Answer all the questions below then check your answers

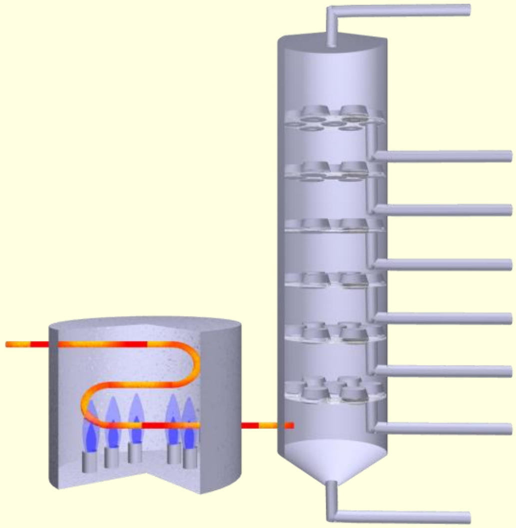
1. Define the term (a) crude oil and (b) fraction, as used in oil refining. (4 marks)

2. Explain why crude oil is separated into fractions rather than used directly. In your answer, refer to the composition of crude oil and the properties of hydrocarbons. (4 marks)

3. Describe how the temperature changes inside a fractionating column and explain how this allows hydrocarbons of different boiling points to be separated. (5 marks)

4. A student says: "Fractions are pure substances with a single boiling point." Explain why this statement is incorrect. (3 marks)

5. The diagram opposite represents a simplified fractionating column.



(a) Where would you expect refinery gases to be collected? (1 mark)

(b) Where would you expect bitumen to be collected? (1 mark)

(c) Explain your answers in terms of boiling point and molecular size. (4 marks)

6. State and explain the trend in boiling point across a series of alkanes as chain length increases. (4 marks)

7. Kerosene (paraffin) is collected part-way up a fractionating column.
(a) Explain why kerosene condenses at this height rather than at the top of the column. (3marks)
(b) Give two uses of kerosene. (2 marks)

8. Crude oil is heated before it enters the fractionating column.
(a) Explain why most of the crude oil is vaporised before entering the column. (2 marks)
(b) Some of the crude oil is not vaporised and collects at the bottom. Explain why. (2 marks)

9. A refinery increases the temperature at the base of the fractionating column.
Predict and explain one effect this could have on where a particular fraction condenses/gets collected. (3 marks)

10. A fraction contains hydrocarbons with 10–14 carbon atoms per molecule.
(a) Predict whether this fraction would be more volatile or less volatile than a fraction containing hydrocarbons with 3–4 carbon atoms per molecule. (1 mark)
(b) Explain your answer. (3 marks)

11. Explain what is meant by the term volatility and describe the relationship between volatility and boiling point for hydrocarbons. (3 marks)

12. Extended response: Using the ideas of intermolecular forces and molecular size, explain why crude oil can be separated by fractional distillation. (6 marks)

Answers

1. (a) Crude oil: a naturally occurring mixture of hydrocarbons (and small amounts of other compounds) extracted from the ground. (b) Fraction: a mixture of hydrocarbons collected over a narrow boiling point range / containing hydrocarbons of similar chain length and similar boiling points. (4)

2. Crude oil is a complex mixture containing many hydrocarbons with different chain lengths and properties. Different hydrocarbons have different boiling points/volatility and therefore different uses (fuels, lubricants, feedstocks). Separating allows useful products to be obtained and matched to required properties. (4)

3. Column is hot at the bottom and cooler towards the top (temperature gradient). Vapours rise; when they reach a region where the temperature is below their boiling point they condense. High-boiling (less volatile, larger) hydrocarbons condense lower down; low-boiling (more volatile, smaller) hydrocarbons rise higher before condensing. (5)

4. Fractions are mixtures, not pure substances. They contain many different hydrocarbons with similar (not identical) chain lengths, so they boil over a range rather than a single sharp boiling point. (3)

5. (a) Refinery gases: collected at/near the top (coolest region). (1)
(b) Bitumen: collected at the bottom/residue. (1)
(c) Refinery gases have very small molecules → low boiling points → remain as vapour until high up where it’s cool enough to condense (or are drawn off as gases). Bitumen has very large molecules → very high boiling points → condense low down or may not vaporise at all and remain as residue. (4)

6. Boiling point increases as chain length increases. Longer chains have larger surface area and more electrons, leading to stronger London dispersion forces (instantaneous dipole–induced dipole). More energy is required to overcome these forces, so boiling point rises. (4)

7. (a) Kerosene has a higher boiling point than fractions collected at the top, so it needs a warmer region to condense; it condenses where the column temperature falls just below its boiling point. (3)
(b) Uses: aviation fuel/jet fuel; heating; lamps; solvents (any two). (2)

8. (a) Vaporising most of the crude oil ensures components can rise and separate by repeated evaporation/condensation in the column. (2)

(b) The largest molecules have very high boiling points, so at the furnace temperature they may not vaporise; they remain liquid and collect as residue at the bottom (bitumen/greases). (2)

9. Higher base temperature may vaporise more of the heavier fractions. As a result, a heavier fraction could rise further before condensing, so it may be collected higher up than before (or yield of lighter fractions may increase). (3)

10. (a) Less volatile. (1)
(b) C10–C14 molecules are larger → stronger London forces → higher boiling point → evaporate less easily at room temperature, so lower volatility. (3)

11. Volatility: how easily a liquid evaporates (tendency to form vapour). More volatile hydrocarbons have lower boiling points; less volatile hydrocarbons have higher boiling points. (3)

12. Hydrocarbons differ in molecular size/chain length. Intermolecular forces between hydrocarbon molecules are mainly London dispersion forces. These forces get stronger as molecules get larger (greater surface area/more electrons). Therefore larger molecules have higher boiling points and are less volatile; smaller molecules have lower boiling points and are more volatile. In a fractionating column with a temperature gradient, vapours rise and condense at different heights depending on boiling point, allowing separation into fractions (mixtures with similar boiling points). (6)