Quiz (Preparation, Separation and Purification)

1. When 5.0 cm^3 of pure ethanol (density = 0.8 g cm^{-3}) is oxidized by excess acidified potassium dichromate solution, 3.32 g of ethanoic acid is obtained. Calculate the percentage yield of ethanoic acid.
(Relative atomic masses: H = 1.0, C = 12.0, O = 16.0)

2. 5.00 g of ethanoic acid and 5.00 g of ethanol are mixed and heated in the presence of an acid under reflux for two hours. The resultant mixture is then treated to separate the ester. The mass of ester obtained after distillation is 5.50 g.

(a) Write an equation for the reaction.
(b) Name the ester formed in the reaction.
(c) Which reactant is in excess? Show your calculation.
(d) Calculate the theoretical mass of the ester produced.
(e) Calculate the percentage yield of the ester.
(Relative atomic masses: H = 1.0, C = 12.0, O = 16.0)

3. To convert pentan-3-ol to 3-bromopentane, a student plans to perform dehydration of pentan-3-ol to give pent-2-ene first. Then pent-2-ene is converted to 3-bromopentane through an addition reaction. Her teacher comments that she can actually carry out the conversion in a single step.

(a) Suggest the reagent and condition for the dehydration reaction involved.
(b) Name the type of addition reaction for the second step of the plan.
(c) Name the type of reaction involved for the single-step conversion.
(d) Write a chemical equation for the single-step conversion.
(e) Apart from being a single-step reaction, suggest ONE advantage of using the reaction in (d) for the conversion. Explain briefly.

4. When 7.0 cm^3 of pure butan-1-ol (density = 0.81 g cm^{-3}) was oxidized by excess acidified potassium dichromate solution, 4.80 g of butanoic acid was obtained. The butanoic acid obtained was then mixed with excess ethanol and heated under reflux for three hours. The resultant mixture was treated so that an ester was obtained. The mass of ester obtained after distillation was 3.40 g.
(Relative atomic masses: H = 1.0, C = 12.0, O = 16.0)

(a) Calculate the percentage yield of butanoic acid.
(b) Give the systematic name of the ester obtained.
(c) Calculate the percentage yield of ester from the second reaction.
(d) Calculate the overall yield of the whole process.

Suggested Answer

1. The overall equation is:

   $3CH_3CH_2OH + 2Cr_2O_7^{2-} + 16H^+ \longrightarrow 3CH3COOH + 4Cr^{3+} + 11H_2O$

   Mass of ethanol used = 5.0 × 0.8 = 4.0 g

   Number of moles of ethanol used = 4.0 / (12.0×2 + 1.0×6 + 16.0×1) = 0.087 mol

   From the equation, mole ratio of ethanol to ethanoic acid is 1 : 1,

   ∴ number of moles of ethanoic acid obtained = 0.087 mol

   Theoretical mass of ethanoic acid obtained
   = 0.087 × (12.0×2 + 16.0×2 + 1.0×4)
   = 5.22 g

   Percentage yield of ethanoic acid = (3.32 / 5.22) × 100% = 63.6%

2. (a) $CH_3COOH(l) + CH_3CH_2OH(l) \leftrightarrows CH_3COOCH_2CH_3(l) + H_2O(l)$

   (b) Ethyl ethanoate

   (c) Number of moles of CH_3CH_2OH
   = 5.00 / (12.0×2 + 1.0×6 + 16.0)
   = 0.109 mol

   Number of moles of CH_3COOH
   = 5.00 / (12.0×2 + 1.0×4 + 16.0×2)
   = 0.0833 mol

   From the equation, 0.0833 mole of CH_3COOH only requires 0.0833 mole of CH_3CH_2OH for reaction. Hence, CH_3CH_2OH is in excess.

   (d) From the equation, mole ratio of CH_3COOH to $CH_3COOCH_2CH_3$ = 1 : 1.

   ∴ number of moles of $CH_3COOCH_2CH_3$ formed = 0.0833 mol

   Theoretical mass of $CH_3COOCH_2CH_3$ formed
   = 0.0833 × (12.0×4 + 1.0×8 + 16.0×2)
   = 7.33 g

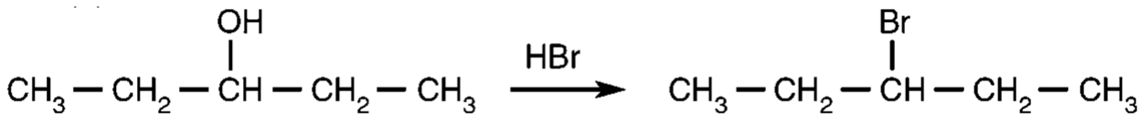
   (e) Percentage yield of $CH_3COOCH_2CH_3$ = (5.50 / 7.33) × 100% = 75.0%

3. (a) Conc. H_2SO_4, heat **OR** Al_2O_3, heat

   (b) Hydrohalogenation

   (c) Substitution reaction

   (d)



   (e) The reaction in (d) forms 3-bromopentane only. 2-bromopentane also forms if the synthetic route suggested by the student is used.
   OR The reaction in (d) has a higher percentage yield of 3-bromopentane.

4. (a) Number of moles of butan-1-ol used
   $= 7.0 \times 0.81 / (12.0\times4 + 1.0\times10 + 16.0)$
   $= 0.0766$ mol

   Number of moles of butanoic acid formed = 0.0766 mol

   Theoretical mass of butanoic acid formed
   $= 0.0766 \times (12.0\times4 + 1.0\times8 + 16.0\times2)$ g
   $= 6.74$ g

   $\therefore$ percentage yield of butanoic acid $= (4.80 / 6.74) \times 100\% = 71.2\%$

   (b) Ethyl butanoate

   (c) Number of moles of butanoic acid used
   $= 4.80 / (12.0\times4 + 1.0\times8 + 16.0\times2)$
   $= 0.0545$ mol

   Number of moles of the ester formed = 0.0545 mol

   Theoretical mass of the ester formed
   $= 0.0545 \times (12.0\times6 + 1.0\times12 + 16.0\times2)$
   $= 6.32$ g

   $\therefore$ percentage yield of the ester formed $= (3.40 / 6.32) \times 100\% = 53.8\%$

   (d) Overall yield of the whole process $= 71.2\% \times 53.8\% = 38.3\%$