Chapter 5: Exploring Mixtures and their Separation

Exercises — Revise, Reflect, Refine

Q1 Which of the following mixtures are correctly classified as homogeneous (Hm) and heterogeneous (Ht)? Choose the correct option.
(i) Air — Hm, Milk — Ht, Sugar solution — Hm, Smoke — Hm
(ii) Brass — Ht, Fog — Ht, Vinegar — Ht, Muddy water — Hm
(iii) Copper sulfate solution — Hm, Salt solution — Hm, Milk — Hm, Bronze — Hm
(iv) Muddy water — Ht, Milk — Ht, Blood — Ht, Brass — Hm

SOLUTION

Recall the definitions: a homogeneous (Hm) mixture has uniform composition throughout (solutions and alloys); a heterogeneous (Ht) mixture has a visibly non-uniform composition.

Evaluate option (i): Air — Hm ✓ (uniform gas mixture), Milk — Ht ✓ (colloid, not a true solution), Sugar solution — Hm ✓ (true solution). However, Smoke — Hm is wrong: smoke is a colloidal aerosol (solid/liquid particles dispersed in gas), which is heterogeneous → Ht. Option (i) is incorrect.

Evaluate option (ii): Brass — Ht is wrong (brass is a metallic alloy with uniform composition → Hm). Vinegar — Ht is also wrong (vinegar is a dilute acetic acid solution → Hm). Muddy water — Hm is wrong (muddy water is a suspension → Ht). Option (ii) has multiple errors.

Evaluate option (iii): Milk — Hm is wrong (milk is a colloid, not a true solution — it is heterogeneous → Ht). So option (iii) has an error.

Evaluate option (iv): Muddy water — Ht ✓ (visibly non-uniform suspension), Milk — Ht ✓ (colloidal — heterogeneous), Blood — Ht ✓ (colloidal suspension — heterogeneous), Brass — Hm ✓ (metallic alloy — homogeneous). All four classifications in option (iv) are correct.

Answer: Option (iv): Muddy water — Ht, Milk — Ht, Blood — Ht, Brass — Hm. All four are correctly classified.

Q2 Choose the correct options, and explain the reason for the correct and incorrect options.

Which among the following mixtures show the Tyndall Effect? A mixture of:

(a) air and dust particles

(b) copper sulfate and water

(c) starch and water

(d) acetone and water

(i) a and b (ii) b and d (iii) a and c (iv) c and d

SOLUTION

The Tyndall effect is the scattering of a beam of light by the dispersed particles in a colloid or suspension. It occurs when the dispersed particles are large enough (1–1000 nm range) to scatter light.

Analyse each mixture:

(a) Air and dust particles — dust particles (colloid/suspension) scatter light → shows Tyndall effect. ✓

(b) Copper sulfate solution in water — $CuSO_4$ dissolves to form a true solution with particle size < 1 nm; particles are too small to scatter light → does NOT show Tyndall effect. ✗

(c) Starch and water — starch forms a colloidal dispersion with particle size 1–1000 nm; colloidal particles scatter light → shows Tyndall effect. ✓

(d) Acetone and water — acetone is completely miscible with water; forms a true solution with particle size < 1 nm → does NOT show Tyndall effect. ✗

Only (a) and (c) show the Tyndall effect. This corresponds to option (iii).

Answer: Option (iii): a and c. Air-dust (colloid/suspension) and starch-water (colloid) scatter light due to their particle sizes in the 1–1000 nm range. $CuSO_4$ solution and acetone-water are true solutions whose sub-nanometre particles cannot scatter light.

Q3 A mixture can be categorised as a solution, a suspension, or a colloid, each possessing distinct properties. Utilise the words or phrases provided in the box to fill in Table 5.2.
Words and Phrases: Large-sized particles; Particles remain evenly distributed; Small-sized particles (less than 1 nm diameter); Moderate-sized particles (1–1000 nm); Settles down when left undisturbed (more than 1000 nm in diameter); Does not settle down; Scatters light; Separates by filtration; Transparent; Salt solution; Milk; Sand in water; Smoke; Heterogeneous mixture; Cannot be separated by filtration; Mud; Butter; Brass.

SOLUTION

Fill in Table 5.2 based on the properties of solutions, suspensions, and colloids:

SOLUTION — Properties:
• Small-sized particles (less than 1 nm diameter)
• Particles remain evenly distributed
• Does not settle down
• Transparent
• Cannot be separated by filtration
SOLUTION — Examples: Salt solution; Brass

SUSPENSION — Properties:
• Large-sized particles (more than 1000 nm in diameter)
• Settles down when left undisturbed
• Separates by filtration
• Heterogeneous mixture
SUSPENSION — Examples: Sand in water; Mud

COLLOID — Properties:
• Moderate-sized particles (1–1000 nm)
• Particles remain evenly distributed
• Does not settle down
• Scatters light (Tyndall effect)
• Cannot be separated by filtration
COLLOID — Examples: Milk; Smoke; Butter

Answer: Solution: small particles (<1 nm), transparent, does not settle, cannot be filtered; examples — salt solution, brass. Suspension: large particles (>1000 nm), settles on standing, separated by filtration; examples — sand in water, mud. Colloid: moderate particles (1–1000 nm), does not settle, scatters light; examples — milk, smoke, butter.

Q4 Solve the following problems:
(i) A cake recipe uses dry ingredients, namely 75 g of sugar for 420 g of all-purpose flour and 5 g of sodium hydrogencarbonate. Express the concentration of each component in the mixture using an appropriate method.
(ii) A brass alloy contains 70% copper by mass. Calculate the quantities of copper and zinc present in 120 g of brass.

SOLUTION

Part (i): Use mass percentage (% m/m) because the mixture consists of solids mixed together.
Total mass of dry ingredients = 75 + 420 + 5 = 500 g

Mass% of sugar = (75 / 500) × 100 = 15.0%
Mass% of flour = (420 / 500) × 100 = 84.0%
Mass% of $NaHCO_3$ = (5 / 500) × 100 = 1.0%

Verification: 15.0 + 84.0 + 1.0 = 100% ✓

Part (ii): Brass = copper + zinc, with copper = 70% by mass.
Mass of copper = 70% of 120 g = (70/100) × 120 = 84 g
Mass of zinc = 120 − 84 = 36 g

Answer: (i) Sugar: 15.0%, All-purpose flour: 84.0%, Sodium hydrogencarbonate: 1.0% (by mass). (ii) Copper: 84 g, Zinc: 36 g (in 120 g of brass).

Q5 The label on a cooking oil pack says one litre (910 g). If this oil is mixed with water, will it form a separate layer? If so, which substance will be on top? How will you separate the two layers? Also, draw the diagram of the apparatus used.

SOLUTION

Determine whether oil and water mix: Cooking oil is non-polar and water is polar — they are immiscible liquids. Therefore they will form two separate layers.

Determine which layer is on top: The density of cooking oil = mass/volume = 910

g / 1000 mL = 0.91 g/mL. The density of water = 1.0 g/mL. Since oil is less dense than water, the oil layer floats on top.

Separation method: Use a separating funnel. The two immiscible layers can be separated because they do not mix and have different densities.

Procedure: Pour the mixture into a separating funnel and allow it to stand undisturbed until two distinct layers form. Open the stopcock to drain the denser lower layer (water) into a beaker. Close the stopcock when the oil–water interface reaches the stopcock. The oil remains in the funnel.

Diagram: A separating funnel consists of a conical funnel with a glass stopcock at the bottom, clamped on a stand. The upper layer (oil) sits above the lower layer (water). A beaker is placed below the stopcock to collect the water layer.

Answer: Yes, oil and water form two separate layers because they are immiscible. Oil (density 0.91 g/mL) floats on top of water (1.0 g/mL). The two layers are separated using a separating funnel by draining the denser water layer from the bottom.

Q6 Assertion (A): Solutions do not exhibit the Tyndall effect.
Reason (R): The particles in solutions are larger than 100 nm, so they cannot scatter light.
Choose the correct option:
(i) Both A and R are true, and R is the correct explanation of A.
(ii) Both A and R are true, but R is not the correct explanation of A.
(iii) A is true, but R is false.
(iv) A is false, but R is true.

SOLUTION

Evaluate Assertion (A): In a true solution, the solute particles are smaller than 1 nm in diameter. Particles this small cannot scatter visible light, so solutions do not show the Tyndall effect. Assertion A is TRUE.

Evaluate Reason (R): The reason states that 'particles in solutions are larger than 100 nm'. This is incorrect — solution particles are actually smaller than 1 nm (< 1 nm). The Tyndall effect is NOT shown by solutions precisely because the particles are TOO SMALL (< 1 nm), not too large. Reason R is FALSE.

So A is true but R is false. This matches option (iii).

Answer: Option (iii): A is true, but R is false. Solutions do not show the Tyndall effect (A is correct), but the reason is wrong — solution particles are smaller than 1 nm (not larger than 100 nm), and it is their very small size that prevents light scattering.

Q7 How would you separate the mixtures given in Table 5.3? Mention the reason for choosing your method. If a mixture cannot be separated, explain why.
Mixtures: Mud from muddy water | Plasma from other components in the blood sample | Naphthalene and sand | Chalk powder and common salt | Common salt and water | Oil from water | Pigments of the flower

SOLUTION

1. Mud from muddy water:
Method: Sedimentation followed by decantation, or filtration.
Reason: Mud particles are large and insoluble in water; they settle on standing (sedimentation) and can be removed by decantation or filtered through filter paper.

2. Plasma from other components in the blood sample:
Method: Centrifugation.
Reason: Blood is a colloidal mixture; the components cannot be separated by ordinary filtration. Centrifugation spins the sample at high speed, causing denser components (red blood cells, white blood cells, platelets) to settle to the bottom, leaving the lighter plasma on top.

3. Naphthalene and sand:
Method: Sublimation.
Reason: Naphthalene sublimes (converts directly from solid to vapour) on gentle heating, while sand does not sublime. The naphthalene vapour is collected on a cold surface, leaving sand behind.

4. Chalk powder and common salt:
Method: Filtration followed by evaporation.
Reason: Common salt dissolves in water but chalk powder ($CaCO_3$) does not. Add water to dissolve the salt, filter the mixture to collect chalk powder on the filter paper, then evaporate the filtrate to recover the salt.

5. Common salt and water:
Method: Evaporation or distillation.
Reason: Salt is a non-volatile solute. On evaporation, water turns to vapour and

escapes, leaving salt behind. Distillation is used if pure water also needs to be recovered.

6. Oil from water:
Method: Separating funnel.
Reason: Oil and water are immiscible liquids that form two distinct layers. A separating funnel allows the denser water layer to be drained from the bottom, leaving oil in the funnel.

7. Pigments of the flower:
Method: Paper chromatography.
Reason: The pigments in flowers are a mixture of different coloured compounds with different solubilities in a solvent. As the solvent moves up the chromatography paper, different pigments travel different distances and separate into distinct bands.

Answer: Mud from muddy water — filtration/sedimentation; Plasma — centrifugation; Naphthalene and sand — sublimation; Chalk and salt — filtration then evaporation; Common salt and water — evaporation/distillation; Oil and water — separating funnel; Flower pigments — paper chromatography.

Q8 Two miscible liquids, A and B, are present in a mixture. The boiling point of A is 60 °C and the boiling point of B is 90 °C. Suggest a method to separate them. Also, draw a labelled diagram of the method suggested.

SOLUTION

Since A and B are miscible liquids with different boiling points (60 °C and 90 °C), simple distillation may not be effective if the boiling points are close. However, with a difference of 30 °C, fractional distillation is the appropriate method for reliable separation.

Method: Fractional distillation.

Principle: When the mixture is heated, both liquids vaporise, but the more volatile liquid A (lower boiling point, 60 °C) vaporises preferentially. The vapours pass through a fractionating column packed with glass beads or rings. The less volatile liquid B (90 °C) condenses and flows back, while the vapours of A pass through and are collected after condensation in a condenser.

Procedure:
1. Place the mixture in a round-bottom flask fitted with a fractionating column.

2. Heat the flask — liquid A (BP 60 °C) vaporises first and rises through the fractionating column.
3. The vapours of A pass through the condenser and are collected as the first distillate.
4. Continue heating; once A is fully collected, the temperature rises to 90 °C and liquid B distils over.

Labelled diagram components: Round-bottom flask (mixture), fractionating column, thermometer (at column top), condenser (water in/water out), collection flask (distillate).

Answer: Fractional distillation. The mixture is heated in a round-bottom flask with a fractionating column; liquid A (BP 60 °C) distils first and is collected separately, followed by liquid B (BP 90 °C).

Q9 Compare evaporation, crystallisation and distillation. In which situation, would you prefer each of these over the others?

SOLUTION

Evaporation: The solvent (usually water) is converted to vapour by heating, leaving the non-volatile solute behind as a dry solid. The solvent is lost to the atmosphere.
Prefer evaporation when: Only the solid solute needs to be recovered and the solvent is not required, AND the solute does not decompose on heating (e.g., recovering common salt from sea water on a large scale).

Crystallisation: A hot saturated solution is prepared and then allowed to cool slowly. As the solution cools, the solubility decreases and the excess solute comes out of solution as well-formed pure crystals.
Prefer crystallisation when: Pure, well-shaped crystals of the solute are required, OR the solute would decompose if heated to dryness (e.g., purifying copper sulfate or alum from impure samples, as simple evaporation to dryness would decompose copper sulfate).

Distillation: The mixture is heated until the solvent vaporises; the vapour is then cooled in a condenser and collected as pure liquid.
Prefer distillation when: The pure solvent also needs to be recovered along with the solute, OR two miscible liquids with different boiling points need to be separated (e.g., separating water from acetone, or obtaining pure distilled water).

Key distinctions: Evaporation discards the solvent; distillation recovers both solvent and solute; crystallisation gives purer solid product than evaporation to dryness.

Answer: Evaporation is preferred when only the solid solute is needed. Crystallisation is preferred when pure crystals of solute are required or the solute would decompose on strong heating. Distillation is preferred when the pure solvent must also be recovered, or to separate two miscible liquids.

Q10 Blood is an example of a colloidal mixture. (i) What would happen if blood behaved like a true suspension inside the body? (ii) In a blood sample, identify the dispersed phase and the dispersion medium.

SOLUTION

Part (i): If blood behaved like a true suspension:
In a true suspension, the dispersed particles are very large (>1000 nm) and settle down under gravity when left undisturbed. If blood behaved like a true suspension, the blood cells (red blood cells, white blood cells, platelets) would settle to the bottom of the blood vessels due to gravity instead of remaining uniformly distributed. This would mean the cells would not circulate effectively through the body. Oxygen delivery to tissues would fail, and the blood could not perform its transport functions. Such a condition would be life-threatening.

Part (ii): Dispersed phase and dispersion medium in blood:
Blood plasma is the continuous liquid part.
The blood cells (red blood cells, white blood cells, platelets) are the dispersed particles.
Therefore:
Dispersed phase = blood cells (and proteins such as haemoglobin)
Dispersion medium = blood plasma (an aqueous solution)

Answer: (i) If blood were a true suspension, blood cells would settle to the bottom of the vessels and could not circulate, making oxygen transport impossible — a fatal condition. (ii) Dispersed phase = blood cells (RBCs, WBCs, platelets); dispersion medium = blood plasma.

Q11 You are given a mixture of sand, common salt and naphthalene (Fig. 5.25a). The Fig. 5.25b depicts various steps (labelled 1, 2, 3) used to separate the components of this mixture. Identify and write down the correct sequence of separation techniques.

SOLUTION

The mixture contains three components: sand (insoluble solid), common salt (soluble solid), and naphthalene (sublimable solid).

Reading Fig. 5.25(b):
Step 1 shows a heating setup (china dish or evaporating dish with gentle heat and an inverted funnel with cotton plug) — this is sublimation to remove naphthalene.
Step 2 shows filtration through filter paper in a funnel — this separates insoluble sand from the salt solution.
Step 3 shows an evaporating dish with a flat surface and crystals visible — this is evaporation to recover common salt from the filtrate.

However, to perform filtration, the salt must first be dissolved in water. So water is added after sublimation to dissolve the salt, and then the mixture of salt water + sand is filtered.

Correct sequence:
Step 1 — Sublimation: Heat the mixture gently. Naphthalene sublimes and is collected on the cold inner surface of an inverted funnel, leaving behind sand and common salt.
Step 2 — Filtration: Add water to the sand-salt residue. Common salt dissolves in water. Filter the mixture — sand is collected on the filter paper and the salt solution (filtrate) passes through.
Step 3 — Evaporation: Heat the salt solution (filtrate) to evaporate water. Common salt is recovered as the residue.

Answer: Correct sequence: Sublimation (Step 1, removes naphthalene) → Filtration (Step 2, separates sand from salt solution) → Evaporation (Step 3, recovers common salt from solution).

Q12 Why is distillation an effective method for separating a mixture of water and acetone?

SOLUTION

Water and acetone are completely miscible liquids — they mix in all proportions and cannot be separated by filtration or by using a separating funnel.

Distillation is effective because the two liquids have significantly different boiling points:

• Boiling point of acetone = 56 °C

• Boiling point of water = 100 °C

Difference = 44 °C

When the mixture is heated, acetone (lower boiling point) vaporises preferentially at around 56 °C. The acetone vapour passes into the condenser where it is cooled back to liquid and collected separately. The water remains in the flask until the temperature rises to 100 °C.

The large difference in boiling points (44 °C) ensures clean separation without the vapours contaminating each other significantly, making simple distillation (or fractional distillation) highly effective for this pair.

Answer: Water (BP 100 °C) and acetone (BP 56 °C) are miscible but have a 44 °C difference in boiling points. On heating the mixture, acetone vaporises first, is condensed in the condenser, and collected separately — giving a clean separation by distillation.

Q13 Answer the following questions with the help of the data given in Table 5.4 (Solubility of various salts in g per 100 g of water at different temperatures):
Table 5.4 — KNO3: 10°C=21, 20°C=32, 30°C=45, 40°C=62, 60°C=106, 80°C=167; NaCl: 10°C=36, 20°C=36, 30°C=36.3, 40°C=36.5, 60°C=37, 80°C=37; KCl: 10°C=35, 20°C=35, 30°C=37.4, 40°C=40, 60°C=46, 80°C=54; NH4Cl: 10°C=24, 20°C=37, 30°C=41, 40°C=41, 60°C=55, 80°C=66.
(i) What mass of potassium nitrate would be needed to prepare its saturated solution in 50 g of water at 40 °C?
(ii) A student makes a saturated solution of potassium chloride in water at 80 °C and leaves the solution to cool at room temperature (25 °C). What would she observe as the solution cools? Explain.
(iii) What is the effect of a change in temperature on the solubility of salts? Also, compare the changes in the solubility of the four given salts with increasing temperature from 10 °C to 80 °C.

SOLUTION

Part (i): KNO3 saturated solution in 50 g water at 40 °C.
From Table 5.4: solubility of KNO3 at 40 °C = 62 g per 100 g of water.
For 50 g of water: mass of KNO3 = (62 / 100) × 50 = 31 g.
Answer: 31 g of KNO3 is needed.

Part (ii): KCl saturated at 80 °C, cooled to room temperature (25 °C).
From Table 5.4: solubility of KCl at 80 °C = 54 g per 100 g water.
Solubility of KCl at 20 °C = 35 g/100 g water; at 30 °C = 37.4 g/100 g water.
By interpolation, solubility at 25 °C ≈ 35 + (37.4 − 35) × (25 − 20)/(30 − 20) = 35 + 1.2 = 36.2 g/100 g water.
At 80 °C, the solution holds 54 g KCl per 100 g water. On cooling to 25 °C, the solution can only hold about 36.2 g. The excess = 54 − 36.2 ≈ 17.8 g per 100 g water crystallises out.
Observation: As the solution cools, crystals of potassium chloride will appear (the solution becomes turbid and solid KCl deposits form at the bottom of the container).

Part (iii): Effect of temperature on solubility.
Generally, the solubility of solid solutes in water increases with increasing temperature.

Comparing the four salts from 10 °C to 80 °C:
• KNO3 shows the greatest increase: 21 g → 167 g (increase of 146 g) — highly

temperature-sensitive.
• NH_4Cl shows a moderate increase: 24 g → 66 g (increase of 42 g).
• KCl shows a moderate increase: 35 g → 54 g (increase of 19 g).
• NaCl shows almost no change: 36 g → 37 g (increase of only 1 g) — nearly temperature-independent.

Conclusion: KNO_3 is the most temperature-sensitive salt; NaCl solubility is nearly constant with temperature. All four salts show some increase in solubility with temperature, but the degree of change varies greatly.

Answer: (i) 31 g of KNO_3. (ii) KCl crystals will form as the solution cools from 80 °C to 25 °C (≈17.8 g crystallises per 100 g water). (iii) Solubility of all four salts increases with temperature; KNO_3 shows the largest increase (146 g/100 g water from 10 to 80 °C), NaCl shows almost no change (only ~1 g increase).

Q14 Three students, A, B and C, are preparing sugar solutions for an experiment:
- Student A dissolves 20 g of sugar in 80 g of water.
- Student B dissolves 20 g of sugar in 100 g of water.
- Student C dissolves 30 g of sugar in 80 g of water.
(i) Calculate the mass percentage (% m/m) concentration of sugar in each student's solution.
(ii) Whose solution is the most concentrated? Explain why.

SOLUTION

Formula: Mass percentage = (mass of solute / mass of solution) × 100
Mass of solution = mass of solute + mass of solvent.

Student A: mass of solution = 20 + 80 = 100 g
% m/m = (20 / 100) × 100 = 20.0%

Student B: mass of solution = 20 + 100 = 120 g
% m/m = (20 / 120) × 100 = 16.67%

Student C: mass of solution = 30 + 80 = 110 g
% m/m = (30 / 110) × 100 = 27.27%

Verification: C > A > B in concentration order (27.27 > 20.0 > 16.67) ✓

Answer: (i) Student A: 20.0%, Student B: 16.67%, Student C: 27.27%. (ii) Student C has the most concentrated solution (27.27%) because they dissolved the most sugar (30 g) in the least amount of water (80 g), giving the highest mass of solute per unit mass of solution.

Q15 Examine Fig. 5.26.
(i) Identify the separation technique marked as 'S'.
(ii) Label the apparatus A, B and C.
(iii) Which of the following mixtures can be separated by the technique identified above? Use the data given in Table 5.5.
Mixtures: (a) water — acetone, (b) water — salt, (c) acetone — alcohol, (d) sand — salt, (e) alcohol — chloroform, (f) alcohol — benzene.
Table 5.5: Boiling points — Water: 100 °C, Acetone: 56 °C, Alcohol: 78 °C, Chloroform: 61 °C, Benzene: 80 °C.

SOLUTION

Part (i): From Fig. 5.26, the apparatus shows a round-bottom flask heated from below, a vertical fractionating column (S), and a condenser. The technique marked 'S' is the fractionating column, and the overall technique is fractional distillation.

Part (ii): Labelling from the figure:
A = Round-bottom flask (contains the liquid mixture to be separated, placed on the heat source)
B = Fractionating column (marked as S — the column packed with glass beads/rings that allows efficient vapour-liquid equilibration)
C = Condenser (the slanted tube where vapour is cooled by surrounding water to form liquid distillate)

Part (iii): Fractional distillation is used to separate miscible liquids with different boiling points.
The technique requires both components to be liquids (miscible) and to have different boiling points.

Evaluate each mixture using Table 5.5 boiling points:
(a) Water (100 °C) — Acetone (56 °C): Both miscible liquids, BP difference = 44 °C → CAN be separated by fractional distillation. ✓
(b) Water — Salt: Salt is a solid (ionic compound), not a liquid. Fractional distillation does not apply — use evaporation or distillation. ✗

(c) Acetone (56 °C) — Alcohol (78 °C): Both miscible liquids, BP difference = 22 °C → CAN be separated by fractional distillation. ✓
(d) Sand — Salt: Both are solids — fractional distillation does not apply. ✗
(e) Alcohol (78 °C) — Chloroform (61 °C): Both miscible liquids, BP difference = 17 °C → CAN be separated by fractional distillation (needs an efficient column due to smaller difference). ✓
(f) Alcohol (78 °C) — Benzene (80 °C): Both miscible liquids, BP difference = only 2 °C — too close to be separated practically by fractional distillation. ✗

Answer: (i) The technique marked S is the fractionating column; the overall method is fractional distillation. (ii) A = round-bottom flask, B = fractionating column (S), C = condenser. (iii) Mixtures separable by fractional distillation: (a) water-acetone (BP diff 44 °C), (c) acetone-alcohol (BP diff 22 °C), (e) alcohol-chloroform (BP diff 17 °C). Not separable: (b) water-salt (salt is a solid), (d) sand-salt (both solids), (f) alcohol-benzene (BP diff only 2 °C).