good) or negative (bad). Change can be planned or unexpected. Change can be linear or cyclic.

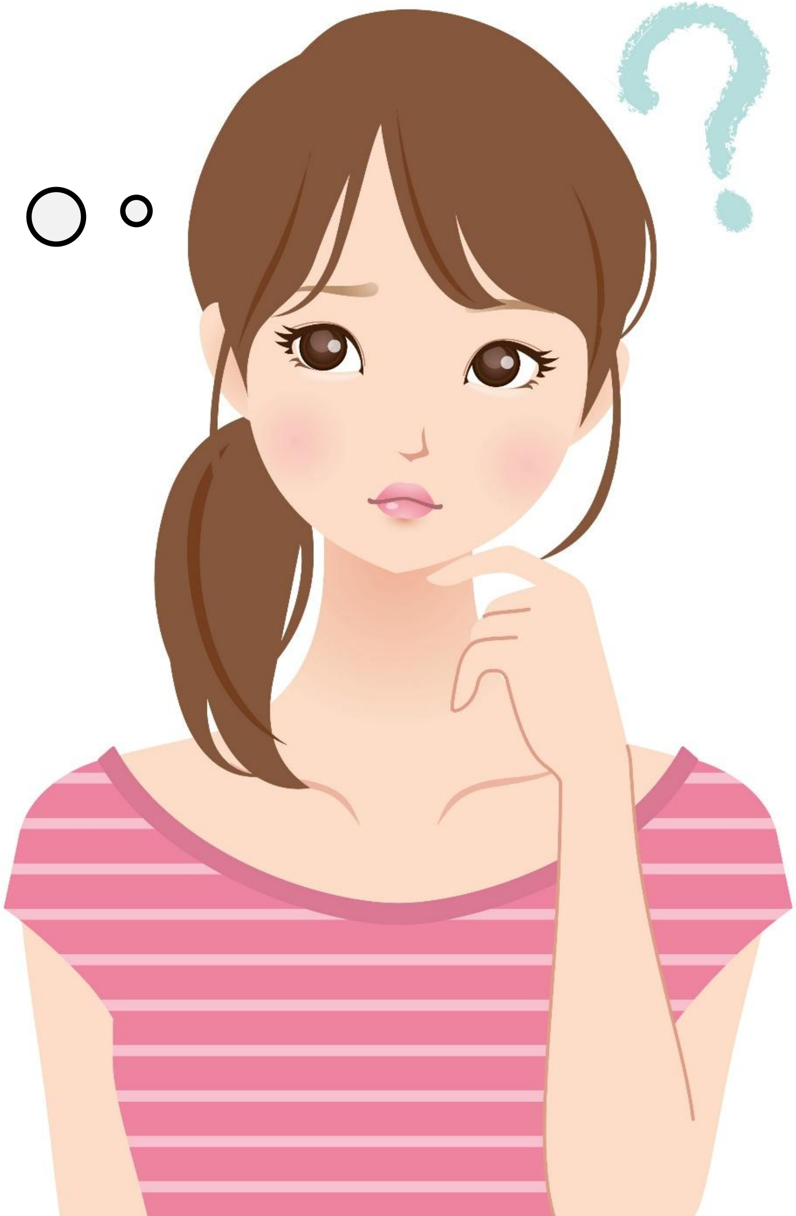
- **Answer:** Systems

Systems have elements that interact with each other to perform a function. Systems are composed of sub-systems. Systems may be influenced by other systems. Systems follow rules.

Introduction

Separation Techniques – Change & Systems

What do I need to know about separation techniques?



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By the end of this unit you will be able to…

(a) Describe methods of separation and purification for the components of the following types of mixtures:

- **(i)** Solid-solid.
- **(ii)** Solid-liquid.
- **(iii)** Liquid-liquid (miscible and immiscible).

- Techniques to be covered for separation and purification include:
  - **(i)** Use of a suitable solvent, filtration and crystallisation or evaporation.
  - **(ii)** Sublimation.
  - **(iii)** Distillation and fractional distillation.
  - **(iv)** Use of a separating funnel.
  - **(v)** Paper chromatography.

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By the end of this unit you will be able to…

(b) Describe paper chromatography and interpret chromatograms including comparison with “known” samples and the use of R_f values.

(c) Explain the need to use locating agents in the chromatography of colourless compounds.

(d) Deduce from the given melting point and boiling point the identities of substances and their purity.

(e) Explain that the measurement of purity in substances used in everyday life, *e.g.* foodstuffs and drugs, is important.

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Guiding Questions

- What are the characteristics of a mixture? How do you recognise a mixture?

- How do we identify which component of a mixture is important?

- Which physical properties of a mixture allow us to choose the most appropriate separation technique?

- Once a mixture has been separated, how do we know that the products are pure? What is purity? What are acceptable levels of purity.

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Guiding Questions

- What are some important separation techniques that are relevant to our everyday lives?
- How do separation techniques improve our everyday lives?
- What would happen if separation techniques were not used in our everyday lives?

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- In the natural world, almost all substances exist as mixtures.

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- **Prior Knowledge:** Are these substances elements, compounds or mixtures?

- **Essential Question:** Why it is important for these mixtures to be free from contamination?

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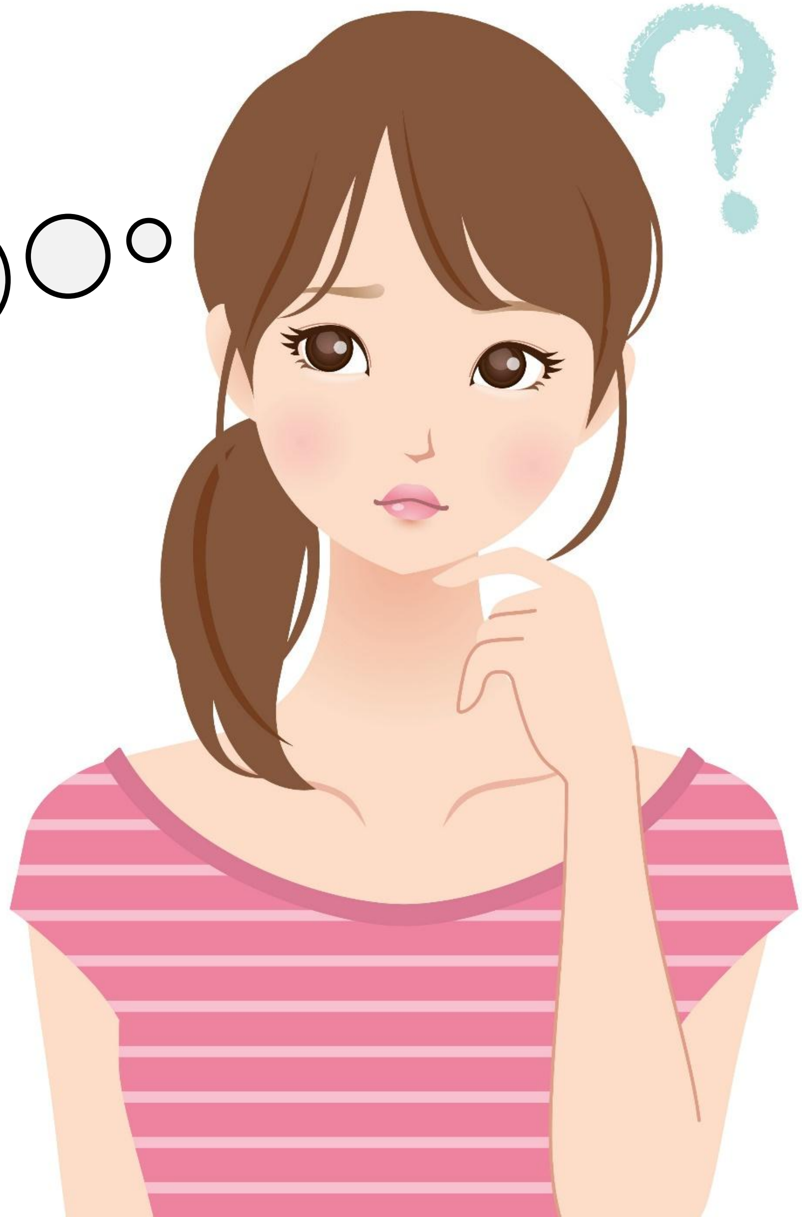
What is an important example that illustrates the need to purify chemicals?



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Example: the case of thalidomide.

- To illustrate why it is important for food and drugs to be free from contamination, search for information on the drug *thalidomide*.

→ What condition was thalidomide used to treat?

→ What serious health problems arose from the use of thalidomide? Why?

→ During the manufacture of the drug, what could have been done to avoid these serious health problems?

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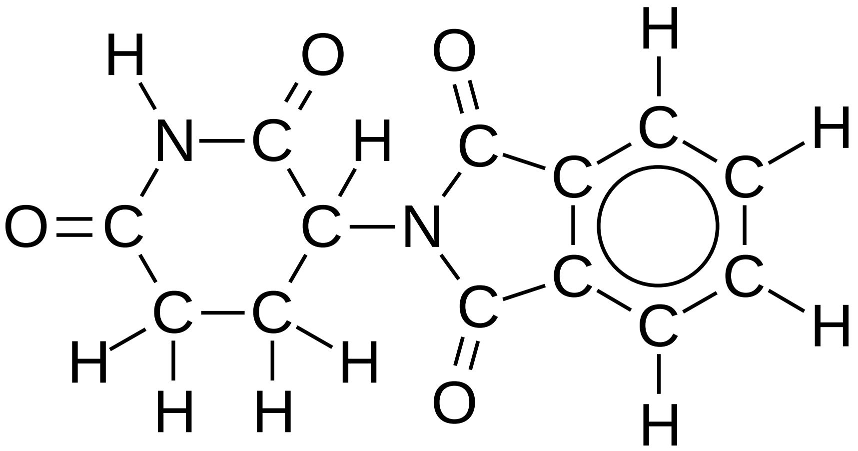
Example: the case of thalidomide.



- Thalidomide was used by pregnant women in the 1950s and 1960s to combat the effects of morning sickness. The thalidomide molecule exists in two different forms called *isomers*.

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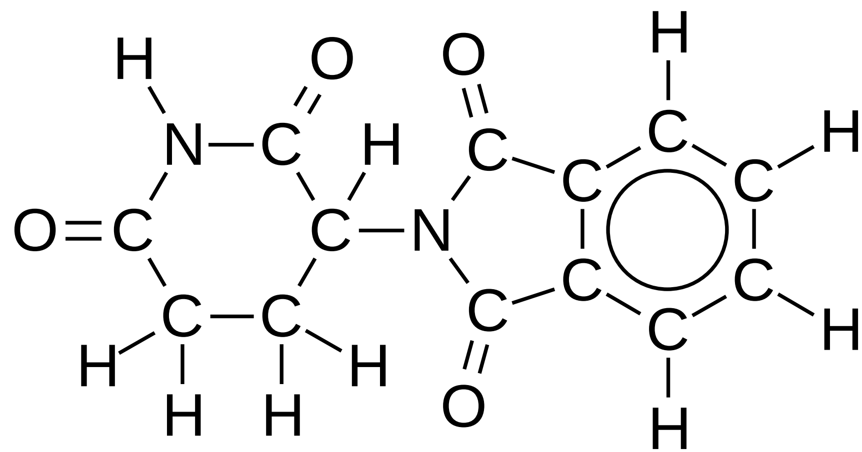
Example: the case of thalidomide.



- One of these isomers was successful in reducing the effects of morning sickness, but the other isomer was found to be *teratogenic* (causes deformities in a developing foetus).

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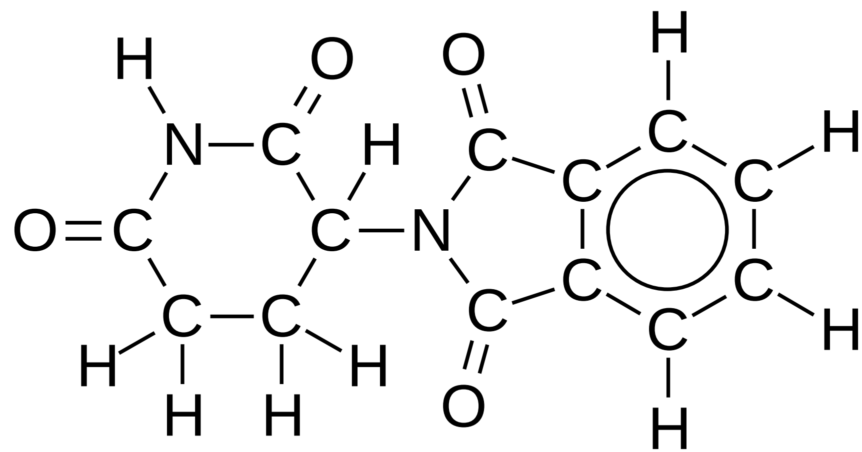
Example: the case of thalidomide.



- Because the two isomers *were not separated* from each other, many of the women who took the drug thalidomide gave birth to children with serious physical deformities.

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Example: the case of thalidomide.

WARNING: SEVERE, LIFE THREATENING HUMAN BIRTH DEFECTS IF THALIDOMIDE IS TAKEN DURING PREGNANCY.

NANYANG GIRLS' HIGH

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In the winter of 2019, a number of children living in India's Jammu region began falling sick with what many thought was a mysterious illness.

The children, suffering from cough and cold, had been prescribed a cough syrup by local doctors. Instead of recovering, they fell seriously ill, vomiting, running high fever and kidneys shutting down. By the time the mystery was solved, 11 children, aged between two months and six years, had died.

Tests found that three samples of the cough syrup, made by an Indian drug company called Digital Vision, contained diethylene glycol or DEG, an industrial solvent used in the making of paints, ink, brake fluids. Kidney failure is common after consuming this poisonous alcohol.

- **India production halted after Gambia child fatalities**

Earlier this month, the World Health Organization (WHO) put out a **global warning** over four India-made cough syrups thought to be linked to the deaths of 66 children in The Gambia. Lab analysis of the samples of a syrup made by a 32-year-old firm called Maiden Pharmaceuticals Limited confirmed the presence of "unacceptable amounts" of diethylene glycol and another toxic alcohol called ethylene glycol.

The tainted drugs and the tragic deaths again shone a spotlight on India's $42bn - half of the revenues come from exports - drug manufacturing industry.

Some 3,000 firms operate 10,000 pharmaceutical factories making generics (copies of branded medicines that usually sell for a fraction of their price), over-the-counter medicines, vaccines and ingredients in what is one of the world's largest drug-making countries. Although India imports 70% of the active ingredient chemicals for its medicines from China, it is trying to make more of them at home.

Cough syrup deaths: Why drugs made in India are sparking safety concerns - BBC News

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Mixtures need to be separated into pure substances for:

- Characterisation.
- Identification.
- Production of useful substances such as medicines.

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Determination of Purity

To determine the *purity* of a chemical, the following experimental techniques may be used:

- Determination of melting point and / or boiling point.
  Note: The melting points and boiling points of pure substances are unique.

- Chromatography.

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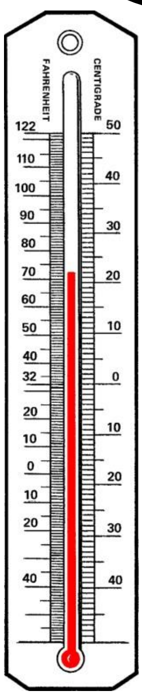
Determination of Purity

Did you know?



A *pure* chemical has a *sharp melting point* and a *sharp boiling point*.

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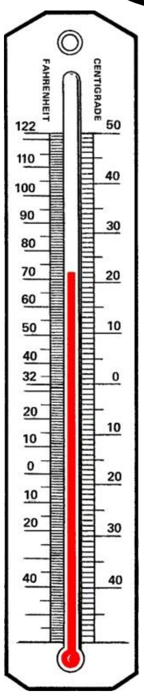
Determination of Purity

Did you know?



Adding an *impurity* to a pure chemical will *lower* the *melting point* of the chemical.

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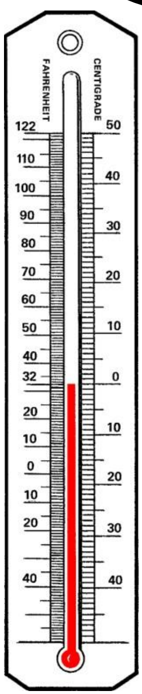
Determination of Purity

Did you know?



m.p.

Adding an *impurity* to a pure chemical will *lower* the *melting point* of the chemical.

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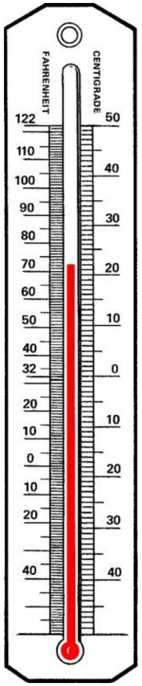
Determination of Purity

Did you know?



Adding an *impurity* to a pure chemical will *increase* the *boiling point* of the chemical.

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Determination of Purity

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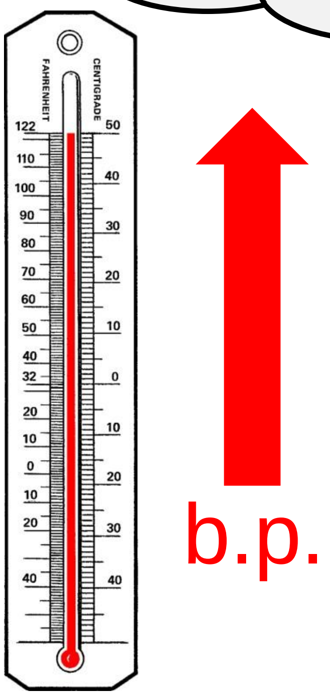
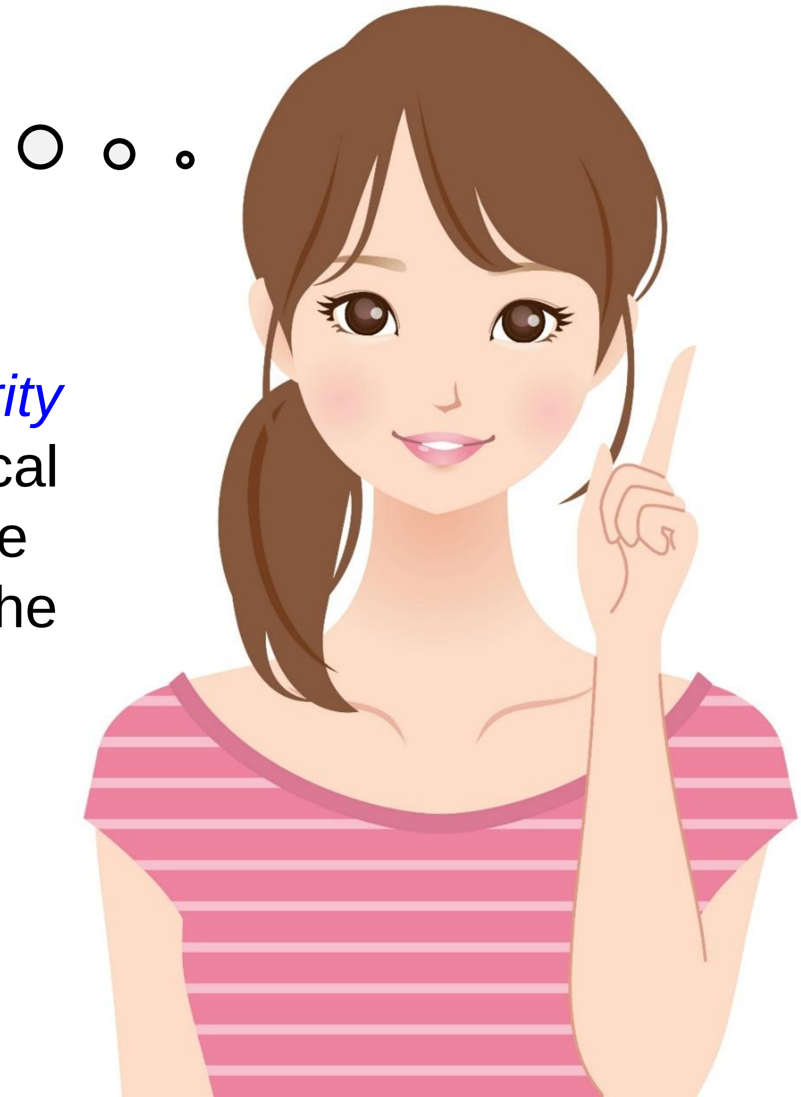


Adding an *impurity* to a pure chemical will *increase* the *boiling point* of the chemical.



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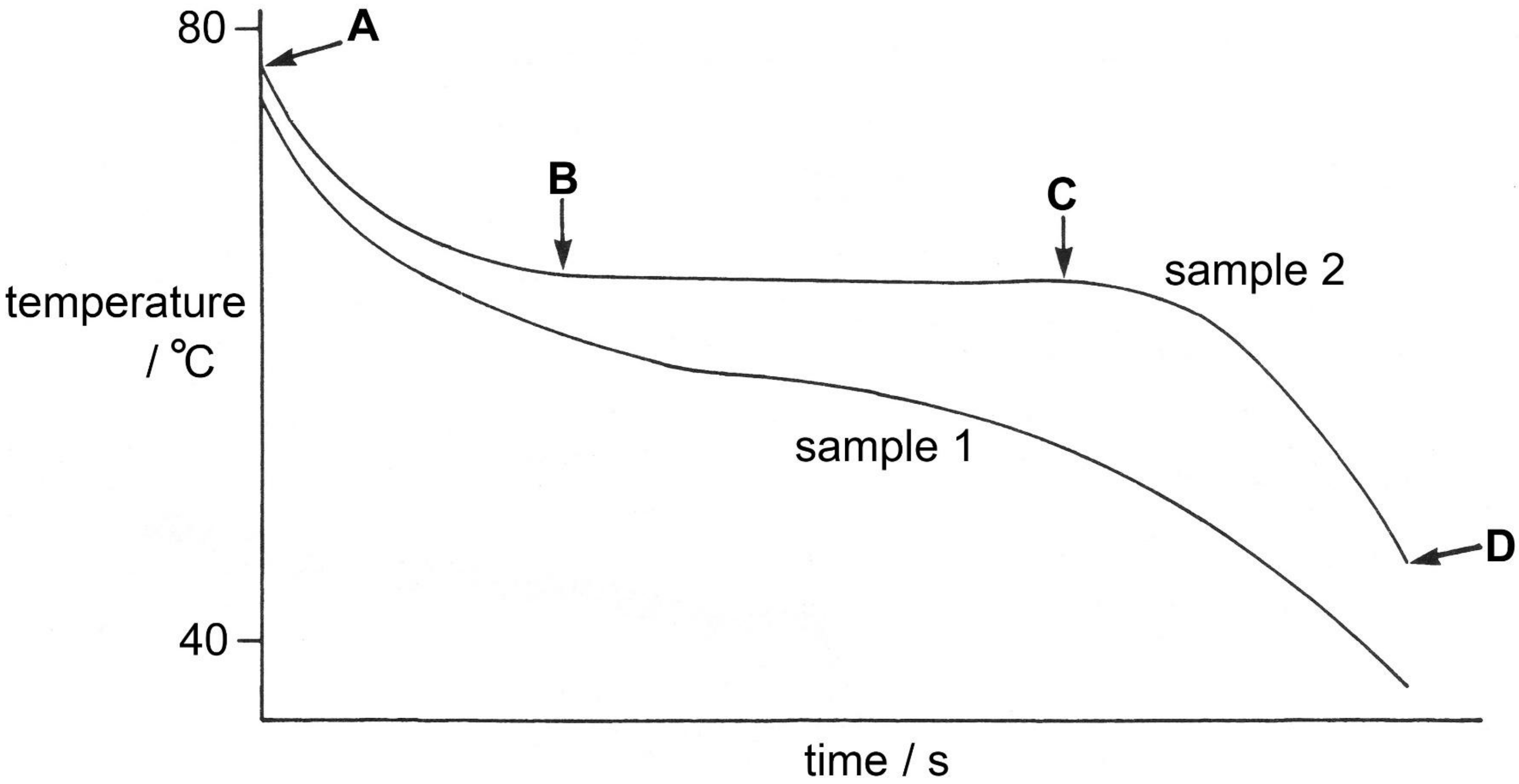

- Two samples of stearic acid were heated until they melted.
- The liquids were allowed to cool. As they cooled, their temperatures were measured at regular intervals and plotted on a graph.

Qu. What state is the stearic acid between **A** → **B**, **B** → **C**, **C** → **D**?

Qu. Which sample is pure – **sample 1** or **sample 2**? Explain why.

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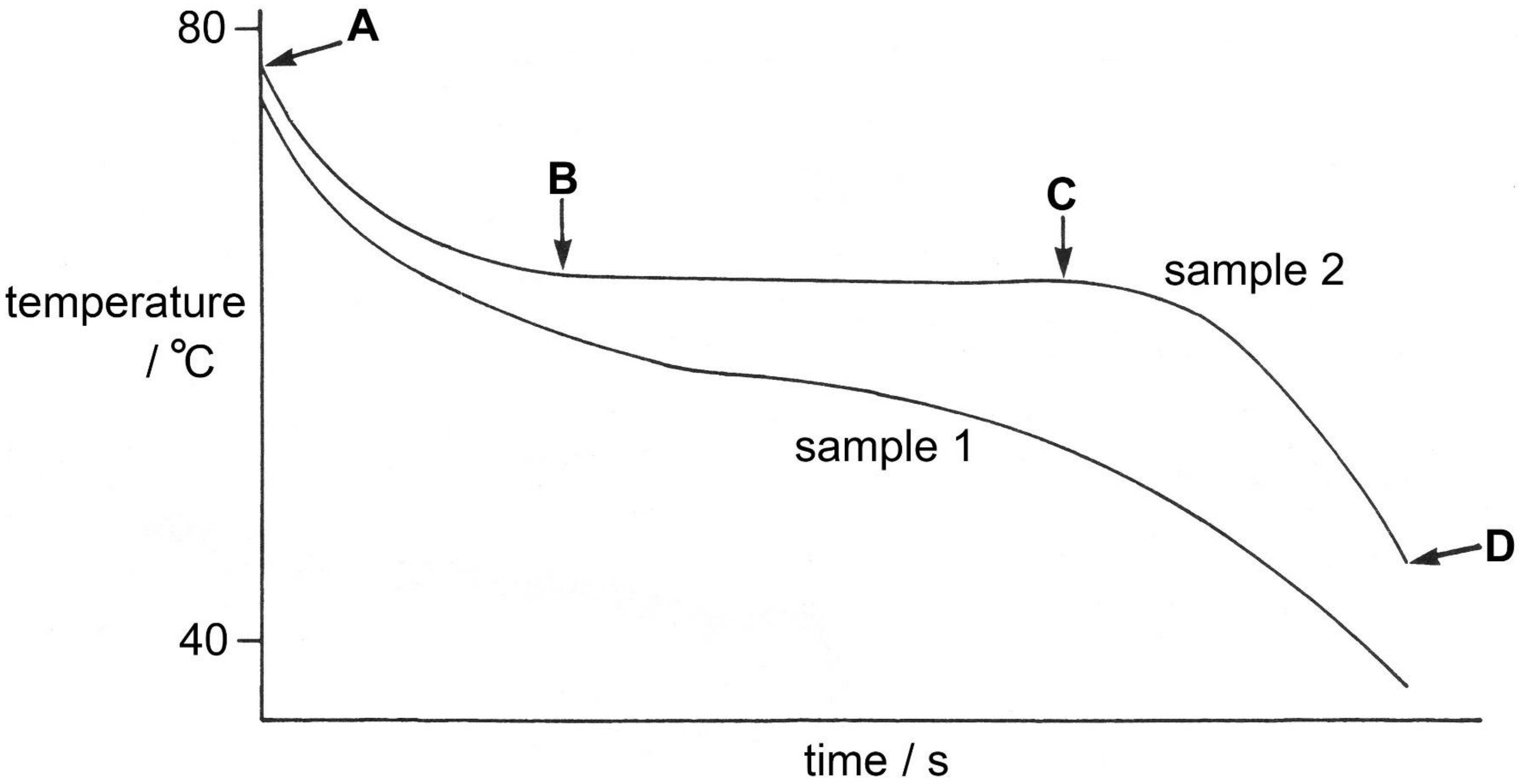

Qu. What state is the stearic acid between **A** → **B**, **B** → **C**, **C** → **D**?

Ans. **A** → **B** = liquid only, **B** → **C** liquid and solid, **C** → **D** solid only.

Qu. Which sample is pure – **sample 1** or **sample 2**? Explain why.

Ans. **Sample 2** is pure. It changes from a liquid to a solid (solidifies) at a fixed / constant / sharp temperature.

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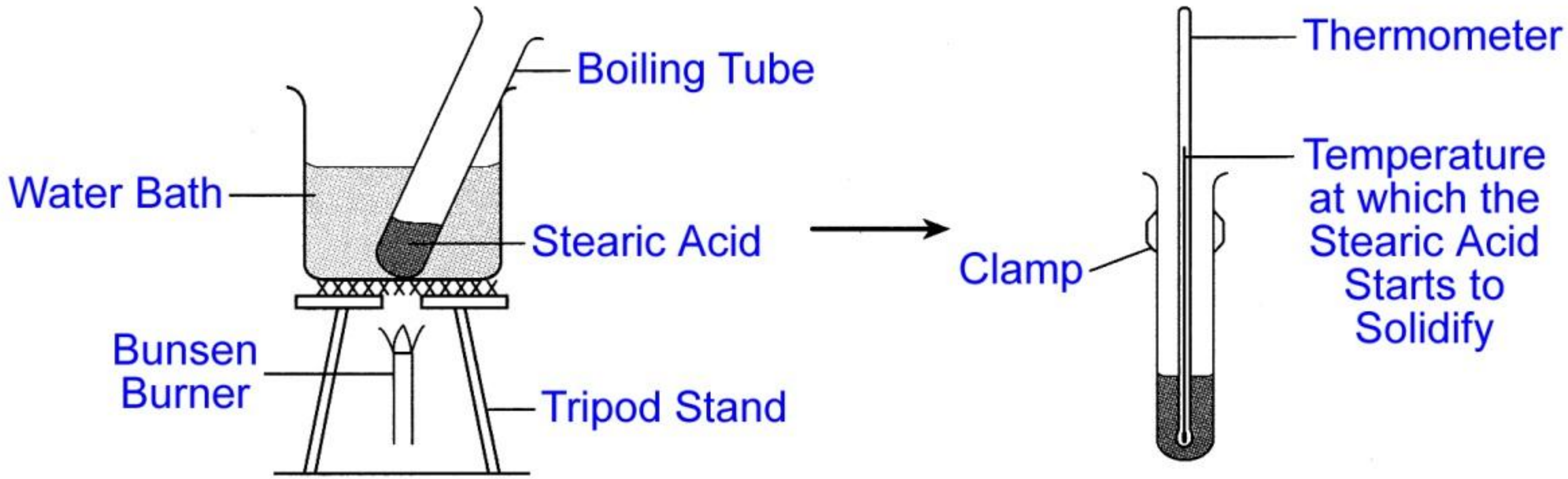
Determination of Melting Point



- Heat the solid until it has all melted.
- Allow the liquid to cool to room temperature while recording its temperature at regular time intervals.
- Find melting point from the graph of Temperature (to the nearest 0.5 °C) against Time (to the nearest whole second).

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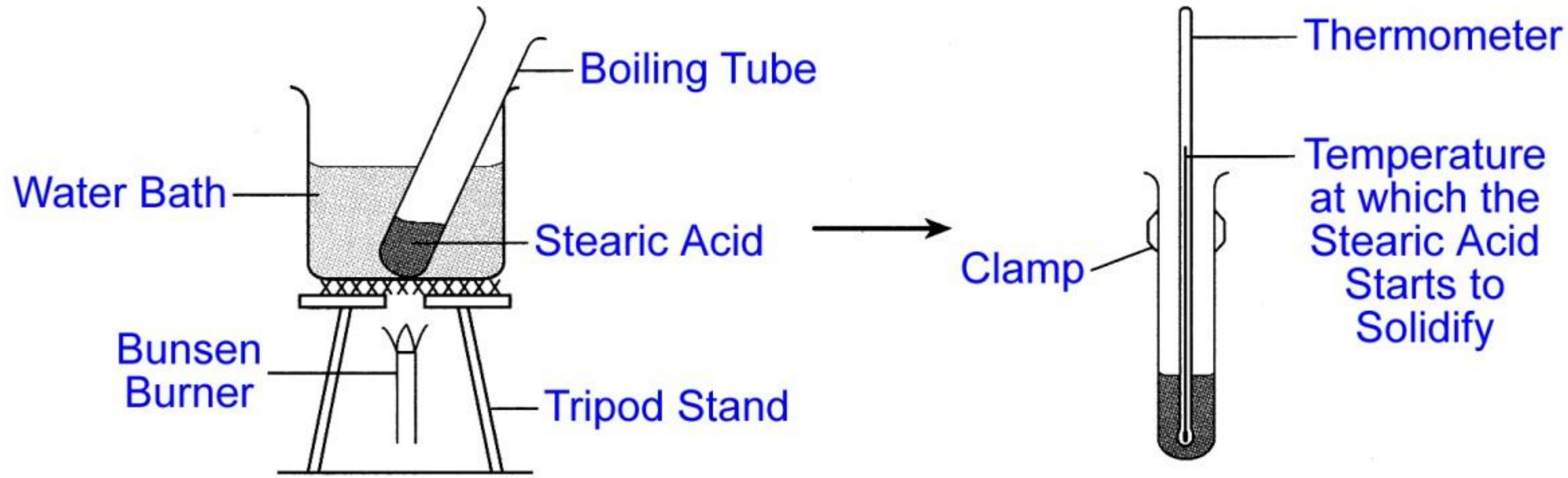
Determination of Melting Point



Question: Why is the chemical heated inside a *water bath*?

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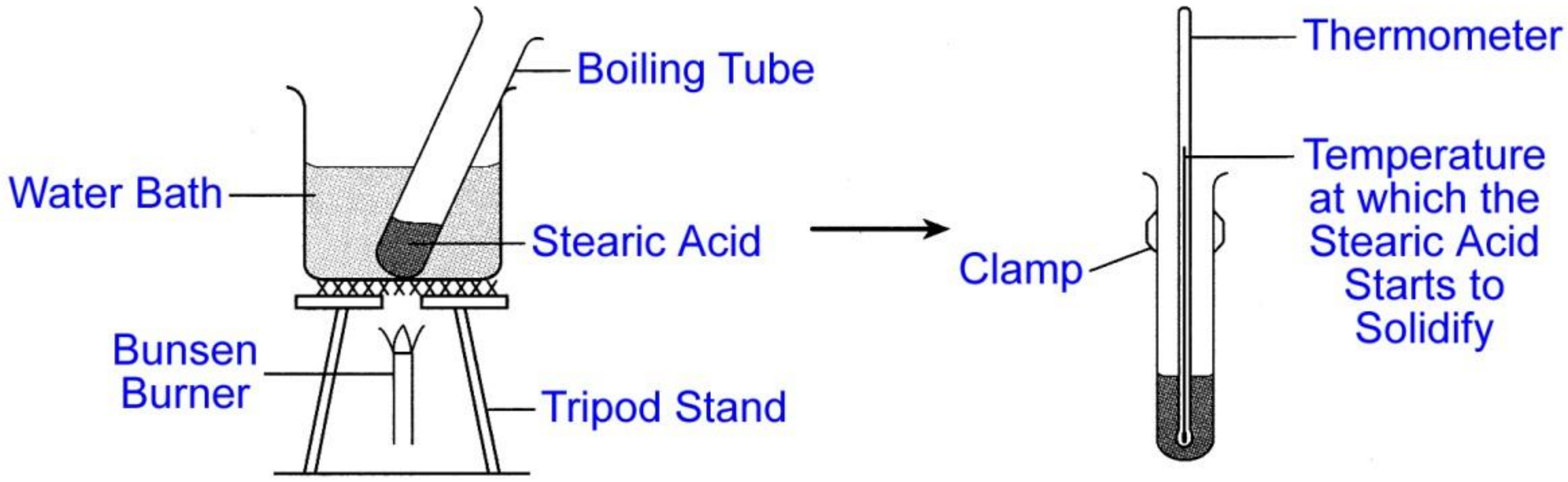
Determination of Melting Point



Question: Why is the chemical heated inside a *water bath*?

→ To supply the heat to all parts of the chemical.

→ To ensure that the substance is not decomposed by strong heating.

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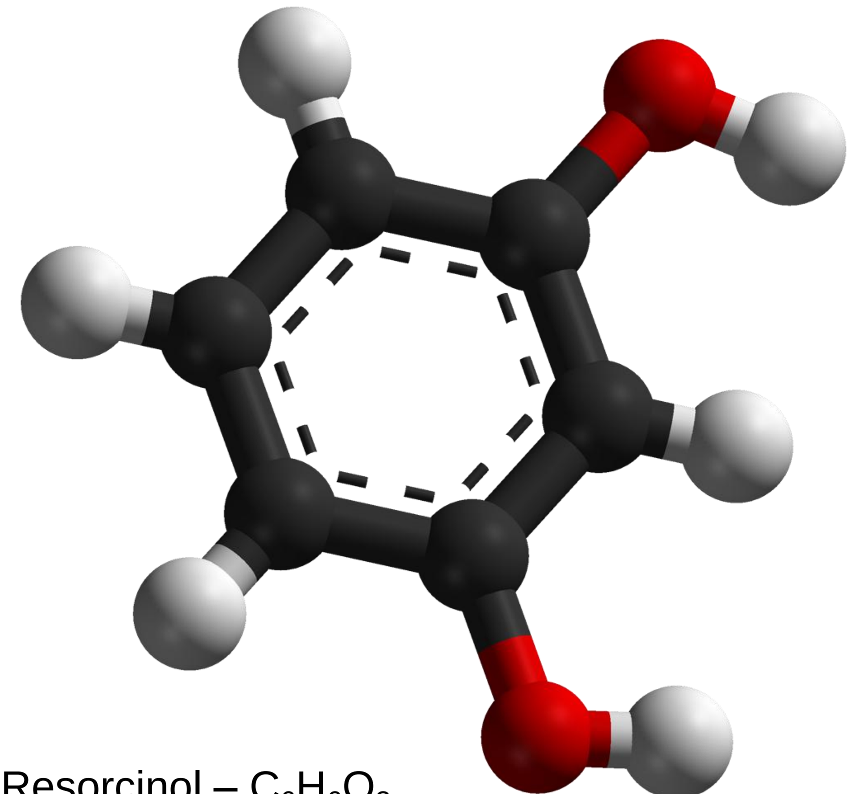
Determination of Purity



Resorcinol – $C_6H_6O_2$

Question: The melting point of resorcinol (formula: $C_6H_6O_2$) is 111 °C. An unknown chemical also has a melting point of 111 °C. What can you conclude about the unknown chemical?

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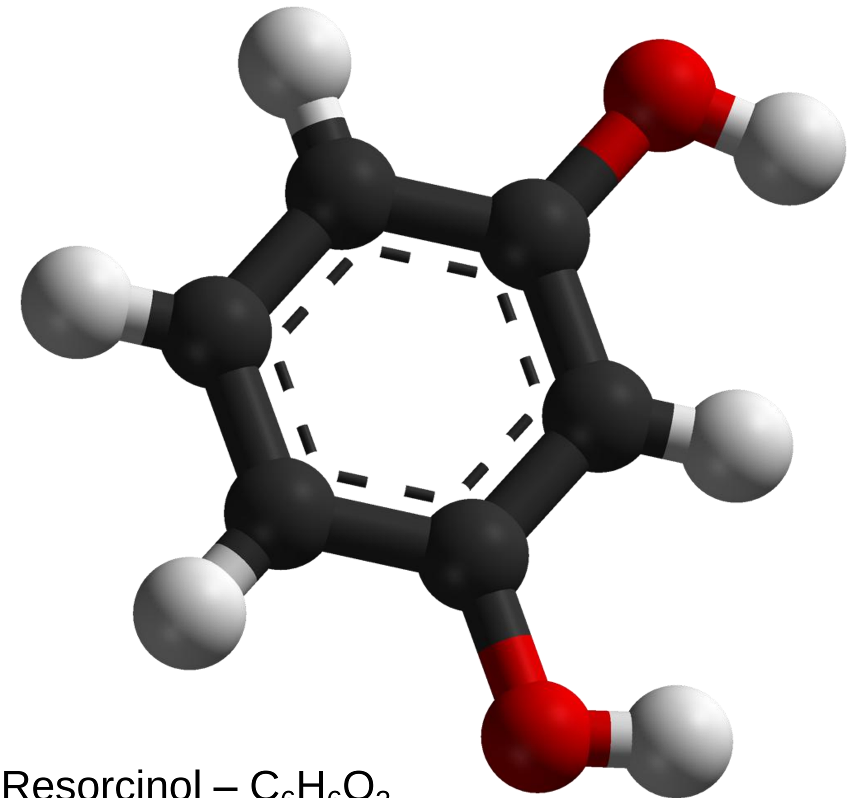
Determination of Purity



Resorcinol – $C_6H_6O_2$

Question: The melting point of resorcinol (formula: $C_6H_6O_2$) is 111 °C. An unknown chemical also has a melting point of 111 °C. What can you conclude about the unknown chemical?

→ The unknown chemical could be resorcinol.

→ The unknown chemical could be a different substance that happens to have the same melting point as resorcinol.

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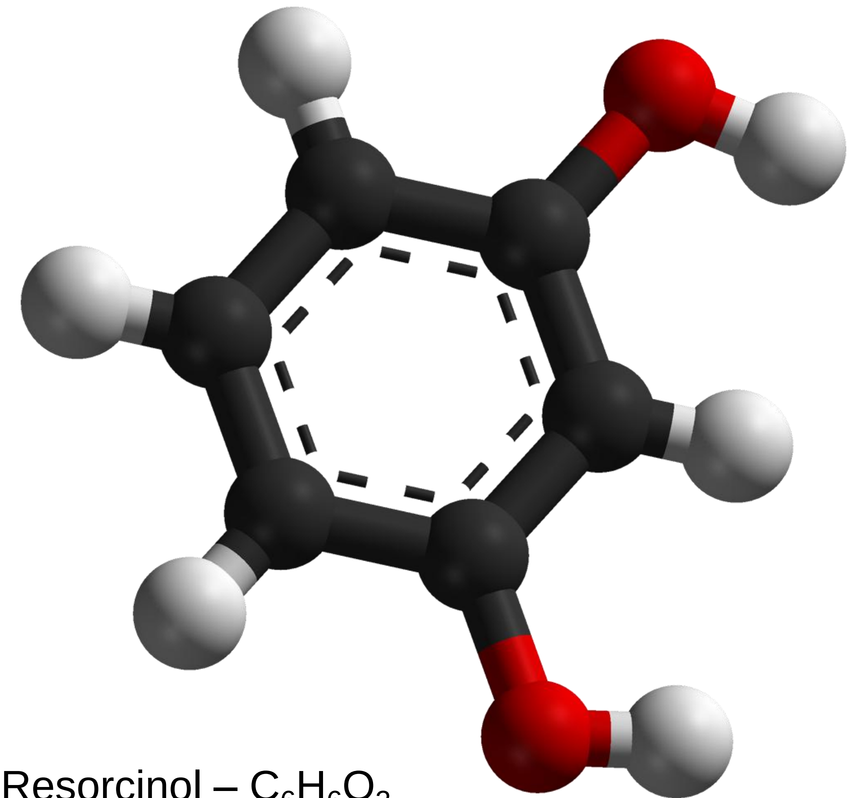
Determination of Purity



Resorcinol – $C_6H_6O_2$

Question: How can you confirm whether or not the unknown chemical is resorcinol?

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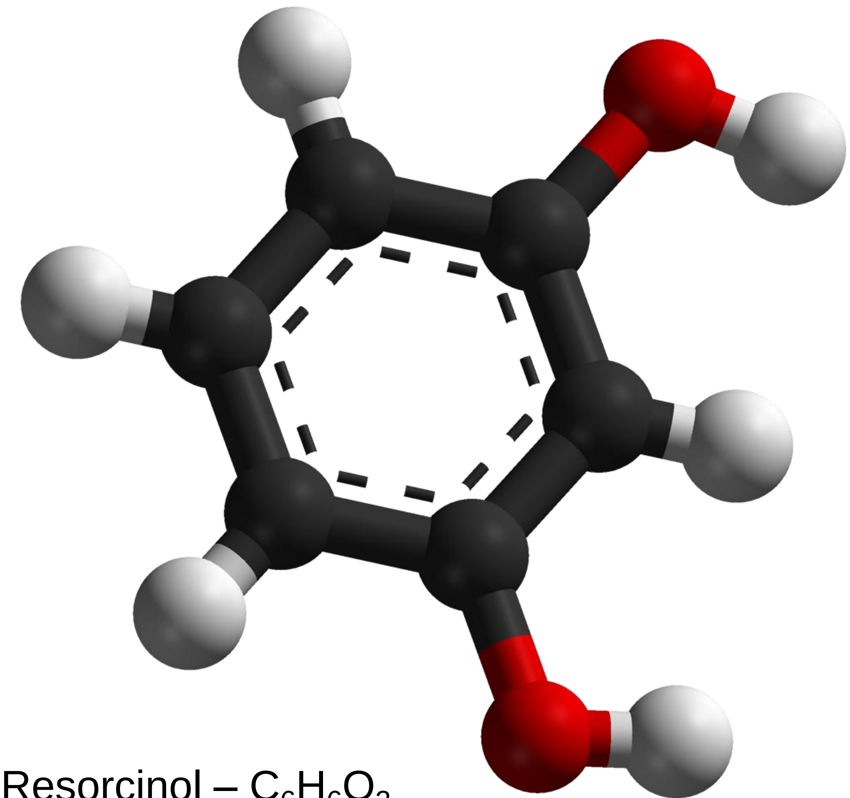
Determination of Purity



Resorcinol – $C_6H_6O_2$

Question: How can you confirm whether or not the unknown chemical is resorcinol?

1) Add pure resorcinol to the unknown chemical and find the melting point of the mixture.

2) If the melting point of the mixture is exactly 111 °C, then the unknown chemical is resorcinol.

3) If the melting point of the mixture is lower than 111°, then the unknown chemical is not resorcinol.

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Question: Why is table salt (sodium chloride) added to water that is used for cooking?

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Question: Why is table salt (sodium chloride) added to water that is used for cooking?

Answer: The sodium chloride is an *impurity* that will *increase* the *boiling point* of the water. The food will cook at a faster rate.

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Separation Techniques – Change & Systems

Question: Why is table salt (sodium chloride) added to snow and ice on frozen roads during winter time?

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Question: Why is table salt (sodium chloride) added to snow and ice on frozen roads during winter time?

Answer: The sodium chloride is an *impurity* that will *decrease* the *melting point* of the ice. The ice will therefore melt, even at temperatures below 0 °C, thus making the roads safer to drive on.

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- Scientists at the National and Space Administration (NASA) believe that these channels on the surface of Mars maybe due to the flow of liquid water.
- But how can liquid water flow on the surface of Mars when its average surface temperature is –60°C*?
- Scientists believe that salts (impurities) dissolved in the water may significantly lower its freezing point, thus allowing water to exist in its liquid state at temperatures below 0°C.

* The surface temperature on Mars varies between +20° at the equator during the Martian summer and –125°C at the poles during the Martian winter.

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- Chemicals can be separated because of differences in their *chemical properties* and / or *physical properties*.

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Essential understanding!

- For example, a mixture of *sodium chloride* (table salt) and *sand* can be separated by adding water, stirring and filtering because sodium chloride is *soluble* in water while sand is *insoluble* in water.

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Essential understanding!

- To make your understanding of *separation techniques* easier, make links to what you already know about *Chemistry*.

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Essential understanding!

- For example, *distillation* is essentially the process of *boiling* a *liquid* followed by the process of *condensing* a *vapour*.

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Magnetic Attraction

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Magnetic Attraction

- A magnet can be used to attract a magnetic substance away from a non-magnetic substance.

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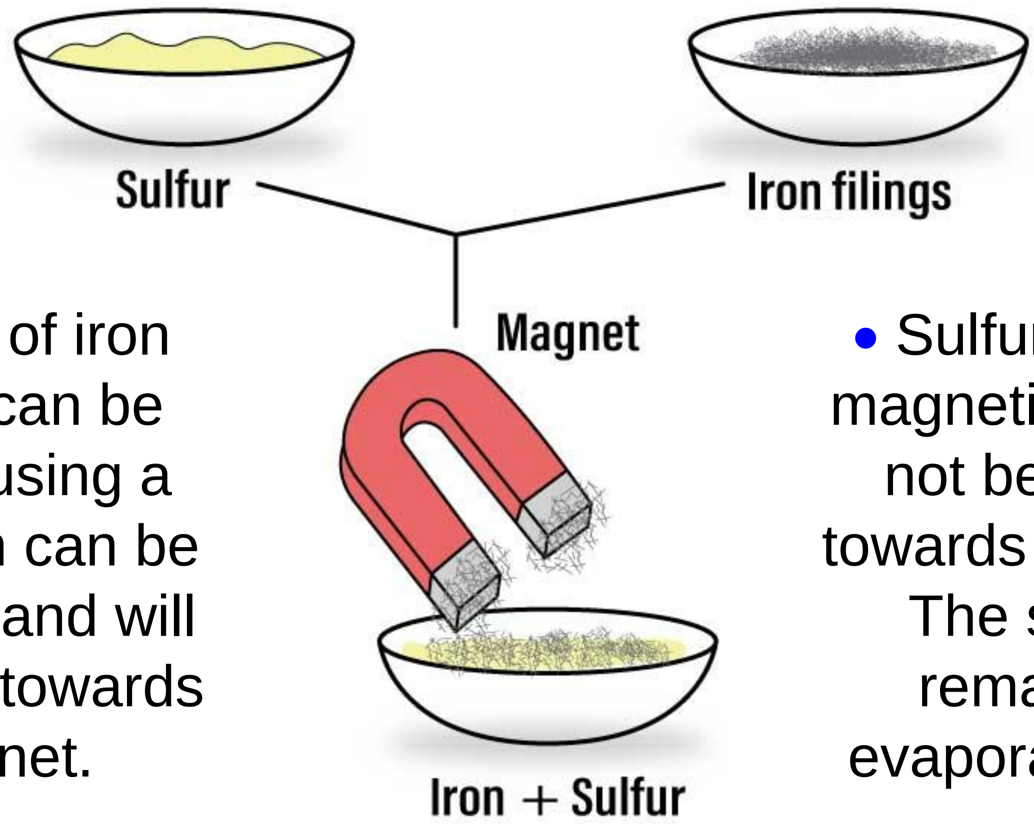
Magnetic Attraction



- A mixture of iron and sulfur can be separated using a magnet. Iron can be magnetised and will be attracted towards the magnet.

- Sulfur cannot be magnetised and will not be attracted towards the magnet. The sulfur will remain in the evaporating basin.

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- Iron and sulfur are both chemical *elements*.
- A *mixture* of iron and sulfur can be separated by a magnet because iron can be magnetised but sulfur cannot.

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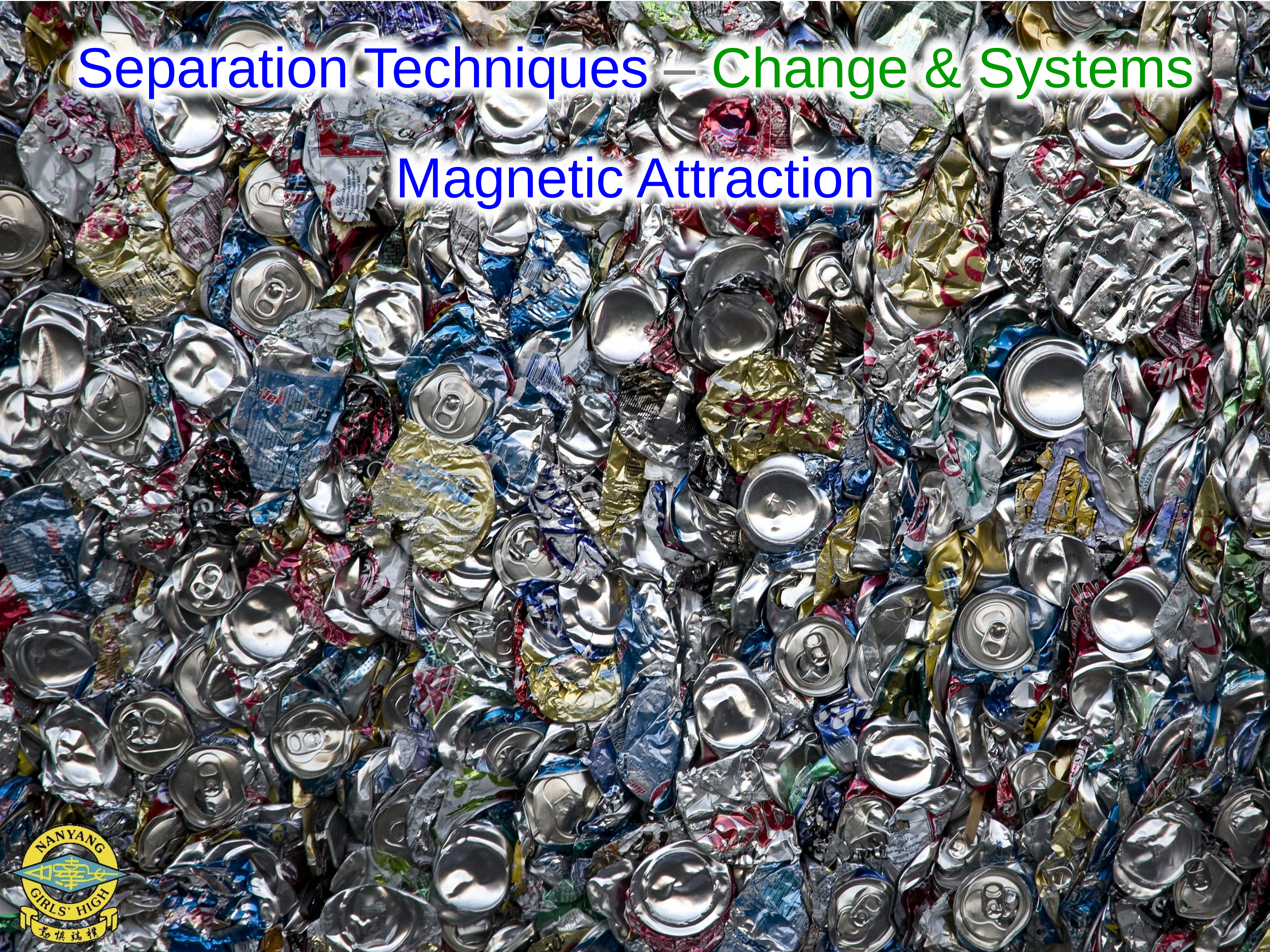
Magnetic Attraction



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Magnetic Attraction

- In the recycling of metals, metals that are magnetic, *e.g*. iron, are separated from metals that are not magnetic, *e.g*. aluminium, by using strong electromagnets.

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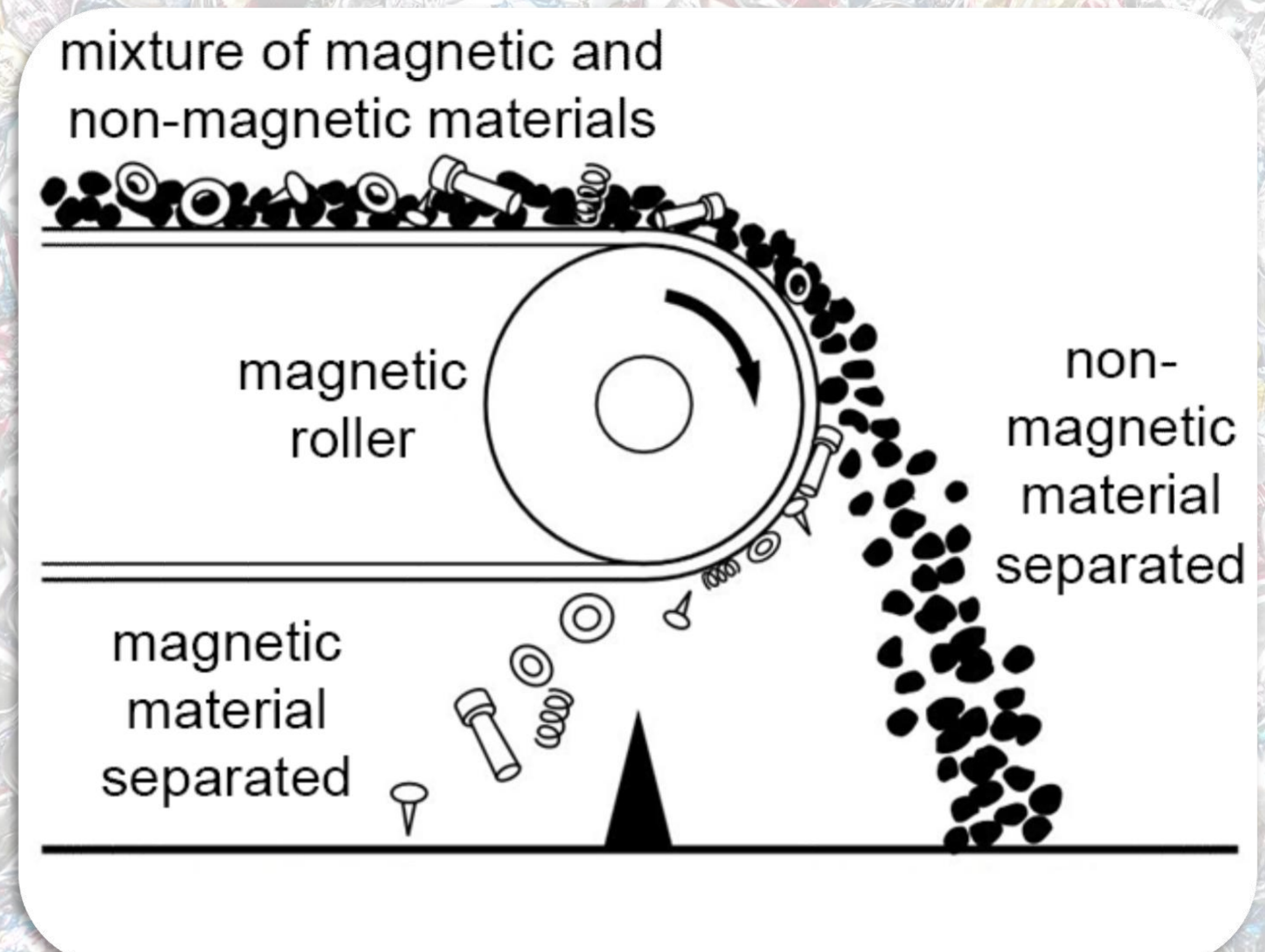
Magnetic Attraction



Filtration

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Filtration

- Filtration is used to separate an *insoluble* chemical from a *liquid*, or separate an *insoluble* chemical from a *solution*. For example, filtration may be used to separate sand from water or separate sand from an aqueous solution of sodium chloride.
- The liquid or solution that passes through the filter paper is referred to as the *filtrate*.
- The insoluble solid that gets trapped in the filter paper is referred to as the *residue*.

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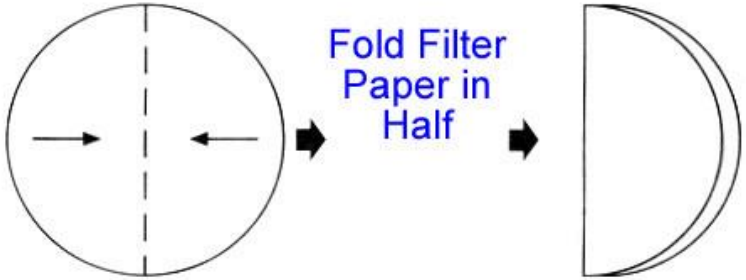
Filtration



- The correct way to fold the filter paper.

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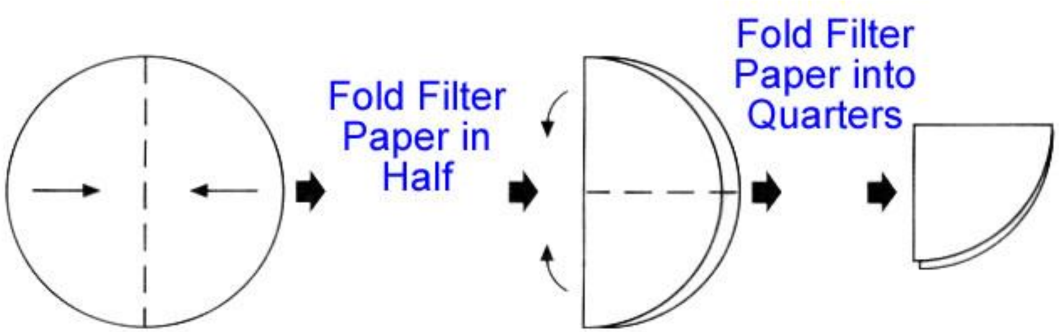
Filtration



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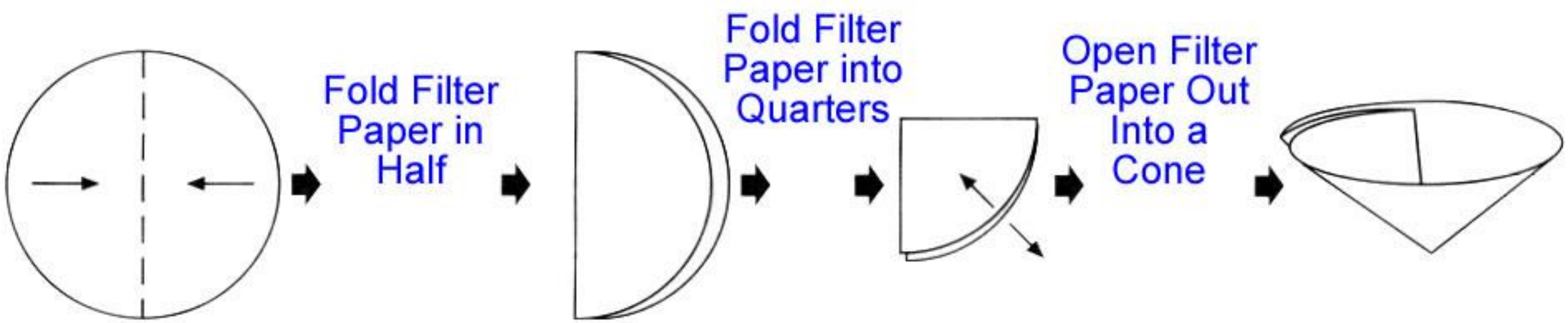
Filtration



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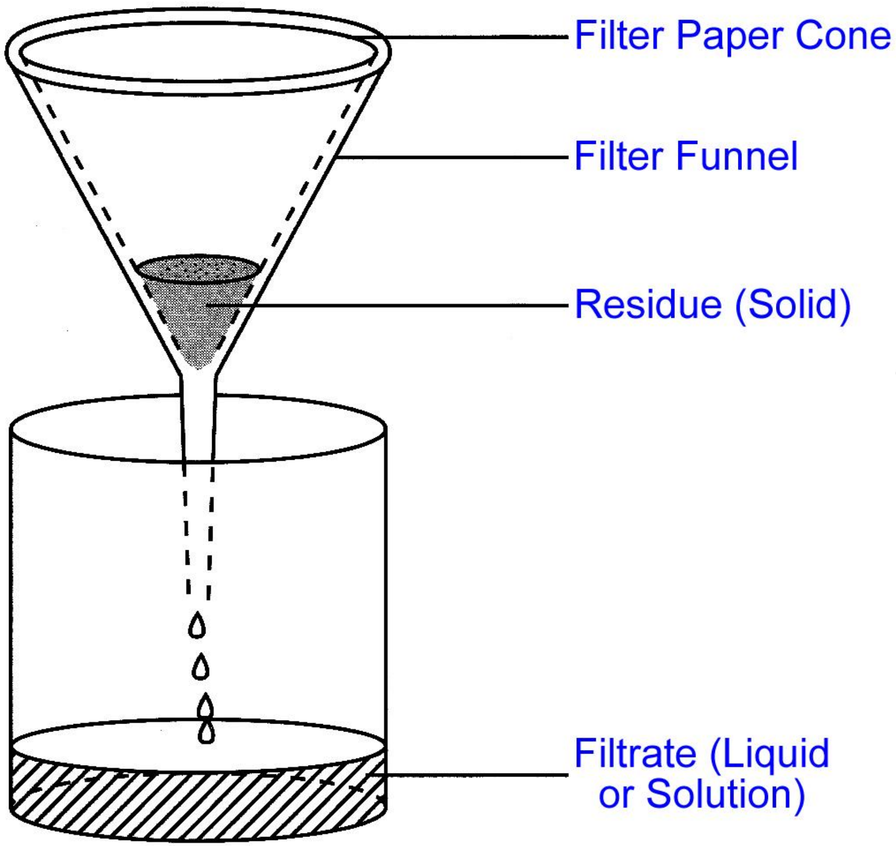
Filtration



- The *residue* should be washed with distilled water and then dried by pressing between layers of filter paper.
- If the filtrate is a *solution*, then the *solute* can be separated from the *solvent* by either *distillation* or *crystallisation*.

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Filtration

Filtration

- Particles of the solvent and / or the solute are small enough to pass in-between the fibres of the filter paper.
- Particles of the insoluble solid are generally too large to fit in-between the fibres of the filter paper.

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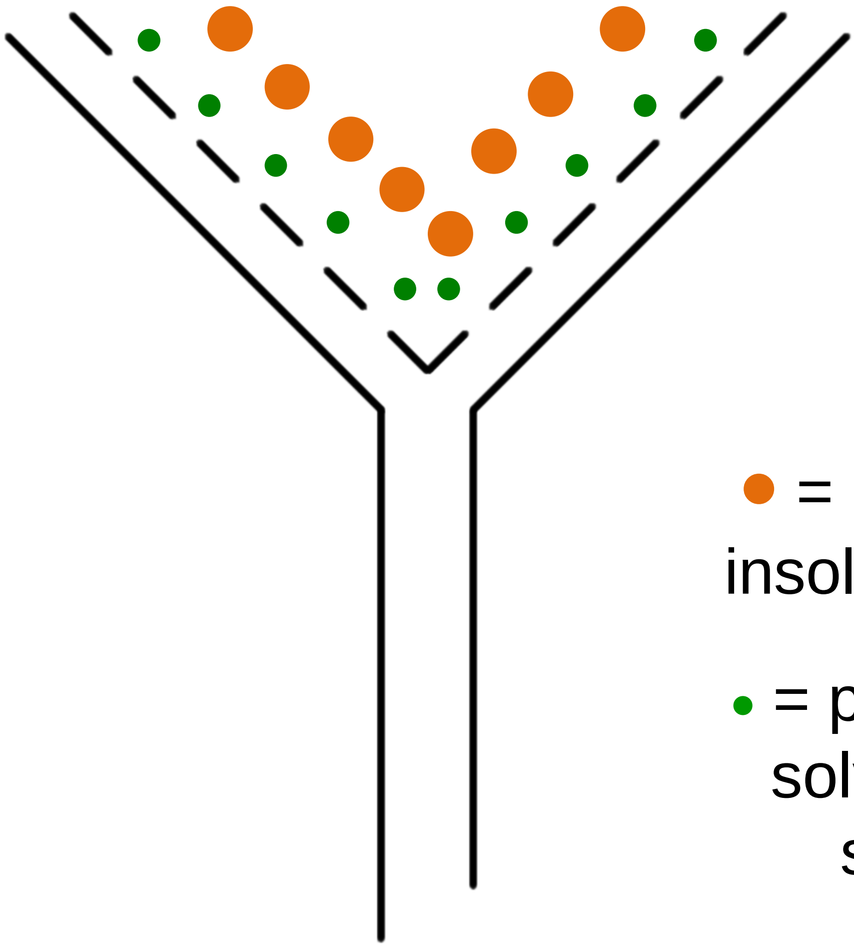
Filtration



● = particle of insolube solid.

● = particles of solvent and solute.

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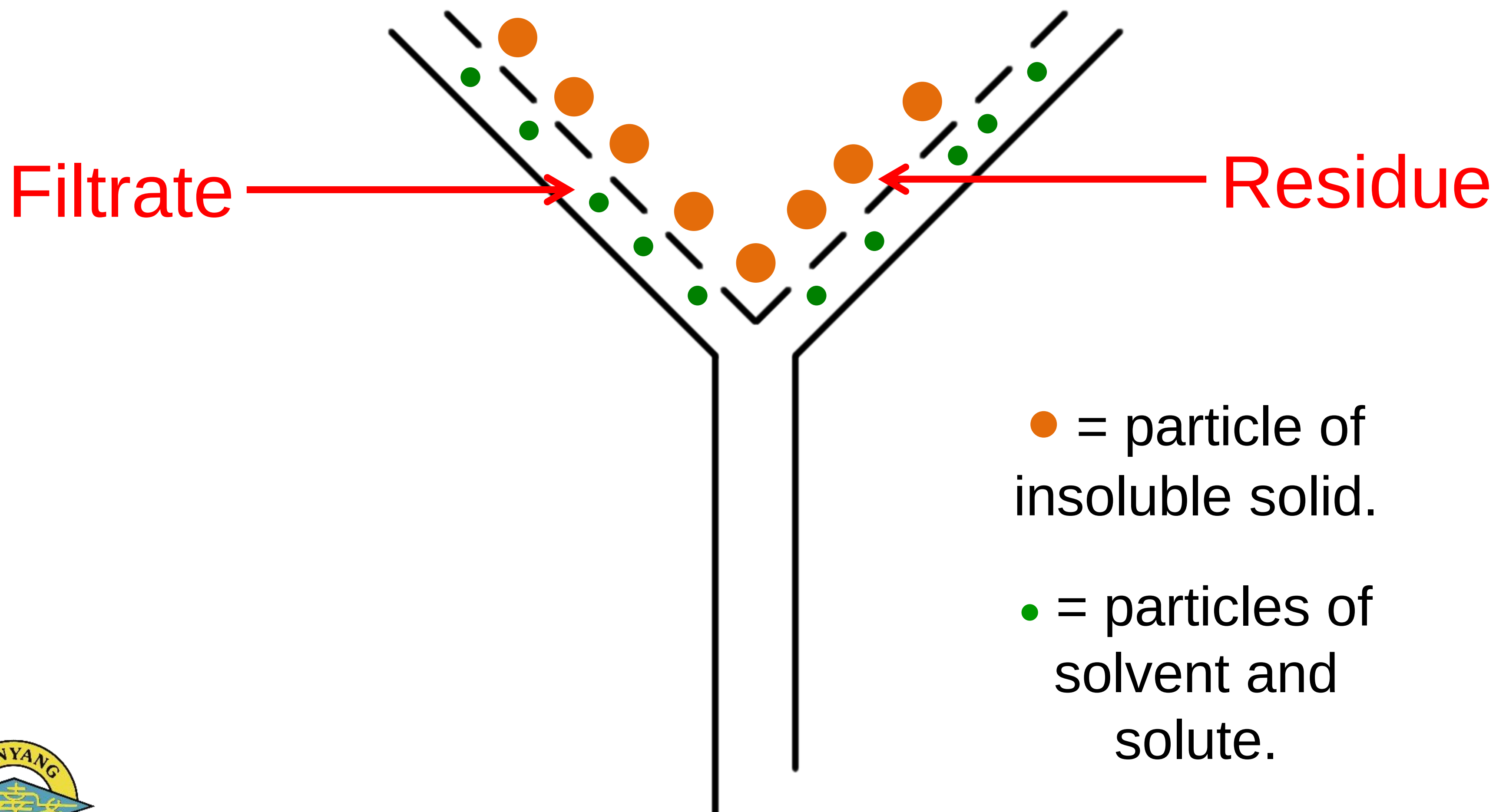
Filtration



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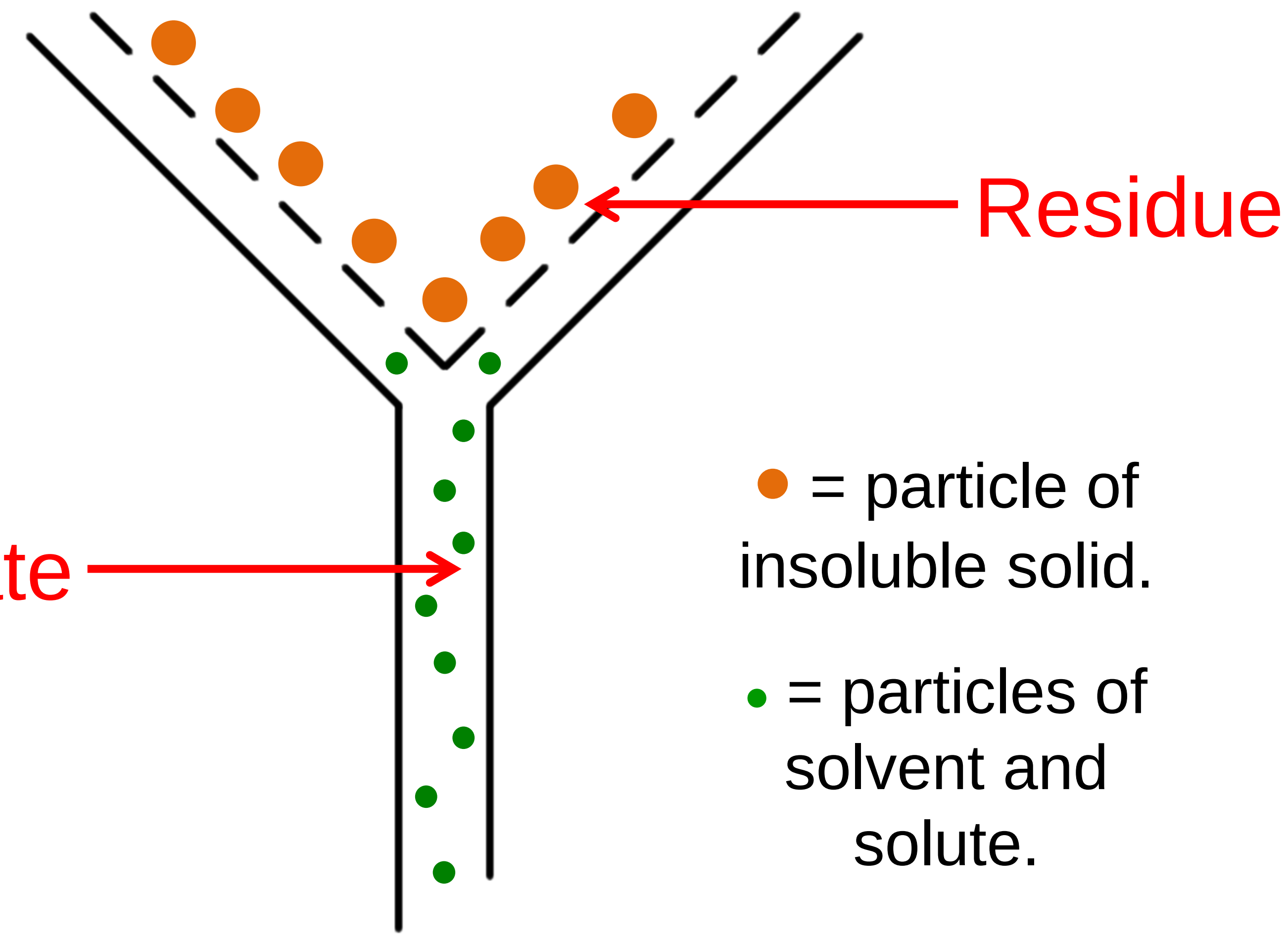
Filtration



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Filtration

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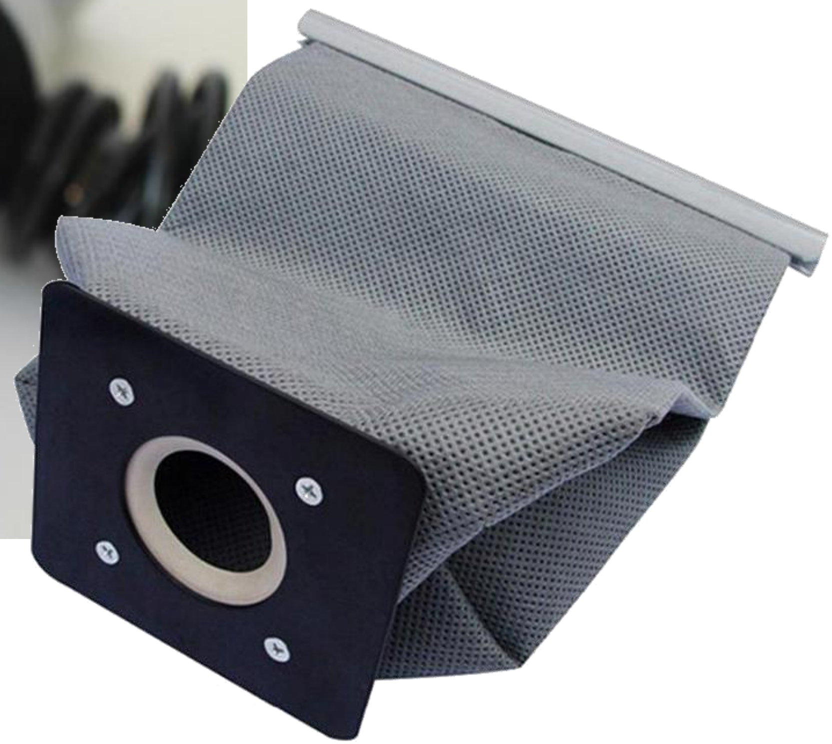
Filtration



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Filtration

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Filtration

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Filtration

- Filtration is one of the many stages in the purification of drinking water. The impure water is passed through layers of gravel and fine sand in order to remove insoluble impurities.

Crystallisation

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Crystallisation

- Blue Crystals of Copper(II) Sulfate

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Crystallisation

- Crystallisation is used to separate a *solute* from a *solvent*, *e.g.* crystallisation can be used to separate copper(II) sulfate (*solute*) from water (*solvent*).

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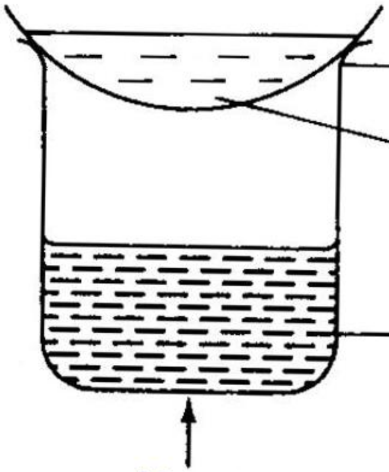
Crystallisation



- The *dilute solution* is heated over a water bath in order to boil away most of the water.

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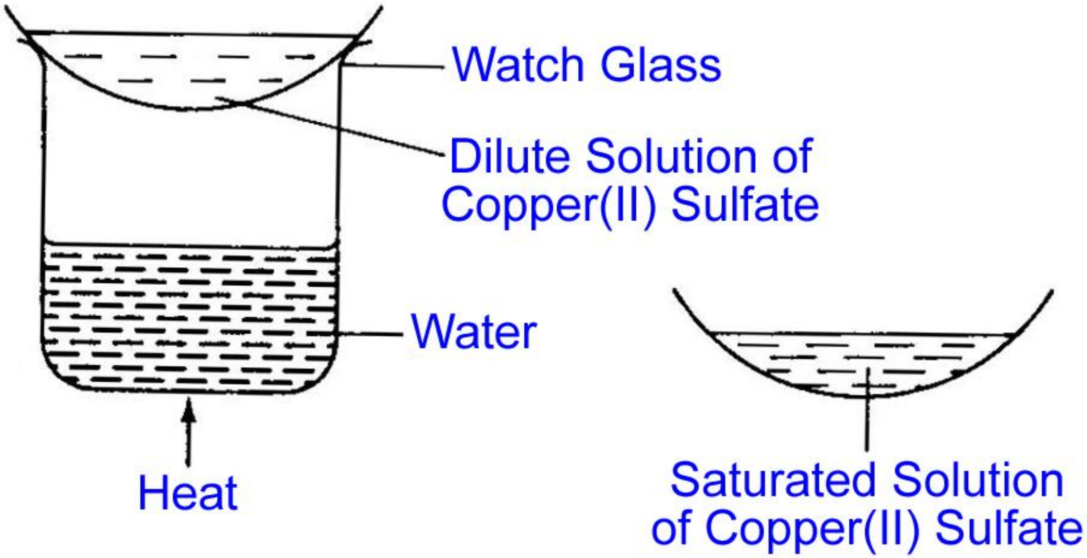
Crystallisation



- This results in the formation of a *saturated solution*, *i.e.* a solution in which no more of the solute can dissolve.

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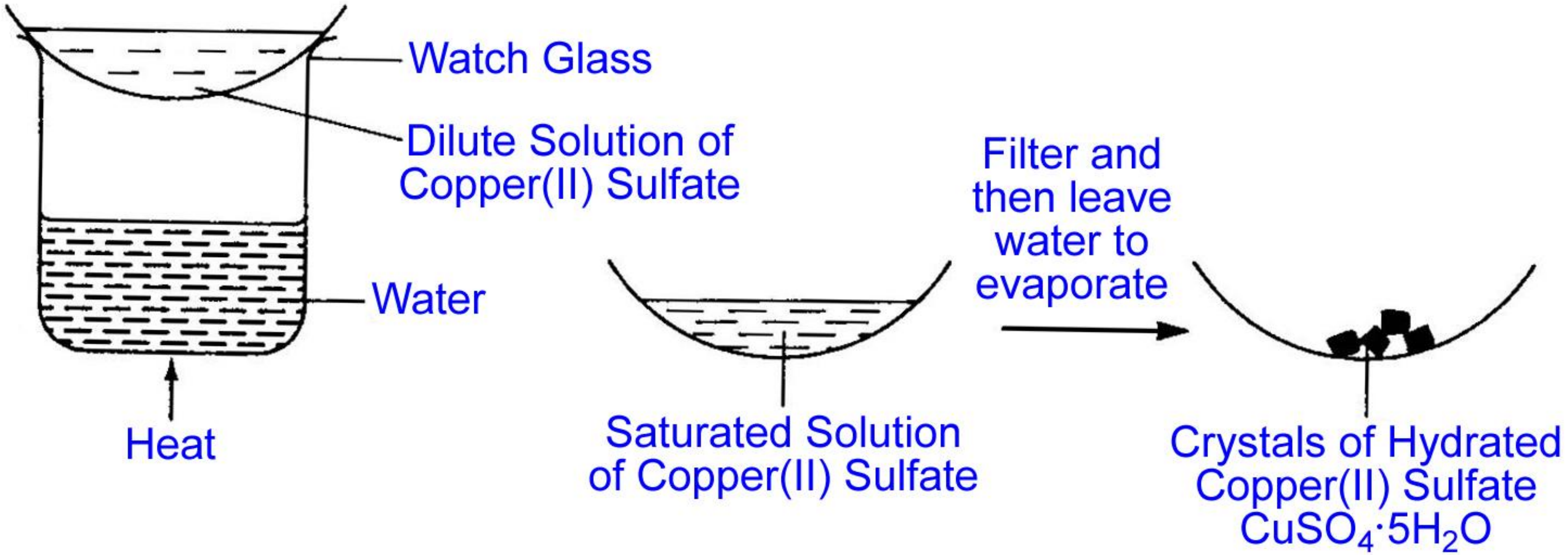
Crystallisation



- The remaining water is allowed to evaporate at room temperature, forming large and well-defined crystals of copper(II) sulfate.

Crystallisation

Note: Heating to remove all of the water, instead of allowing the water to evaporate, can result in the formation of *small, irregular crystals*. Heating to remove all of the water can also result in the thermal decomposition of the salt, especially if the salt is *hydrated*. Heating *hydrated crystals* may result in the formation of an undesirable *anhydrous powder*:

$$CuSO_4{\cdot}5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(l)$$

Note: Crystallisation is used to purify raw sugar. Crystallisation is also used to obtain pure silicon, used in the manufacture of computer processors and computer memory. This is done by freezing molten silicon at 1410 °C.

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Crystallisation

Solubility Curve

- In the preparation of soluble salts, the solid salt is obtained by evaporating away most of the water and allowing the hot solution to cool. As the solution cools, it becomes *saturated*, meaning that it has the maximum amount of solute (*i.e.* salt) dissolved in the solvent.

- *Solubility* is the maximum amount of salt (mass in grams) that dissolves in a solvent (usually 100 cm^3) at a given temperature. *Solubility decreases* as *temperature decreases*. Therefore, as the solution continues to cool, there is a decrease in the amount of salt that can remain dissolved – all of the extra salt *crystallises*.

Crystallisation

Solubility Curve

- It is important to leave some water after evaporation for two reasons:

1. Any impurities will be left in the remaining solution after cooling, and will not contaminate the crystals.

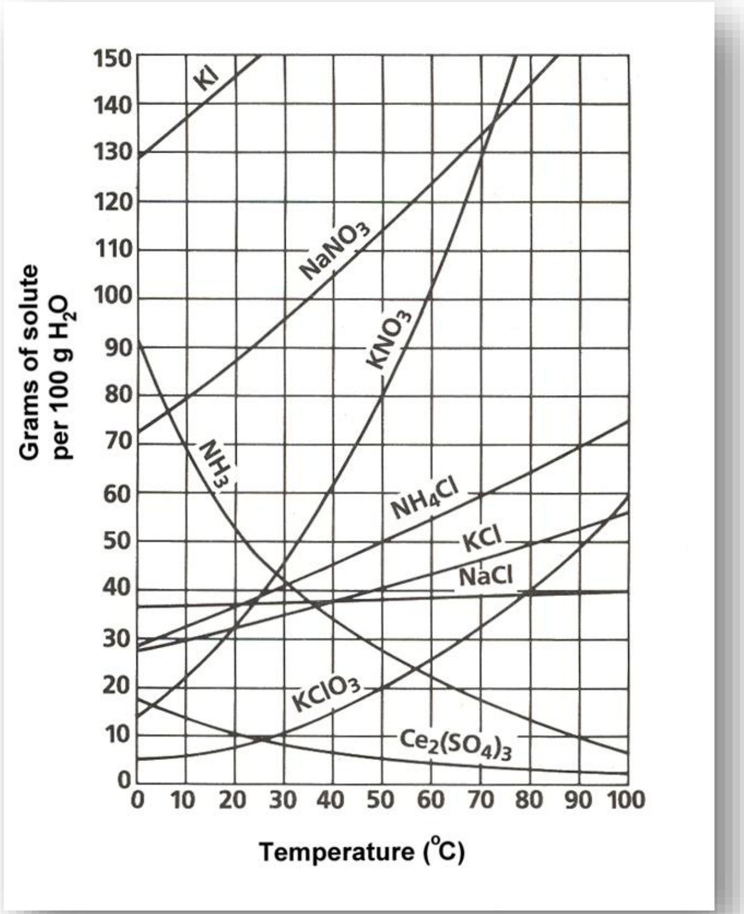
2. Many salts require water to be present in order to form crystals – known as *water of crystallisation* – *e.g.* hydrated copper(II) sulfate – $CuSO_4{\cdot}5H_2O$.

Separation Techniques – Change & Systems

Crystallisation

Solubility Curve

- *Solubility* is a measure of how many grams of solute dissolve in 100 cm^3 of solvent.



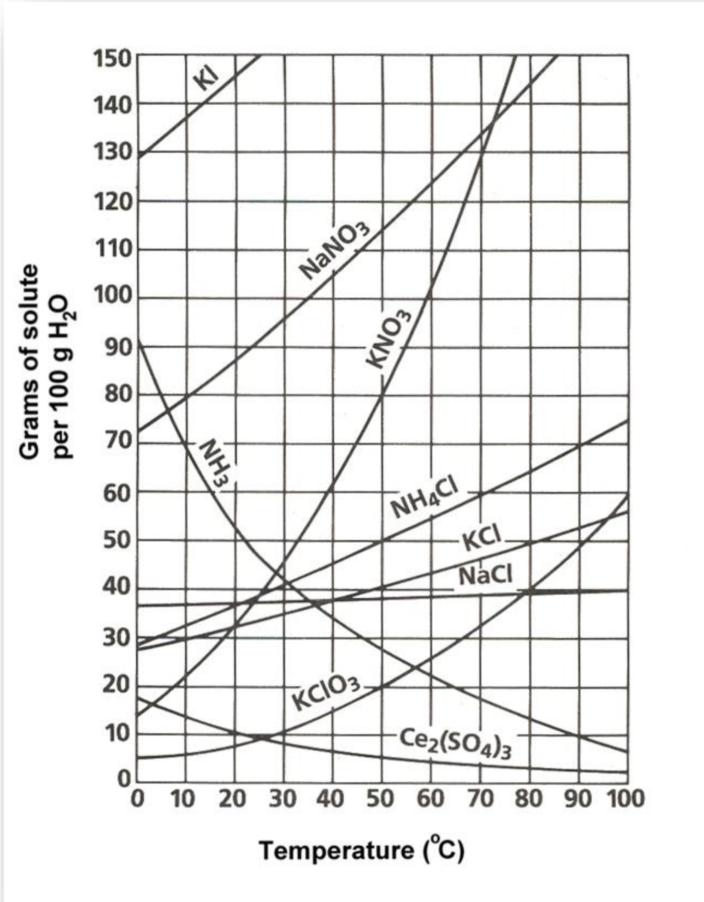
- A *solubility curve* is a graph of solubility plotted against temperature. It shows how the solubility of a chemical changes with temperature.

Separation Techniques – Change & Systems

Crystallisation

Solubility Curve

- The solubility of some salts, *e.g.* KNO_3, decrease a lot on cooling, so large amounts of these salts crystallise on cooling a *hot saturated solution*.



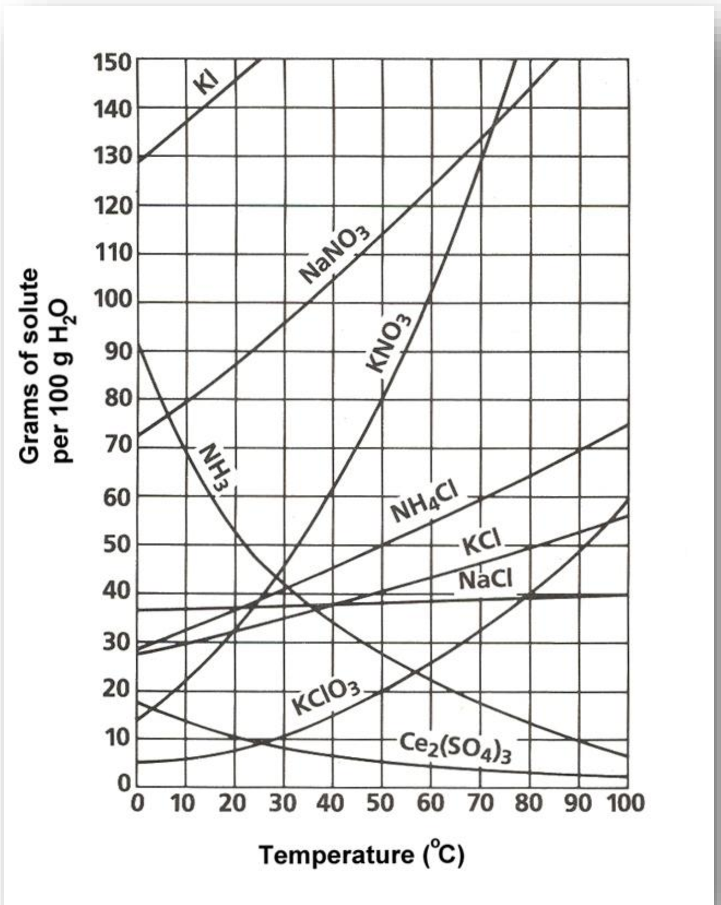
- The crystals of many salts can be obtained by cooling a hot saturated solution of the salt, a process called *crystallisation*.

Separation Techniques – Change & Systems

Crystallisation

Solubility Curve

- The solubility of other salts, *e.g.* NaC*l*, show very little variation on cooling, so very little solid is formed when a hot saturated solution of NaC*l* is cooled.



- To obtain crystals of NaC*l* from an aqueous solution, all of the water must be heated / evaporated, a process known as *evaporation to dryness*.

Separation Techniques – Change & Systems

Crystallisation

Separation Techniques – Change & Systems

Crystallisation

- The Dead Sea is a salt lake bordered by Jordan to the East and Israel and Palestine to the West.

- The shore of the Dead Sea are 429 m *below* sea level, making it the Earth's lowest elevation on land.

- At 304 m deep, the Dead Sea is the world's deepest hypersaline lake. With 32.4 % salinity, the Dead Sea is 9.6 times more salty than the ocean.

- The concentration of ions in g/kg of water at the surface of the Dead Sea is Cl^- = 181.4, Br^- = 4.2, SO_4^{2-} = 0.4, HCO_3^- = 0.2, Ca^{2+} = 14.1, Na^+ = 32.5, K^+ = 6.2 and Mg^{2+} = 35.2.

Separation Techniques – Change & Systems

- For a project called *Salt Bride*, Israeli artist Sigalit Landau submerged a black dress in the Dead Sea.

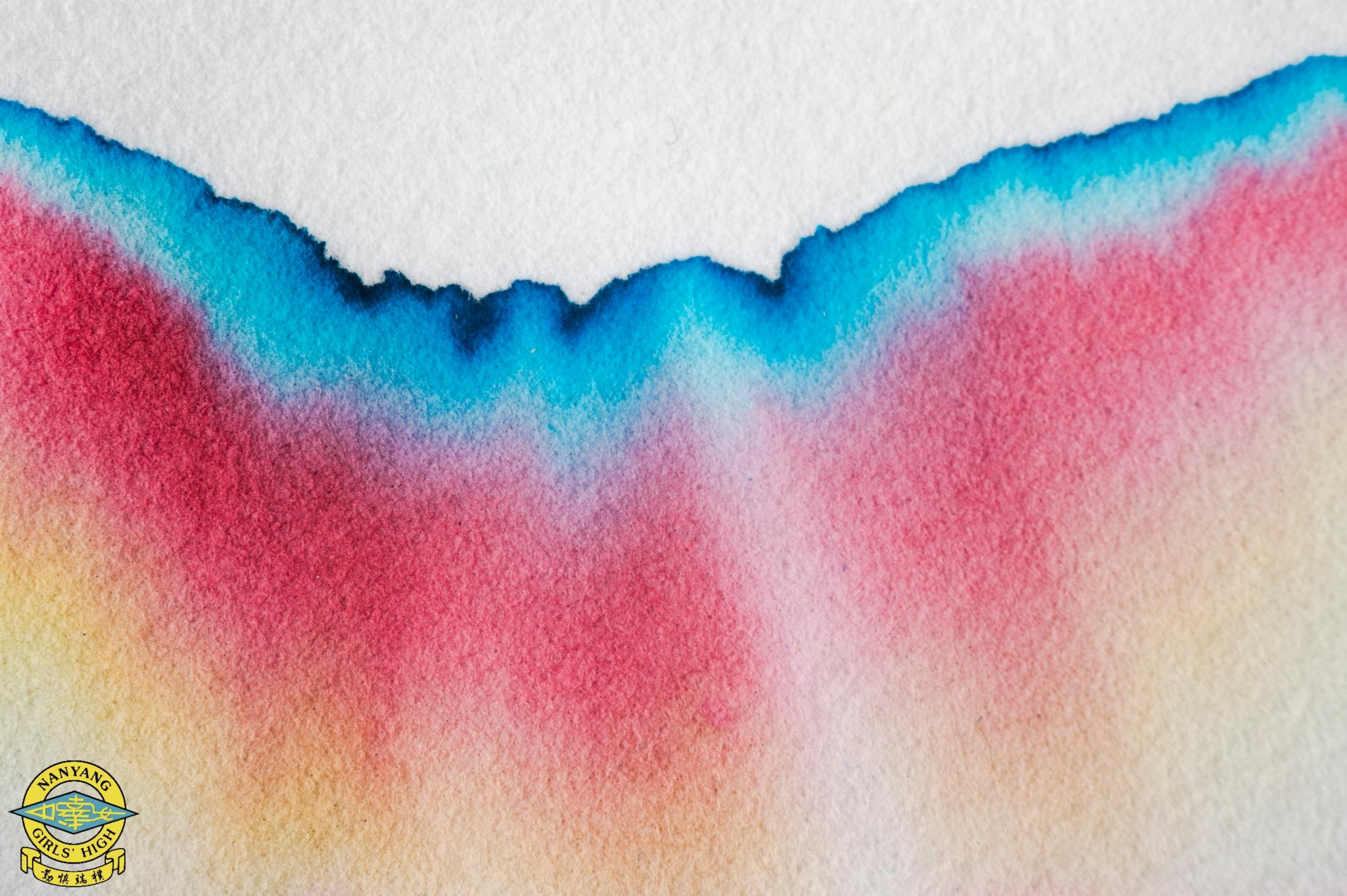
- The dress was submerged in the hypersaline waters of the Dead Sea for two months.

Separation Techniques – Change & Systems

- Over two months, various salts, *e.g.* NaC*l* and MgCl_2 crystallised over the surface of the dress.

- The formation of salt crystals changed the appearance of the dress from dull black to sparling white.

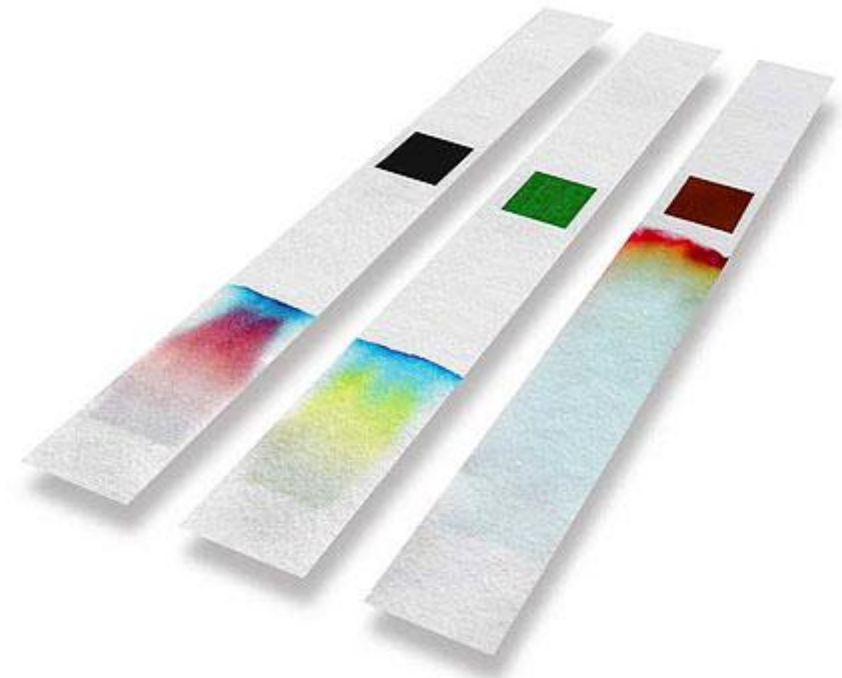
Separation Techniques – Change & Systems



Chromatography

Separation Techniques – Change & Systems

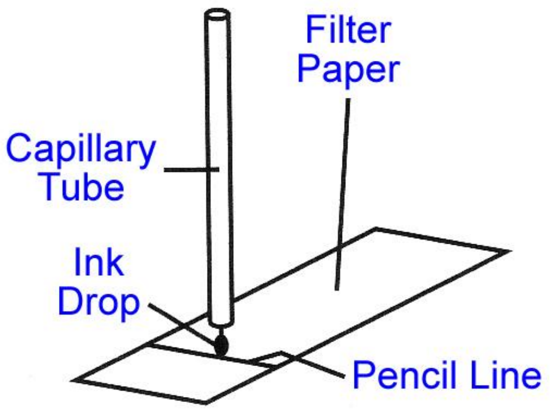
Chromatography



- Chromatography is used to *separate* and *identify* the chemicals that are present in a mixture.
- Chromatography can be used to separate chemicals that have a *different solubility in the same solvent*.
- Chromatography can be used to test the *purity* of a chemical. A pure chemical will only produce one spot on the chromatogram while an impure chemical will produce several spots on the chromatogram.

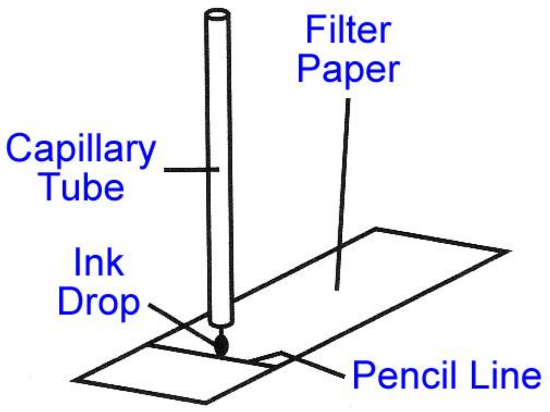
Separation Techniques – Change & Systems

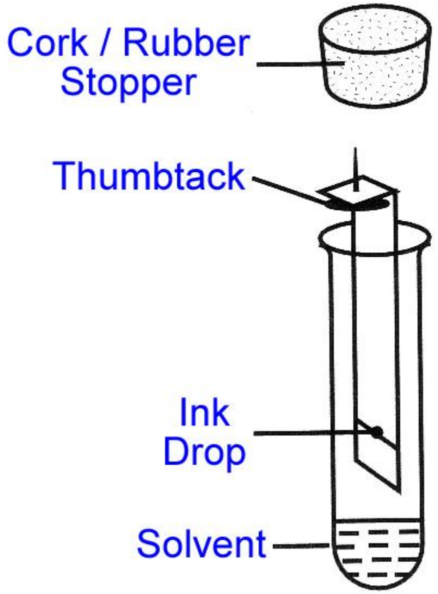
Chromatography



Separation Techniques – Change & Systems

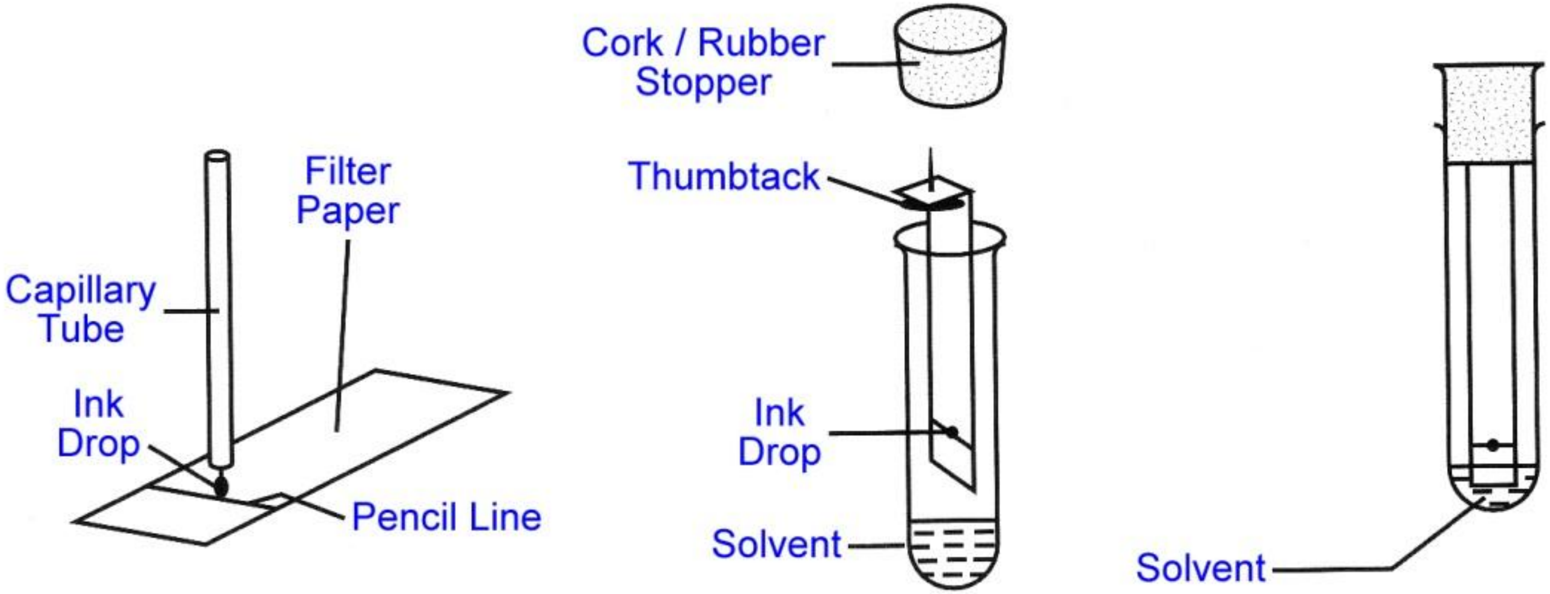
Chromatography





Separation Techniques – Change & Systems

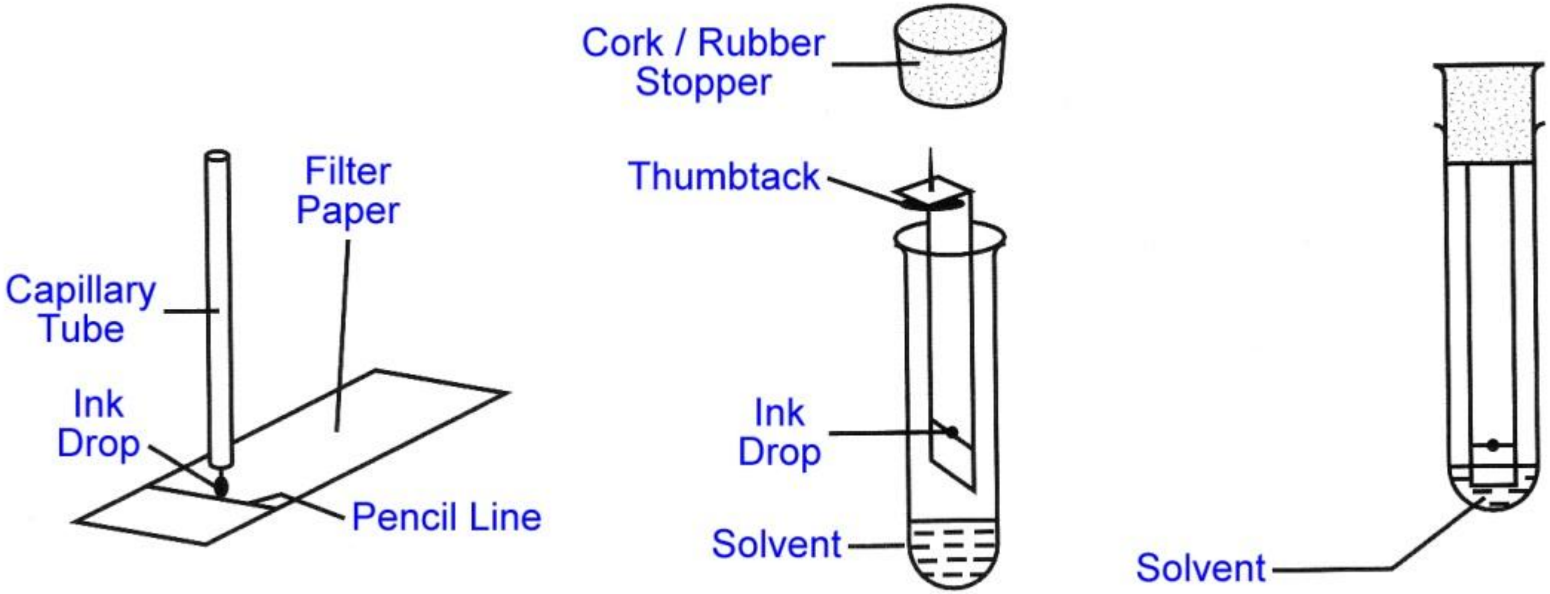
Chromatography



Note: The starting line must be drawn in *pencil*, because graphite (a component of pencil lead) is insoluble in all solvents. If the starting line were drawn in *ink*, then the ink would dissolve in the solvent and travel up the chromatography paper, contaminating the results.

Separation Techniques – Change & Systems

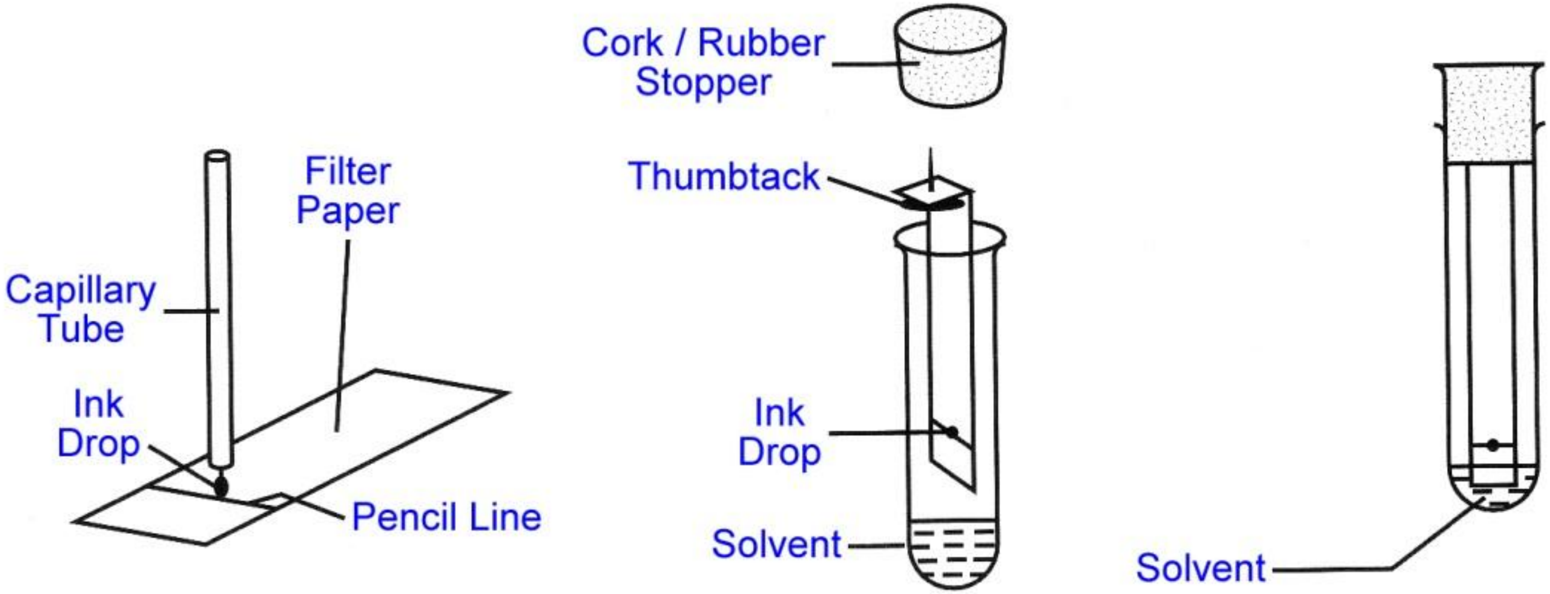
Chromatography



Note: The mixture of chemicals spotted on the filter paper must be *above the level of the solvent*, otherwise the mixture will simply dissolve in the solvent instead of travelling up the filter paper.

Separation Techniques – Change & Systems

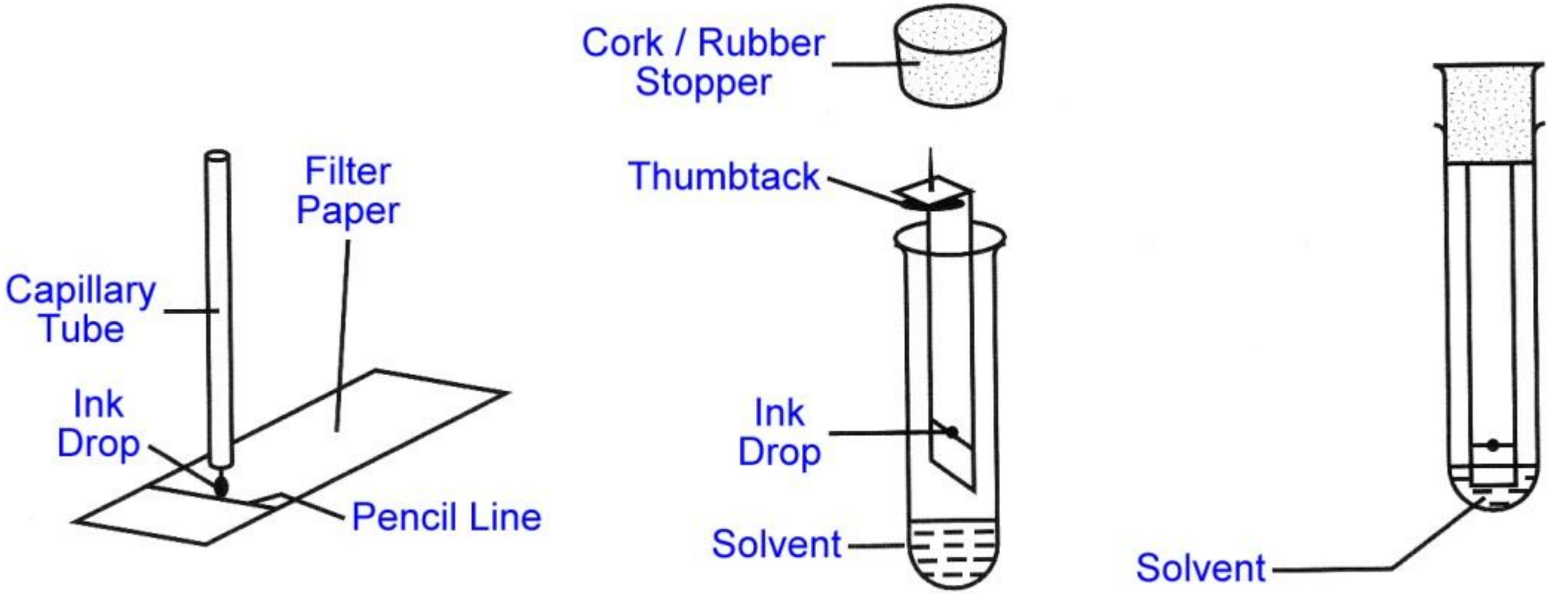
Chromatography



Note: When the mixture of chemicals is placed on the filter paper using the capillary tube, care should be taken to ensure that the spot is *small* and *concentrated*. This is to ensure that the results are clear and observable at the end of the experiment. It also ensures that – in the case that several spots are placed on the same sheet of paper – that the spots do not "run" or merge into each other as they move up the filter paper.

Separation Techniques – Change & Systems

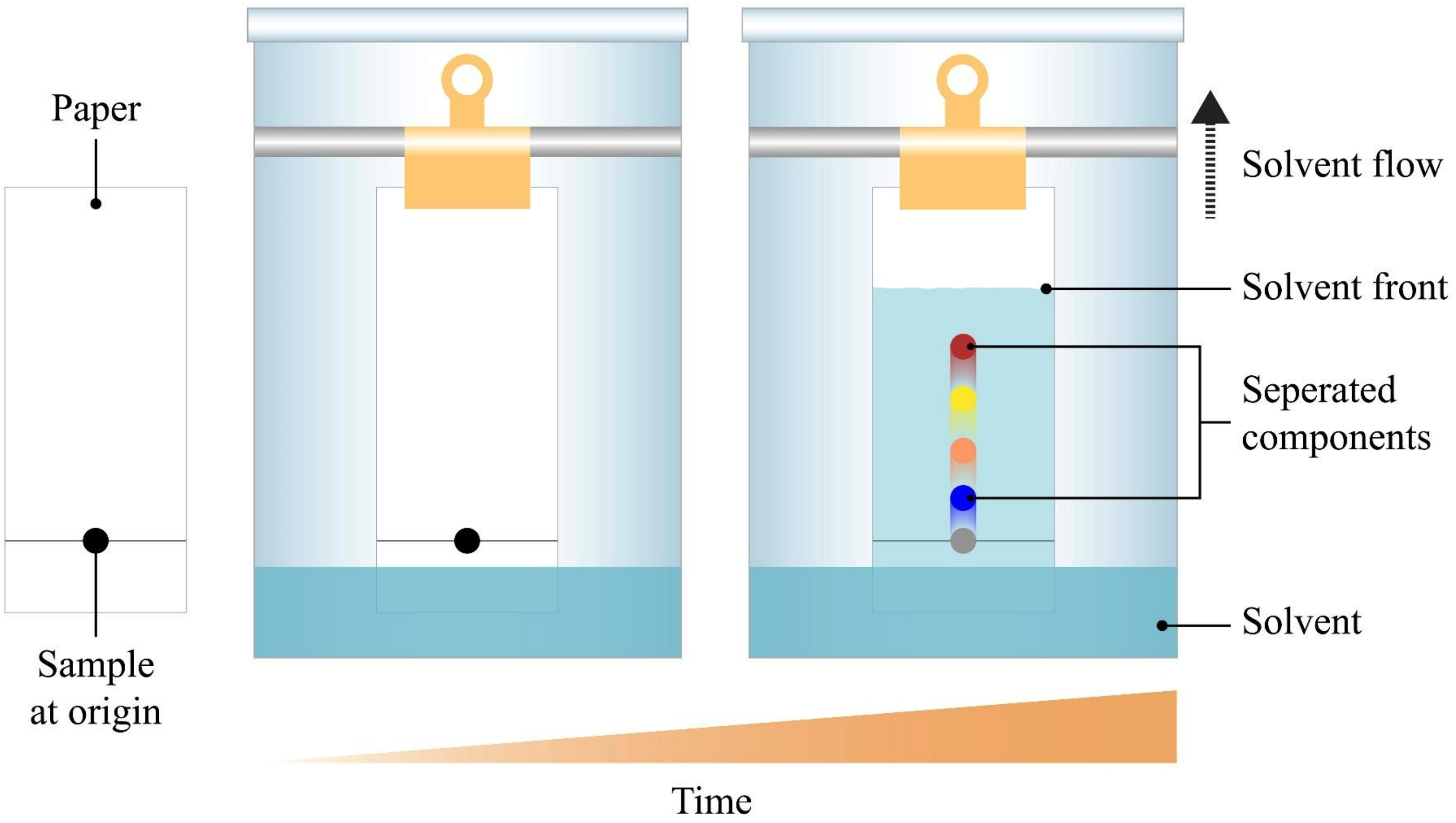
Chromatography



Note: The solvent should be allowed to soak up the filter paper and travel to a position as *close to the top of the filter paper* as possible (but the solvent should *not* be allowed to reach the very top of the filter paper). This will ensure that the mixture of dyes in the ink drop are separated from each other as far as possible, and reduces the chance of them overlapping with each other.

Separation Techniques – Change & Systems

Chromatography

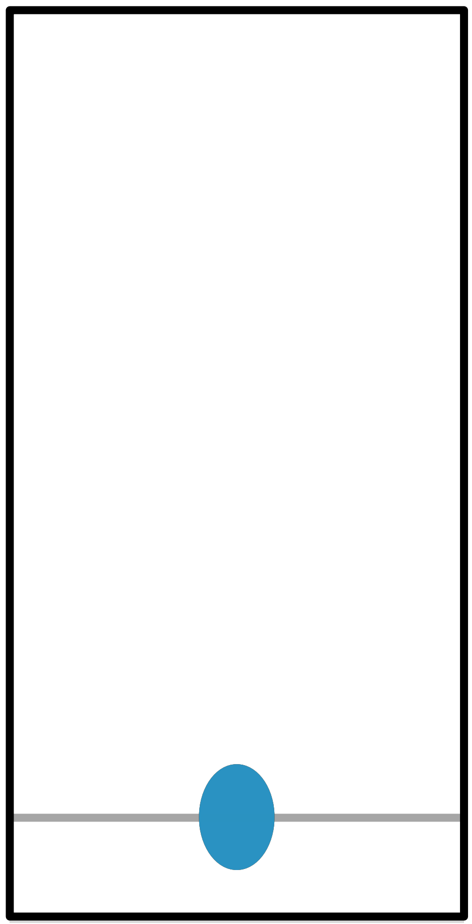


Separation Techniques – Change & Systems

Chromatography

- As the solvent (*mobile phase*) travels up the filter paper (*stationary phase*) the dye dissolves in the solvent.

- Some dyes are very *soluble* in the solvent and do not *adsorb* (“stick”) to the filter paper. These dyes travel the furthest distance.



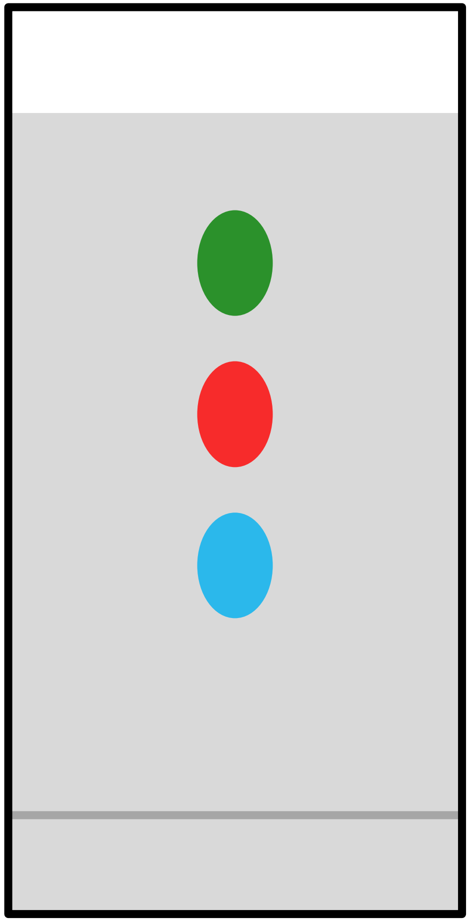
- Other dyes are only slightly *soluble* in the solvent and *adsorb* (“stick”) quite strongly to the filter paper. These dyes travel the shortest distance.

Separation Techniques – Change & Systems

Chromatography

- As the solvent (*mobile phase*) travels up the filter paper (*stationary phase*) the dye dissolves in the solvent.

- Some dyes are very *soluble* in the solvent and do not *adsorb* (“stick”) to the filter paper. These dyes travel the furthest distance.



- Other dyes are only slightly *soluble* in the solvent and *adsorb* (“stick”) quite strongly to the filter paper. These dyes travel the shortest distance.

Separation Techniques – Change & Systems

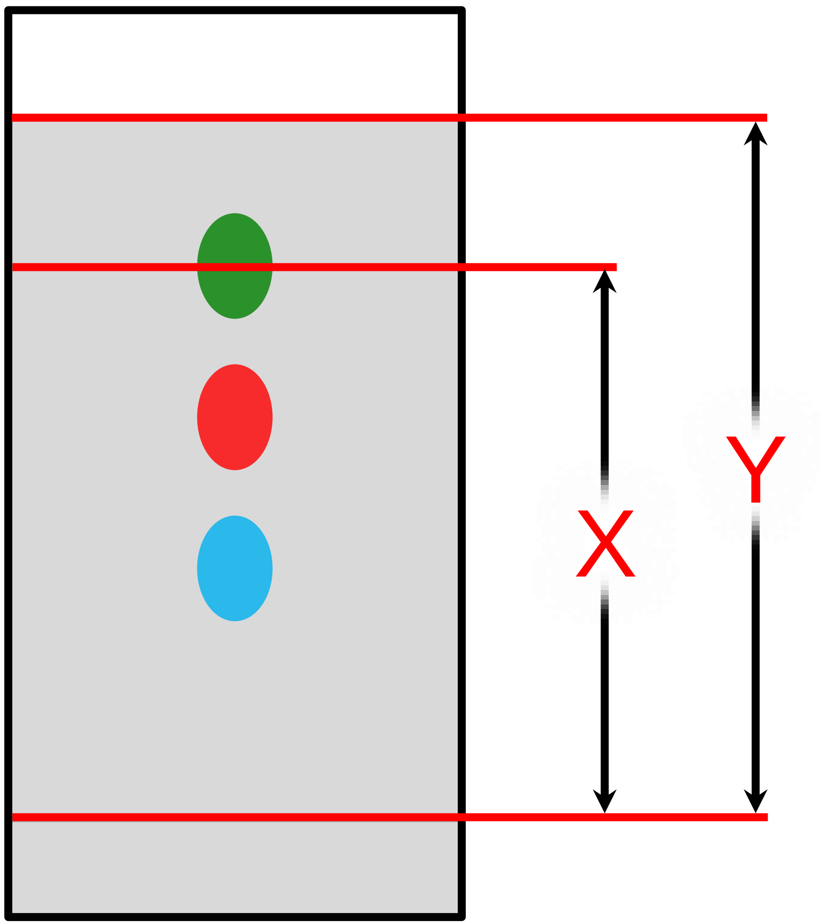
Chromatography

- Unknown substances that have been separated by chromatography can be identified from their R_f values:

$$R_f = X \div Y$$

Note: An R_f value is a ratio and therefore does not have any units. R_f values are always less than 1.

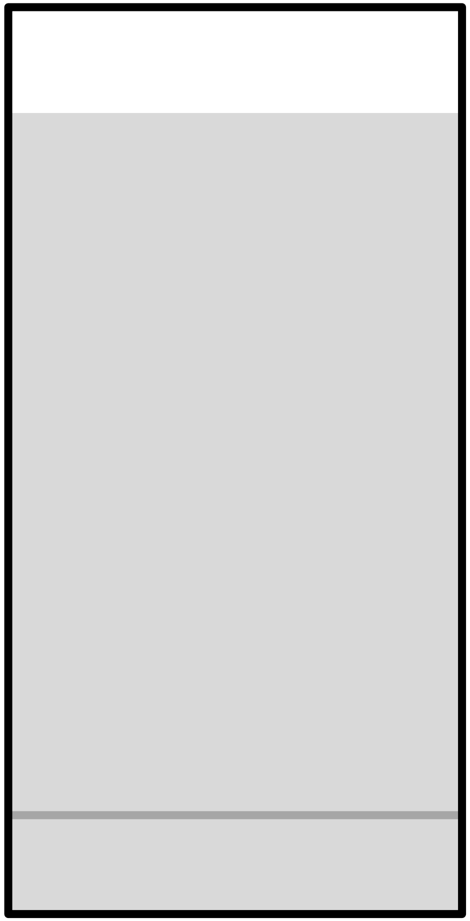
- Identical chemicals will have R_f values that are exactly the same.



Separation Techniques – Change & Systems

Chromatography

- In the case of *colourless* compounds (*e.g.* drugs and pesticides) the chromatogram is sprayed with a *locating agent* at the end of the experiment.
- The locating agent is a chemical that reacts with the colourless spots to produce coloured products that are visible to the naked eye.



Separation Techniques – Change & Systems

Chromatography

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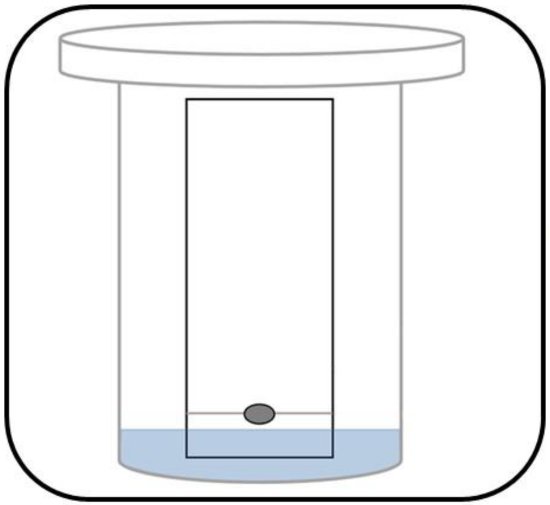
- The locating agent is a chemical that reacts with the colourless spots to produce coloured products that are visible to the naked eye.

Separation Techniques – Change & Systems

Alison
It's okay to draw the start line in pen ink or marker.

Barbara
Once calculated, the R_f value should always be less than one.



- Chromatography Set-up

Claire
Chromatography can only be conducted on coloured dyes.

Debbie
The spot should always be small and concentrated.

- Who do you agree with, and who do you disagree with? Why?

Separation Techniques – Change & Systems

Alison
It's okay to draw the start line in pen ink or marker.

Barbara
Once calculated, the R_f value should always be less than one.

- Alison is *incorrect*.

Ink from the pen or marker might dissolve in the solvent and travel up the chromatography paper, interfering with and obscuring the results.

Claire
Chromatography can only be conducted on coloured dyes.

Debbie
The spot should always be small and concentrated.

- Who do you agree with, and who do you disagree with? Why?

Separation Techniques – Change & Systems

Alison
It's okay to draw the start line in pen ink or marker.

Barbara
Once calculated, the R_f value should always be less than one.

- Barbara is *correct*.

The R_f value is the distance travelled by the spot divided by the distance travelled by the solvent. The solvent always travels further than the spot, so the answer must always be less than one.

Claire
Chromatography can only be conducted on coloured dyes.

Debbie
The spot should always be small and concentrated.

- Who do you agree with, and who do you disagree with? Why?

Separation Techniques – Change & Systems

Alison
It's okay to draw the start line in pen ink or marker.

Barbara
Once calculated, the R_f value should always be less than one.

- Claire is *incorrect*.

Chromatography can be conducted on chemicals that are colourless, but they must be sprayed with a locating agent to make them visible to the naked eye.

Claire
Chromatography can only be conducted on coloured dyes.

Debbie
The spot should always be small and concentrated.

- Who do you agree with, and who do you disagree with? Why?

Separation Techniques – Change & Systems

Alison
It's okay to draw the start line in pen ink or marker.

Barbara
Once calculated, the R_f value should always be less than one.

- Debbie is *correct*.

Spots should be small and concentrated so that they do not spread out too much as they travel up the chromatography paper and start to overlap with each other, making the results difficult to interpret.

Claire
Chromatography can only be conducted on coloured dyes.

Debbie
The spot should always be small and concentrated.

NANYANG GIRLS' HIGH

- Who do you agree with, and who do you disagree with? Why?

Separation Techniques – Change & Systems

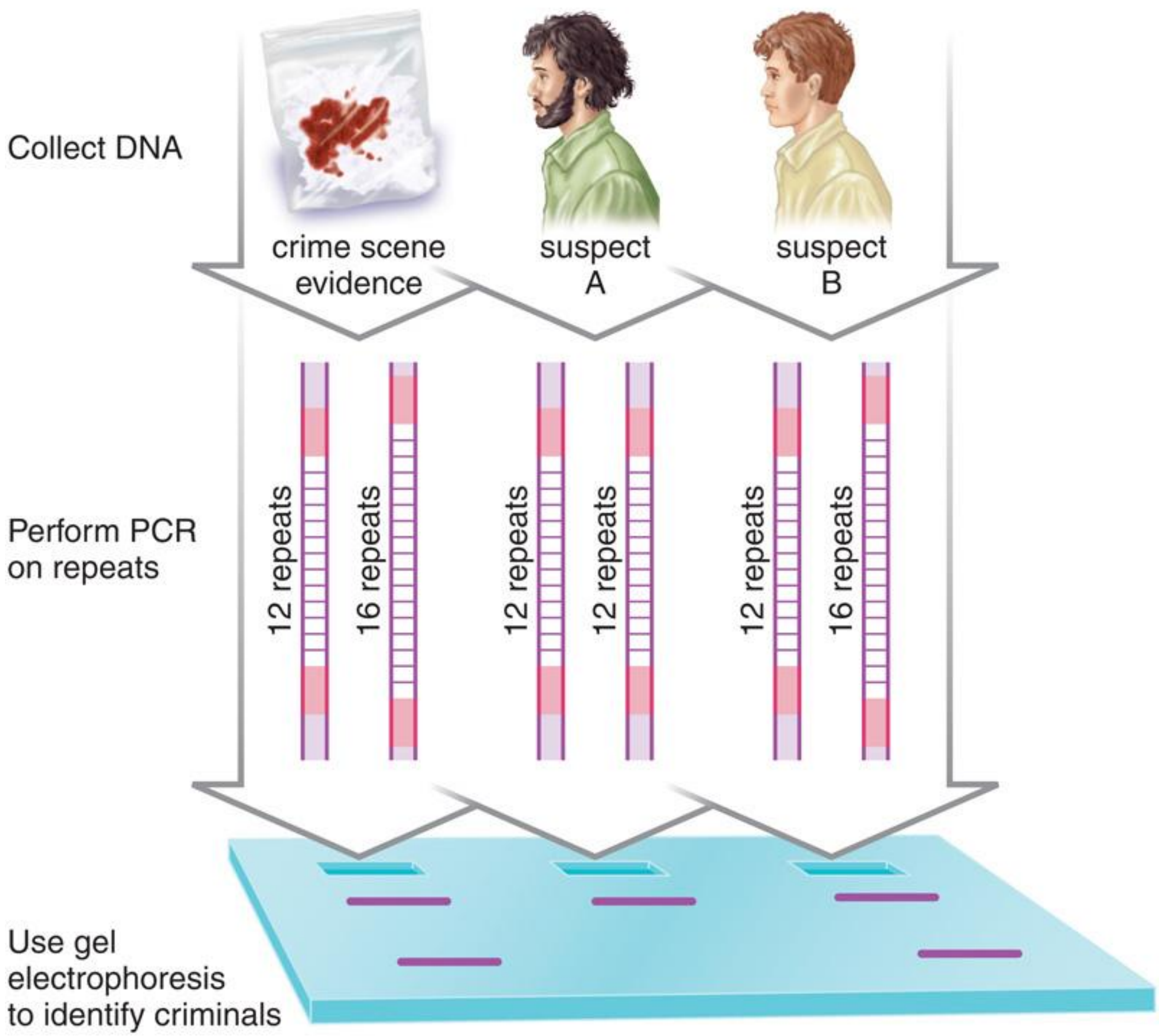
Chromatography

Separation Techniques – Change & Systems

Chromatography

- Complex forms of chromatography, known as *electrophoresis*, are used in the analysis of proteins and DNA.

Separation Techniques – Change & Systems



Distillation

Separation Techniques – Change & Systems

Distillation

- Distillation is used to separate a *solvent* and a *solute*.

a) The mixture could be two *miscible liquids*, *e.g.* alcohol and water. The liquid present in the largest amount is considered to be the solvent.

b) The mixture could be a *solid* (*solute*) dissolved in a *liquid* (*solvent*), *e.g.* blue crystals of copper(II) sulfate dissolved in water.

- Distillation separates chemicals by virtue of their *different boiling points*.

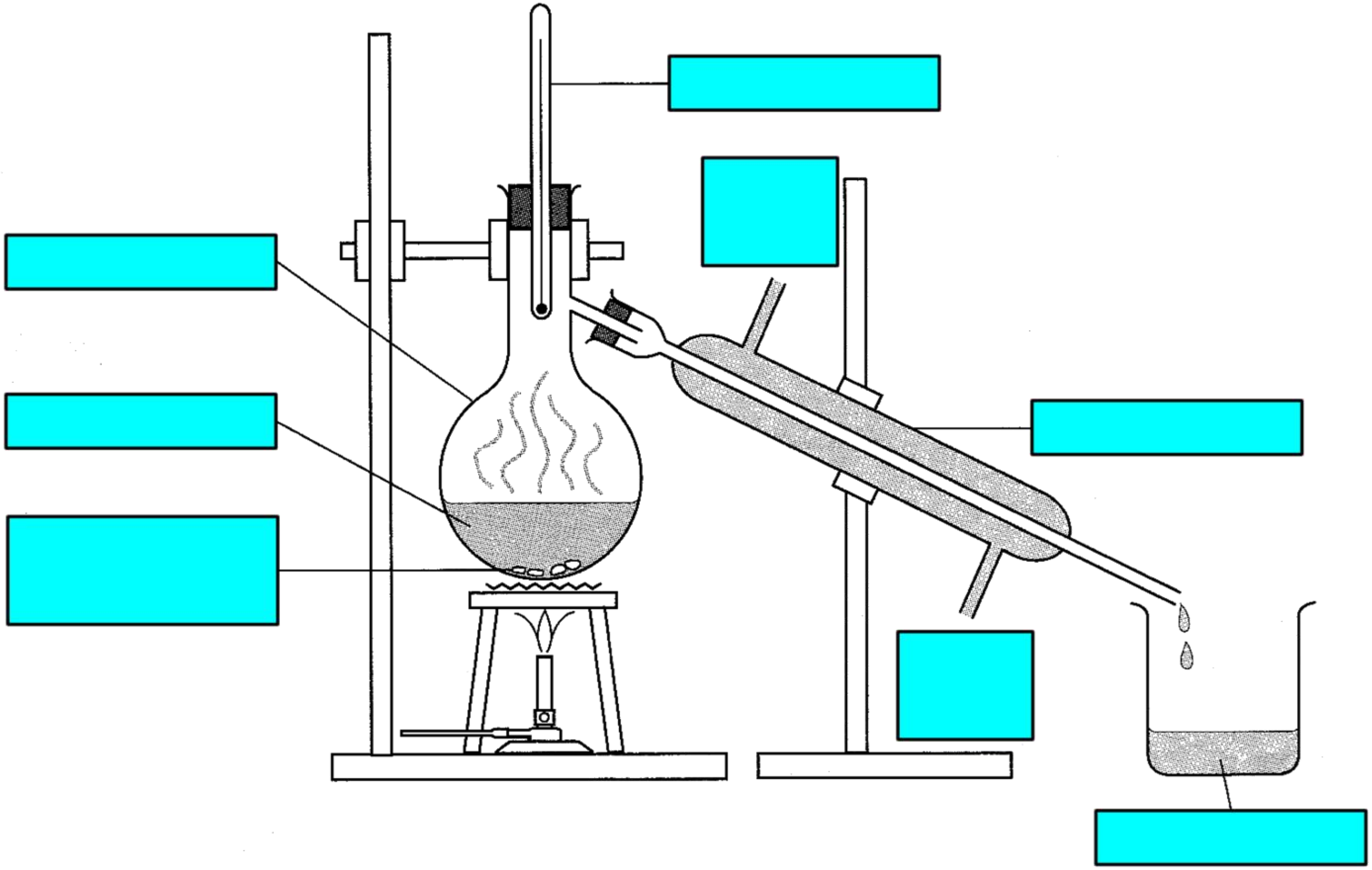
Separation Techniques – Change & Systems

Distillation

- During distillation, the mixture of chemicals is heated. The chemical with the *lowest boiling point* will change from a liquid into a gas (boil). The hot vapour enters the condenser where it cools and changes back into a liquid (condenses). The chemical with the *highest boiling point* remains in the distillation flask.
- The chemical with the lowest boiling point that "distils over" and is collected in the receiver, is known as the *distillate*.
- The chemical with the highest boiling point that remains in the distillation flask is known as the *residue*.

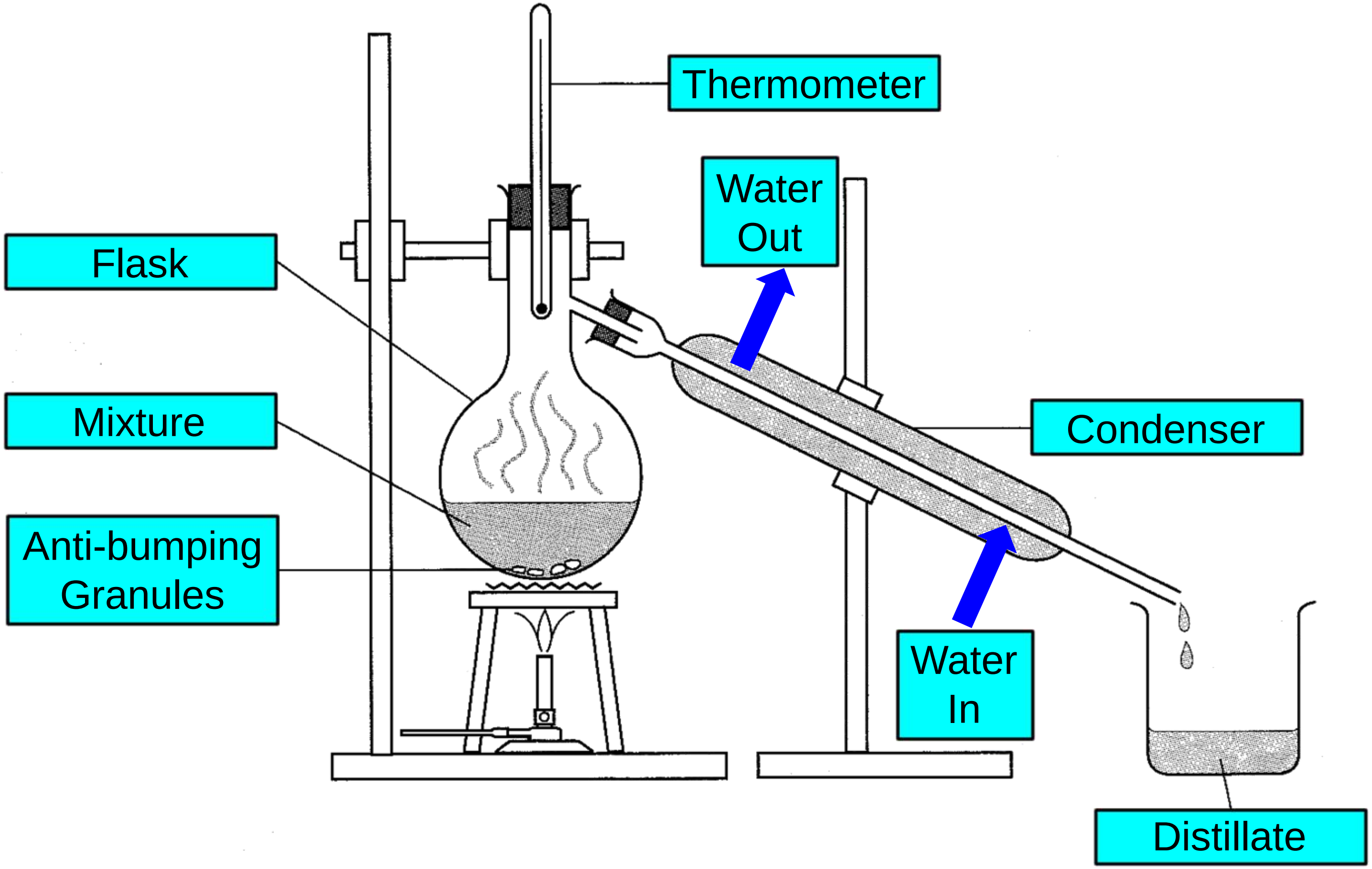
Separation Techniques – Change & Systems

Distillation



Separation Techniques – Change & Systems

Distillation



Separation Techniques – Change & Systems

Distillation

Note: Water *enters* the condenser at the *bottom* and *exits* the condenser at the *top*. Cold water flows through the condenser in the *opposite direction* to the hot vapour. This allows the condenser to cool the hot vapour with the *greatest efficiency*.

Note: The bulb of the thermometer is located at the top-end of the condenser. At this location, some hot vapour will condense on the bulb of the thermometer while the rest of the vapour enters the condenser. By virtue of its position, the thermometer will measure the *boiling point* of the *pure distillate*. This is the only position in the apparatus where the boiling point of the pure distillate can be measured.

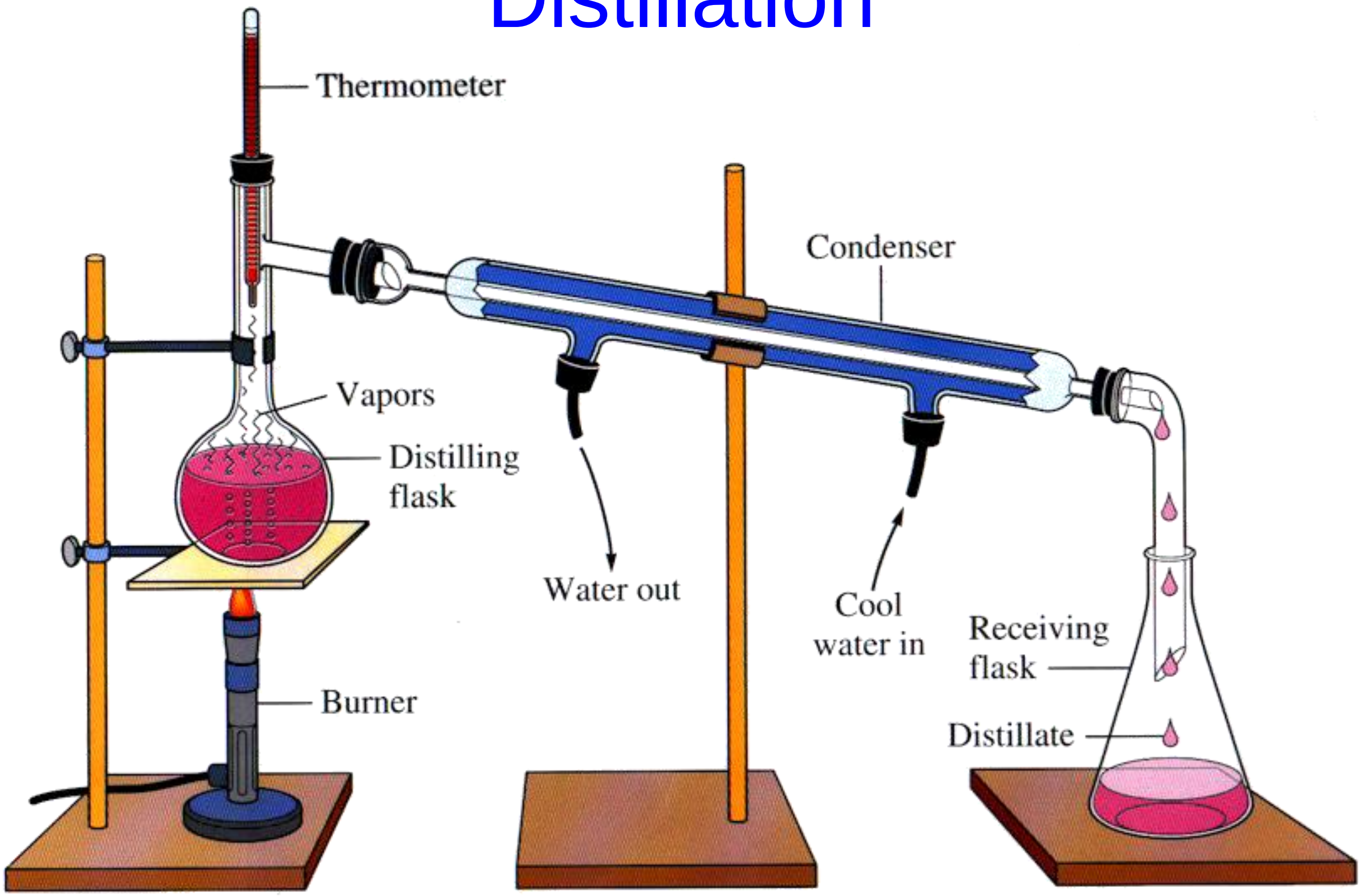
Separation Techniques – Change & Systems

Distillation

Note: *Anti-bumping granules* or *smooth boiling chips* offer a large surface area over which many small bubbles can form. When these small bubbles burst, they do not cause the apparatus to *bump* or *shake*. Without the anti-bumping granules, large bubbles would form. The large bubbles would cause the apparatus to shake when they burst at the surface of the mixture.

Separation Techniques – Change & Systems

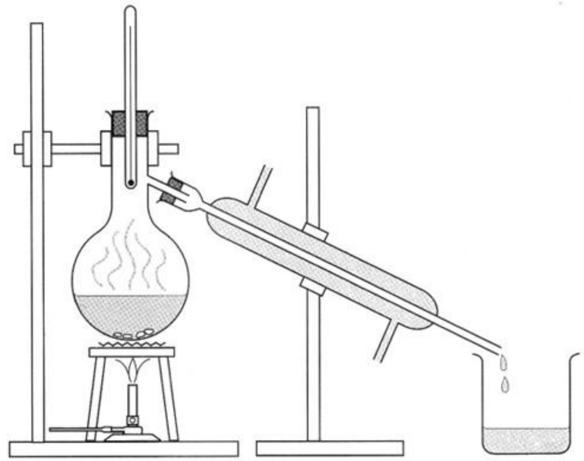
Distillation



Separation Techniques – Change & Systems

Alison
Simple distillation can only be used to separate a mixture of two miscible liquids.

Barbara
The chemical with the higher boiling point will boil first and be collected as the distillate.



- Simple Distillation Set-up

Claire
Smooth boiling granules prevent the formation of large bubbles.

Debbie
Water enters the condenser at the bottom and exits the condenser at the top.

- Who do you agree with, and who do you disagree with? Why?

Separation Techniques – Change & Systems

Alison
Simple distillation can only be used to separate a mixture of two miscible liquids.

Barbara
The chemical with the higher boiling point will boil first and be collected as the distillate.

- Alison is *incorrect*.

Simple distillation can be used to separate a mixture of miscible liquids, and it can also be used to separate a solid solute (*e.g.* table salt) from the solvent (*e.g.* water) that it is dissolved in.

Claire
Smooth boiling granules prevent the formation of large bubbles.

Debbie
Water enters the condenser at the bottom and exits the condenser at the top.

- Who do you agree with, and who do you disagree with? Why?

Separation Techniques – Change & Systems

Alison
Simple distillation can only be used to separate a mixture of two miscible liquids.

Barbara
The chemical with the higher boiling point will boil first and be collected as the distillate.

- Barbara is *incorrect*.

The chemical with the *lower* boiling point will boil first.

For example, if there are three liquids in the mixture, boiling points 50°C, 70°C and 90°C, then the liquid that boils at 50°C will boil and be collected first.

Claire
Smooth boiling granules prevent the formation of large bubbles.

Debbie
Water enters the condenser at the bottom and exits the condenser at the top.

- Who do you agree with, and who do you disagree with? Why?

Separation Techniques – Change & Systems

Alison
Simple distillation can only be used to separate a mixture of two miscible liquids.

Barbara
The chemical with the higher boiling point will boil first and be collected as the distillate.

- Claire is *correct*.

The smooth boiling granules provide a large surface area for *small* bubbles to form on. When the small bubbles burst, they cause no disturbance or harm to the apparatus.

Claire
Smooth boiling granules prevent the formation of large bubbles.

Debbie
Water enters the condenser at the bottom and exits the condenser at the top.

- Who do you agree with, and who do you disagree with? Why?

Separation Techniques – Change & Systems

Alison
Simple distillation can only be used to separate a mixture of two miscible liquids.

Barbara
The chemical with the higher boiling point will boil first and be collected as the distillate.

- Debbie is *correct*.

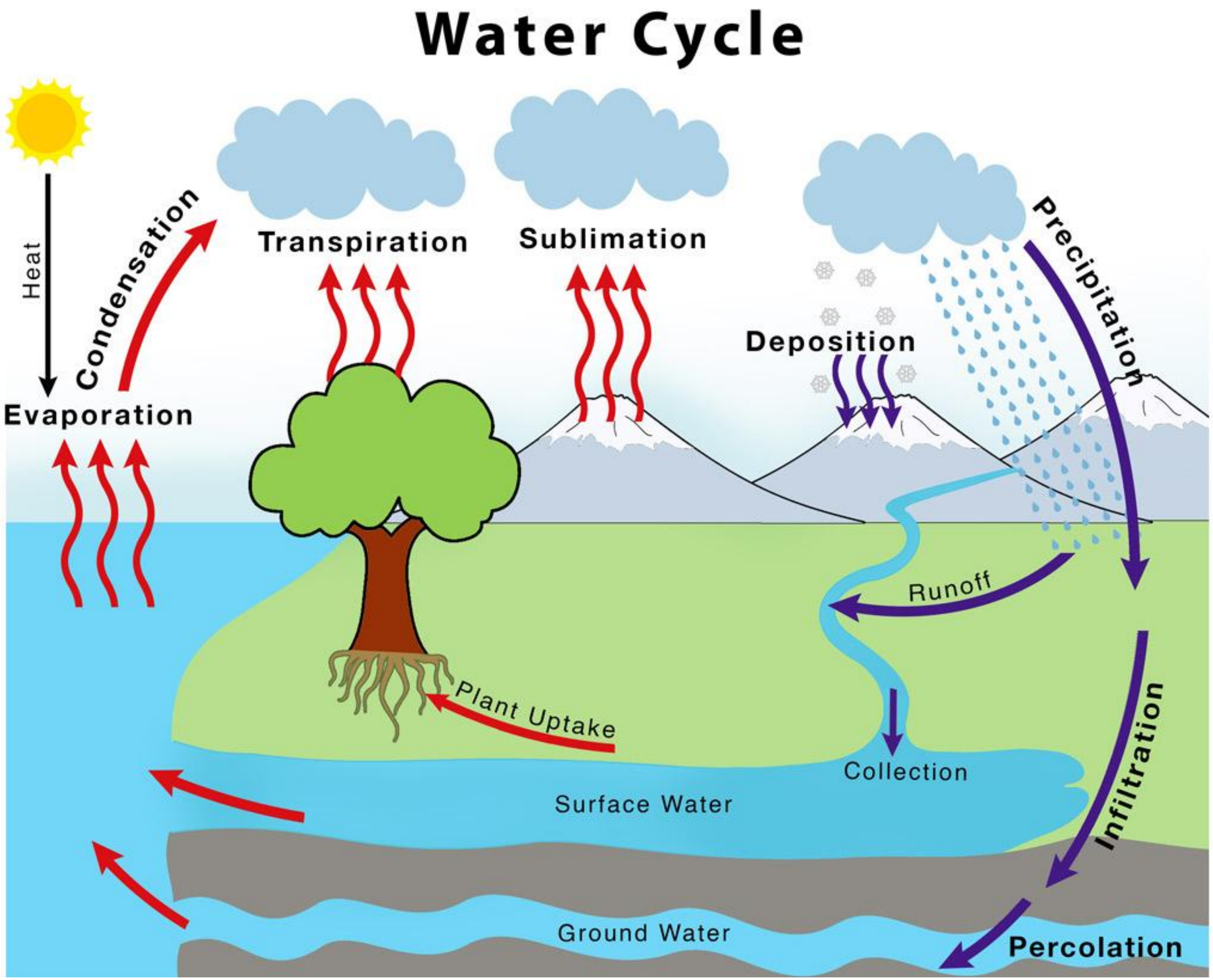
When cold water flows through the condenser from the bottom to the top, it flows in the opposite direction to the hot vapour, cooling the vapour efficiently.

Claire
Smooth boiling granules prevent the formation of large bubbles.

Debbie
Water enters the condenser at the bottom and exits the condenser at the top.

- Who do you agree with, and who do you disagree with? Why?

Separation Techniques – Change & Systems



Separation Techniques – Change & Systems

Distillation

Separation Techniques – Change & Systems

Distillation

- Distillation is used to separate sodium chloride from water in desalination plants. This produces drinking water from seawater.

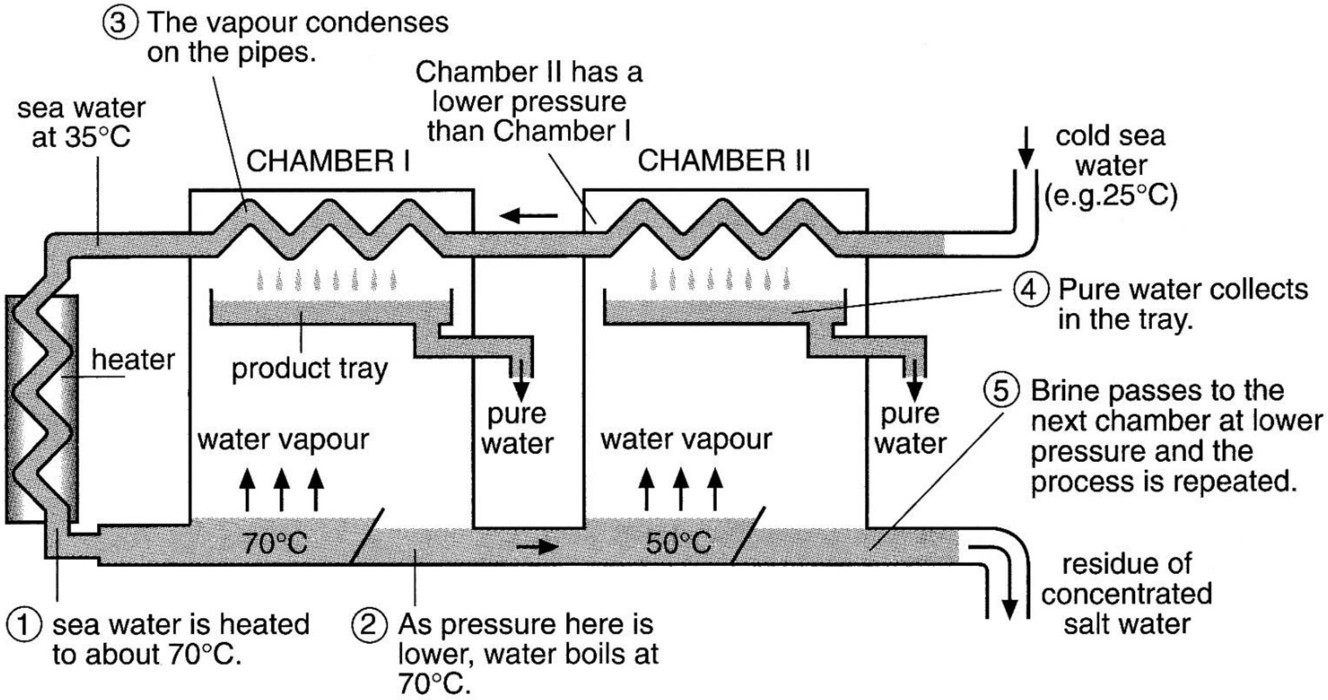
- Distillation is also used to separate ethanol (alcohol) from water during the production of strong alcoholic drinks.

- This desalination plant in Saudi Arabia can produce 800 000 m^3 of drinking water per day.

Separation Techniques – Change & Systems

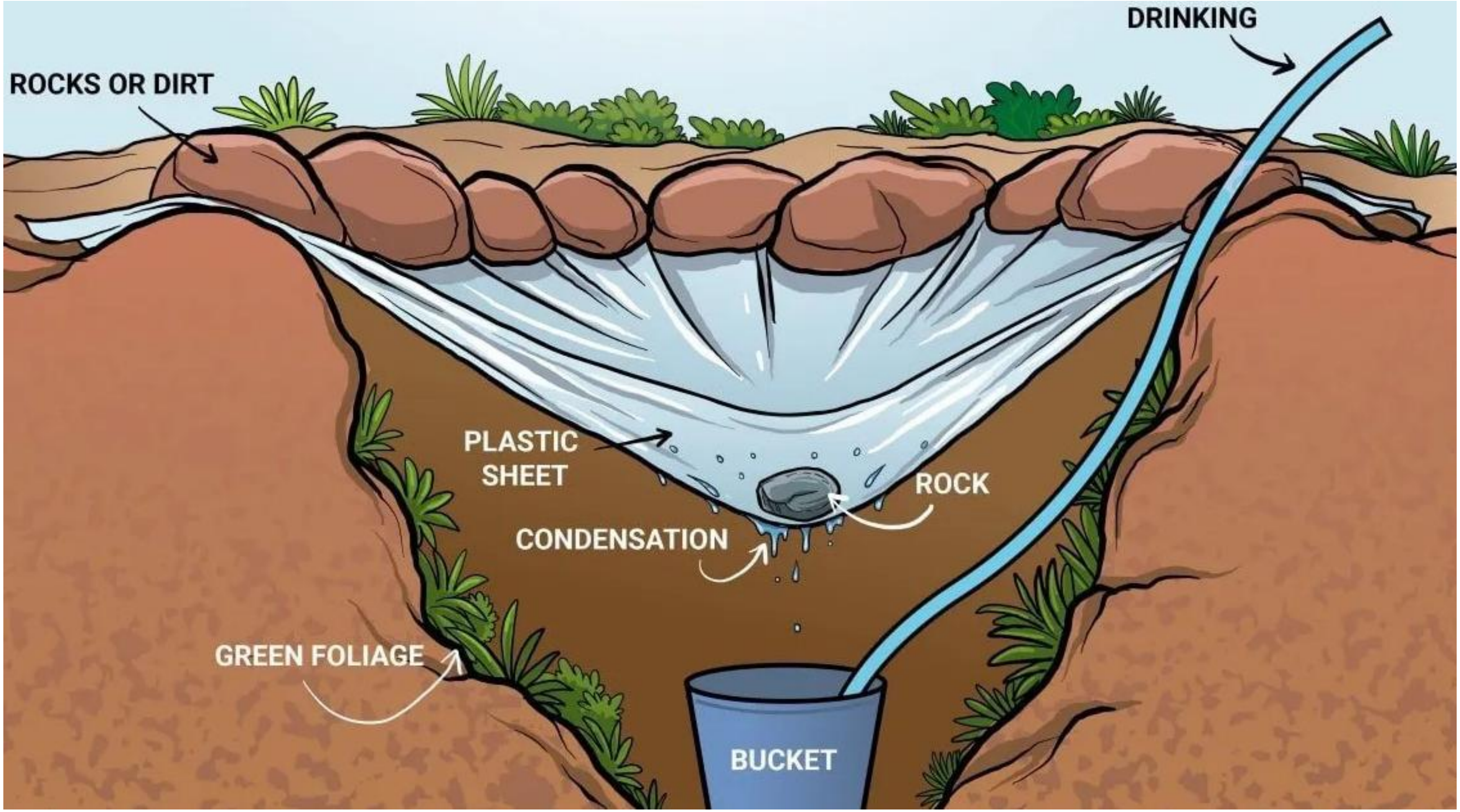
Distillation

Water for All: Conserve, Value, Enjoy



Schematic Diagram of a Desalination Plant in Singapore

Separation Techniques – Change & Systems



- How does the system shown above allow clean drinking water to be obtained from the surroundings?

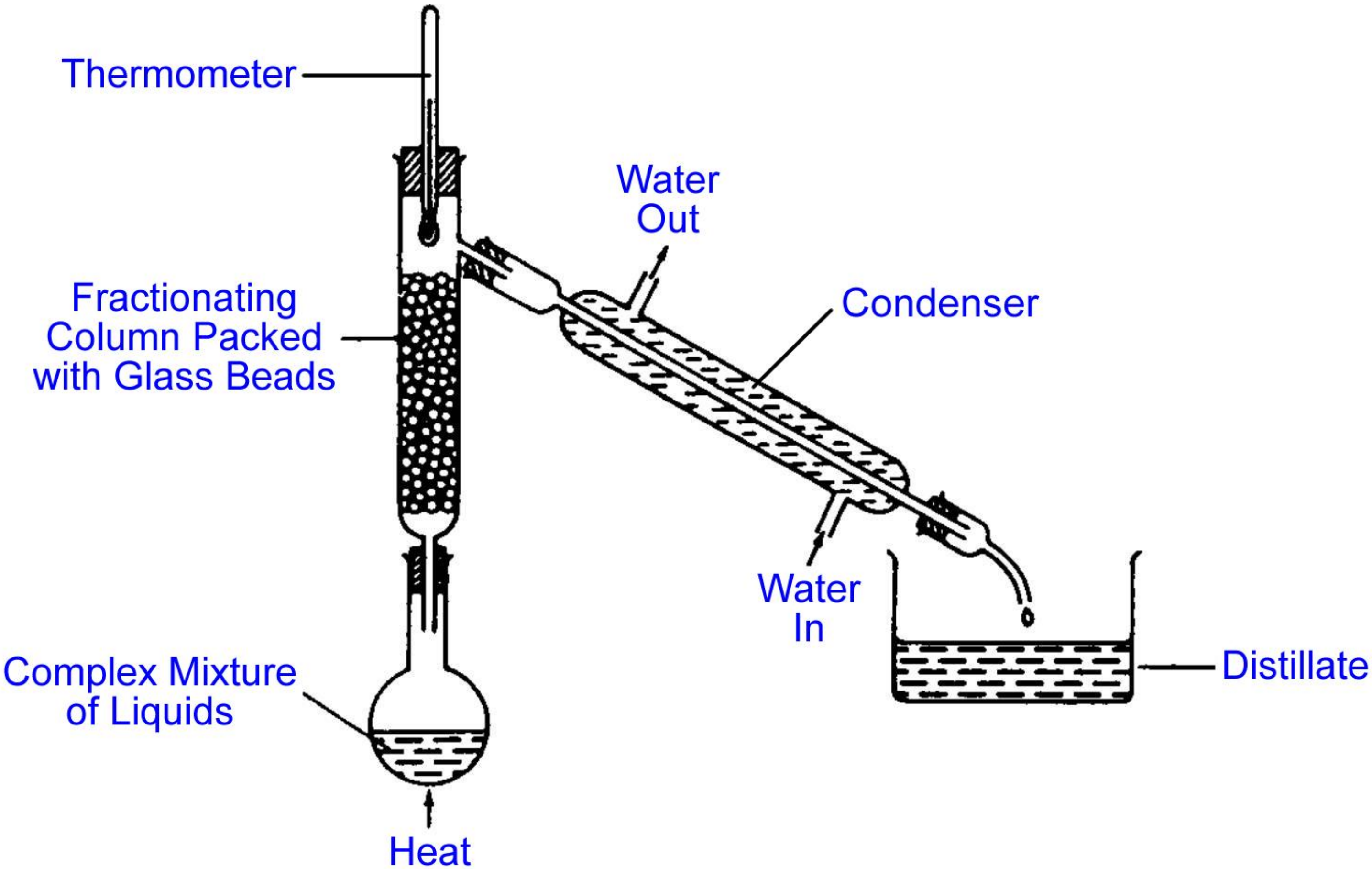
Fractional Distillation

- *Fractional distillation* is more efficient than simple distillation. Fractional distillation can be used to separate complex mixtures of chemicals with similar boiling points that cannot be separated by simple distillation.

- The main difference between simple distillation and fractional distillation is that fractional distillation uses a *fractionating column* – a vertical column packed with glass beads. The glass beads offer a large surface area over which the vapours of higher boiling point chemicals can condense and return to the distillation flask without contaminating the distillate.

Separation Techniques – Change & Systems

Fractional Distillation



Separation Techniques – Change & Systems

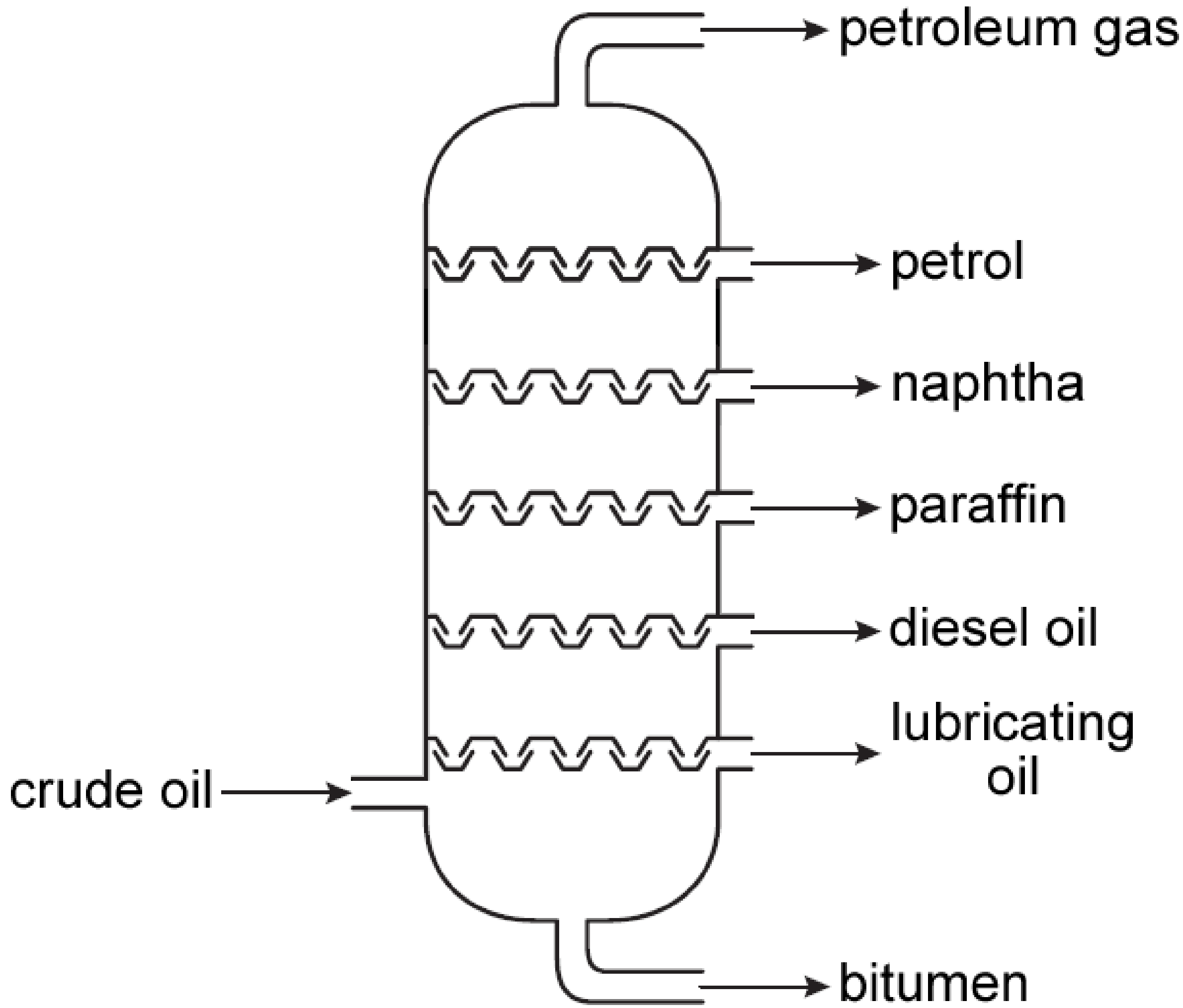
Fractional Distillation of Crude Oil

Fractional Distillation of Crude Oil

- Crude oil is an extremely complex mixture of organic compounds. The crude oil is separated into useful components, such as petrol and diesel, by fractional distillation. This takes place on an industrial scale at oil refineries.

Separation Techniques – Change & Systems

Fractional Distillation of Crude Oil



Separating Funnel

(Tap Funnel)

Separation Techniques – Change & Systems

Separating Funnel (Tap Funnel)

- A separating funnel is used to separate two *immiscible liquids*, *i.e.* liquids that do not mix.

- A common example of two immiscible liquids is *oil* and *water*.

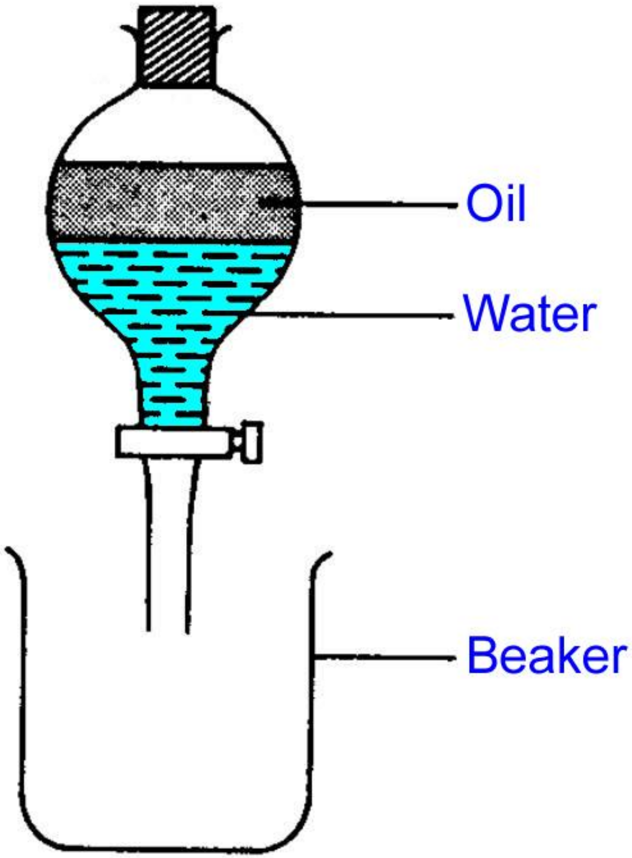
- **Note:** The liquid with the *smaller density* will be *top layer* while the liquid with the *greater density* will be the *bottom layer*.

NANYANG GIRLS' HIGH

Separation Techniques – Change & Systems

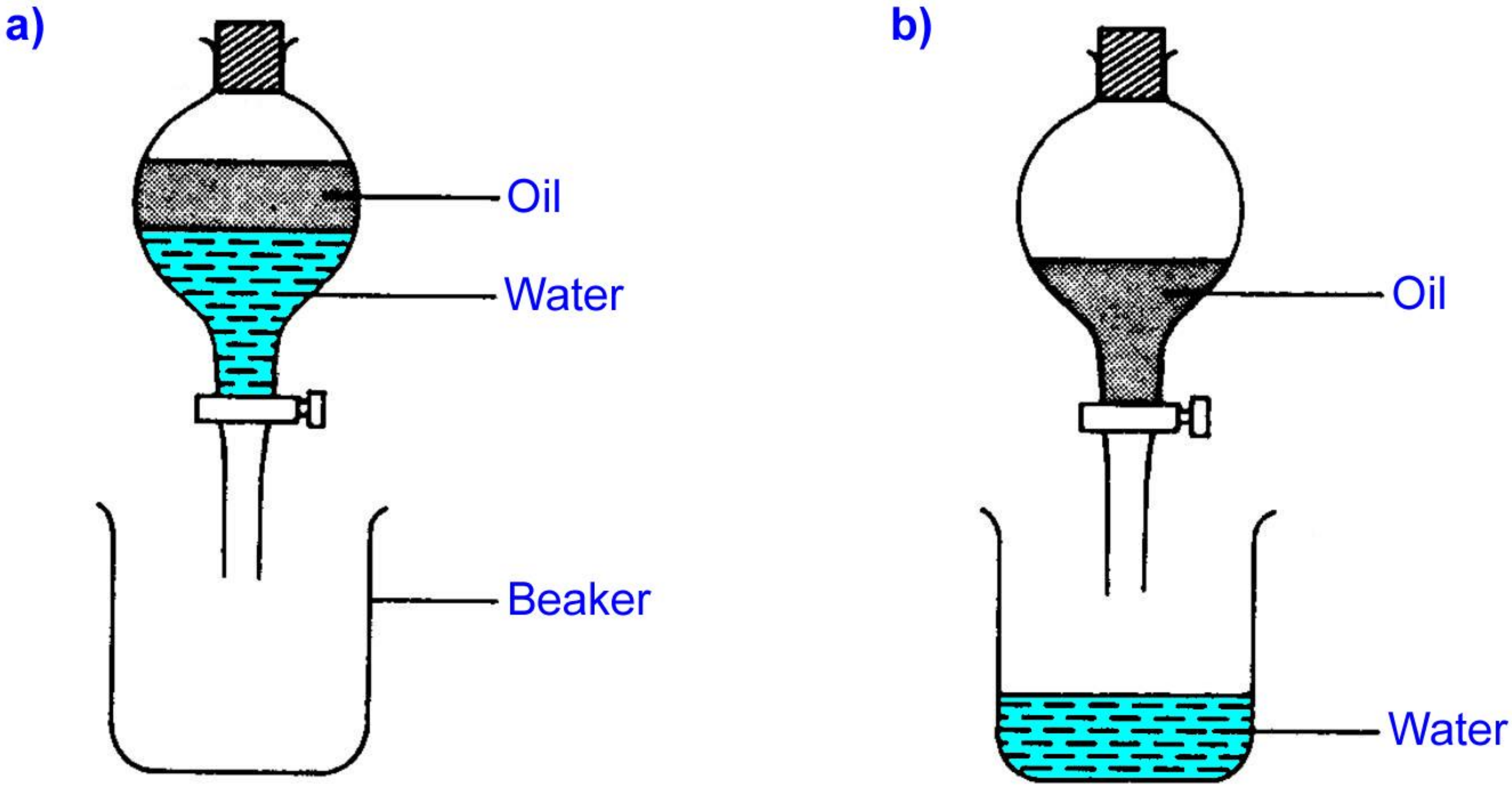
Separating Funnel (Tap Funnel)

a)



Separation Techniques – Change & Systems

Separating Funnel (Tap Funnel)



Separation Techniques – Change & Systems

Sublimation

Sublimation

- Sublimation is used to separate a volatile solid that sublimes (changes directly from a solid to a gas on heating) from a non-volatile solid that does not sublime.

- Common Examples of Solids that Sublime on Heating (worth remembering):

→ Ammonium chloride – NH_4Cl.
→ Solid carbon dioxide (dry ice) – CO_2.
→ Iodine – I_2.
→ Naphthalene (moth balls) – $C_{10}H_8$.

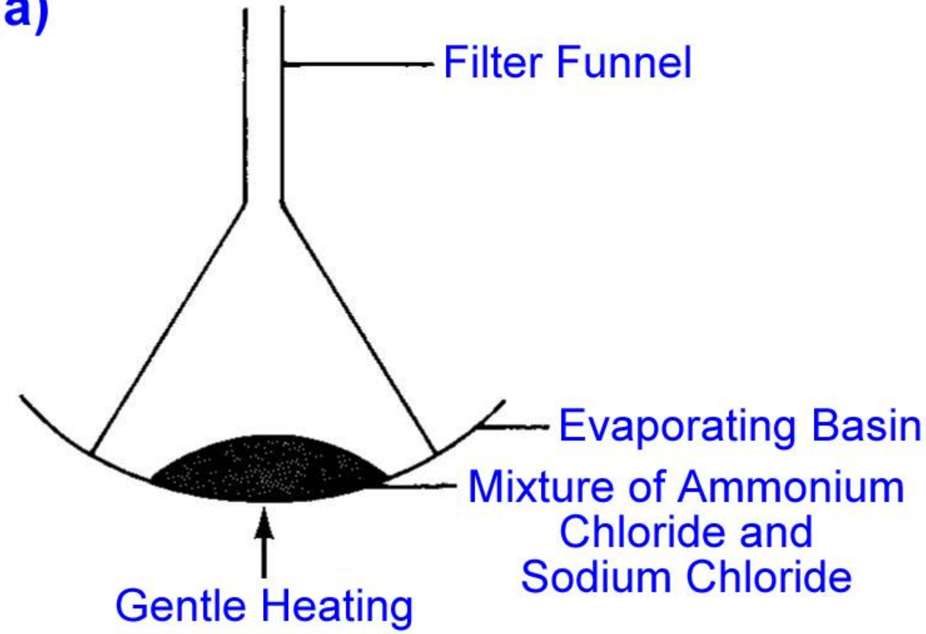
- Other Examples:

→ Anhydrous aluminium chloride – $AlCl_3$.
→ Anhydrous iron(III) chloride – $FeCl_3$.

Separation Techniques – Change & Systems

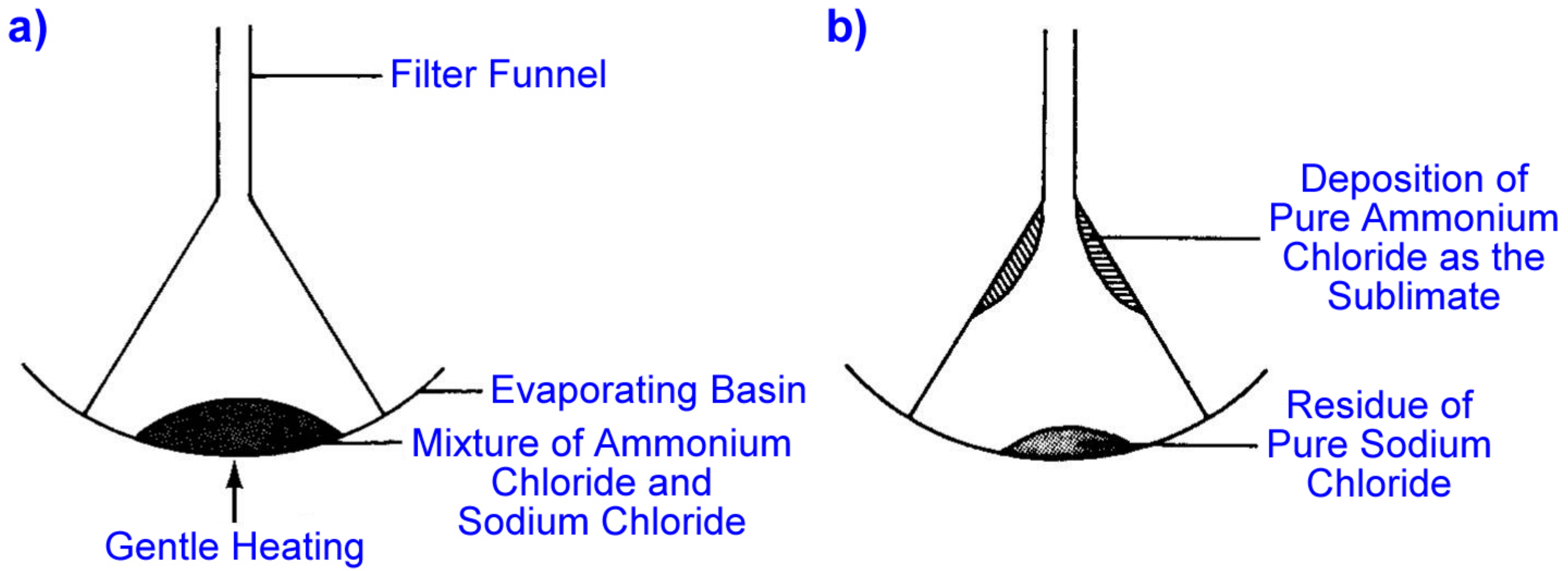
Sublimation

a)



Separation Techniques – Change & Systems

Sublimation



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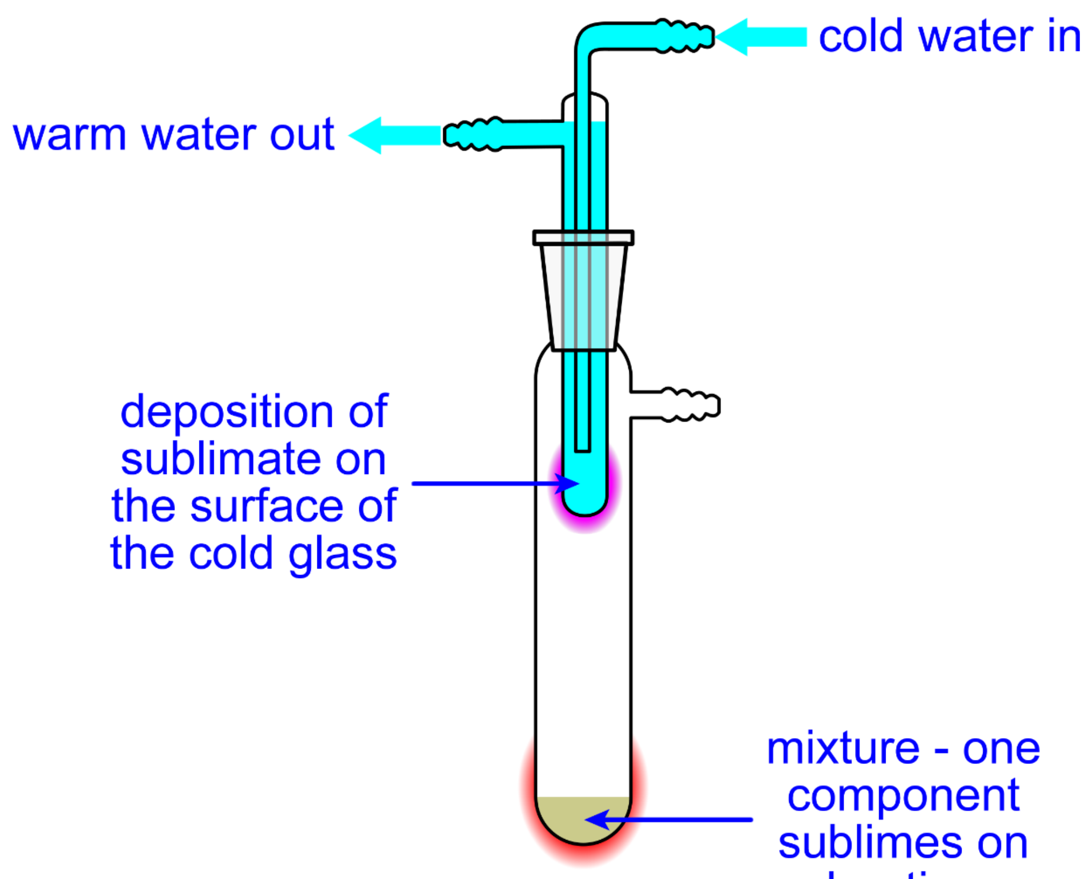
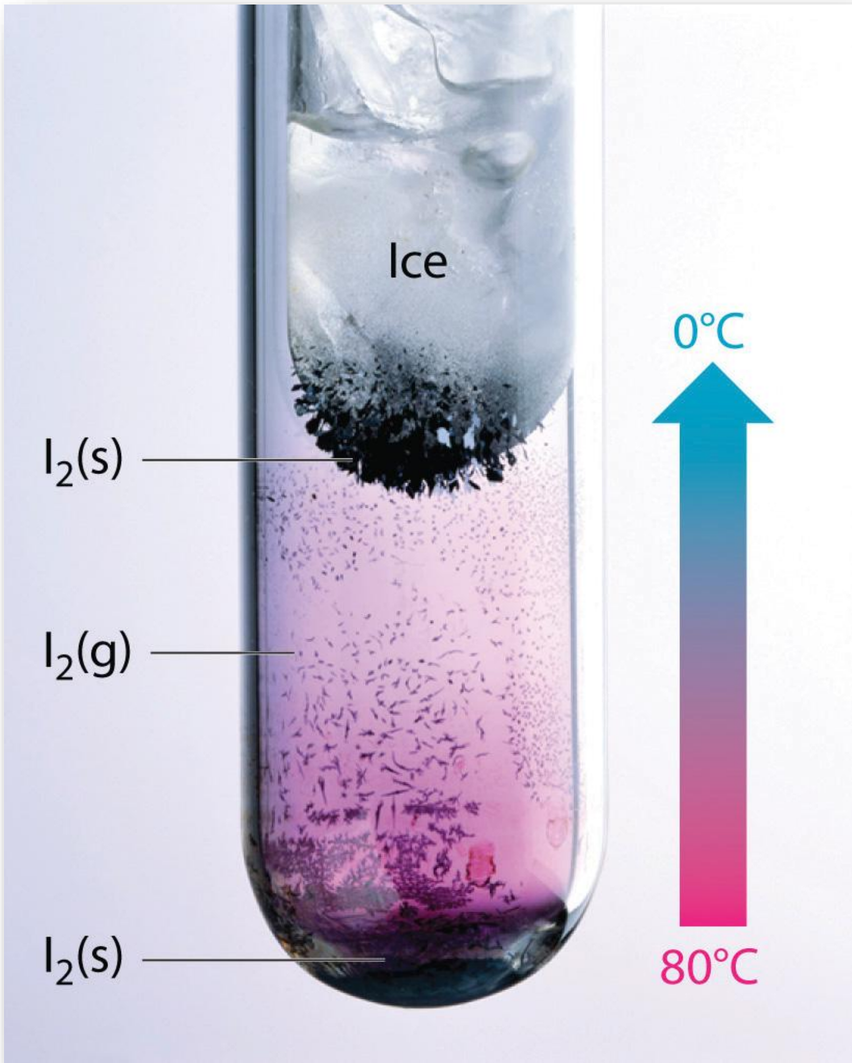
Sublimation



Separation Techniques – Change & Systems

Sublimation

- Sublimation and deposition of iodine.

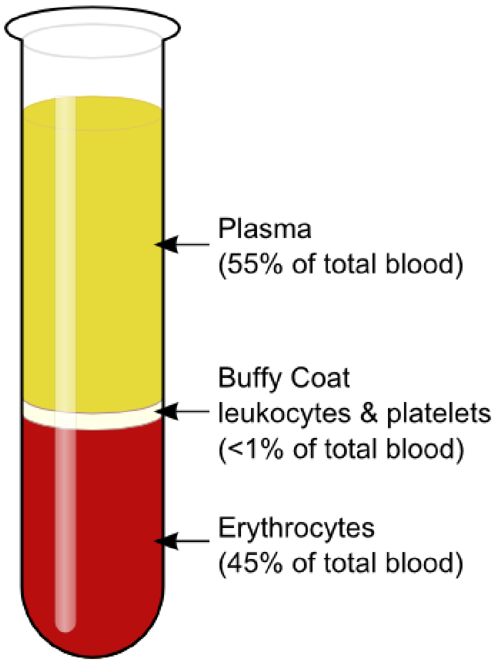


Separation Techniques – Change & Systems

Centrifugation

Separation Techniques – Change & Systems

Centrifugation



- Centrifuges are used to separate fine particles that are suspended in a liquid. Centrifugation is especially used in medicine to separate cells from blood plasma.

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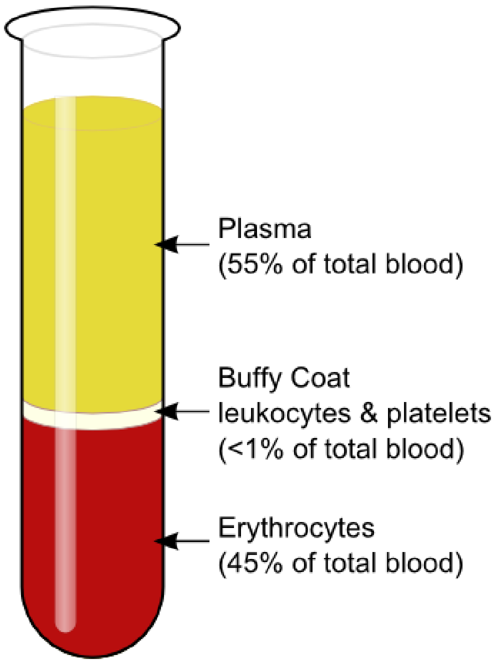
Centrifugation



- The mixture than needs to be separated is spun at a very high speed. Centrifugal force sends heavier particles to the bottom of the test tube, while lighter particle remain near the top.

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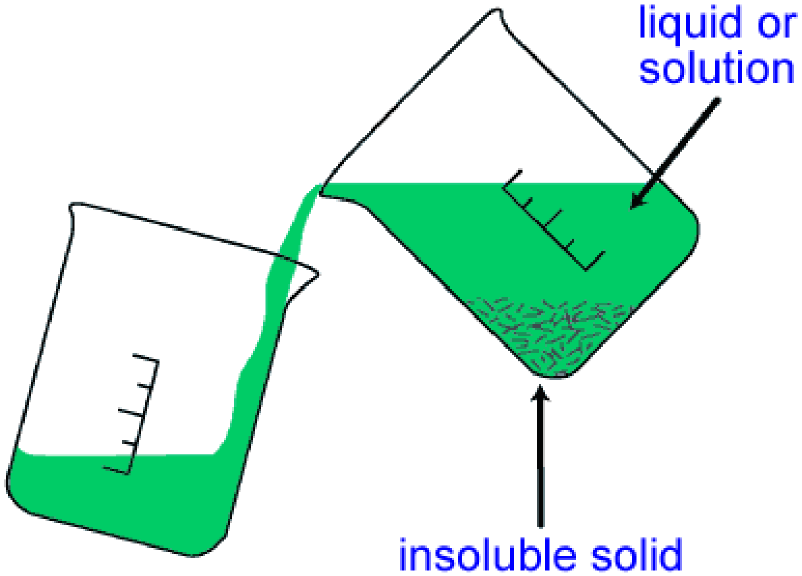
Decanting

Separation Techniques – Change & Systems

Decanting



- Decanting is a simple separation technique that is used to separate an insoluble solid from a liquid or a solution.

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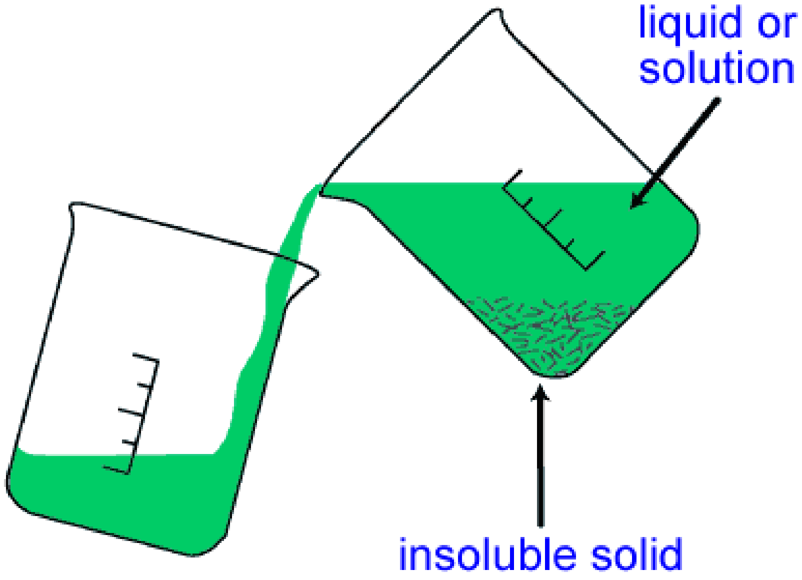
Decanting



- The mixture is left undisturbed to allow the solid to settle at the bottom of the beaker. The liquid or solution is then very carefully poured into a second beaker, without disturbing the solid.

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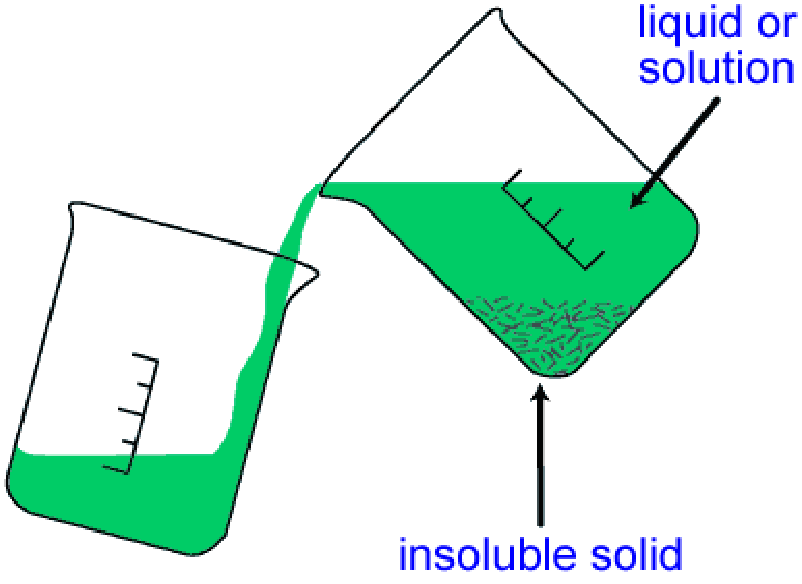
Decanting



- When performed successfully, the liquid or solution is completely transferred into the second beaker, while all of the insoluble solid remains in the first beaker.

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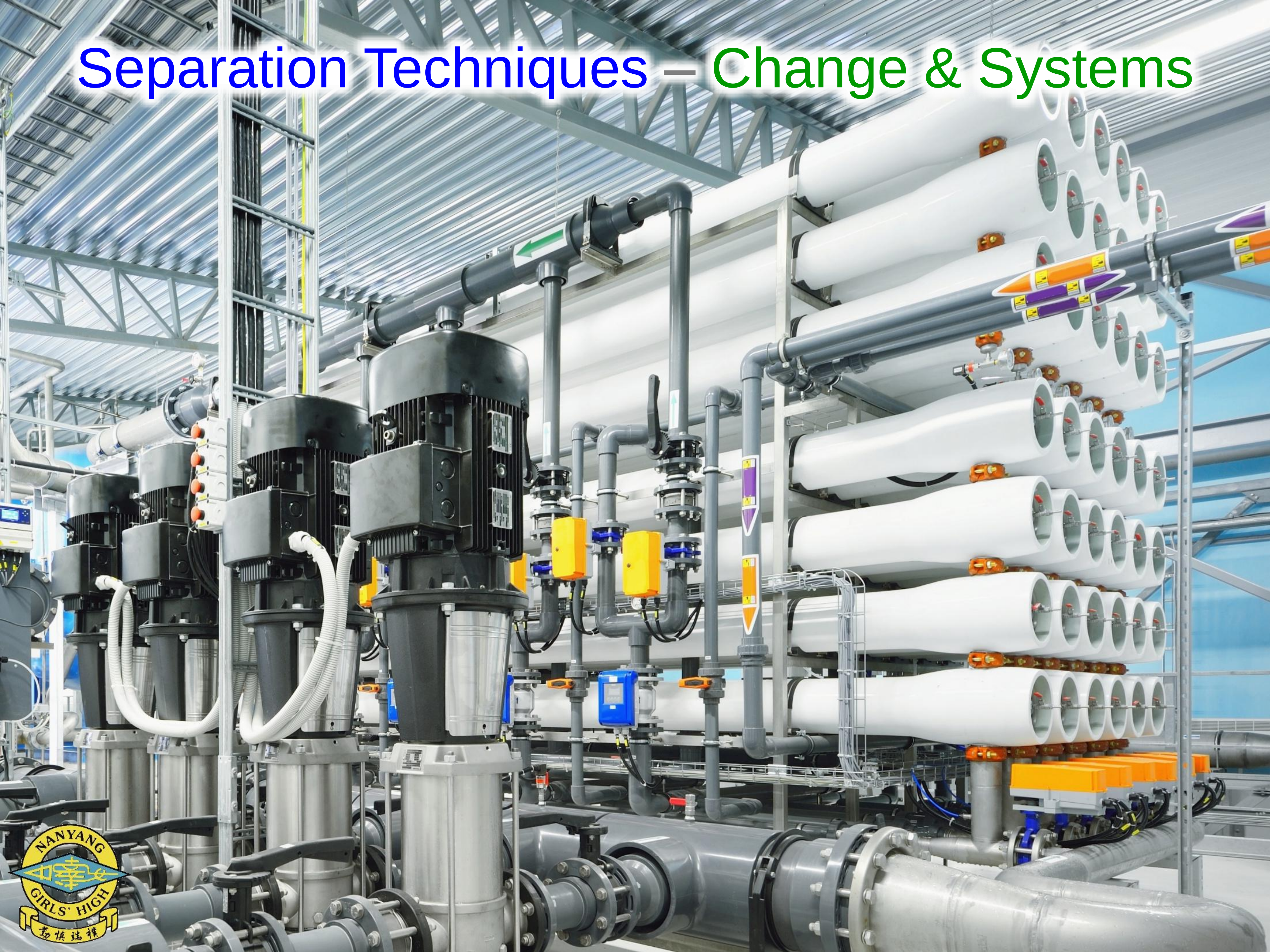

Reverse Osmosis

Separation Techniques – Change & Systems

- Where does our clean drinking water come from?

Separation Techniques – Change & Systems

- Singapore obtains pure water from seawater through a process called *desalination* – the removal of salt from water. Desalination can be carried out by *distillation* or *reverse osmosis*.

- Remember that distillation requires the mixture to be heated to a *high temperature*. To obtain pure water from seawater, sufficient for the population of Singapore to drink, would require a *large volume of fuel* to provide the *large amount of heat energy* that is necessary to boil the water. This is *not sustainable* in terms of cost and damage to the environment. In Singapore, desalination is carried out using reverse osmosis instead of distillation.

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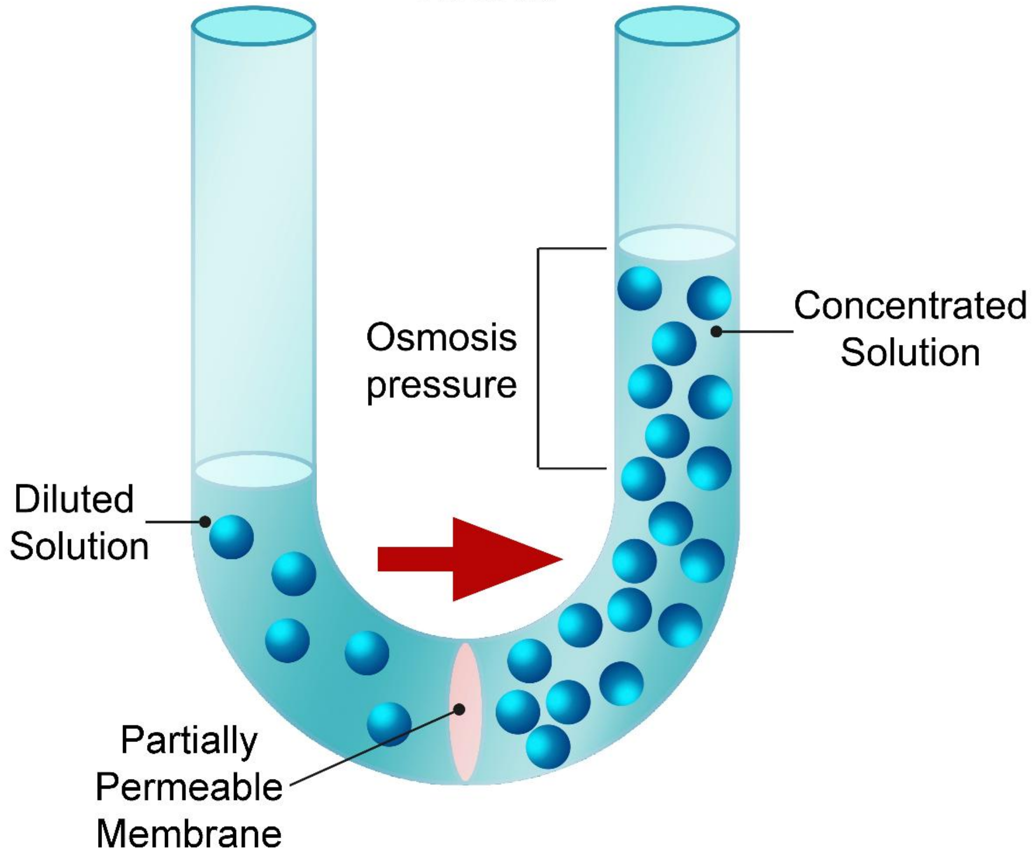

- *Osmosis* is the net movement of water molecules from a region of higher water potential to a region of lower water potential across a partially permeable membrane.

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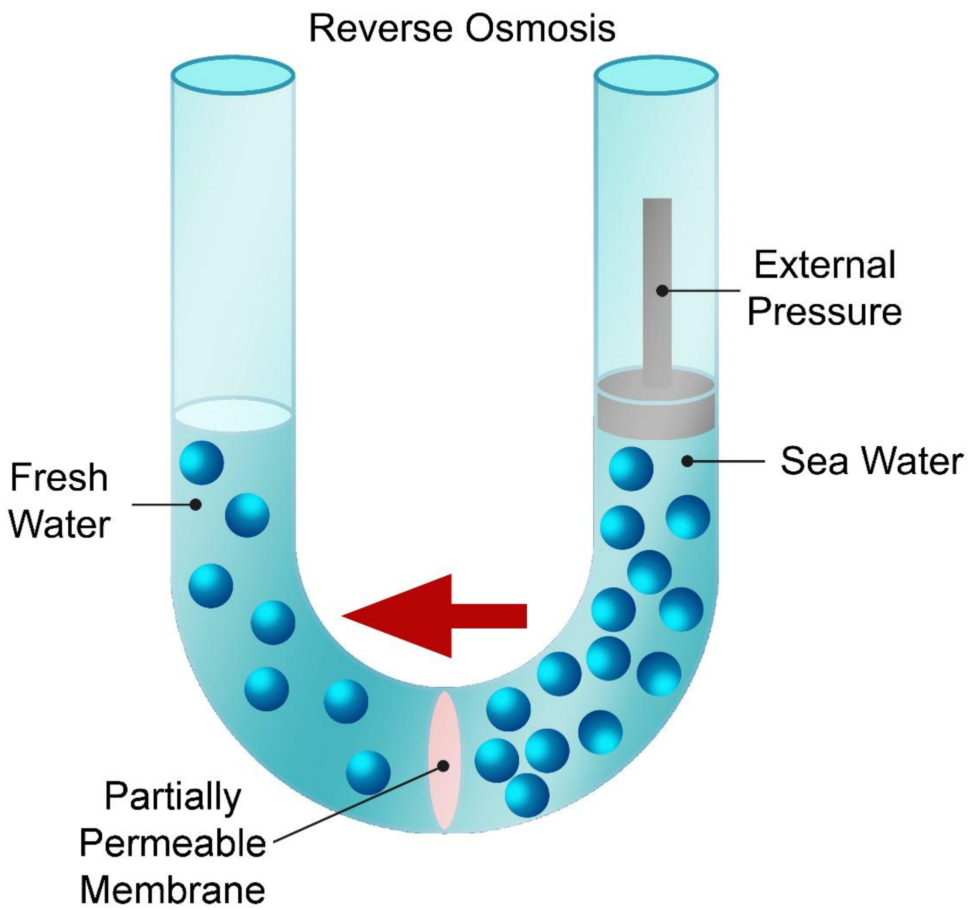

- *Reverse Osmosis* is a process where water is forced to move from a region of lower water potential to a region of higher water potential across a partially permeable membrane under high pressure.

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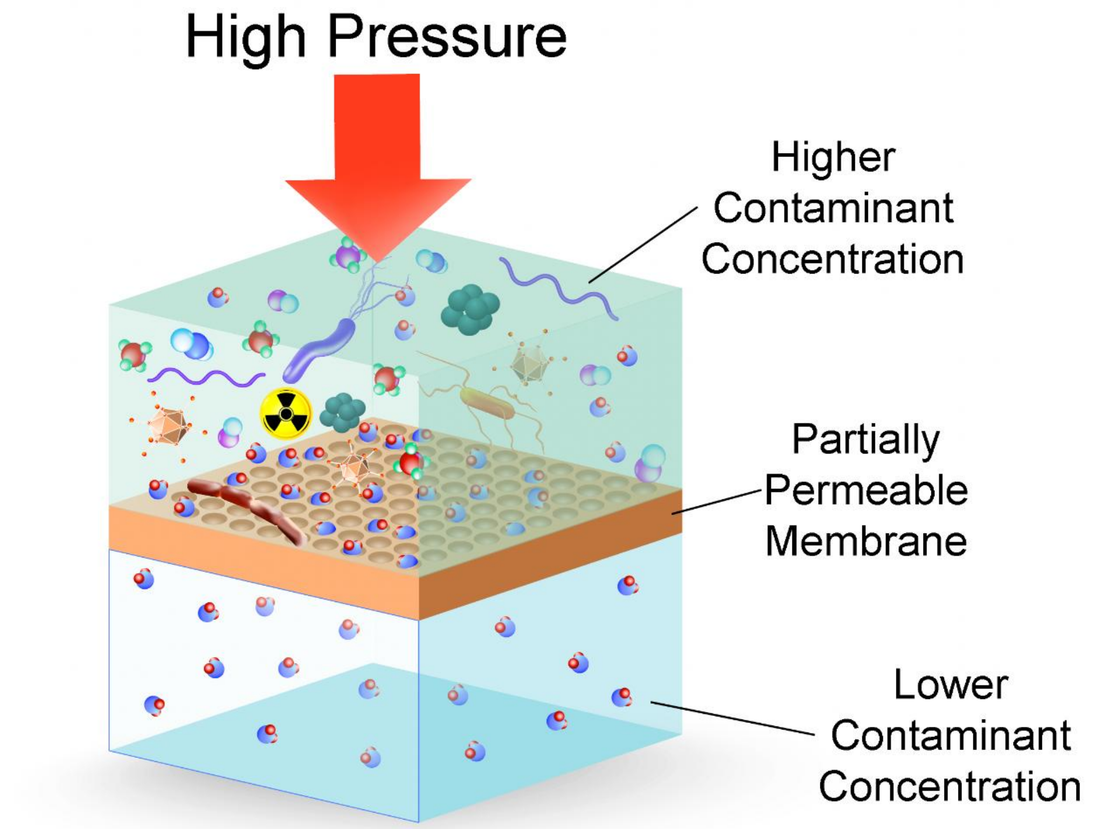

- *Reverse Osmosis* is used to obtain drinking water from seawater. Pre-treated seawater is pumped through a partially permeable membrane under high pressure.

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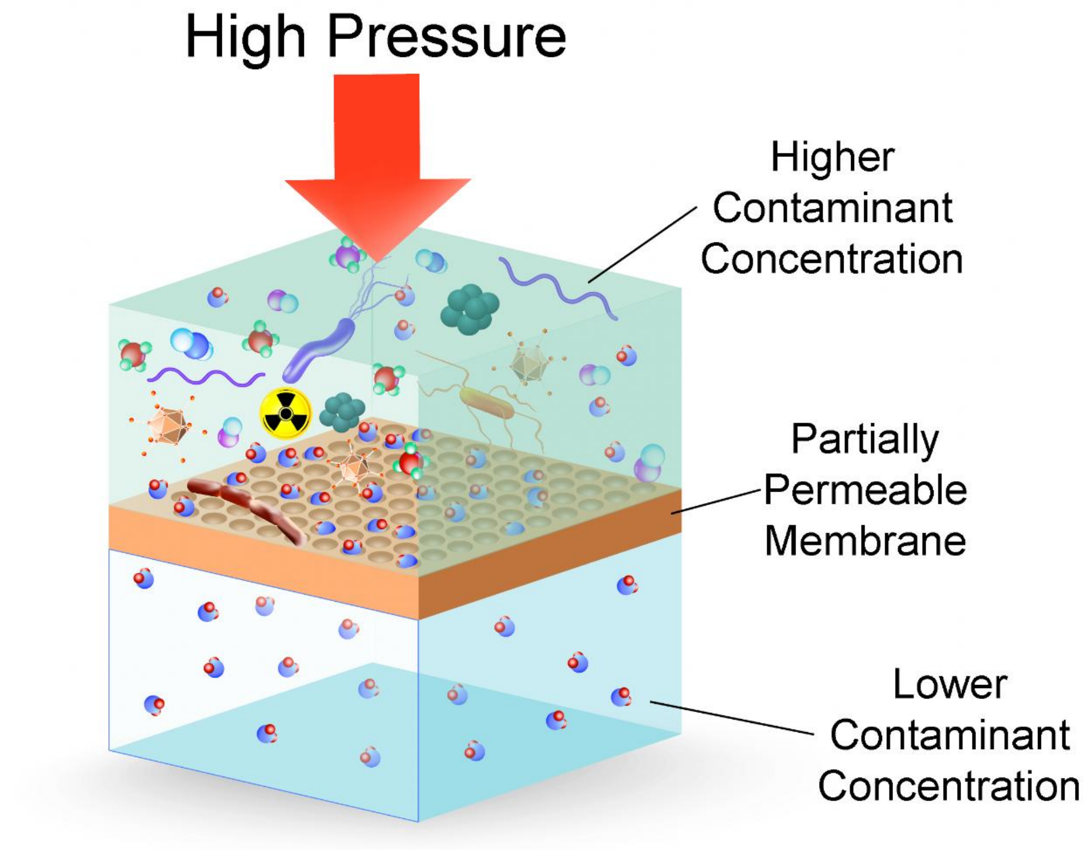

- Each membrane is a thin piece of material with very small pores. The pores allow water molecules, but not salt particles, to pass through. They also do not allow bacteria and chemical contaminants to pass through.

Summary

Separation Techniques – Change & Systems

A summary of separation techniques.

Separation Techniques – Change & Systems

Separation Techniques

- chromatography — separates
- crystallisation — separates
- distillation — separates
- filtration — separates
- magnetic attraction — separates
- separating funnel — separates
- sublimation — separates

Separation Techniques – Change & Systems

Separation Techniques

Technique		Separates
chromatography	separates	substances that dissolve in the same solvent - separated due to difference in solubility
crystallisation	separates	solute (dissolved solid) from solvent (liquid)
distillation	separates	miscible liquids OR solute and solvent - separated due to difference in boiling points
filtration	separates	insoluble solid from liquid or solution - separated due to difference in particle size
magnetic attraction	separates	magnetic substance from non-magnetic substance - separated due to difference in magnetic attraction
separating funnel	separates	two immiscible liquids
sublimation	separates	volatile substance from non-volatile substance - separated due to difference in ability to sublime

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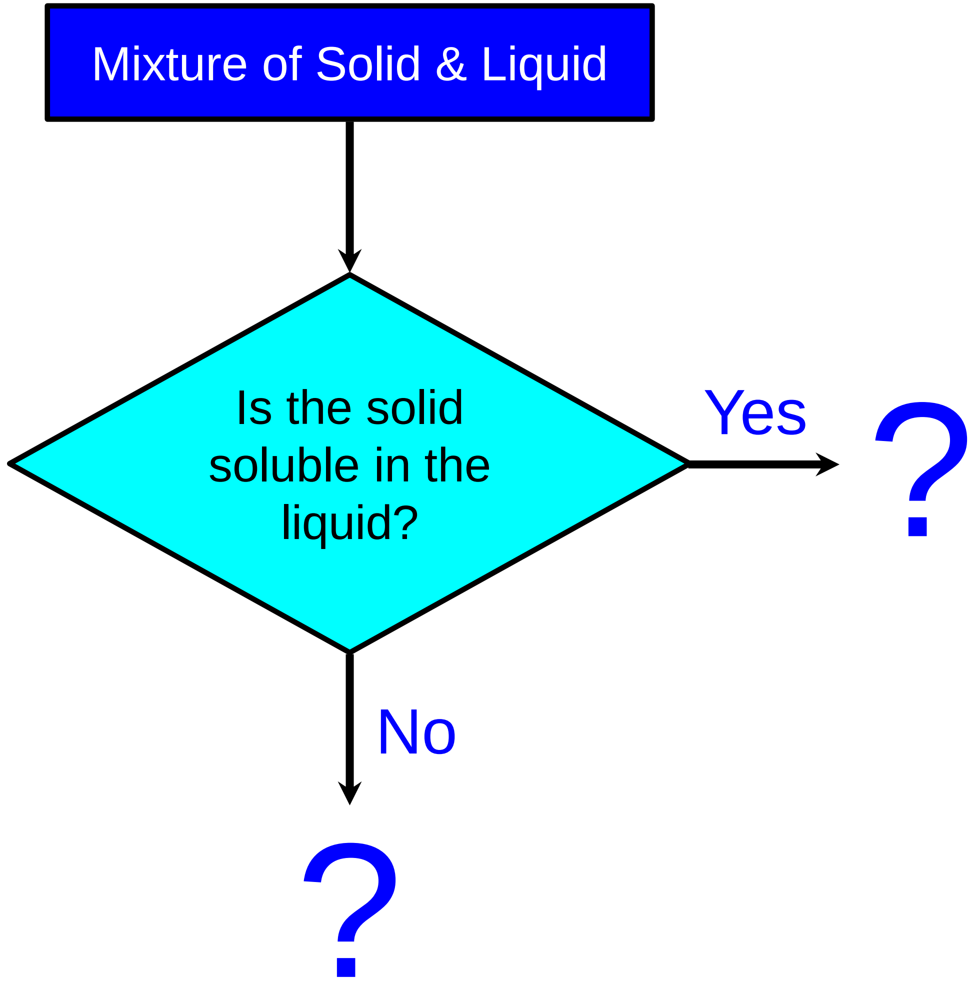

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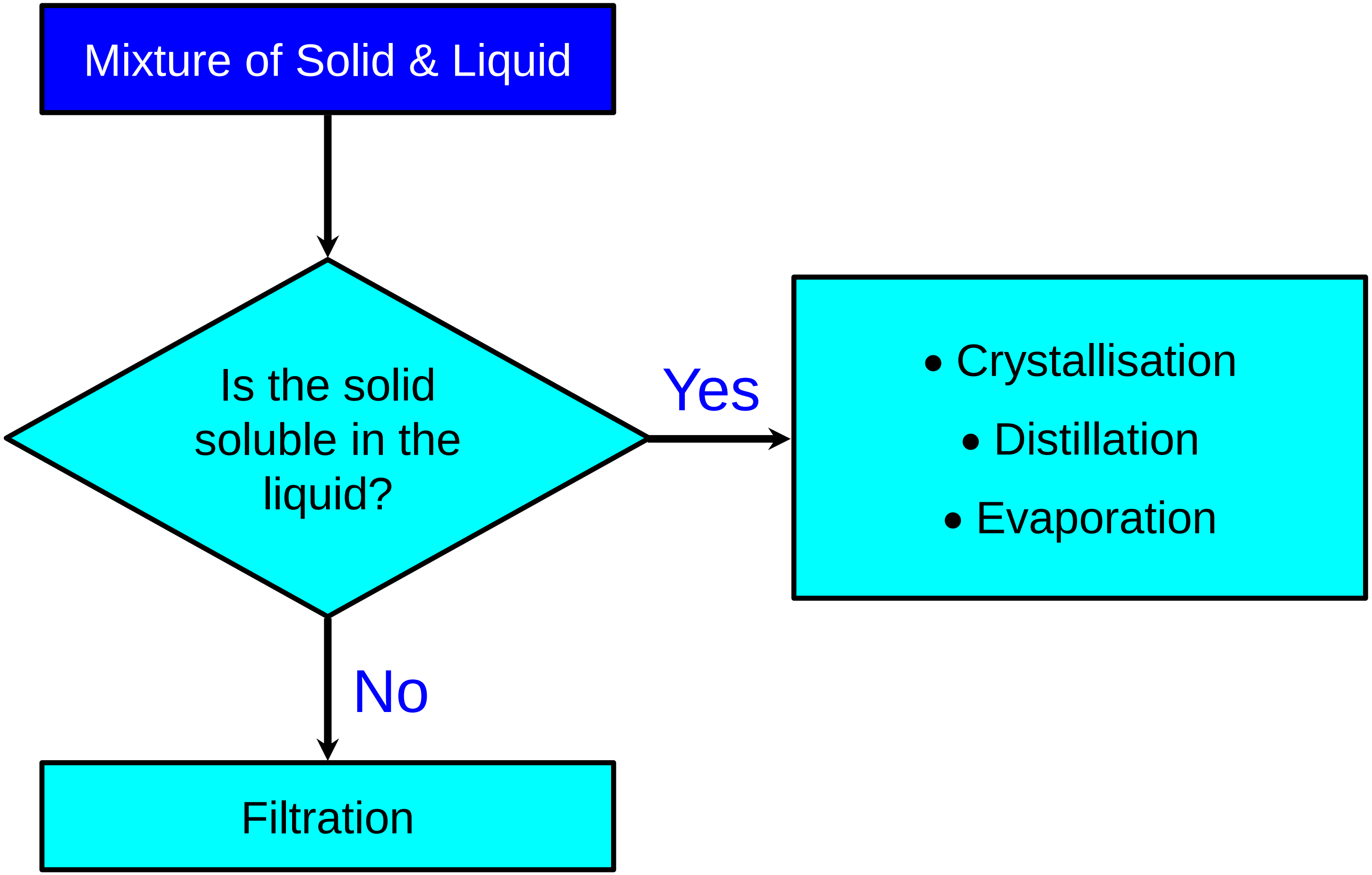

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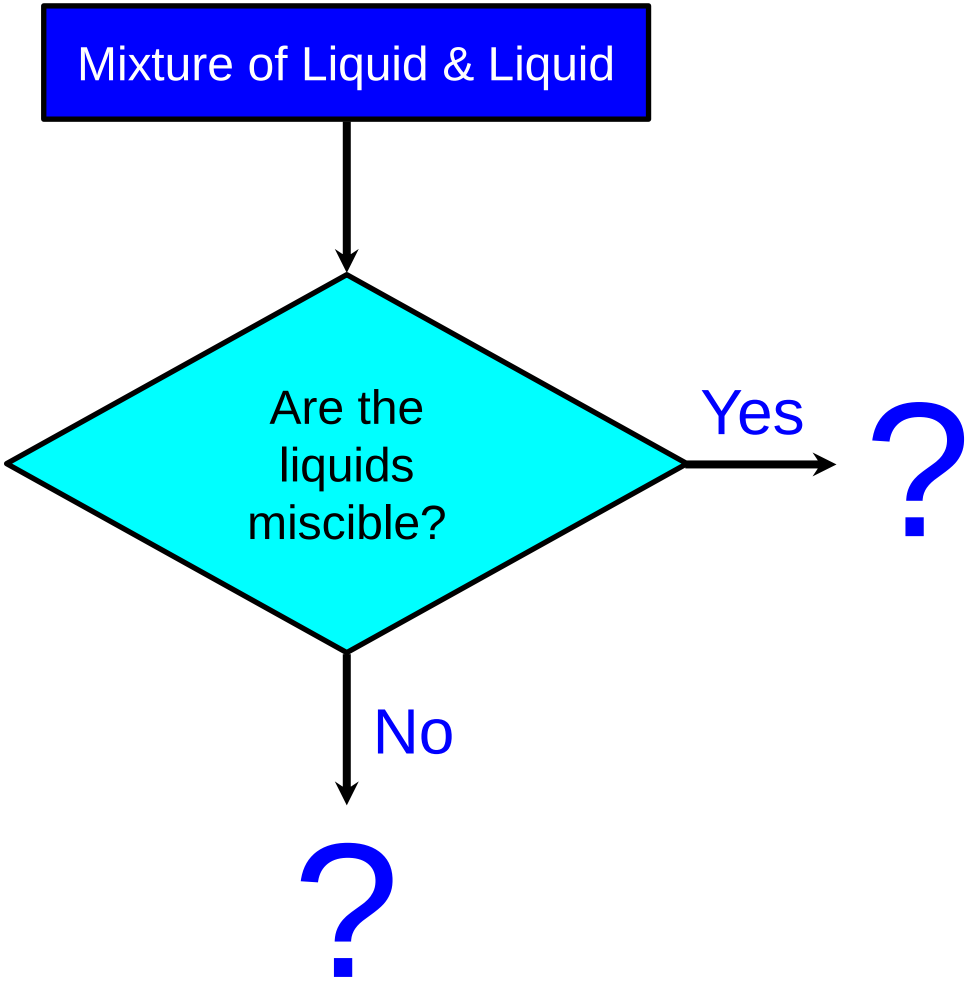

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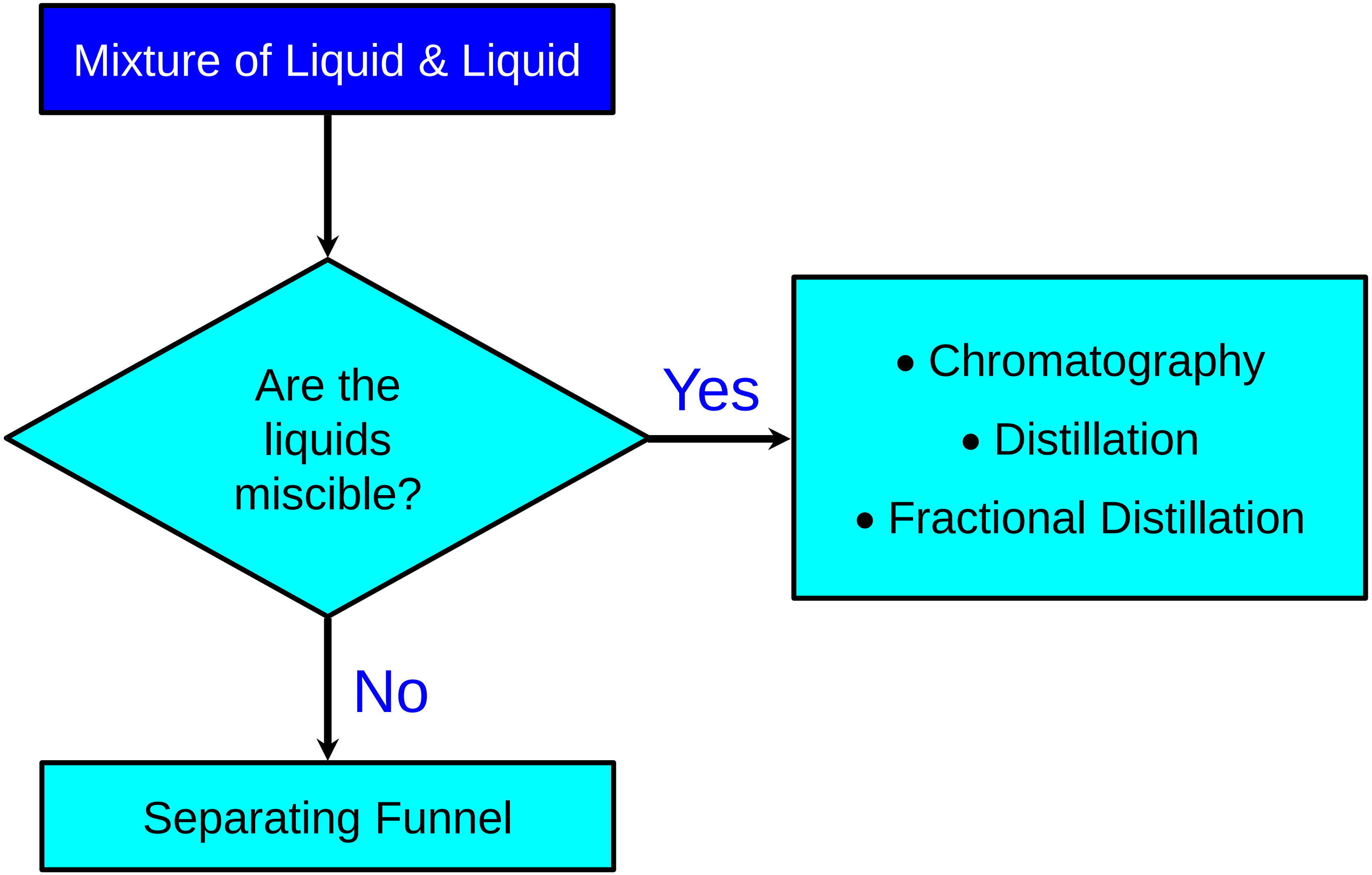

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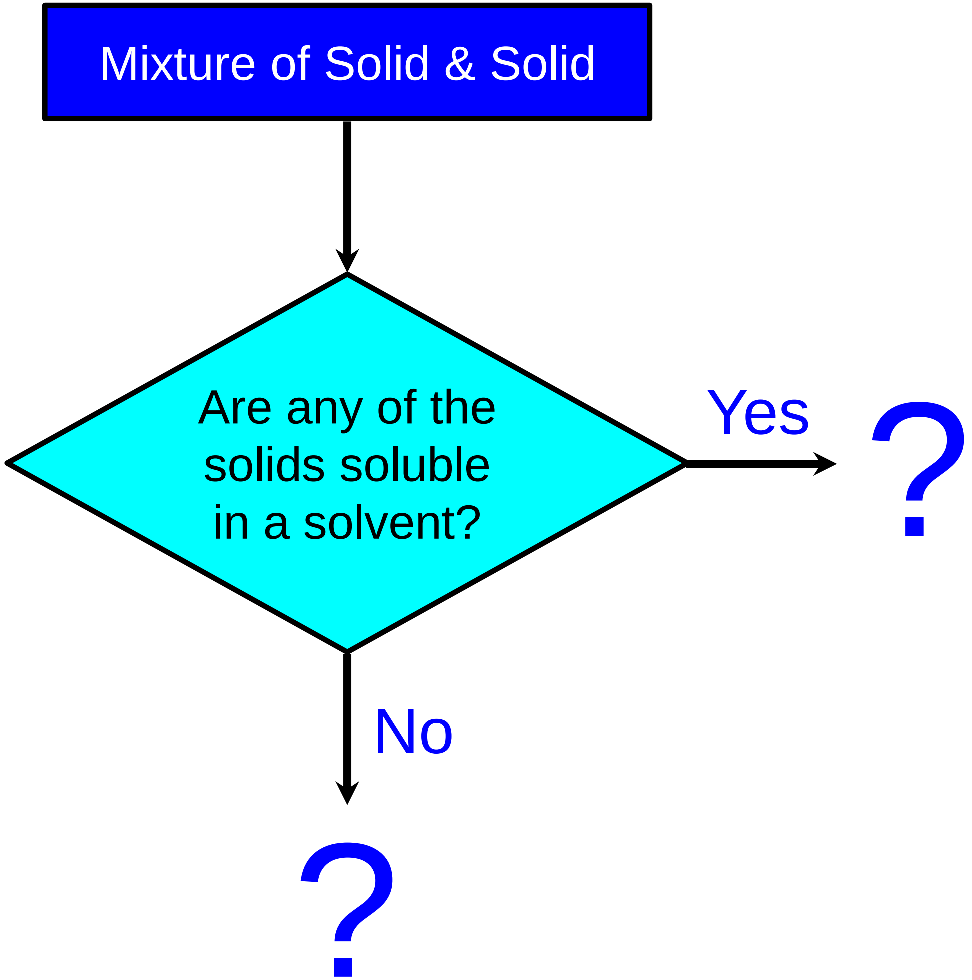

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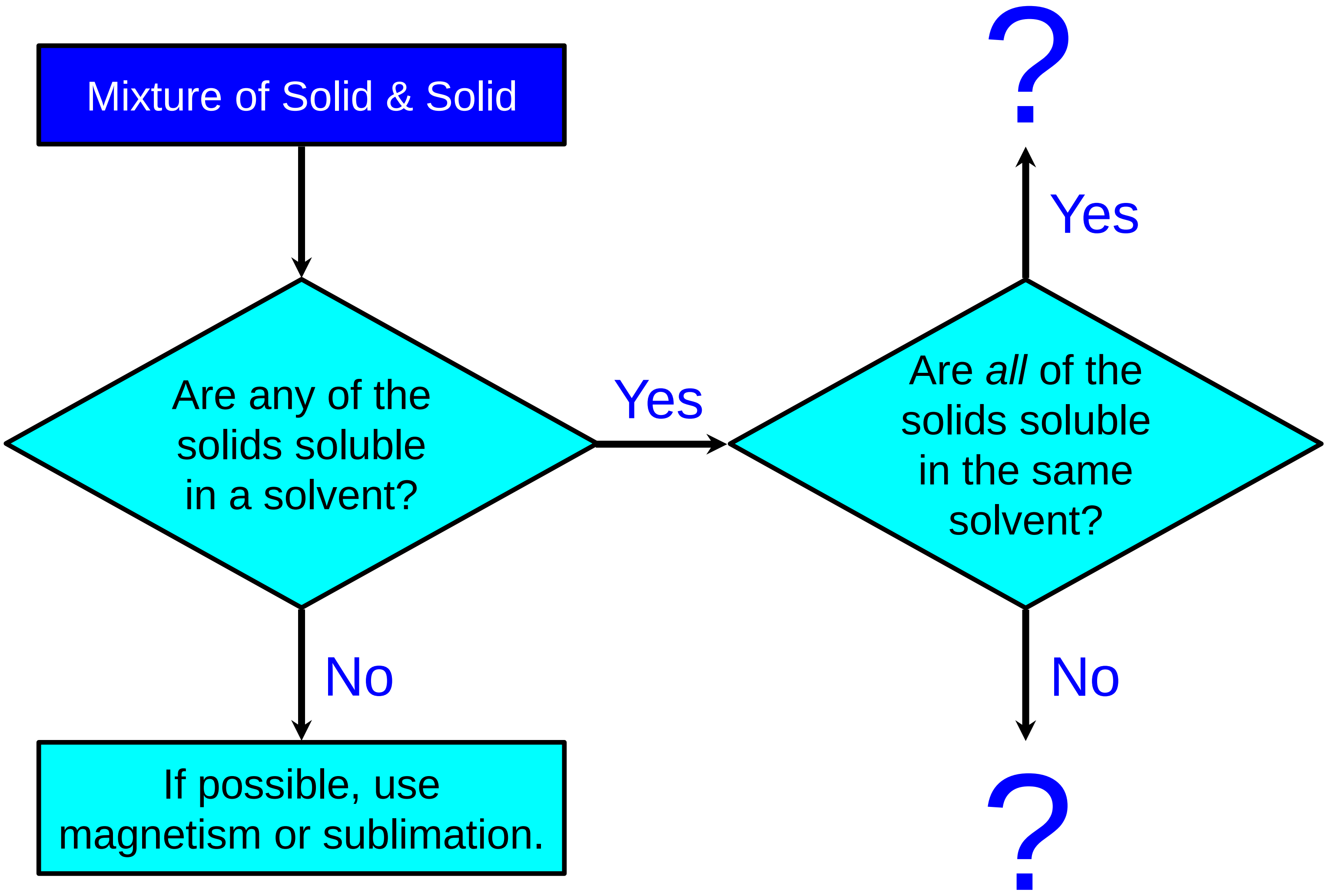

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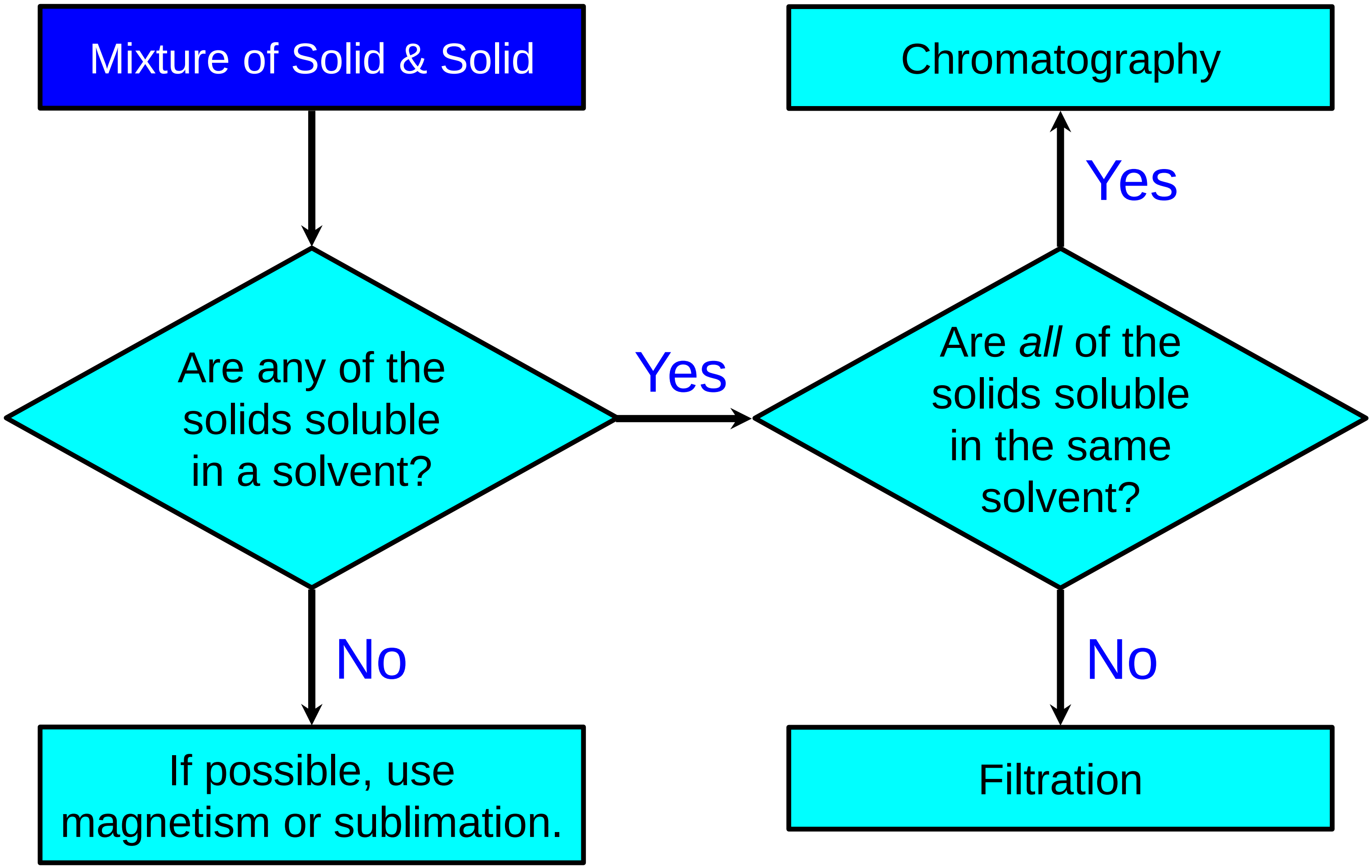


Separation Techniques – Change & Systems

Application

Separation Techniques – Change & Systems

Essential understanding!

- Chemists have a profound impact on the qualities of peoples' lives.

Separation Techniques – Change & Systems

Separation Techniques – Change & Systems

As a Chemist, how can you help this child have access to clean drinking water?

Separation Techniques – Change & Systems

Imagine that the following impurities are present in the water:

a) Copper(II) sulfate

b) Sand (silica)

c) Iron filings

d) Ammonium Chloride

e) Oil

How would you remove them?

Separation Techniques – Change & Systems

Search for information on the following chemicals.

→ Copper(II) sulfate.
→ Sand (silica).
→ Iron filings.
→ Ammonium chloride.
→ Oil.

Separation Techniques – Change & Systems

$CuSO_4$, SiO_2, Fe, NH_4Cl, $C_{16}H_{34}$.

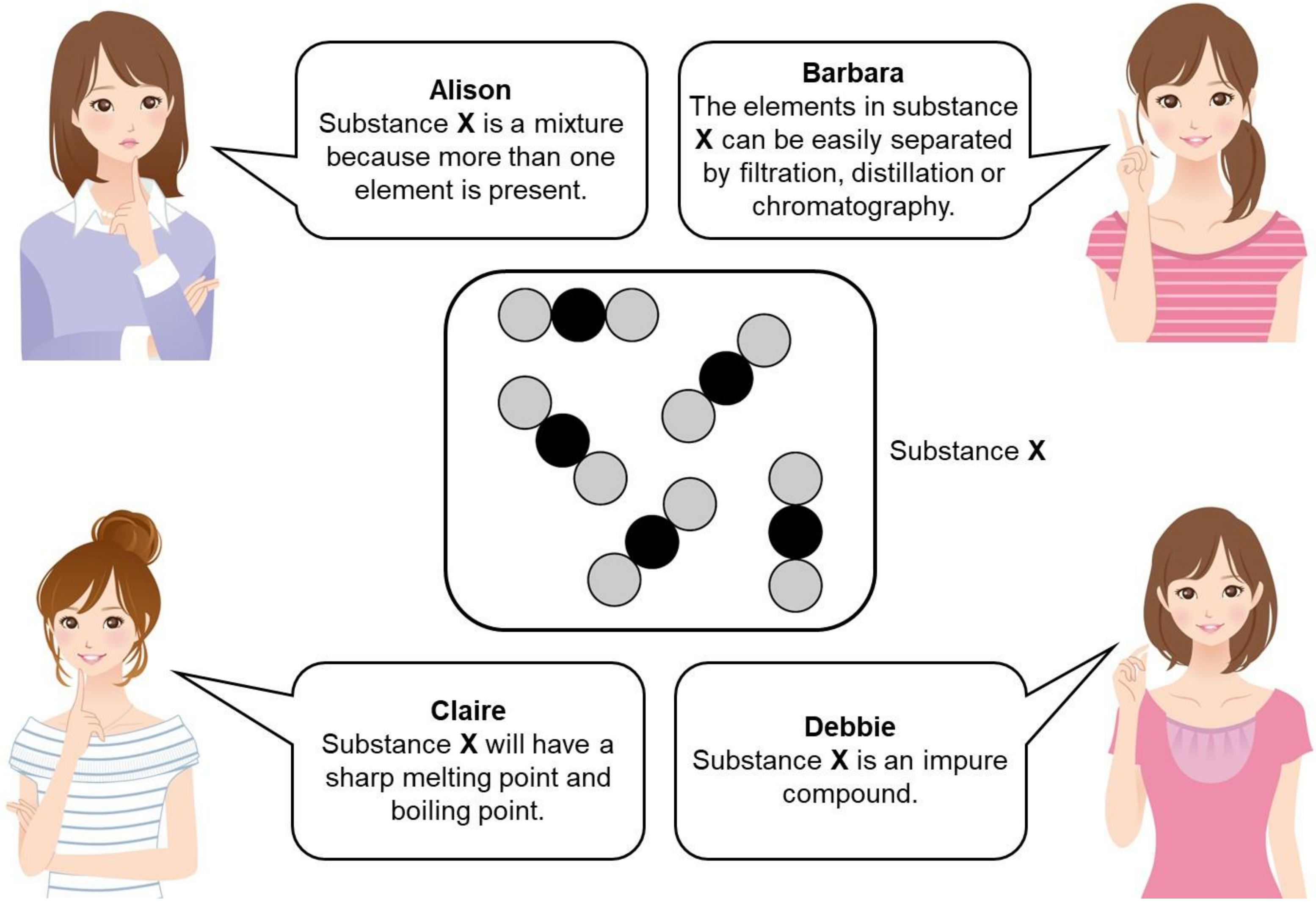
- Once you have identified their essential chemical and physical properties, propose a step-by-step method for removing them from a sample of contaminated water.

Separation Techniques – Change & Systems

Possible Solution

- The iron may be removed from the mixture by attracting it towards a *magnet*, as the iron is the only magnetic substance present.
- The sand may be removed from the mixture by *filtration*. Once the iron as been removed, the sand is the only remaining solid that is insoluble in water.
- The oil may be removed from the mixture by using a *separating funnel*. Oil and water are the only two liquids that are present in the mixture, and oil and water are immiscible.
- The drinking water may be separated from the water soluble ammonium chloride and water soluble copper(II) sulfate by *distillation*.
- The ammonium chloride may be separated from the copper(II) sulfate by *sublimation*. Ammonium chloride is the only chemical in the mixture that sublimes on heating.

Separation Techniques – Change & Systems



- Which student do you agree with, Alison, Barbra, Claire or Debbie?

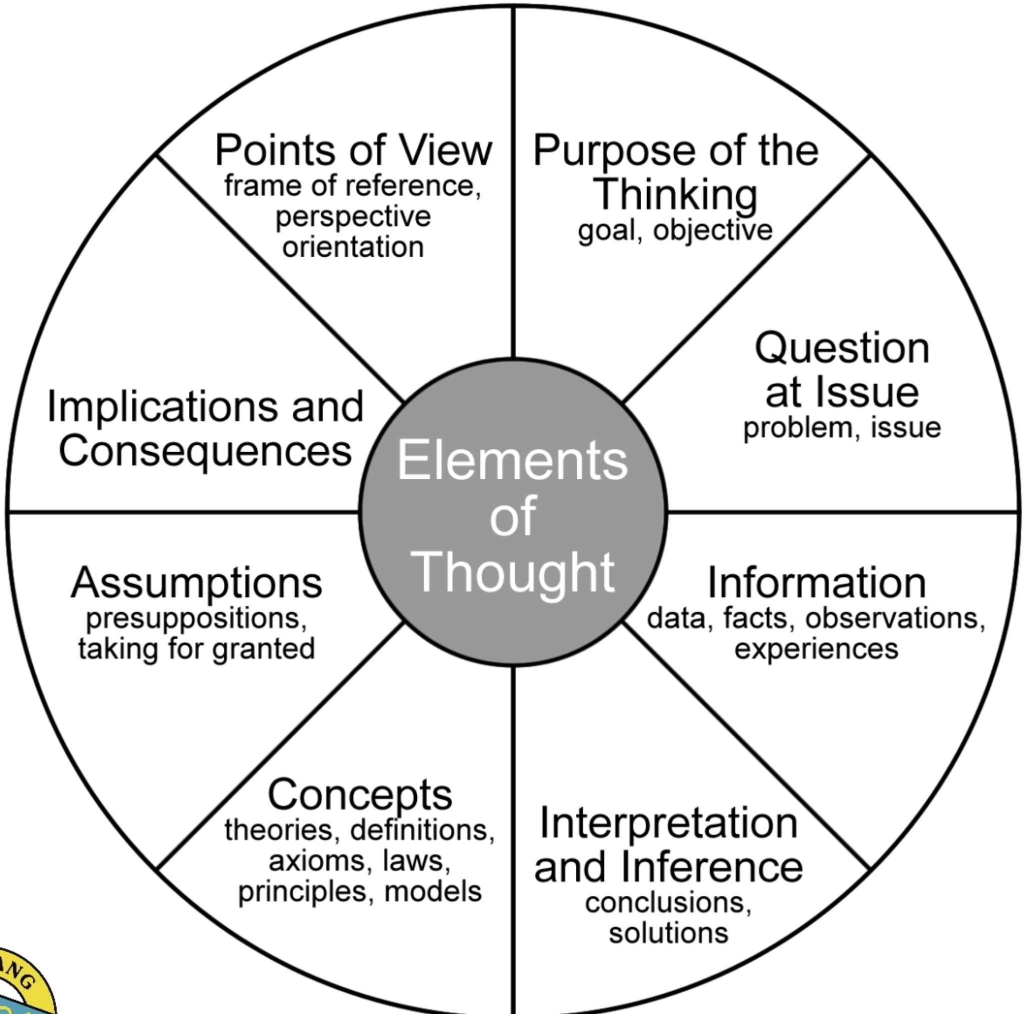
Critical Thinking

Separation Techniques – Change & Systems

Paul's Wheel of Reason is a good way to organise your thinking.

Separation Techniques – Change & Systems

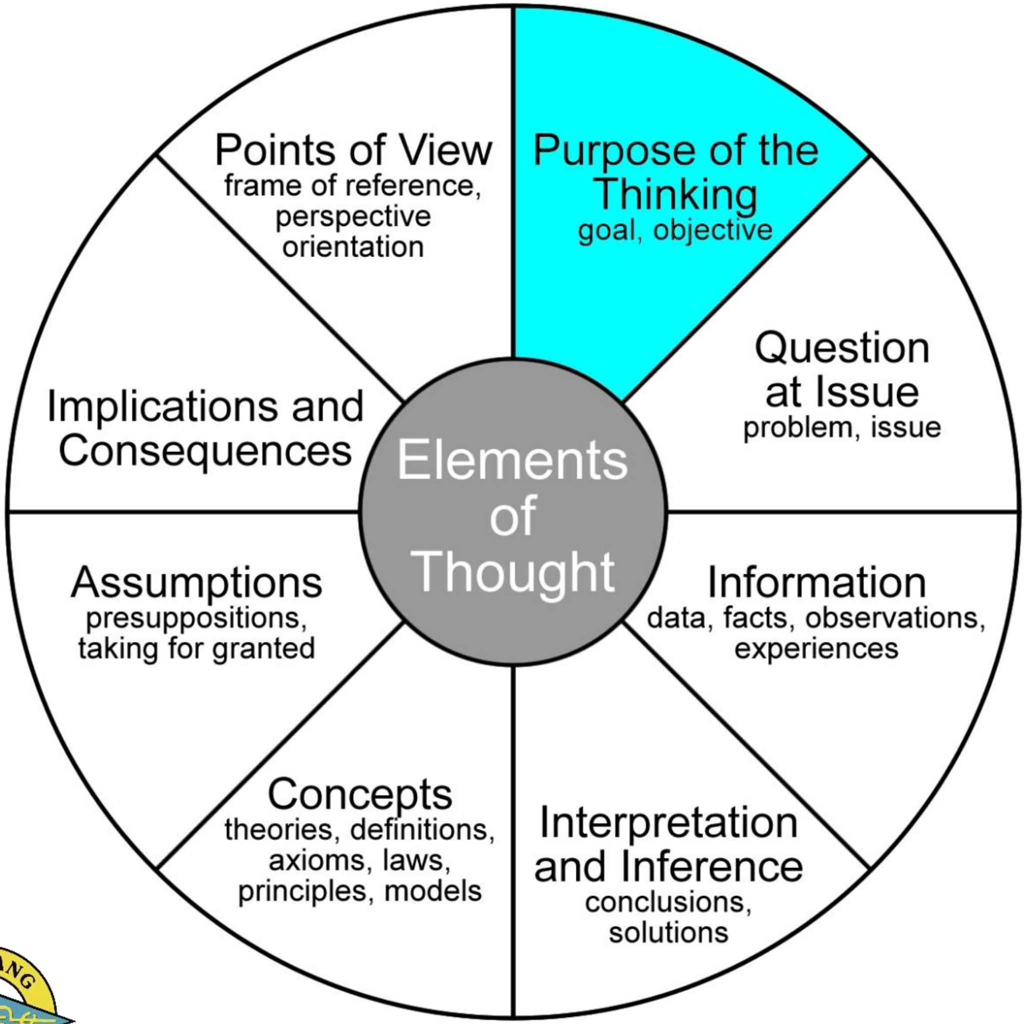
Paul's Wheel of Reason



- Experiments that require the components of a mixture to be separated should be designed using *critical thinking* skills.

Separation Techniques – Change & Systems

Paul's Wheel of Reason



- What is the reason for performing the separation?

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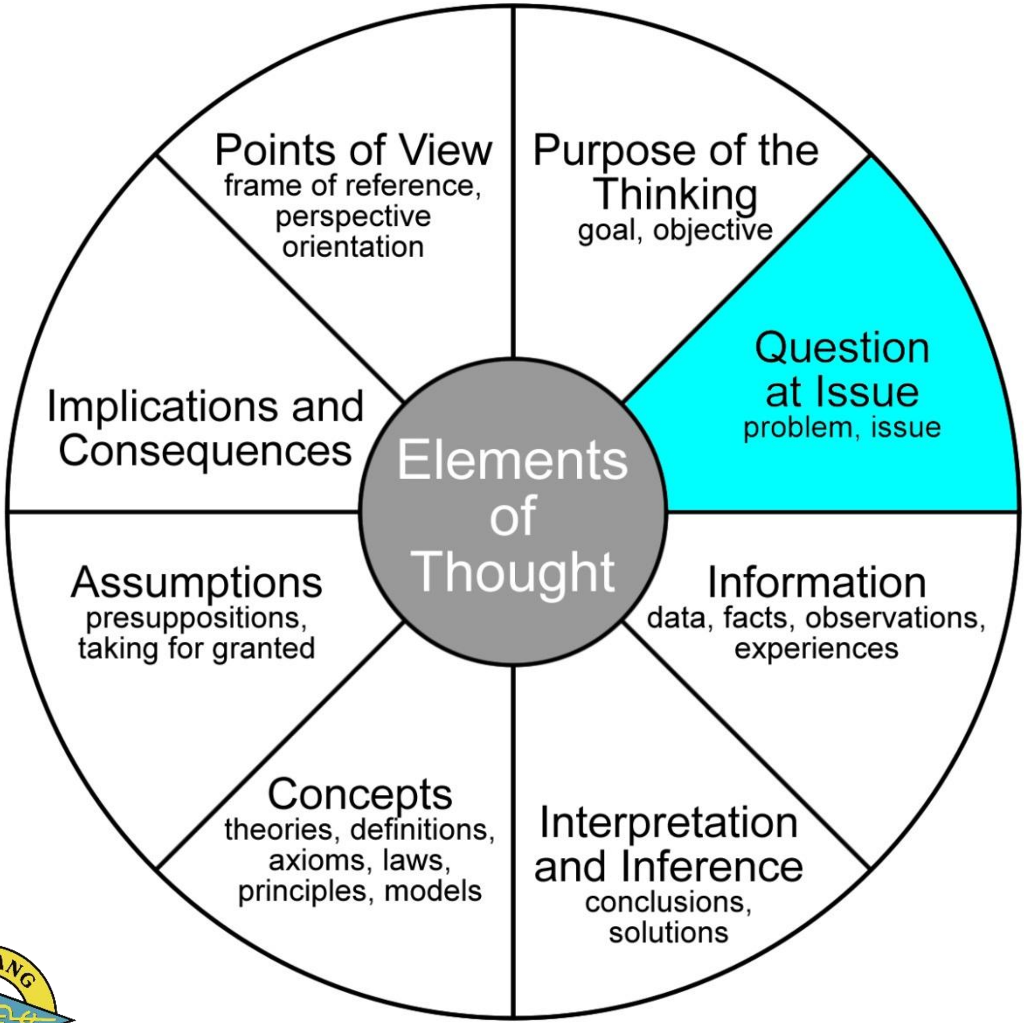
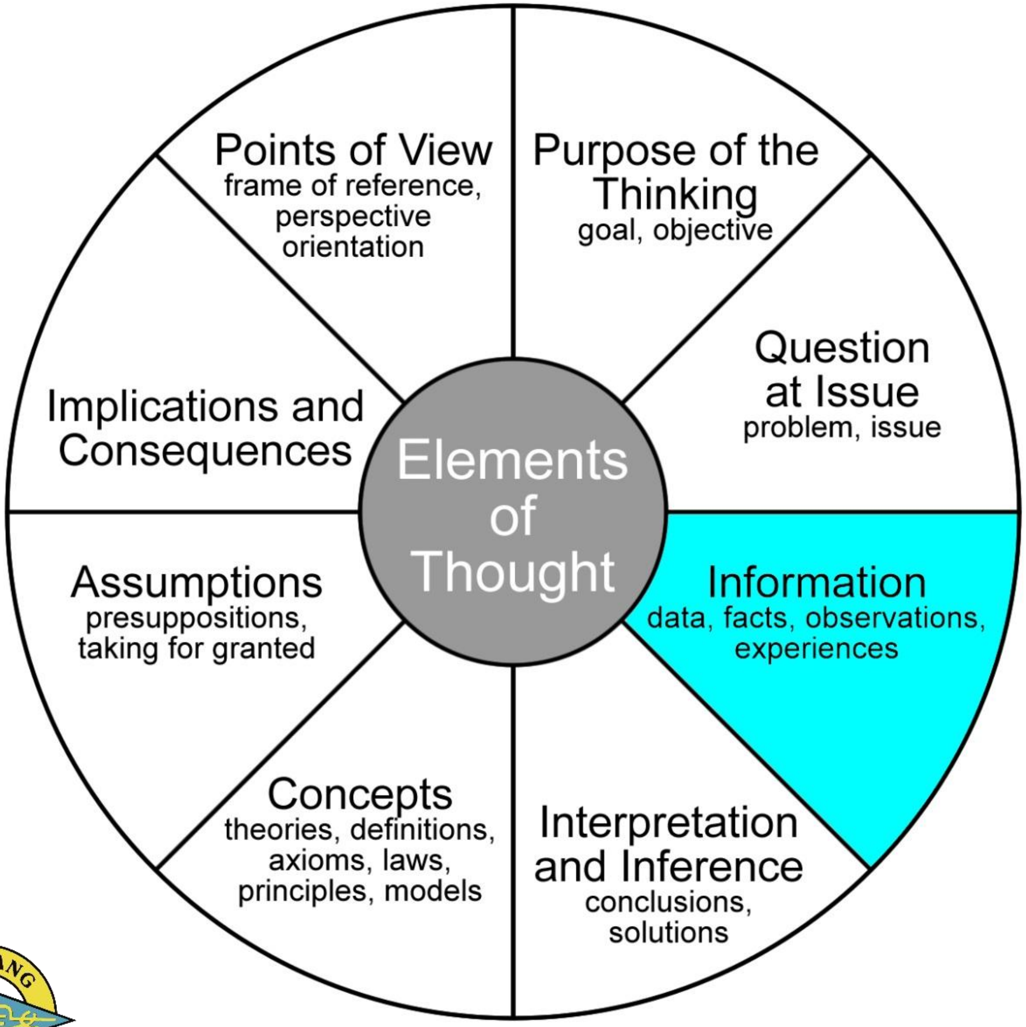
Paul's Wheel of Reason



- What chemicals are in the mixture that needs to be separated?
- Why does the mixture need to be separated?
- Do I need to obtain a pure sample of each component in the mixture?

Separation Techniques – Change & Systems

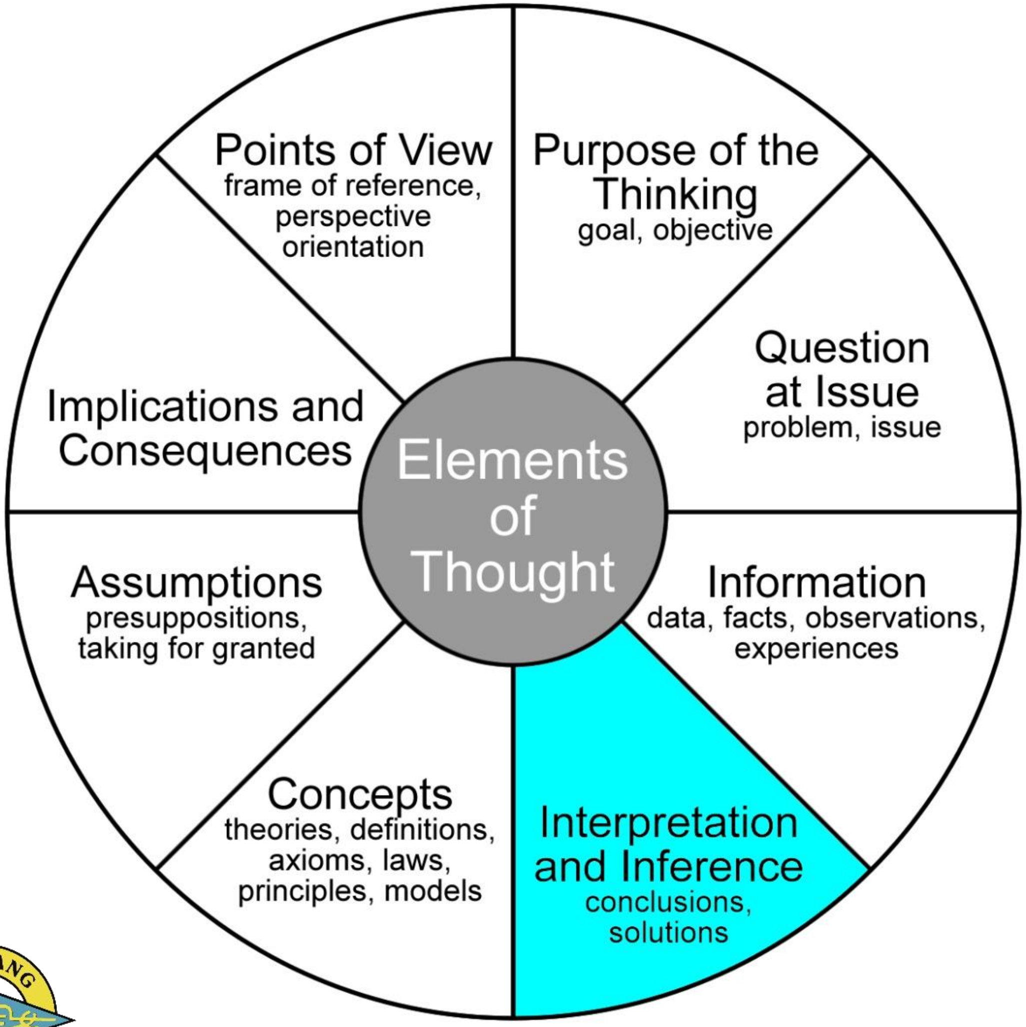
Paul's Wheel of Reason



- What information do I have about the physical properties of the chemicals in the mixture, *e.g.* boiling points and solubilities?
- What other information do I need?

Separation Techniques – Change & Systems

Paul's Wheel of Reason



- How can I interpret the information that is available to me in order to design an experiment that brings about the best possible separation of the components in the mixture?

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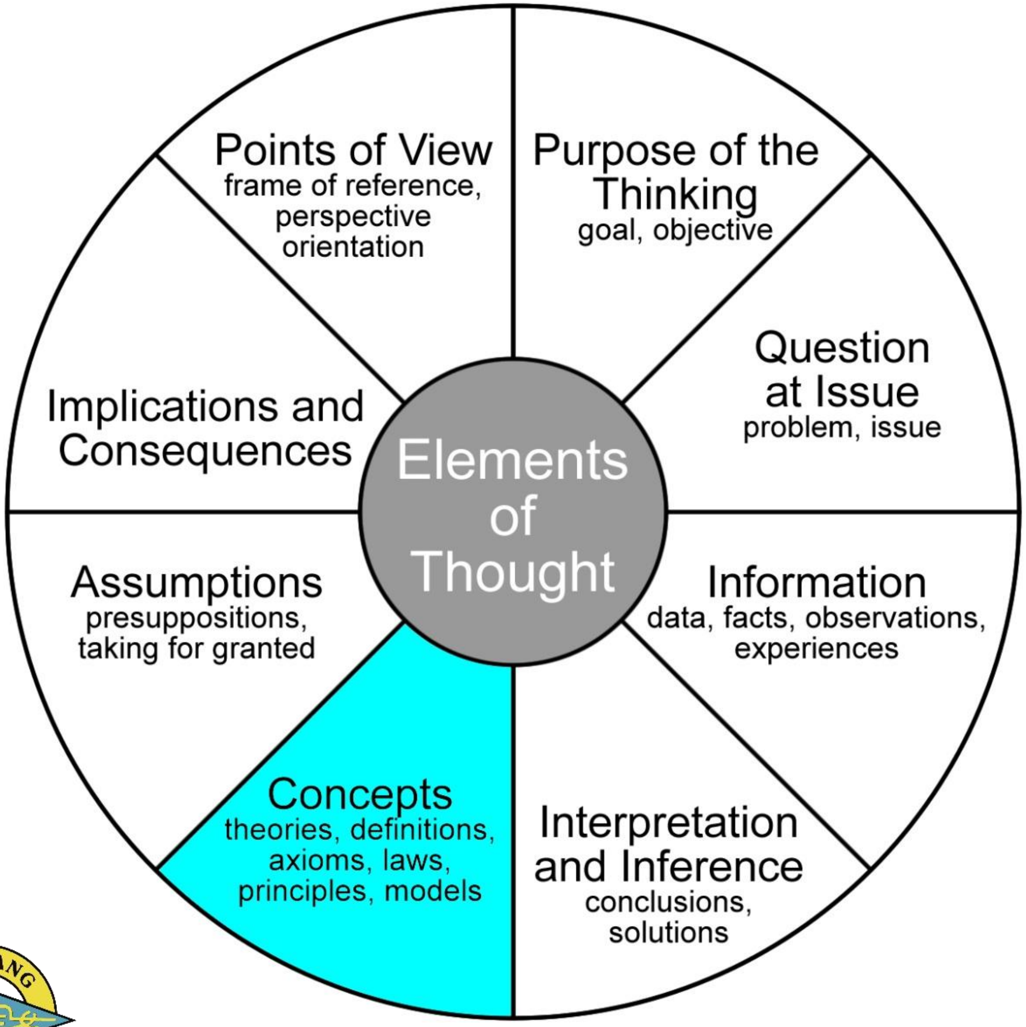
Paul's Wheel of Reason



- What essential concept(s) / law(s) does the design of the separation rely on? For example, to be separated by distillation, the chemicals in the mixture must have different boiling points.

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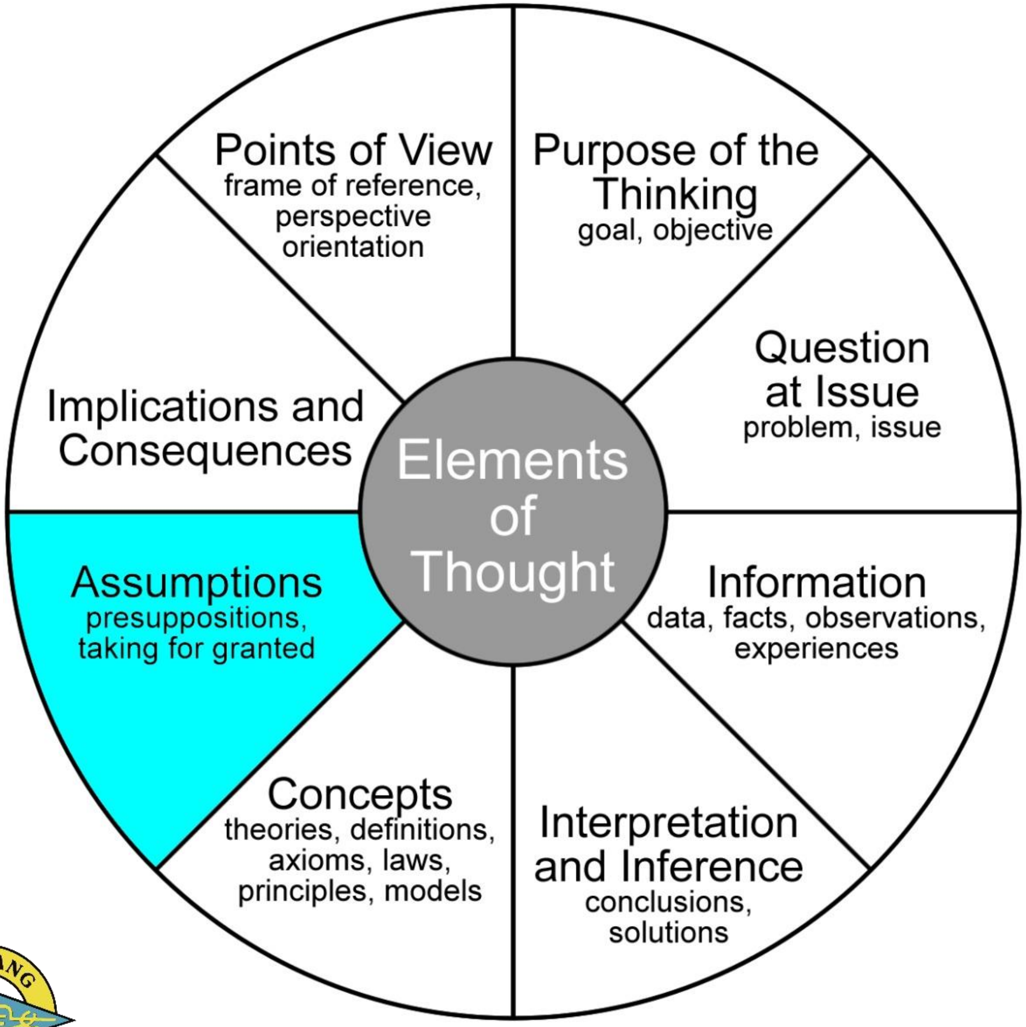
Paul's Wheel of Reason



- What assumptions are being made when designing the separation?
- Is it reasonable to make these assumptions?
- Identifying assumptions can help to identify errors.

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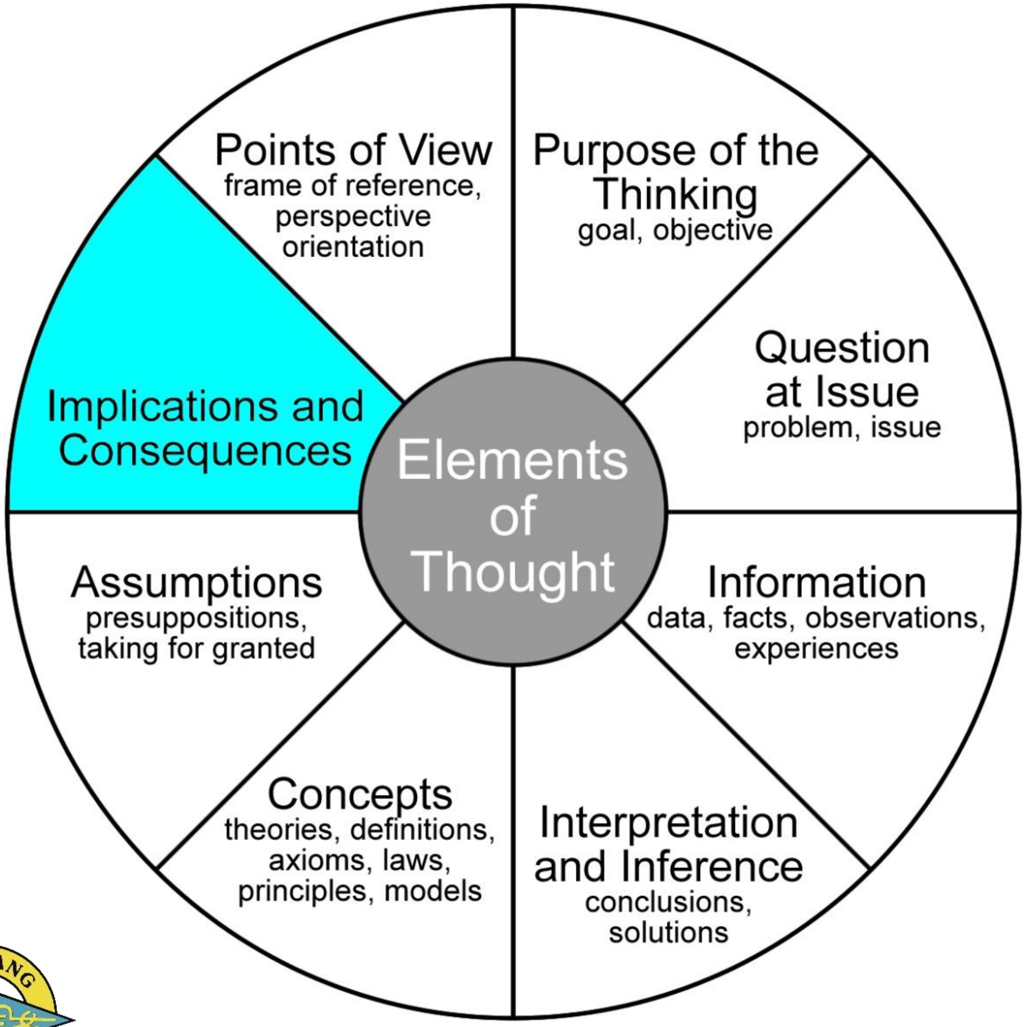
Paul's Wheel of Reason



- What are the implications and consequences if some components of the mixture cannot be separated?

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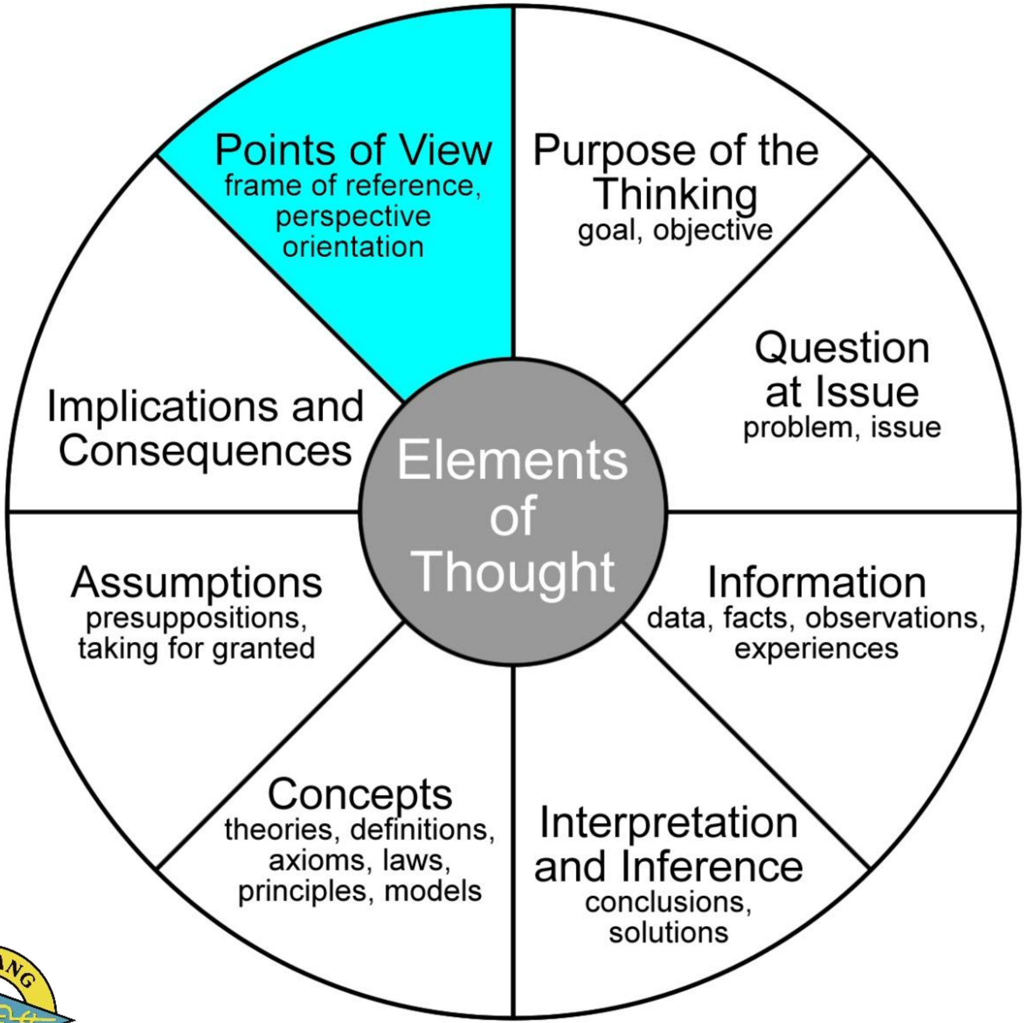
Paul's Wheel of Reason



- Is there more than just one way of performing the separation?
- If there is more than one way, which way is best?

Generalisations

Separation Techniques – Change & Systems

- Physical separation techniques are used to separate components of a mixture, while chemical separation techniques are used to separate the components within a compound.
- Separation techniques are used to obtain the desired component within a mixture, based on the physical properties of all the components that make up the mixture.
- Purity is important as it removes contaminants which endanger lives and / or cause harm to the environment.

Separation Techniques – Change & Systems

CH

Why is separation and purification important in chemistry?

Separation and purification are essential processes in chemistry because they enable us to isolate and purify specific substances from mixtures. Many chemical substances are found in complex mixtures that include impurities, contaminants, and other components that are unwanted or even toxic. These impurities can affect the chemical properties and reactivity of the substance, making it difficult to use it for specific applications or experiments.

Therefore, by separating and purifying the desired substance, we can obtain a pure compound with defined chemical properties and a consistent level of quality. This pure substance can then be used in a variety of applications, such as in pharmaceuticals, food, electronics, and materials science, among others.

In addition, separation and purification are also important in analytical chemistry, where they enable scientists to accurately measure the concentration of specific compounds in a sample. This is essential for many applications, such as environmental monitoring, drug testing, and quality control in manufacturing.

Overall, separation and purification play a crucial role in chemistry, allowing us to obtain pure and well-defined substances that are essential for a wide range of applications and experiments.

Separation Techniques – Change & Systems

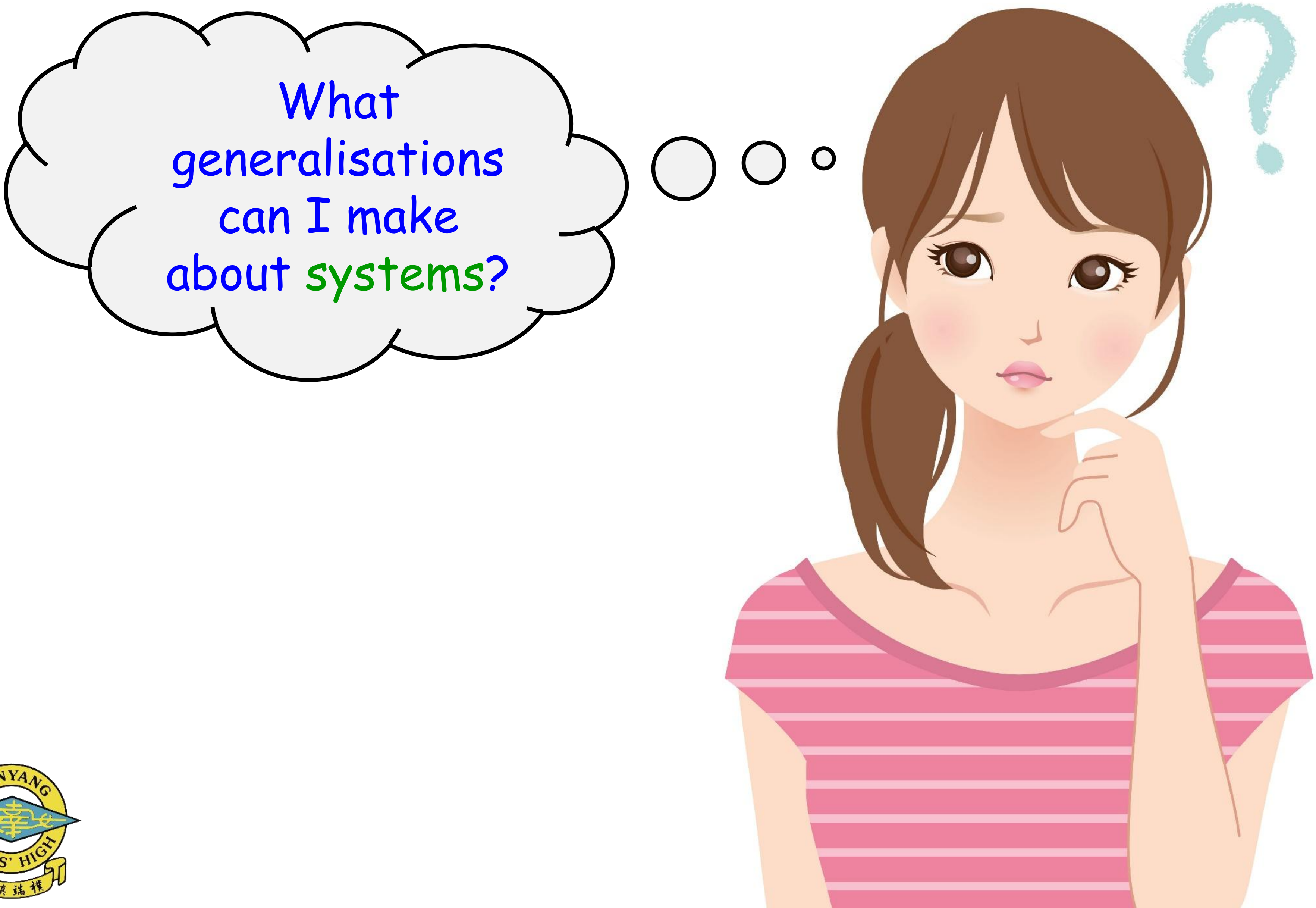
Systems

Separation Techniques – Change & Systems

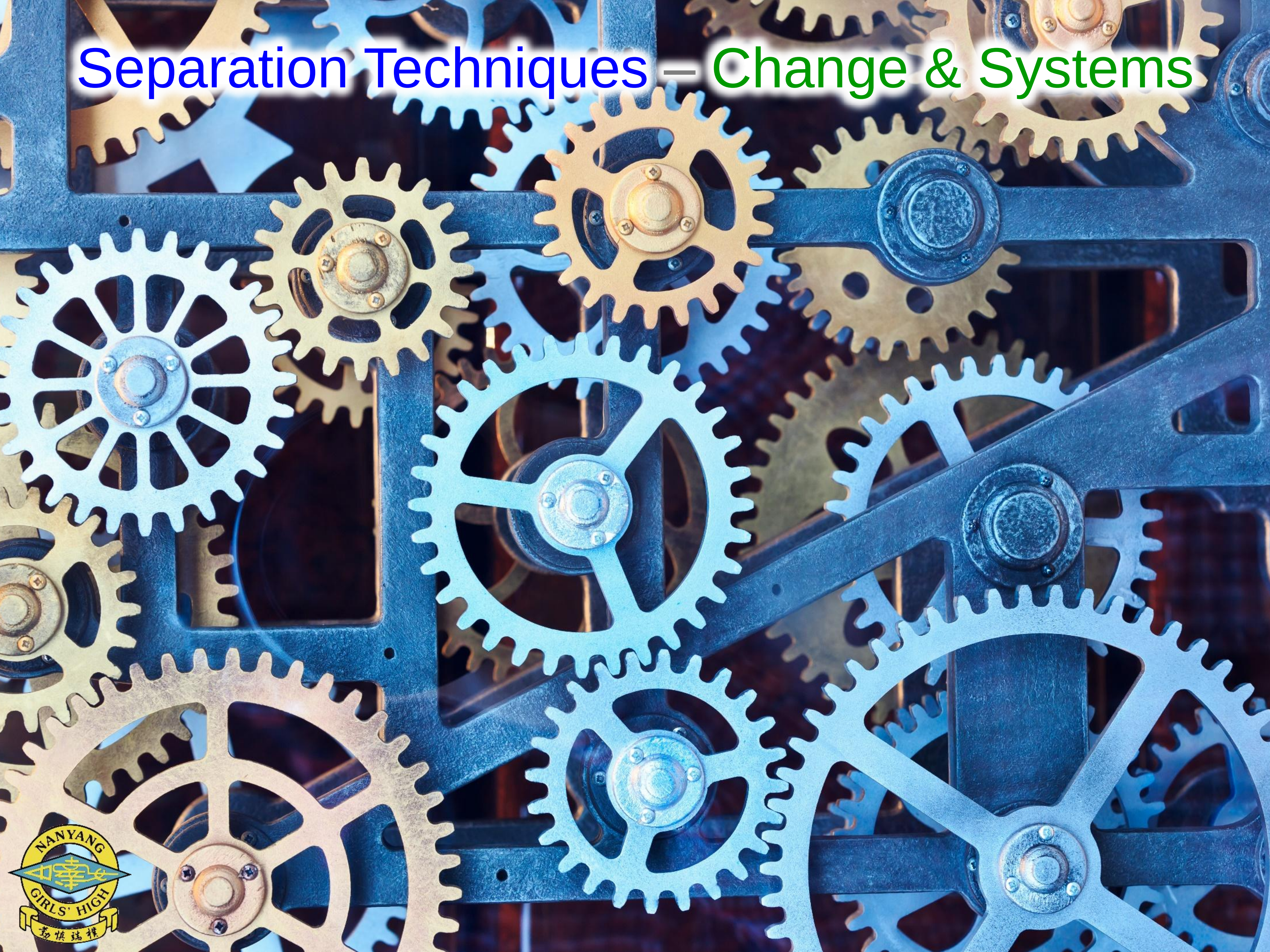
Essential understanding!

- The purification of a chemical may be considered to be a *system* in which each step of the separation brings about a gradual *change* in the mixture.

Separation Techniques – Change & Systems



Separation Techniques – Change & Systems

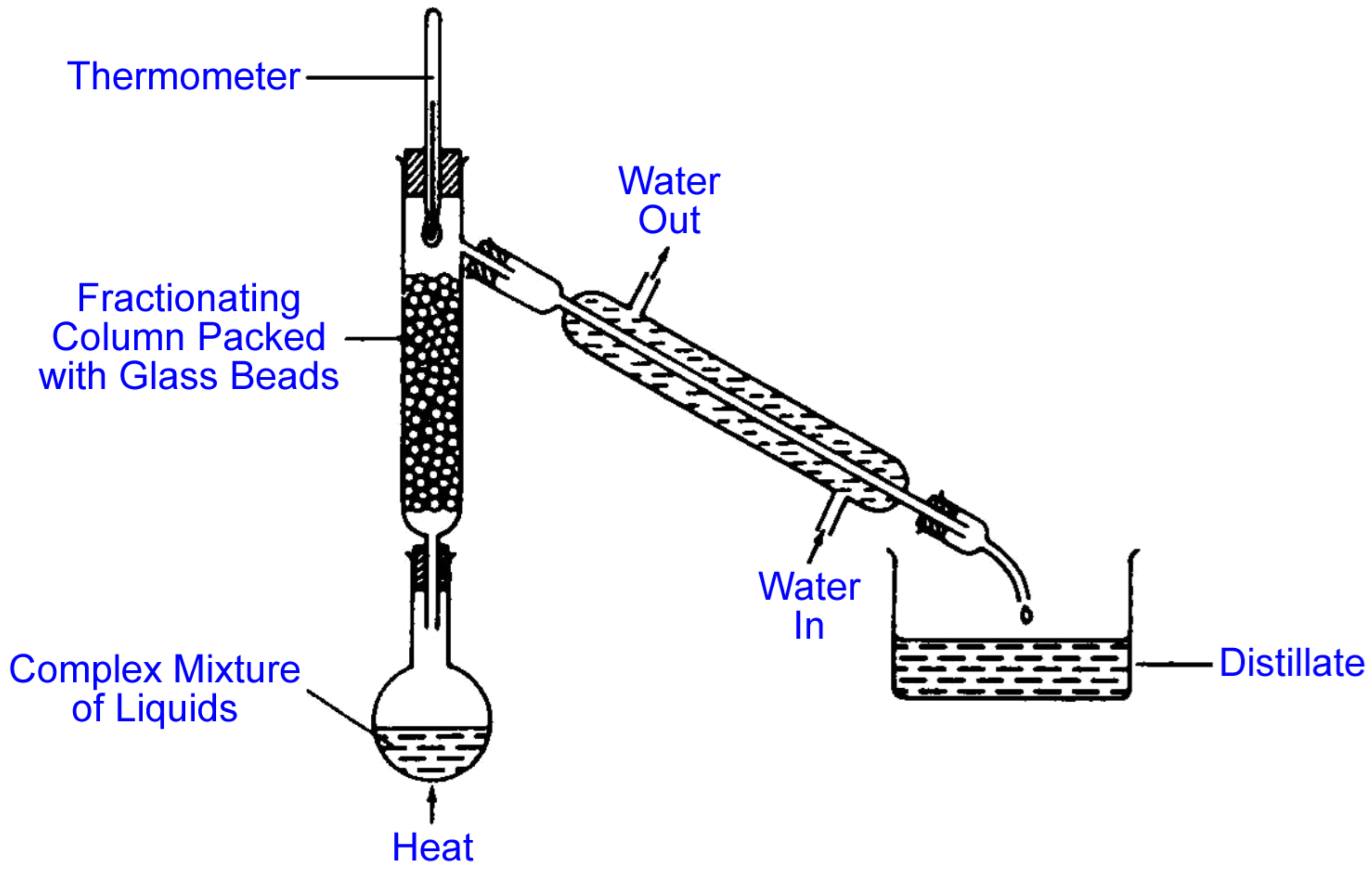


Generalisations About Systems

- Systems have elements that interact with each other to perform a function.
- Systems are composed of sub-systems.
- Systems may be influenced by other systems.
- Systems interact.
- Systems follow rules.

NANYANG GIRLS' HIGH

Separation Techniques – Change & Systems

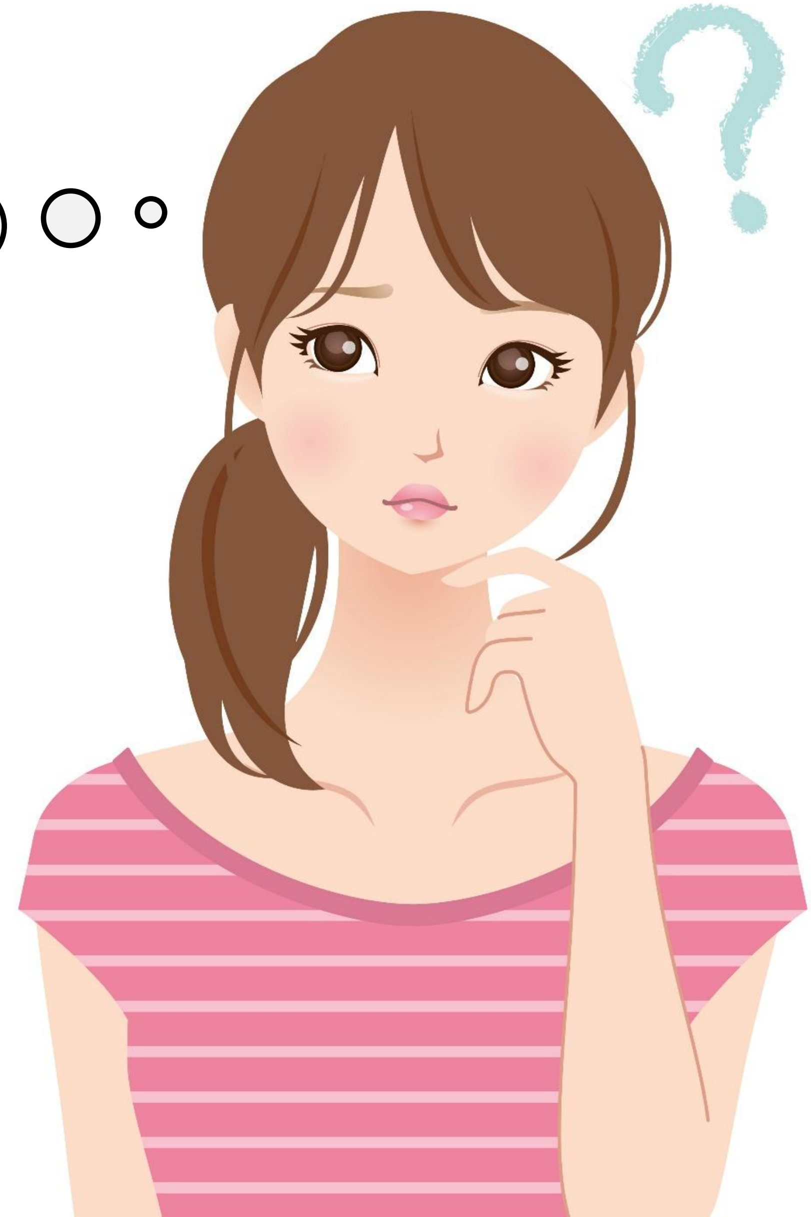


Separation Techniques – Change & Systems

- The fractional distillation set-up is a *system*.
- The flask, fractionating column, thermometer and water cooled condenser are connected together in a specific way, and each one performs a *certain function*.
- Fractional distillation *follows certain rules*, *e.g.* the chemical with the *lowest boiling point* in the mixture will be collected as the *first distillate*.

Separation Techniques – Change & Systems

What are some other examples of systems?



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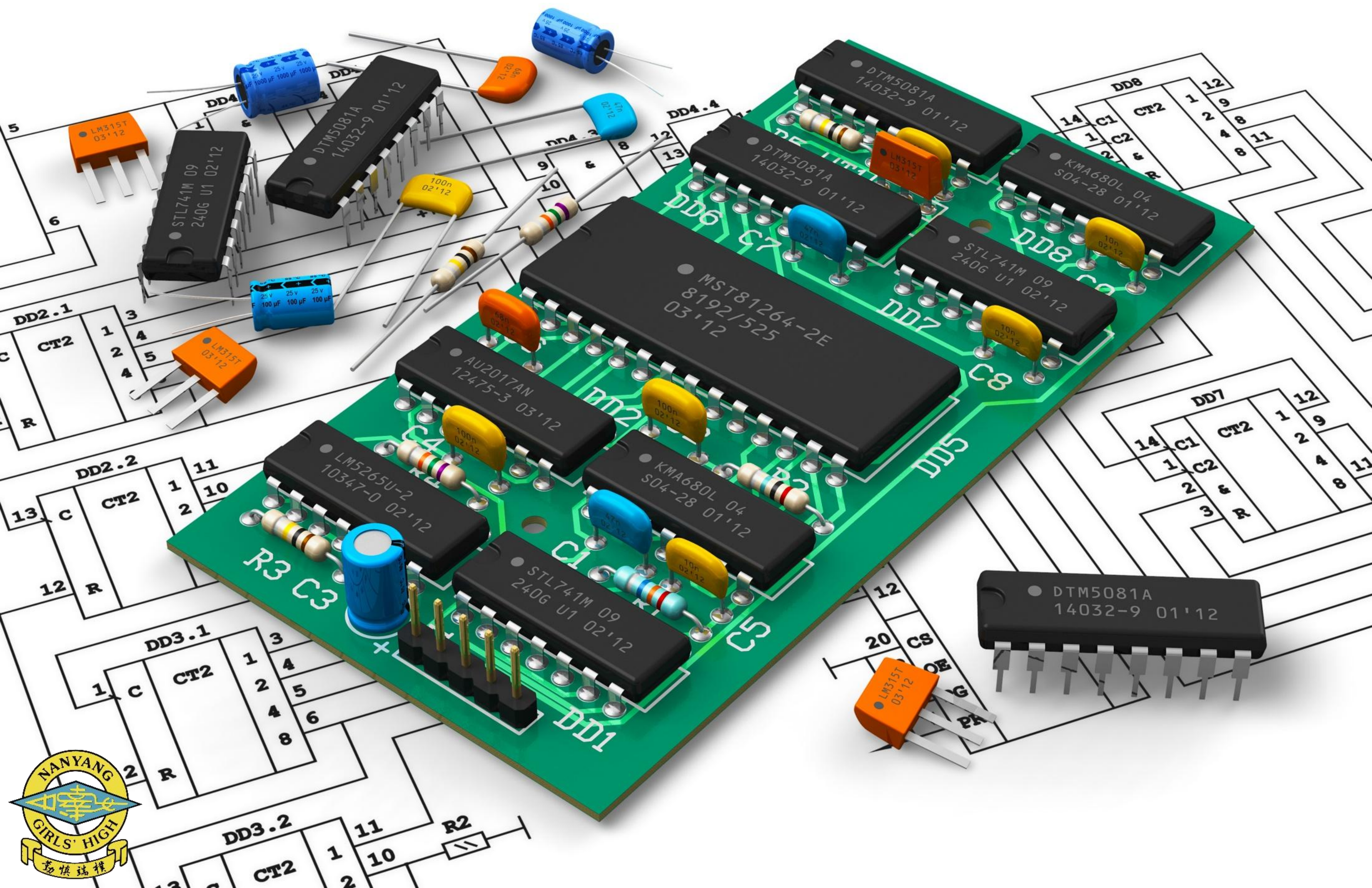


Separation Techniques – Change & Systems

- A printed circuit board is a *system*.
- Each microchip, resistor and capacitor is a *sub-system* that performs a *specific function*.
- The operation of the printed circuit board is controlled by *specific rules* that are coded in the logic operations of the software.

Separation Techniques – Change & Systems

Separation Techniques – Change & Systems

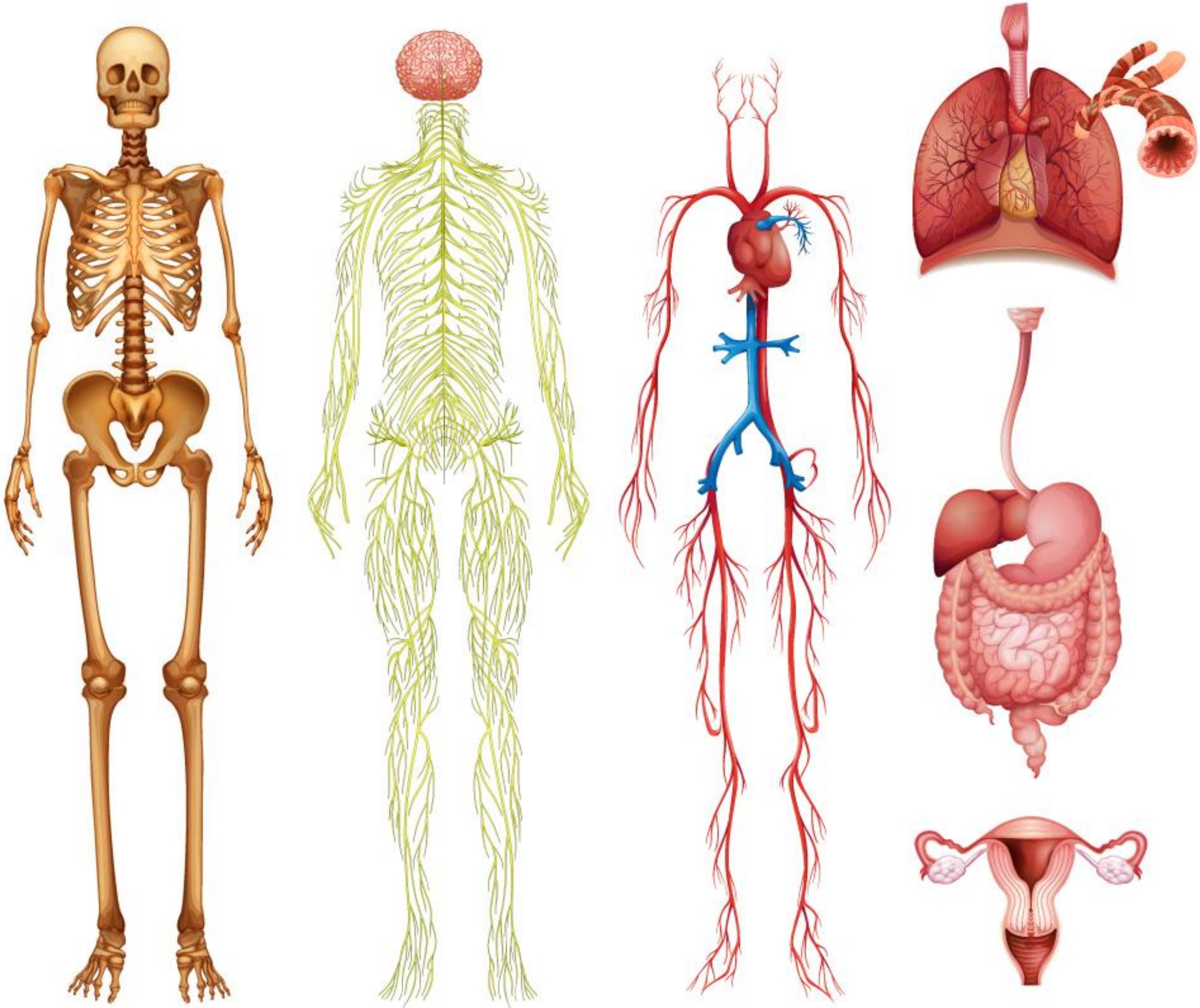
- A tropical storm is a *system*.
- The warm rising air and the cool falling air are both *sub-systems* that *interact* with each other and perform *specific functions* within the storm.
- The movement of the air in a tropical storm *follows certain rules* (fluid dynamics) that can be *modelled* mathematically. These models allow the storm's progress to be *predicted*.

Separation Techniques – Change & Systems

Separation Techniques – Change & Systems

- Public transport is a *system*.
- Each form of transport is a *sub-system*.
- Each form of transport (*sub-system*) *interacts* with the others and performs a *specific function* that allows passengers to reach their destination.
- Each form of transport (*sub-system*) *follows certain rules*, *e.g.* departure and arrival times.

Separation Techniques – Change & Systems



Separation Techniques – Change & Systems

- The human body is a complex *system* that is composed of many *sub-systems*, *e.g.*

→ Skeletal *system.*

→ Central nervous *system.*

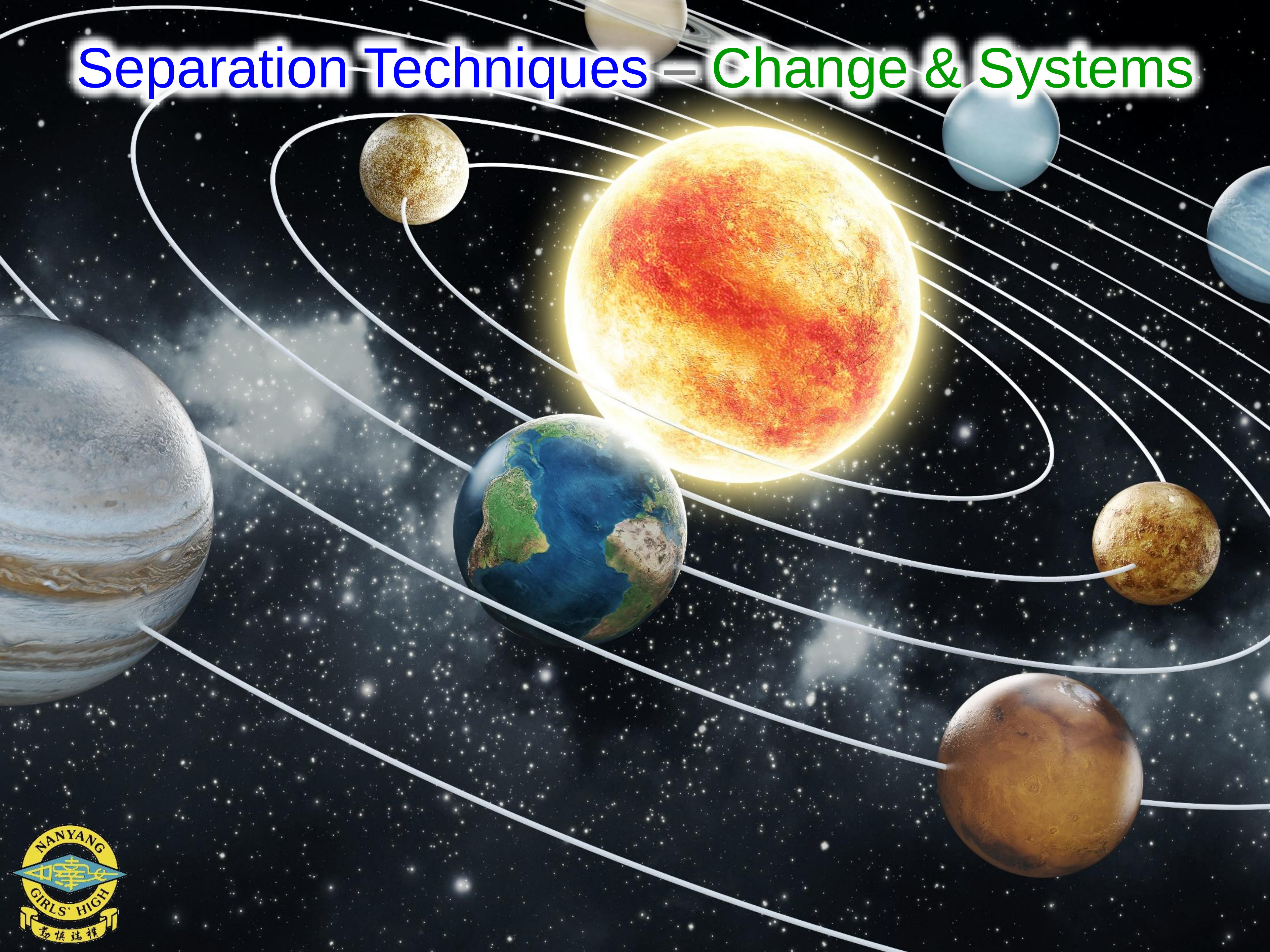
→ Circulatory *system.*

→ Respiratory *system.*

→ Digestive *system.*

→ Reproductive *system.*

Separation Techniques – Change & Systems



Separation Techniques – Change & Systems

- What *system* is this?

→ Solar System.

- What is this *system* composed of?

→ A star, planets and their satellites, asteroids and comets.

- How do the components of this *system interact* and *influence* each other?

→ Through the force of gravity.

- What *rules* does this system follow?

→ The Laws of Physics.

Separation Techniques – Change & Systems

Presentation on
Separation Techniques
by Dr. Chris Slatter
christopher_john_slatter@nygh.edu.sg

Nanyang Girls' High School
2 Linden Drive
Singapore
288683

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