S5 Chemistry Practice Paper (Set 3) | Isomerism, functional group tests, esterification yield, saponification value, polymerisation, combustion analysis

S5 Chemistry | Time allowed: 75 minutes | Total: 100 marks | 24 questions

Section A: Structural isomers

Question 1 (16 marks)

1. Give the names of all the structural isomers of C4H10 and state how many there are. (4 marks)

> **Answer:** C4H10 has 2 structural isomers: butane (straight chain) and 2-methylpropane (branched).

2. Give the names of all the structural isomers of C5H12 and state how many there are. (4 marks)

> **Answer:** C5H12 has 3: pentane, 2-methylbutane and 2,2-dimethylpropane.

3. How many chain compounds with molecular formula C4H8 contain one C=C bond, counting cis-trans isomers? Name each one. (4 marks)

> **Answer:** There are 4: but-1-ene, cis-but-2-ene, trans-but-2-ene and 2-methylprop-1-ene.

4. Explain why 2-methylprop-1-ene does not show cis-trans isomerism. (4 marks)

> **Answer:** Cis-trans isomerism requires each carbon of the C=C bond to carry two different groups. The terminal carbon (C1) of 2-methylprop-1-ene carries two identical hydrogen atoms, so the requirement fails.

Section B: Identifying functional groups

Question 2 (16 marks)

5. Bromine water is decolourised rapidly when compound A is added. State the functional group in A. (4 marks)

> **Answer:** A carbon-carbon double bond (C=C, an alkene); addition across the double bond decolourises bromine water.

6. Bubbles are seen when compound B is added to sodium hydrogencarbonate solution. State the functional group in B and the formula of the gas released. (4 marks)

> **Answer:** A carboxyl group (-COOH); carbon dioxide (CO2) is released: R-COOH + NaHCO3 -> R-COONa + H2O + CO2.

7. Compound C gives an orange-red precipitate with 2,4-dinitrophenylhydrazine. State the functional group in C and describe how an aldehyde can be distinguished from a ketone. (4 marks)

> **Answer:** A carbonyl group (C=O, aldehyde or ketone). Warm with Tollens reagent: an aldehyde gives a silver mirror while a ketone does not; Fehling solution gives a brick-red precipitate only with an

aldehyde.

8. Compound D, warmed with ethanol and a little concentrated sulphuric acid, gives a liquid with a fruity smell. Name the reaction and state the functional groups required in the reactants. (4 marks)

Answer: Esterification; D must contain a carboxyl group (-COOH) and ethanol supplies the hydroxyl group (-OH). Concentrated sulphuric acid acts as a catalyst and removes the water formed.

Section C: Esterification and percentage yield

Question 3 (16 marks)

9. Calculate the number of moles in 12.0 g of ethanoic acid. (Relative atomic masses: C = 12.0, H = 1.0, O = 16.0) (4 marks)

Answer: Molar mass of CH3COOH = 60.0 g mol-1; moles = 12.0 / 60.0 = 0.200 mol.

10. If the ethanoic acid were completely esterified, what mass of ethyl ethanoate would be formed? (4 marks)

Answer: The ratio is 1:1, so 0.200 mol of ethyl ethanoate forms; with molar mass 88.0 g mol-1 the mass is 0.200 x 88.0 = 17.6 g.

11. The experiment actually gives 13.2 g of ethyl ethanoate. Calculate the percentage yield. (4 marks)

Answer: Percentage yield = 13.2 / 17.6 x 100 = 75.0 percent.

12. Suggest two ways to increase the yield of the ester and explain each briefly. (4 marks)

Answer: First, use excess ethanol so the equilibrium shifts to the products. Second, distil off the ester or the water formed so the equilibrium keeps shifting to the right (esterification is reversible).

Section D: Saponification value and fats

Question 4 (16 marks)

13. 2.00 g of a fat is completely saponified by 24.0 cm3 of 0.500 mol dm-3 potassium hydroxide solution. Calculate the number of moles of KOH used. (4 marks)

Answer: Moles = 0.500 x 24.0 / 1000 = 0.0120 mol.

14. Calculate the saponification value of the fat in mg of KOH per gram. (K = 39.1, O = 16.0, H = 1.0) (4 marks)

Answer: Molar mass of KOH = 56.1 g mol-1, so mass = 0.0120 x 56.1 = 0.6732 g; saponification value = 0.6732 / 2.00 x 1000 = 337 mg KOH g-1.

15. The fat is a triglyceride and needs three KOH units per molecule for saponification. Estimate its average molar mass. (4 marks)

Answer: Moles of fat = 0.0120 / 3 = 0.0040 mol; average molar mass = 2.00 / 0.0040 = 500 g mol-1.

16. Explain how soap removes greasy dirt from cloth. (4 marks)

> **Answer:** A soap molecule has a long hydrocarbon tail (oil-soluble) and a carboxylate head (water-soluble). The tails dissolve in the grease while the heads face the water, emulsifying the grease into tiny droplets that are carried away by the water.

Section E: Addition and condensation polymerisation

Question 5 (16 marks)

17. Write the addition polymerisation of prop-1-ene (propene) and draw the repeat unit of the polymer. (4 marks)

> **Answer:** n CH2=CH-CH3 -> [-CH2-CH(CH3)-]n, poly(propene); the repeat unit is -CH2-CH(CH3)-.

18. A sample of poly(propene) has a relative molecular mass of 1.26 x 10^5 and the repeat unit has molar mass 42.0 g mol-1. Calculate the degree of polymerisation. (4 marks)

> **Answer:** Degree of polymerisation = 1.26 x 10^5 / 42.0 = 3000.

19. How does the polymerisation of poly(propene) differ from that of nylon-6,6? (4 marks)

> **Answer:** Poly(propene) forms by addition polymerisation of a monomer containing C=C with no small molecule lost; nylon-6,6 forms by condensation polymerisation of hexane-1,6-diamine with hexanedioic acid, losing one water molecule per amide link formed.

20. Write the structure of the amide linkage in nylon-6,6 and name the other product of the condensation. (4 marks)

> **Answer:** The amide linkage is -CO-NH-, formed from -COOH and -NH2 with loss of water; the other product is water (H2O).

Section F: Combustion analysis and molecular formula

Question 6 (20 marks)

21. 0.580 g of an organic compound containing C, H and O is burnt completely to give 1.320 g of CO2 and 0.540 g of H2O. Calculate the moles of carbon and of hydrogen in the sample. (5 marks)

> **Answer:** n(C) = 1.320 / 44.0 = 0.0300 mol; n(H) = 2 x 0.540 / 18.0 = 0.0600 mol.

22. Calculate the moles of oxygen and hence deduce the empirical formula. (5 marks)

> **Answer:** m(C) = 0.360 g and m(H) = 0.060 g, so m(O) = 0.580 - 0.360 - 0.060 = 0.160 g and n(O) = 0.160 / 16.0 = 0.0100 mol. C:H:O = 3:6:1, so the empirical formula is C3H6O.

23. Mass spectrometry gives a relative molecular mass of 58. Deduce the molecular formula. (5 marks)

> **Answer:** The empirical formula C3H6O has mass 3 x 12 + 6 x 1 + 16 = 58 g mol-1, equal to the relative molecular mass, so the molecular formula is C3H6O.

24. C3H6O has two isomers, propanal and propan-2-one (propanone). Describe one chemical test that distinguishes them and give the observations. (5 marks)

Answer: Both give an orange-red precipitate with 2,4-dinitrophenylhydrazine, so warm with Tollens reagent (or Fehling solution): propanal gives a silver mirror (a brick-red precipitate with Fehling), while propanone gives no reaction.
