UNIT 11

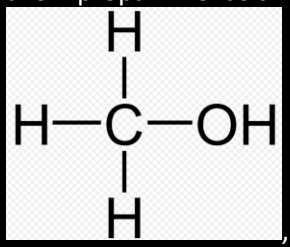
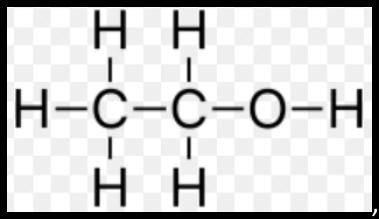
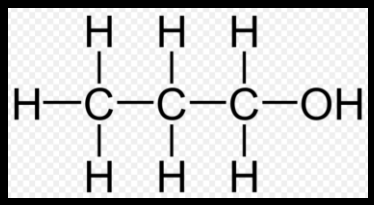
FURTHER ORGANIC CHEMISTRY

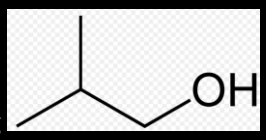
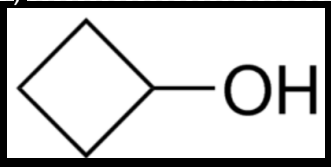
Answers

Lesson 1 – What are alcohols?

Summary Activity 1.1: What are alcohols?

- Methanol (CH_3OH), ethanol (CH_3CH_2OH), propan-1-ol ($CH_3CH_2CH_2OH$) (allow displayed or skeletal formula, allow propan-2-ol as third member)

- Eg  (methylpropane-1-ol); eg  (cyclobutanol)
- Intermolecular attraction between a δ+ve H atom on one molecule and an electronegative atom on an adjacent molecule; alcohols can form hydrogen bonds because the H attached to the O has a partial positive charge and is strongly attracted to the O atom on adjacent molecules
- Alcohols have a higher boiling point than other molecules of similar size; alcohols are likely to be soluble in water
- Beer, wine, cider, whisky, gin etc; they are made by fermenting sugar
- Disinfectants, solvents (students are not expected to know)

Test your knowledge 1.2: Explaining the physical properties and uses of alcohols

(a) Ethanol can form hydrogen bonds between molecules; butane cannot
(b) Ethanol can form hydrogen bonds with water, butane cannot
(c) Butan-1-ol has more electrons per molecule, so more/stronger Van der Waal's forces
(d) Butan-1-ol has a longer alkyl chain (C_3H_7-) which disrupts the hydrogen bonding in water
(e) Solvents, alcoholic drinks

Lesson 2 – How is ethanol made?

Summary Activity 2.1: Distillation and fractional distillation

- Separation of components in a mixture using differences in their boiling point; mixture is boiled and then components rise up the fractionating column; as they do so they cool down; substances with higher boiling points condense first and can be separated out
- Fractional distillation is effective at separating miscible liquids or gases with different boiling points

Test your knowledge 2.2: Understanding fermentation

(a) $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$; CO_2 produced which is a gas
(b) 35 – 55 °C, yeast, no oxygen
(c) Adv: cheap, low technology, low energy, uses renewable raw material; Disadv: slow, batch process, doesn't make pure ethanol
(d) By distillation; mixture is boiled; ethanol boils before water and can be separated, condensed and collected
(e) Presence of methanol (discard first 2 – 3% of distillate); contaminated water (use treated water and hygienic conditions

Summary Activity 2.3: Classifying organic reactions

- A reaction in which one or more atoms are added to an organic molecule but none are removed
- A reaction in which one or more atoms on an organic molecule are replaced by others
- A reaction in which one or more atoms are removed from an organic molecule and not replaced

Test your knowledge 2.4: Understanding hydration

(a) $C_2H_4 + H_2O \rightleftharpoons C_2H_5OH$; 300 °C, 60 atm, conc. H_3PO_4
(b) Adv: faster, continuous, makes purer ethanol; disadv: high cost, high technology; raw material not renewable
(c) But-1-ene and H_2O; addition of H_2O to unsymmetrical alkene like but-1-ene gives two products; the other product is butan-2-ol

Lesson 3 – What are the chemical properties of alcohols?

Test your knowledge 3.1: Classifying alcohols

(a) primary; (b) primary; (c) primary; (d) secondary; (e) primary; (f) primary; (g) primary; (h) tertiary; (i) secondary; (j) primary

Test your knowledge 3.2: Understanding simple reactions of alcohols

(a) $2CH_3CH_2CH_2OH + 2Na \rightarrow 2CH_3CH_2CH_2ONa + H_2$

(b) (i) $CH_3CH_2CH=CH_2$ (but-1-ene) only; (ii) $CH_3CH_2CH=CH_2$ (but-1-ene) and $CH_3CH=CHCH_3$ (but-2-ene) (cis or trans); (iii) $(CH_3)_2CHCH=CH_2$ (3-methylbut-1-ene) only; (iv) $(CH_3)_2C=CHCH_3$ (2-methylbut-2-ene) or $CH_2=C(CH_3)CH_2CH_3$ (2-methylbut-1-ene); (v) cannot be dehydrated – no products possible

Test your knowledge 3.3: Using the iodoform reaction to identify alcohols

(a) no; (b) yes; (c) no; (d) yes; (e) no; (f) no; (g) no; (h) no; (i) yes; (j) no

Lesson 4 – How can we oxidise alcohols?

Test your knowledge 4.1: Understanding the oxidation of alcohols

(a) (i) yes; (ii) yes; (iii) yes; (iv) yes; (v) yes; (vi) yes; (vii) yes; (viii) no; (ix) yes; (x) yes (2-methylbutan-2-ol is a tertiary alcohol; the others are primary or secondary)

(b) methanol, ethanol, butan-1-ol, methylpropan-1-ol, 2-methylbutan-1-ol, 3-methylbutan-1-ol and dimethylpropanol (these are primary alcohols)
$CH_3OH + 2[O] \rightarrow HCOOH + H_2O$; $CH_3CH_2OH + 2[O] \rightarrow CH_3COOH + H_2O$; $CH_3CH_2CH_2CH_2OH + 2[O] \rightarrow CH_3CH_2CH_2COOH + H_2O$; $(CH_3)_2CHCH_2OH + 2[O] \rightarrow (CH_3)_2CHCOOH + H_2O$; $CH_3CH_2CH(CH_3)CH_2OH + 2[O] \rightarrow CH_3CH_2CH(CH_3)COOH + H_2O$; $(CH_3)_2CHCH_2CH_2OH + 2[O] \rightarrow (CH_3)_2CHCH_2COOH + H_2O$; $(CH_3)_3CCH_2OH + 2[O] \rightarrow (CH_3)_3COOH + H_2O$ (allow displayed formulae)

Lesson 5 – What are carboxylic acids?

Test your knowledge 5.1: Introducing carboxylic acids

(a) (i) Propanoic acid - CH_3CH_2COOH; (ii) methylpropanoic acid - $CH_3CH(CH_3)COOH$; (iii) 2-methylbutanoic acid - $CH_3CH_2CH(CH_3)COOH$; (iv) 3-methylbutanoic acid - $(CH_3)_2CHCH_2COOH$; (v) dimethylpropanoic acid - $(CH_3)_3COOH$ (allowed displayed formulae)

(b) Ethanoic acid can form hydrogen bonds with water; the aromatic ring in benzoic acid disrupts the hydrogen bonding between water molecules so does not mix well with water

(c) (i) Preserving food; (ii) preventing bacterial infection; (iii) making polyesters

Summary Activity 5.2: Reactions of acids

- Strong acid completely dissociates in water; eg HCl or HNO or HSO ; weak acid only slightly dissociates in water, eg CH_3 COOH or any carboxylic acid
- $HCl \rightarrow H^+ + Cl^-$; $HCl + NaOH \rightarrow NaCl + H_2O$; $HCl + NaHCO_3 \rightarrow NaCl + CO_2 + H_2O$; these are acid-base or neutralisation reactions
- Salt hydrolysis is the reaction of an anion or cation in a salt with water to give H^+ or OH^- ions; salts of weak acids react with water to give OH^- and salts of weak bases react with water to give H^+; example of a basic salt would be any salt of a weak acid, eg CH_3COONa

Test your knowledge 5.3: Describing acid-base reactions of carboxylic acids

(a) (i) $CH_3CH_2COOH + NaOH \rightarrow CH_3CH_2COONa + H_2O$; (ii) $CH_3CH_2CH_2COOH + NaHCO_3 \rightarrow CH_3CH_2CH_2COONa + CO_2 + H_2O$; (iii) $HCOOH \rightleftharpoons H^+ + HCOO^-$

(b) Add $NaHCO_3$; bubbles will be seen

(c) (i) $CH_3COONa + H_2O \rightleftharpoons CH_3COOH + NaOH$; (ii) $CH_3CH_2COONa + HCl \rightleftharpoons CH_3CH_2COOH + NaCl$

Lesson 6 – What are esters and how are they made?

Test your knowledge 6.1: Understanding esterification and ester hydrolysis

(a) (i) $CH_3CH_2COOH + CH_3OH \rightleftharpoons CH_3CH_2COOCH_3 + H_2O$ (methyl propanoate); (ii) $CH_3COOH + CH_3CH_2CH_2CH_2OH \rightleftharpoons CH_3COOCH_2CH_2CH_2CH_3 + H_2O$ (butyl methanoate); (iii) $HCOOH + CH_3CH_2CH_2OH \rightleftharpoons HCOOCH_2CH_2CH_3 + H_2O$ (propyl methanoate)

(b) Add some ethanoic acid and a few drops of concentrated sulphuric acid and heat; a fruity smell should be detectable

(c) $CH_3COOCH_2CH_3 + H_2O \rightleftharpoons CH_3COOH + CH_3CH_2OH$ (ethanoic acid and ethanol); $CH_3CH_2COOCH_3 + H_2O \rightleftharpoons CH_3CH_2COOH + CH_3OH$ (propanoic acid and methanol); $CH_3CH_2COOCH_2CH_3 + NaOH \rightarrow CH_3CH_2COONa + CH_3CH_2OH$ (sodium propanoate and ethanol); $CH_3COOCH_2CH_2CH_3 + KOH \rightarrow CH_3COOK + CH_3CH_2CH_2OH$ (potassium ethanoate and propan-1-ol)

Lesson 7 – How can we identify simple organic functional groups?

Summary Activity 7.1: Tests for functional groups in organic compounds

- Decolorises bromine water
- Fizzes with NaHCO3
- Gives a fruity smell when warmed with ethanoic acid and concentrated sulphuric acid

Practical 7.1: Observe the characteristic test tube reactions of alkenes, carboxylic acids and alcohols

Equipment needed per group: 15 test tubes, one boiling tube, two test tube racks, access to cyclohexene, ethanol and ethanoic acid, each with its own dropping pipette (20 cm^3 per group), access to; Br_2 water, 0.02 $moldm^{-3}$ $KMnO_4$ in 1 $moldm^{-3}$ H_2SO_4, 0.02 $moldm^{-3}$ $K_2Cr_2O_7$ in 1 $moldm^{-3}$ H_2SO_4, 0.5 $moldm^{-3}$ I_2 in 2.5 moldm KI, 2 $moldm^{-3}$ NaOH, each with its own dropping pipette (10 cm^3 per group) access to concentrated H_2SO_4 with dropping pipette (1 cm^3 per group), access to $NaHCO_3$ with spatula (1 g per group), access to hot water (kettle or water bath)

- These chemicals are hazardous; provide a waste bottle for disposal of the chemicals and then incinerate in line with Ministry guidelines

Organic Compound	Reagents					
	with Br_2	with acidified $KMnO_4$	with acidified $K_2Cr_2O_7$	with $NaHCO_3$	With I_2/NaOH	With concentrated H_2SO_4
cyclohexene	decolorises	decolorises	no change	no change	No precipitate	
ethanol	no change	decolorises	decolorises	no change	pale yellow precipitate	Fruity smell and loss of vinegar smell
ethanoic acid	no change	no change	no change	effervescence	No precipitate	

- For alkene: decolorises bromine water
- For carboxylic acid: effervesces with $NaHCO_3$
- I_2/NaOH only works for alcohols with -$CH(CH_3)OH$ group
- Acidified $K_2Cr_2O_7$ only works for primary and secondary alcohols
- For alcohol: warm with ethanoic acid and concentrated H_2SO_4 – fruity smell produced

Lesson 8 – What are amines and what are their properties?

Test your knowledge 8.1: Introducing amines and amino acids

(a) (i) Butylamine (or 1-aminobutane); (ii) diethylamine (or N-ethyl,aminoethane); (iii) 2-aminopropane

(b) (i) $CH_3NH_2 + CH_3COOH \rightleftharpoons CH_3CONHCH_3 + H_2O$; (ii) $CH_3CH_2NH_2 + CH_3CH_2COOH \rightleftharpoons CH_3CH_2CONHCH_2CH_3 + H_2O$; (iii) $CH_3CH_2CH_2NH_2 + HCOOH \rightleftharpoons HCONHCH_2CH_2CH_3 + H_2O$

(c) Amide or peptide

(d) 2-aminobutanoic acid

(e) (i) $CH_3CH_2CH(NH_2)COOH + HCl \rightarrow CH_3CH_2CH(NH_3Cl)COOH$; (ii) $CH_3CH_2CH(NH_2)COOH + NaOH \rightarrow CH_3CH_2CH(NH_2)COONa + H_2O$; (iii) $2CH_3CH_2CH(NH_2)COOH \rightleftharpoons CH_3CH_2CH(NH_2)CONHCH(C_2H_5)COOH + H_2O$

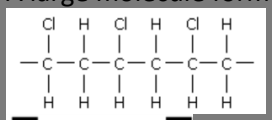
Lesson 9 – What are polymers and plastics and how are they made?

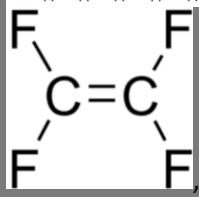
Summary Activity 9.1: Addition and condensation reactions

- Joining of two molecules without loss of any atoms (eg $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$ or any reaction between an alkene and a halogen, halogen halide or H_2O)
- Joining or two organic molecules accompanied by the loss of a small molecule (eg $CH_3COOH + CH_3OH \rightarrow CH_3COOCH_3 + H_2O$ or $CH_3COOH + CH_3NH_2 \rightarrow CH_3CONHCH_3 + H_2O$ or any reaction between a carboxylic acid and an alcohol to make an ester or between a carboxylic acid and an amine to make an amide)
- Alkenes are unsaturated, which means atoms can be added by breaking the C=C bond without have to remove any atoms

Test your knowledge 9.2: Describing addition polymers

(a) A large molecule formed by the joining together of many small molecules

(b) 

(c)  , tetrafluoroethene, polytetrafluoroethene (PTFE)

(d) A material which can be shaped by the action of heat of pressure; thermoplastics can reversibly soften when heated and harden when cooled, as the polymer chains are held together by Van der Waal's forces only; thermosetting plastics are initially soft but become irreversibly hard when heated, as the heating process cases covalent bonds to form between the polymer chains which fix them in place

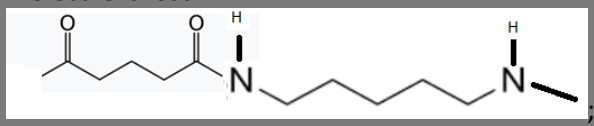
(e) They are non-biodegradable, which means that it is difficult to get rid of them as they cannot be broken down naturally

(f) a solid or viscous liquid which can be converted into a polymer or plastic

Lesson 10 – What are polyesters and polyamides and how are they made?

Test your knowledge 10.1: Describing condensation polymers

(a) They are formed by joining monomers together; each time a new organic molecule joins the chain, a small molecule is lost

(b)  ; condensation polymer (polyamide)

(c)  ; condensation polymer (polyester)

(d) Used in making fibres for clothes and fabrics; they are very strong and can be elastic

(e) Condensation polymers are biodegradable; they are broken down naturally by acids and alkalis, so they do not linger in the environment

(f) A homopolymer is made from a single monomer (eg polyethene or most other addition polymers); a co-polymer is made from more than one monomer

(g) A synthetic polymer is man-made; a natural polymer is naturally occurring

Lesson 11 – What is the chemical composition of food that we eat?

Test your knowledge 11.1: Understanding fats, oils and how we digest them

(a) An ester made by combining glycerol with three fatty acid molecules

(b) Fats contain mostly saturated fatty acids which are straight; this makes the Van der Waal's forces stronger, causing the triglyceride to be solid at room temperature; oils contain mostly cis-unsaturated fatty acids which are bent; this makes the Van der Waal's forces weaker, causing the triglyceride to be liquid at room temperature

(c) By adding hydrogen with a nickel catalyst; the hydrogen adds across the C=C bond which straightens the fatty acid chains

(d) Triglycerides are hydrolysed by lipase into fatty acids (which are used to build cell membanes) and glycerol (which is used as an energy source

Test your knowledge 11.2: Understanding carbohydrates

(a) (i) a carbohydrate consisting of a single ring of carbon and oxygen; (ii) a carbohydrate consisting of two monosaccharides joined together by condensation (iii) a carbohydrate consisting of many monosaccharides joined together by condensation

(b) Plants store glucose by converting it into starch; animals store excess glucose by converting it into glycogen

(c) The polysaccharides are hydrolysed by amylase and broken down into monosaccharides which can be absorbed into the blood and converted into energy

(d) Reducing: glucose, fructose, maltose; non-reducing: sucrose

(e) Reducing sugars will turn Benedict's solution from blue to orange if heated gently for a few minutes

(f) Starch will turn iodine solution from orange to blue-black

Lesson 12 – How can we test for the presence of different nutrients in food?

Test your knowledge 12.1: Understanding proteins

(a) A naturally occurring polymer made up of one or more long chains of amino acids, joined by condensation
(b) Proteins are hydrolysed by protease and broken down into amino acids; the body can use its DNA to convert these amino acids into other useful proteins which it needs
(c) Biuret (blue → purple; any molecule with a peptide link); ninhydrin (colourless → purple; any molecule containing $-NH_2$); xanthoproteic (colourless → yellow; tyrosine or tryptophan or any protein containing them); Millon (colourless → red; any molecule containing a benzene ring with an -OH group on it)

Practical 12.2: Test for protein, starch and reducing sugars in food

Equipment needed per group: a biscuit, an apple and an egg; one mortar, one pestle, one stirring rod, one funnel, three pieces of filter paper, two 100 cm^3 beakers, nine test tubes, one test tube rack, access to a hot water bath (a 250 cm^3 beaker half-full of boiling water is sufficient), access to Benedict's solution with dropping pipette; access to Biuret reagent with dropping pipette, access to 0.5 M iodine solution with dropping pipette (10 cm^3 per group)

- the biscuit should turn iodine solution from brown to blue-black (if this test doesn't work, try adding the iodine solution directly onto the biscuit – a blue-black colour will be visible)
- the biscuit and the apple should turn Benedict's solution from brown to orange
- the egg should turn Biuret solution from blue to purple

		nutrient		
		protein	reducing sugar	starch
Food	biscuit	no	yes	yes
	apple	no	yes	no
	egg	yes	no	no

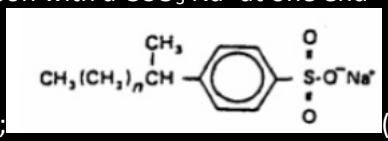
Lesson 13 – What is soap and how is it made?

Summary Activity 13.1: Miscibility of organic compounds in water

- compounds with ionic groups (eg $-COO^-$); also groups which can hydrogen bond (eg -OH, -COOH and $-NH_2$)
- compounds with long hydrocarbon chains or aromatic rings
- compounds with long hydrocarbon chains or aromatic rings (which are least soluble in water) are generally the most soluble in non-polar solvents; compounds with ionic groups and hydrogen bonds (which are most soluble in water) are generally the least soluble in non-polar solvents
- the molecule needs an ionic group AND a long hydrocarbon chain

Test your knowledge 13.2: Understanding soaps and soapless detergents

(a) soap: any long chain hydrocarbon with a COO^-Na^+ at one end; soapless detergent: any long chain hydrocarbon or aromatic hydrocarbon with a $OSO_3^-Na^+$ at one end

eg  (soap);  (soapless detergent)

(b) hydrocarbon chain is hydrophobic and attracts oil and grease molecules; anionic end is hydrophilic and attracts water; hence the oil and water will mix

(c) alkaline hydrolysis of triglycerides (saponification); fat or oil is heated with sodium hydroxide

(d) they are more water soluble so less of it is needed for efficient cleaning; they work well in hard water

(e) they are more biodegradable; they are made from a renewable resource

Lesson 14 – How can we isolate, purify and analyse organic compounds?

Summary Activity 14.1: Separation Techniques

- Using a funnel and filter paper to separate an insoluble solid from a liquid; it only works when the solid is insoluble in the liquid; most insoluble salts (eg $BaSO_4$) can be separated by filtration
- Using a condenser to separate two miscible liquids with different boiling points; it only works when the two liquids have significantly different boiling points; ethanol and water, ethanol and methanol, the components of air and the fractions of crude oil are all separated by distillation
- Separating a solid from a soluble solvent by evaporating off most of the solvent and then cooling the mixture down; most solids are less soluble at lower temperatures; it is an efffective separation technique for removing a non-volatile soluble solid from a solution; most soluble salts such as $CuSO_4$ or $(NH_4)_2SO_4$ are separated from water by crystallisation

Test your knowledge 14.2: Understanding separation and purification techniques

(a) Filter the mixture; the sand is the residue and can be collected; it should be dried in filter paper and then left to dry further in an oven

(b) Heat the mixture in a distillation apparatus; collect the water in a beaker below the end of the condenser

(c) Heat the mixture gently in an evaporating dish until 75% of the water has evaporated; then allow the mixture to cool until crystals form; use a spatula to collect the crystals, dry them in filter paper and then leave them in an oven for a short time to dry further

(d) Dissolve the aspirin in a small quantity of hot water; filter the mixture whilst hot, cool down the distillate and then place the beaker in an ice bath; filter the cold mixture; dry the residue in filter paper and leave to dry further in an oven at low temperature

Test your knowledge 14.3: Determining the molecular formula of an organic compound

(a) $m_r = \frac{mRT}{PV}$ 0.060 $kgmol^{-1}$ = 60 $gmol^{-1}$; moles in 1.00 g = 1/60 = 0.0167; mass of C = 12/44 x 1.47 = 0.40; moles of C = .40/12 = 0.033; 0.033/0.0167 = 2 so 2 C atoms; mass of H = 2/18 x 0.6 = 0.0667; moles of H = 0.0667/1 = 0.0667; 0.0667/0.0167 = 4 so 4 H atoms; 2 x 12 + 4 x 1 = 28; remainder of mr = 60 – 28 = 32 comes from O so 32/16 = 2 O atoms so molecular formula = $C_2H_4O_2$

(b) $m_r = \frac{mRT}{PV}$ = 0.094 $kgmol^{-1}$ = 94 $gmol^{-1}$; moles in 1.00 g = 1/94 = 0.0106; mass of C = 12/44 x 2.81 = 0.766; moles of C = .766/12 = 0.063; 0.063/0.0106 = 6 so 6 C atoms; mass of H = 2/18 x 0.574 = 0.0638; moles of H = 0.0667/1 = 0.0638; 0.0638/0.0106 = 6 so 6 H atoms; 6 x 12 + 6 x 1 = 78; remainder of mr = 94 – 78 = 16 comes from O so 16/16 = 1 O atom so molecular formula = C_6H_6O

Lesson 15 – What have I learned about further organic chemistry?

15.1 END-OF-UNIT QUIZ
UNIT 11 – FURTHER ORGANIC CHEMISTRY

1. Hydrogen bonding between molecules causes stronger intermolecular forces and higher boiling point; hydrogen bonding with water molecules causes miscibility with water
2. (a) by fermentation; 35 – 55 ^{o}C, no oxygen, yeast, $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$
   (b) presence of methanol; discard first 5% of distillate during distillation
3. (a) butan-1-ol and methylpropan-1-ol are primary; propan-2-ol is secondary; methylpropan-2-ol is tertiary
   (b) propan-2-ol
   (c) propan-2-ol, butan-1-ol and methylpropan-1-ol
   (d) butan-1-ol $CH_3CH_2CH_2COOH$, methylpropan-1-ol $CH_3CH(CH_3)COOH$
4. (a) $CH_3CH_2CH_2OH \rightarrow CH_3CH{=}CH_2 + H_2O$
   (b) $2CH_3CH_2CH_2OH + 2Na \rightarrow 2CH_3CH_2CH_2ONa + H_2$
   (c) $CH_3CH_2CH_2OH + CH_3COOH \rightleftharpoons CH_3COOCH_2CH_2CH_3 + H_2O$
5. (a) $CH_3CH_2COOH + NaOH \rightarrow CH_3CH_2COONa + H_2O$
   (b) $2CH_3CH_2COOH + Na_2CO_3 \rightarrow 2CH_3CH_2COONa + CO_2 + H_2O$
   (c) $CH_3CH_2COOH + CH_3OH \rightleftharpoons CH_3CH_2COOCH_3 + H_2O$
6. (a) propan-1-ol and methanoic acid
   (b) propan-1-ol and sodium methanoate (or any methanoate)
7. (a) ethylamine or aminoethane
   (b) 2-aminopropane
   (c) dimethylamine or N-methylaminomethane
8. Addition polymer: made when monomers join together in an addition reaction (ie no small molecule is lost); condensation polymer: made when monomers join together in a condensation reaction (ie a small molecule is lost); co-polymer: do not consist of a single repeating unit (usually addition polymers)
9. (a) $-CH_2CH(CH_3)-$ (also allow displayed or skeletal)
   (b) $-OCH_2CH_2OOC(CH_2)_2CO-$ (also allow displayed or skeletal)
   (c) $-NHCH(CH_3)CO-$
10. Trimester; glycerol joined to three fatty acid molecules by ester links; hydrolysis of lips gives fatty acids and glycerol
11. monosaccharides consist of a single C-O ring (glucose, fructose); disaccharides consist of two adjoining C-O rings (sucrose, maltose), polysaccharides consist of many adjoining C-O rings (eg starch, glycogen, cellulose)
12. one or more chains of amino acids joined together with an amide (peptide) link as a result of a condensation reaction
13. (a) Benedict's or Fehling's solution – blue solution becomes orange precipitate
    (b) iodine – blue-black complex formed
    (c) Biuret's – blue solution turns purple
14. Soap – salt of fatty acid; soapless detergent – sulphonate salt of aromatic or long-chain hydrocarbon; both have a hydrophilic end which binds to water and a hydrophobic end which binds to grease; soap is carbon-neutral and biodegradable; soapless detergents are more effective in hard water
15. Recrystallisation - dissolve in minimum quantity of hot water; filter hot; cool distillate in ice bath; filter cold; wash residue in a little cold water; dry