EXTRA

CHEMISTRY

for use with the IB Diploma Programme

OPTIONS: STANDARD AND HIGHER LEVELS

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Chapter 1 Review questions

Standard level questions

1 In the past, single-beam IR spectrometers have been used. These instruments did not have a second beam passing through a reference. Describe the advantage that a double-beam spectrophotometer has over a single-beam instrument.

2 Consider the description of each of the following infrared absorption bands and suggest a functional group that might be responsible for this absorption.

a A strong absorption band at 3200 cm^{-1}

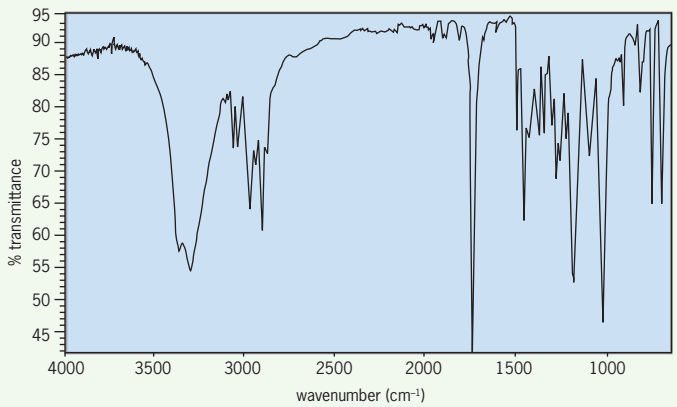
b A reasonably strong absorption band at 2950 cm^{-1}

c A strong absorption band at 1200 cm^{-1}

d A strong absorption band at 1725 cm^{-1}

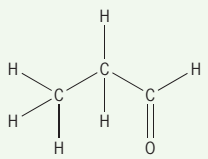
3 Explain how the mass spectrum of an organic compound can provide information about its molecular structure.

4 Determine which of the molecules C_3H_7OH, C_2H_5COOH, C_3H_8, CH_3COCH_3 would have a structure that is consistent with the infrared spectrum shown below.



Explain your reasons for selecting that particular molecule.

5 If the molecule at right was analysed by mass spectroscopy, predict the masses of three fragments that might occur in the spectrum.

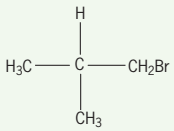


6 For each of the compounds below consider the possible appearance of the ^1H NMR spectrum and suggest:

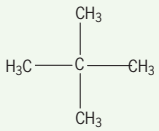
i how many peaks you would expect to see

ii the expected ratio of the areas under these peaks.

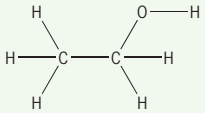
a



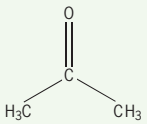
b



c



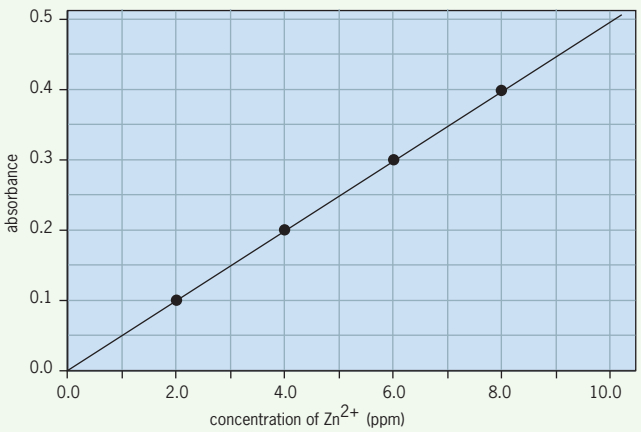
d



7 The level of zinc in a vitamin tablet was determined by atomic absorption spectroscopy. A 0.50 g sample of tablet was crushed, dissolved and made up to a volume of 1.0 dm^3. Standard solutions of zinc were prepared and their absorbances tested to produce the calibration curve shown below. The absorbance of the tablet solution was found to be 0.27.

a Determine the zinc concentration of the tablet solution (ppm or mg dm^{-3}).

b Explain why it was necessary to produce a calibration curve for this determination.



8 The mass spectrum of a compound with molecular formula C_2H_5OH is found to be made up of a number of peaks.

Identify the possible structure of the fragments causing the peaks at a relative isotopic mass of:

a 45

b 31

c 29

9 **a** Describe the type of qualitative information that a ^{1}H NMR spectrum provides.

b Describe the type of quantitative information that a ^{1}H NMR spectrum provides.

10 A compound is known to be either ethanoic acid (CH_3COOH) or methyl methanoate ($HCOOCH_3$). Spectroscopic analysis is used to help identify the compound.

a The ^{1}H NMR spectrum for each compound is produced.

i State how many peaks you would expect to see in the ^{1}H NMR spectrum of each compound.

ii State the expected ratio of areas for the peaks for each compound.

iii Describe the information obtained from the NMR spectra that might help distinguish between these two compounds.

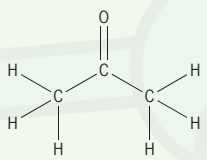
b Describe how infrared spectroscopy could be used to:

i distinguish between the two compounds

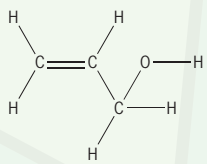
ii confirm the identity of each compound.

11 Three possible structures for an organic compound under investigation are shown below.

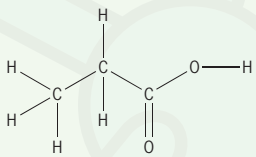
I



II



III



The correct structure is to be determined using spectroscopic analysis.

a The infrared spectrum of the compound shows a distinct absorption peak at 1710 cm^{-1}.

i Briefly explain what happens to the molecule when it absorbs radiation in the infrared section of the electromagnetic spectrum.

ii Using the data provided in table 1.2.3, determine which two of the three possible structures are most likely to be correct. Explain your choice.

b The ^{1}H nuclear magnetic resonance spectrum of the compound shows a single peak at a chemical shift of 2.1 ppm.

i State the type of electromagnetic radiation that is absorbed by atoms in molecules to produce an NMR spectrum.

ii Describe the information that the chemical shift of a peak on the ^{1}H NMR spectrum provides.

iii On the basis of the NMR spectrum, determine which of the two structures that you chose in part **a ii** is most likely to be correct. Explain your choice.

12 Suggest an analytical procedure that could be employed to conduct each of the following analyses.

a Determine whether an unconscious patient has taken an overdose of barbiturates

b Analyse a water sample to test for the presence of chromium

c Separate the components of the dyes used in fluorescent marker pens

13 Using paper chromatography as an example, explain the meaning of the following terms.

a Stationary phase

b Mobile phase

c Retention factor (R_f)

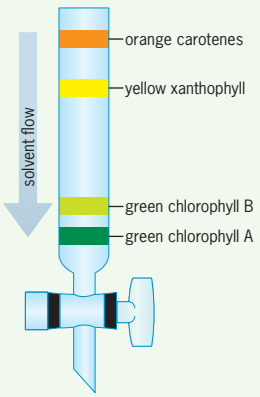
d Adsorption

e Desorption

14 The diagram below shows leaf pigments being separated by column chromatography.

a Determine which pigment is most strongly adsorbed to the stationary phase.

b Determine which pigment will have the shortest retention time.

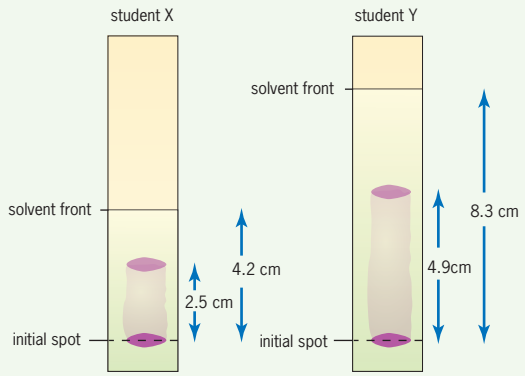


15 During a paper chromatography experiment, a dye sample was separated into three components. The colours and R_f values of these components were blue, 0.60; red, 0.45; and yellow, 0.35.

a Draw the expected appearance of the chromatogram (to scale) when the solvent front had moved 12 cm from the origin.

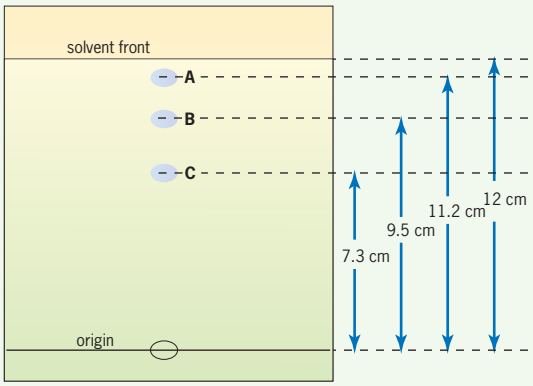
b Determine which component was most strongly adsorbed to the stationary phase and explain your answer.

16 Two students were each provided with a small sample of an unknown substance. To investigate their sample, they each conducted a thin-layer chromatography experiment. Each student used the same type of solvent and the same type of chromatography sheet. Their results are shown below.



Determine whether the two students had the same unknown substance in their sample. Explain your answer.

17 A mixture of amino acids was separated using thin-layer chromatography. The amino acids were sprayed with ninhydrin solution to make them visible. The chromatogram obtained is shown below.



The table below shows the R_f values of some pure amino acids obtained using the same apparatus and conditions.

Amino acid	R_f value
Alanine	0.61
Valine	0.79
Isoleucine	0.85
Proline	0.93

a Calculate the R_f values for the components labelled A, B and C on the chromatogram.

b On the basis of the data provided, identify components A, B and C.

c Consider whether it is possible that your identifications could be wrong, that is, components A, B and/or C may not be the amino acids stated in your answer to part **b**? Explain.

d Explain why it is important that the same apparatus and conditions be used for both the mixture and the pure amino acids.

18 Match each analytical technique to its appropriate use.

Technique	Use
Nuclear magnetic resonance spectroscopy	Determination of the sodium content of mineral water
Atomic absorption spectrometry	Identification of the presence of a C=O group in a molecule
High performance liquid chromatography	Separation of plant leaf pigments
Thin-layer chromatography	Separation of drugs found in a urine sample
UV–visible spectrometry	Determination of the structure of a branched hydrocarbon
Infrared spectroscopy	Measurement of the hemoglobin content of a blood sample

19 Parts **a** to **d** all relate to the same compound and should enable you to answer part **e** of this question.

a **i** The percentage composition of an unknown compound is 33.2% carbon; 4.6% hydrogen; 32.7% chlorine; 29.5% oxygen. Calculate the empirical formula of the compound.

ii The molar mass of the compound is 108.53. deduce the molecular formula of the compound.

b If this organic compound is acidic and one mole of it reacts with one mole of NaOH, state a functional group you would expect to find in the compound.

c The infrared spectrum of the compound has a broad band at 3300 cm^{-1} and a sharp band at 1710 cm^{-1}. Identify the functional groups that would produced these two bands in the IR spectrum.

d The ^1H NMR spectrum shows three peaks in the ratio 2 : 2 : 1.

i State how many different environments there are for hydrogen atoms in this compound.

ii State how many hydrogen atoms have each of these different environments.

e Deduce the structure of a molecule of this unknown compound and name the compound.

20 The absorption of infrared radiation causes molecular vibrations.

a Using H_2O and CO_2 to illustrate your answer, explain what is meant by the terms:

i symmetrical stretch

ii asymmetrical stretch.

b Explain why the dipole moment of CO_2 changes when it undergoes an asymmetrical stretching vibration.

Higher level questions

21 Explain why each of the following procedures would be carried out during an analysis experiment using a UV–visible spectrometer.

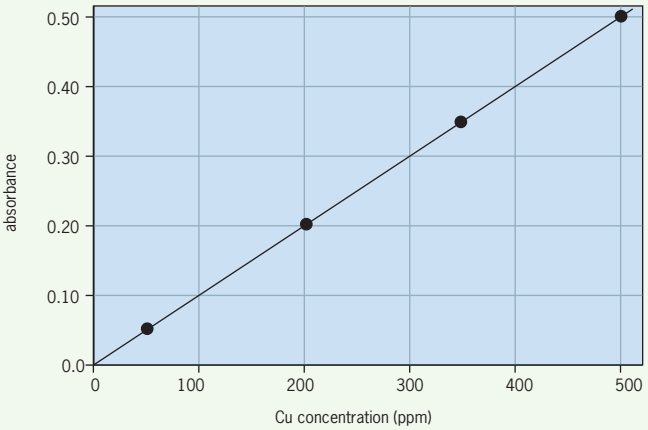
a Readings of the absorbance of a pure substance are obtained at various wavelengths.

b Readings of the absorbances of a range of solutions of various concentrations are obtained at a selected wavelength.

c A reading of the absorbance of a pure solvent is obtained at a selected wavelength.

22 A copper(II) sulfate solution was analysed using a spectrophotometric technique. A 5.00 cm^3 aliquot of the solution was collected, placed in a 250.0 cm^3 volumetric flask and diluted to the mark with distilled water. A 20.0 cm^3 aliquot of this solution was then transferred to a 100.0 cm^3 volumetric flask and 10 cm^3 of a dilute ammonia solution was added in order to form the deep blue tetrammine copper(II) complex ion. The contents of this flask were then diluted to the mark with distilled water. A previously calibrated spectrophotometer was used to measure the absorbance of this final solution at a wavelength of 610 nm. The absorbance was found to be 0.30.

The results obtained are shown in the graph below.



a **i** Determine the concentration of Cu in the 100.0 cm^3 solution.

ii Hence determine the concentration of Cu in the original 5.00 cm^3 aliquot.

b **i** Suggest why the spectrophotometer was set at a wavelength of 610 nm for the analysis.

ii Given that copper(II) sulfate is a blue solution, suggest what colour light of wavelength 600 nm would most likely be.

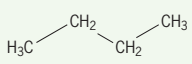
23 In question **22** the initial copper(II) sulfate solution was a light blue colour, whereas the tetrammine copper(II) complex ion was described as deep blue.

a Describe the feature of the electron structure of copper(II) ions that enables it to form coloured complexes.

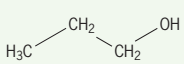
b Explain why the two Cu^{2+} solutions are different colours.

24 Predict the number of ^{1}H NMR signals (peaks) and also the splitting patterns of each of the peaks on the ^{1}H NMR spectra of the compounds shown below.

a



b



25 In the ^{1}H NMR spectrum of each of the following compounds, predict:

- **i** the number of peaks
- **ii** the relative peak heights
- **iii** the splitting pattern
- **iv** the chemical shift for each peak.

a CH_3CHBr_2

b $(CH_3)_2CHCl$

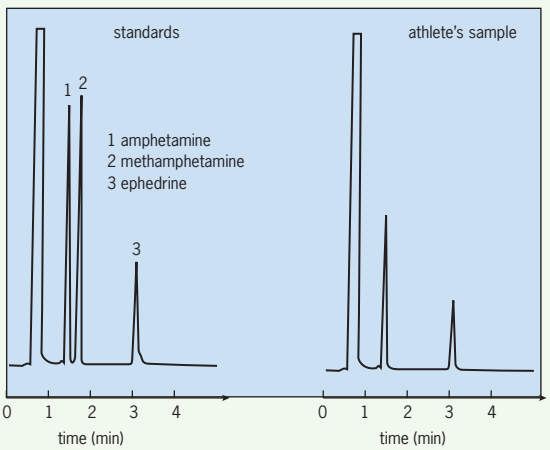
c $(CH_3)_3CBr$

26 a In high performance liquid chromatography (HPLC), name the state of the:

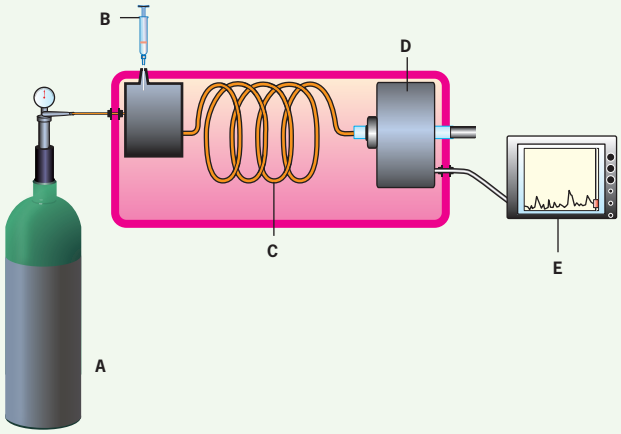
- **i** mobile phase
- **ii** stationary phase
- **iii** sample to be tested.

b Draw the expected chromatogram that would be obtained if three alcohols—butanol (C_4H_9OH), pentanol ($C_5H_{11}OH$) and octanol ($C_8H_{17}OH$)—were separated by HPLC.

27 An athlete was tested for suspected use of amphetamines. A urine sample was analysed using gas–liquid chromatography. From the gas chromatograms shown below, explain whether there is evidence that the athlete had been using amphetamines.



28 A schematic diagram of a gas–liquid chromatograph is shown below.



a Name the parts labelled A to E.

b Describe the nature and function of the part labelled C.

c Describe a commonly used device that functions as the part labelled D.

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Weblinks are available on the Companion Website to support learning and research related to this chapter.

Chapter 1 Test

Standard level questions

1 Identify **one** analytical technique, different in each case, that can be used to obtain the following information:

Information	Analytical technique
Isotopic composition of an element	
Functional groups present in an organic compound	
Concentration of Fe^{3+} ions in industrial waste waters	

(3 marks)

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2 Identify **two** effects of the absorption of infrared radiation on the bonds in a molecule of carbon dioxide.

Explain why an oxygen molecule does not absorb infrared radiation.

(3 marks)

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3 Spectra **A** and **B** shown in the next column represent the infrared spectra of two of these compounds:

CH_3CH_2COOH CH_3COOCH_3 $HCOOCH_2CH_3$

a Use table 1.2.3 (p. 14) to identify the groups responsible for the absorption near

1050 cm^{-1}

1700 cm^{-1}

(1 mark)

b Deduce which one of the three compounds produced spectrum A, giving a reason for your choice.

(2 marks)

c Explain why the other two compounds have similar infrared spectra.

(1 mark)

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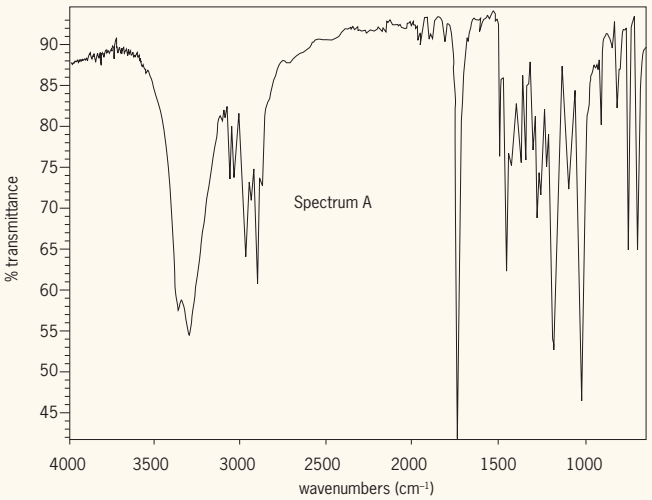
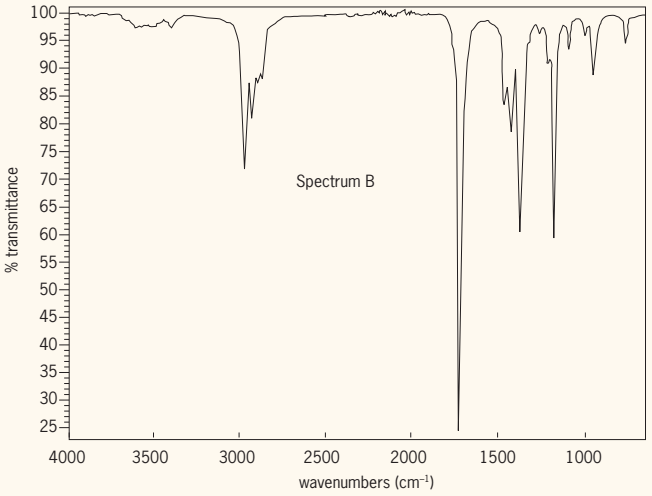




4 An organic compound with three carbon atoms has two structural isomers A and B with the same functional group. The infrared spectrum of the compound shows a broad absorption at above 3350 cm^{-1}.

The mass spectra of the two isomers **A** and **B** are shown on the next page.

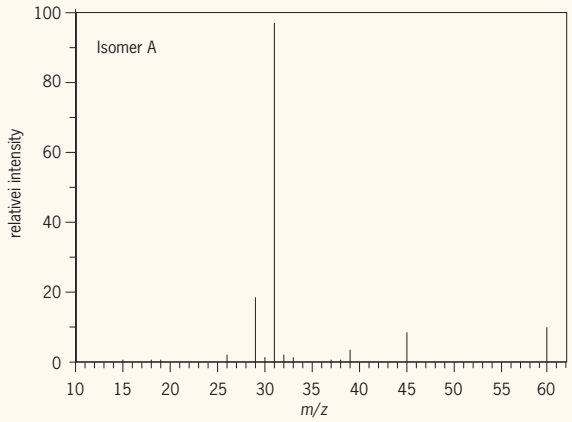
a Deduce, giving a reason, the molecular formula of the organic compound.

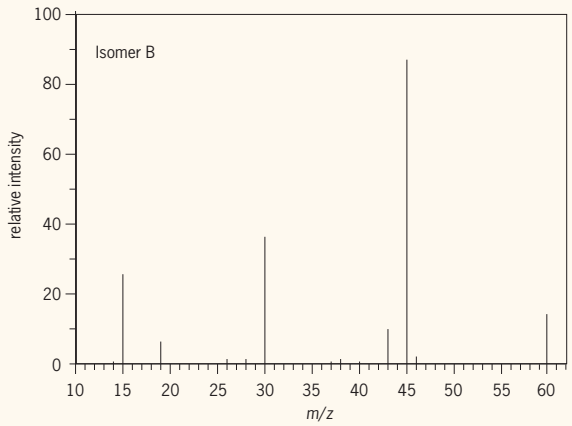
(1 mark)

b Deduce the formula of the fragmentation ion responsible for the peak at each of these *m/z* values.

Isomer A	29
	31
Isomer B	30
	45

(4 marks)

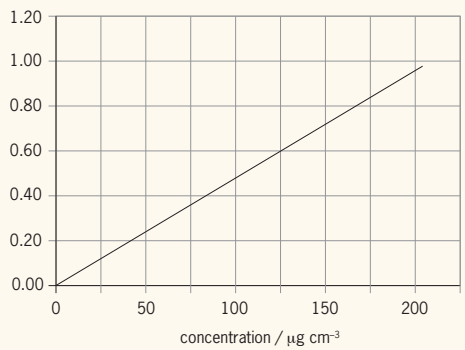




5 a State the main use of atomic absorption spectroscopy (AAS).

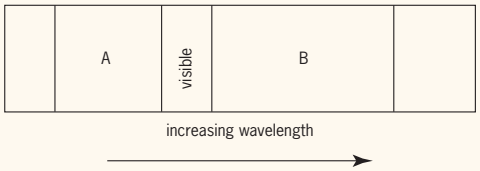
(1 mark)

b Ore samples may be analysed for iron using AAS. An ore sample was prepared in acid and diluted to 1 part in 10. The diluted solution gave an absorbance reading of 0.80. Determine the concentration of iron in the sample in mg cm^{-3}.



(2 marks)

6 The figure below shows the visible region of the electromagnetic spectrum and the two regions nearest to it.



Name the regions labelled A and B, identify the atomic or molecular processes associated with each region and compare the energies of the radiation involve in these processes.

(5 marks)

7 a All chromatographic techniques involve the phenomena of adsorption or partition. They all use a stationary phase and a mobile phase, but these phases can include solids, liquids or gases. Complete the following table to show which states of matter are used in the two phenomena.

	Stationary phase	Mobile phase
Adsorption		
Partition		

(3 marks)

b Explain the term R_f value used in some chromatographic techniques.

(1 mark)

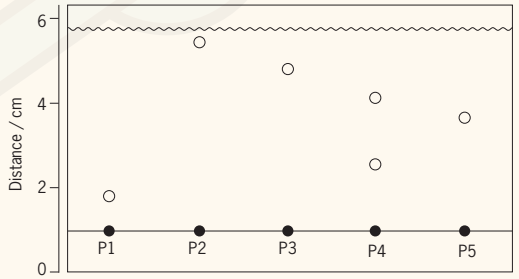
c Outline how the technique of column chromatography could be used to separate a mixture of two coloured substances in solution.

(4 marks)

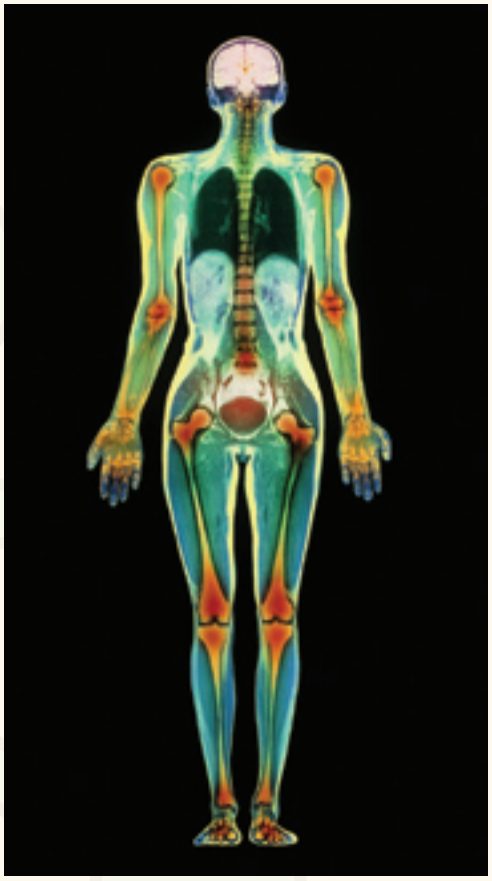
8 A student used the technique of ascending paper chromatography in an experiment to investigate some permitted food dyes (labelled P1–P5). The result is shown on the next page.

By reference to the diagram above, describe how the experiment would be carried out and explain the meaning of the following terms: stationary phase, mobile phase, partition, solvent front and R_f value.

(8 marks)



9 The following is an image of the human body. Such images are used medically in detecting abnormalities and diseased tissue.



State the technique that was used to produce this image.

(1 mark)

10 a Describe a chromatographic technique used to identify the amino acids formed when a protein is hydrolysed.

(4 marks)

b Suggest a chromatographic technique that could be used to detect the alcohol concentration in a sample of blood. Outline the essential features of this technique.

(6 marks)

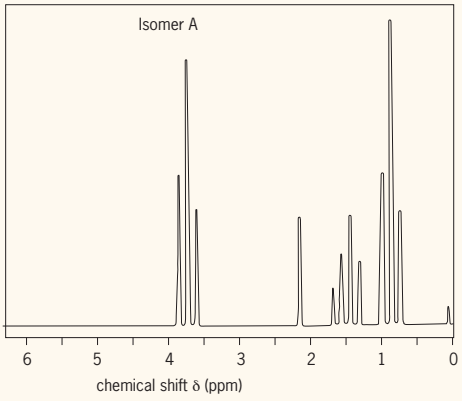
Total (SL): 50 marks

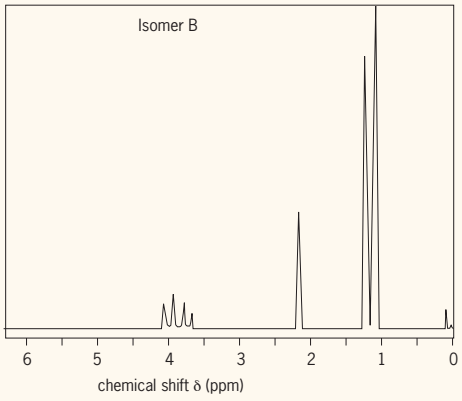
Higher level questions

HL

11 Note that this question follows on from question **4** above.

The ^{1}H NMR spectra of isomers A and B are shown below.





a State the formula and function of the compound responsible for the peak at 0 ppm.

(2 marks)

b Explain what information about the isomers can be obtained from the number of peaks and area under each peak.

(2 marks)

c Deduce the structural formulas of isomers A and B and give the ratio of peak areas in each case.

(4 marks)

d Draw the structural formula of a third isomer C that has the same molecular formula as isomers A and B but a different functional group. Give the ratio of peak areas in isomer C.

(2 marks)

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12 Explain why CH_2=CH–CH=CH_2 shows an absorption band at a longer wavelength than CH_2=CH_2.

(2 marks)

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13 **a** The ^{1}H NMR spectrum of a compound with the formula $C_4H_8O_2$ exhibits three major peaks with chemical shifts, areas and splitting patterns given below.

Chemical shift/ppm	Peak area	Splitting pattern
0.9	3	Triplet
2.0	2	Quartet
4.1	3	Singlet

Using information from table 1.8.1 (p. 57), determine the types of proton present in the molecule.

(3 marks)

b Deduce a structure consistent with the information indicated in part a. Explain your answer.

(5 marks)

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Total (HL): 70 marks

Chapter 2 Review questions

Standard level questions

1 A sample of crushed walnuts weighing 5.00 g was combusted in a bomb calorimeter in the presence of excess oxygen. The temperature of the water surrounding the 'bomb' was found to increase from 20.10°C to 22.72°C. If the calorimeter constant was 500 J g^{-1} and there was 100 cm^3 of water in the calorimeter, calculate the heat of combustion of the walnuts, in kJ g^{-1}.

2 Glucose has a molecular formula of $C_6H_{12}O_6$.

a Draw the three structures of glucose.

b Maltose is a disaccharide formed from α-glucose by condensation reaction. Use a diagram to show this reaction.

c State the molecular formula of maltose.

3 **a** Draw the general structure of a 2-amino acid.

b Aspartic acid has a side group of $–CH_2COOH$. Draw the structure of aspartic acid in a solution of:

i pH = 2

ii pH = 10.

c Draw the dipeptide formed when two molecules of threonine react with each other.

4 Poly(ethene) and proteins are both examples of polymers. Explain why proteins are more complex polymers than poly(ethene).

5 An egg that is cracked and poured into acid soon turns white and resembles a poached egg. Explain what has happened to the egg white in the acid.

6 Outline the importance of hydrogen bonding in:

a proteins

b DNA molecules. HL

7 **a** List four polymers made from glucose and state the role of each.

b State one similarity between the four polymers.

c State one difference between two of the four polymers.

8 State the role of water in each of the following reactions.

a Polymerization of glucose to starch

b Reaction of two amino acids to form a dipeptide

c Breakdown of starch to glucose molecules

9 State the type of linkage that joins:

a two amino acids

b two monosaccharides

c glycerol to a fatty acid in a triglyceride

d guanine to cytosine in a DNA molecule HL

10 Explain why amino acids and monosaccharides are soluble in water.

11 Linoleic acid ($C_{18}H_{32}O_2$) is a polyunsaturated fatty acid used in the biosynthesis of prostaglandins. Draw the structure of a triglyceride formed from glycerol and linoleic acid.

12 In the body linolenic acid is converted into two other omega-3 fatty acids: eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). The molecular formula of docosahexaenoic acid is $C_{22}H_{32}O_2$.

a Determine the number of carbon–carbon double bonds in docosahexaenoic acid.

b Determine the iodine number of docosahexaenoic acid.

13 HDL and LDL cholesterols are both found in the bloodstream. Describe the ideal balance that should be maintained of these two lipoproteins and explain the health hazards of this balance not being kept.

14 **a** Describe an important role that lipids play in the body.

b Describe a negative effect that lipids can have on our health. (Try to avoid the answer that you gave to question 13.)

15 List four micronutrients and describe the main function of micronutrients in general in the body.

16 Draw the structure of one water-soluble vitamin and one fat-soluble vitamin and explain the structural differences that influence their solubilities in water and fat.

17 State the name of the micronutrient that is deficient when each of the following conditions occurs.

a Goitre

b Anemia

c Beriberi

d Scurvy

e Night blindness

f Rickets

18 **a** State one structural feature that is common to cholesterol and to the sex hormones (testosterone, progesterone and estradiol).

b State one structural feature that is different in each of the sex hormones when compared to cholesterol.

19 For each of the following hormones, state the endocrine gland in which it is produced and the effect of the hormone in the body.

a Progesterone

b Testosterone

c Adrenaline (epinephrine)

d Insulin

20 Describe a way in which steroids may be abused and the effect of steroids that make them open to such abuse.

Higher level questions

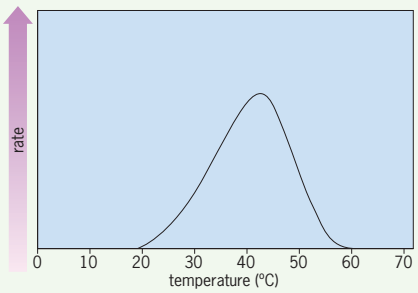
HL

21 **a** **i** Describe the function of an inorganic catalyst.

ii Describe the function of an enzyme.

iii State two ways in which enzymes differ from inorganic catalysts.

b Catalase is an enzyme that can speed up the decomposition of hydrogen peroxide. A graph of the rate of reaction vs temperature is shown. Explain the shape of the curve.



22 Describe what is meant by each of the following terms.

a Substrate

b Enzyme–substrate complex

c Active site

d Induced-fit model

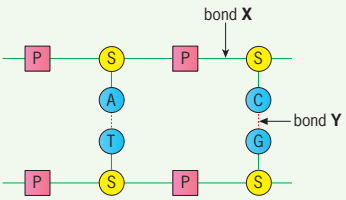
23 Identify the functional groups between which hydrogen bonds occur when the following base pairs link up in a DNA or RNA molecule.

a Cytosine and guanine

b Thymine and adenine

c Uracil and adenine

24 The diagram below is a schematic representation of a section of DNA.



Identify what each of the letters represents, and name the two types of bonding indicated.

25 Condensation and hydrolysis reactions are of critical importance in living things. Give an example of each type of reaction from one of the major food groups: carbohydrates, proteins or fats.

26 Outline the role of iron ions in oxygen storage in blood.

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Weblinks are available on the Companion Website to support learning and research related to this chapter.

Chapter 2 Test

Standard level questions

1 **a** A brand of vegetable fat consists of 88% unsaturated fats and 12% saturated fats. State the major structural difference between unsaturated and saturated fats.

(1 mark)

b Linoleic acid, $CH_3(CH_2)_4CH{=}CHCH_2\,CH{=}CH(CH_2)_7COOH$, and palmitic acid, $CH_3(CH_2)_{14}COOH$ are components of vegetable fat. Explain why palmitic acid has the higher melting point.

(3 marks)

c The energy content of a vegetable oil was determined using a calorimeter. A 5.00 g sample of the oil was completely combusted in a calorimeter containing 1000 g of water at an initial temperature of 18.0°C. On complete combustion of the oil, the temperature of the water rose to 65.3°C.

Calculate the calorific value of the oil in kJ g^{-1}.

(4 marks)

2 Iodine number is defined as the number of grams of iodine that reacts with 100 g of a triglyceride in an addition reaction. The iodine number of palmitic acid ($M_r = 256$) is 0 and linolenic acid ($M_r = 278$) is 274.

Determine the number of double bonds in linolenic acid, showing your working.

(3 marks)

3 Polypeptides and proteins are formed by the condensation reactions of amino acids.

a Give the general structural formula of a 2-amino acid.

(1 mark)

b Give the structural formula of the dipeptide formed by the reaction of alanine and glycine.

State the other substance formed during this reaction.

(2 marks)

c State two functions of proteins in the body.

(2 marks)

d Electrophoresis can be used to identify the amino acids present in a given protein. The protein must first be hydrolysed.

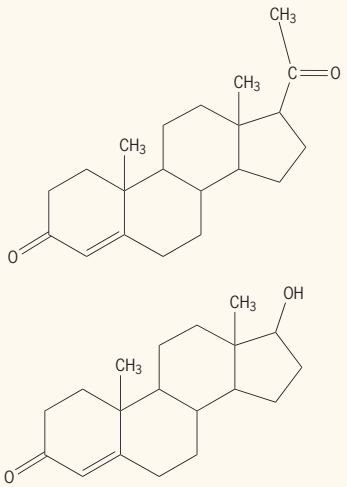
i State the reagent and conditions needed to hydrolyse the protein, and identify the bond that is broken during hydrolysis.

(4 marks)

ii Explain how the amino acids could be identified using electrophoresis.

(4 marks)

4 The structures of two sex hormones, progesterone and testosterone, are shown below.



a State the names of two functional groups that are present in both hormones.

(2 marks)

b Identify which of the two hormones is the female sex hormone and where in the human body it is produced.

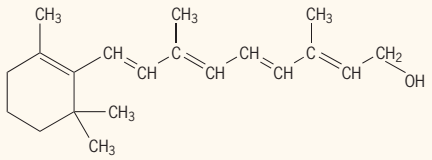
(2 marks)

c Outline the mode of action of oral contraceptives.

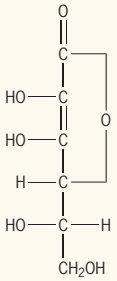
(3 marks)

5 a The structures of three important vitamins are shown below.

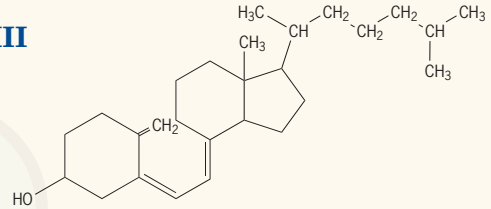
I



II



III



State the name of each one and deduce whether each is water-soluble or fat-soluble, explaining your choices by reference to their structures.

(5 marks)

b Identify the metal ion needed for the maintenance of healthy bones and state the name of the vitamin needed for its uptake.

(2 marks)

c State the name of the vitamin responsible for maintaining healthy eyesight and the name of the functional group which is most common in this vitamin.

(2 marks)

6 The three major nutrients required by humans are proteins, carbohydrates and fats.

State **one** major function that is common to these three nutrients in the human body.

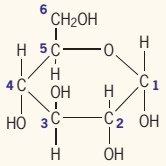
(1 mark)

7 a Draw the straight chain structure of glucose.

(1 mark)

b The structure of α-glucose is shown.

Outline the structural difference between α-glucose and β-glucose.



(1 mark)

c Glucose molecules can condense to form starch, which can exist in two forms: amylose and amylopectin. Describe the structural differences between the two forms.

(2 marks)

d 1.00 g of sucrose, $C_{12}H_{22}O_{11}$, was completely combusted in a food calorimeter. The heat evolved was equivalent to increasing the temperature of 631 g of water from 18.36°C to 24.58°C.

Calculate the calorific value of sucrose (in kJ mol^{-1}) given that the specific heat capacity of water is 4.18 kJ kg^{-1} K^{-1}.

(3 marks)

Total (SL): 48 marks

Higher level questions

HL

8 a Explain, with reference to the active site, how enzymes are able to catalyse biological reactions.

(3 marks)

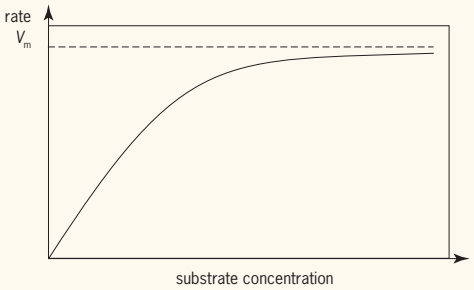
b State and explain the effect on the rate of an enzyme-catalysed reaction of gradually increasing the temperature from 10°C to 60°C.

(4 marks)

9 a Discuss the effect of a competitive inhibitor on an enzyme-catalysed reaction.

(4 marks)

b The effect of a competitive inhibitor on an enzyme-catalysed reaction can be shown on the graph below.

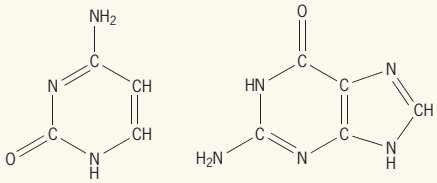


Annotate the graph to show the position of K_m for the reaction. Draw a line on the graph to represent the effect of competitive inhibition.

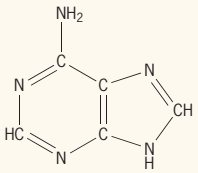
(2 marks)

10 a The structural formulas of cytosine and guanine present in nucleic acids are given below. Draw the correct number of hydrogen bonds between these two bases.

(2 marks)



b The structural formula of adenine is shown below.



Copy an appropriate base from table 2.8.1, page 122 present in RNA that will pair with adenine. Draw the correct number of hydrogen bonds between these two bases.

(2 marks)

c Explain the term *triplet code*.

(1 mark)

d Food is oxidized by a series of redox reactions involving the transport of electrons. Identify the ions of two different metals used in these reactions.

(2 marks)

Total (HL): 68 marks

Chapter 3 Review questions

Standard level questions

1 Explain why it is more difficult to extract aluminium from bauxite than iron from haematite.

2 **a** Outline the reactions by which iron is extracted from its ores in the blast furnace.

b List the substances that make up the blast furnace charge.

3 Compare the composition of pig iron and the iron produced by the basic oxygen process.

4 **a** Identify the principal aluminium ore.

b Identify the aluminium compound used in the Hall–Héroult cell.

c Explain how cryolite is used in aluminium production.

5 Describe three negative impacts of iron and aluminium production on the environment.

6 Discuss the benefits of using crude oil fractions for fuel production, rather than as a feedstock.

7 Comment on the statement that the world would be better off without polymers.

8 Define the terms *homogeneous catalyst* and *heterogeneous catalyst* and describe an example of each.

9 **a** List three functions of fuel cell electrodes.

b Compare the reactions occurring in an acid and an alkaline hydrogen–oxygen fuel cell.

10 Identify the:

a lead–acid cell discharge reaction

b nickel–cadmium cell recharge reaction

c lithium ion cell anode reaction during discharge

11 Explain why fuel cells are preferred for space travel rather than secondary cells.

12 List four examples of natural liquid crystals and label them as either lyotropic or thermotropic.

13 **a** Describe one example of nanotechnology.

b Outline the similarities and differences between single-walled and multi-walled nanotubes.

Higher level questions

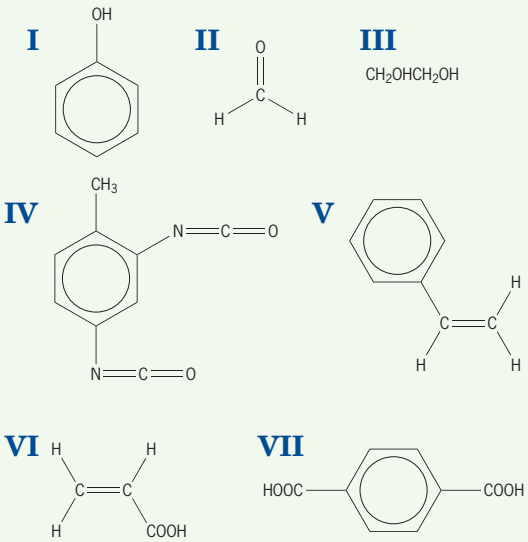
HL

14 From the molecules in the diagram below, choose two that could form:

a a polyester

b polyurethane

c phenol–methanal plastic.



15 Describe how benzoyl peroxide is used to produce LDPE.

16 **a** Define the term *doping*.

b Compare the results of doping silicon with a group 3 element or a group 5 element.

17 Describe how solar cells produce an electric current.

18 Outline the circumstances under which twisted nematic crystals:

a block light

b allow light to pass through.

19 Draw up a table showing the advantages and disadvantages of the three chlor-alkali cells.

20 Explain the measures used by chlor-alkali plants to minimize their environmental impact.

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Weblinks are available on the Companion Website to support learning and research related to this chapter.

Chapter 3 Test

Standard level questions

1 The production of aluminium involves purification and electrolysis.

a State the ore from which aluminium is extracted.
(1 mark)

b Name one impurity which is removed at the purification stage.
(1 mark)

c State why aluminium is not obtained from its oxide by carbon reduction.
(1 mark)

d Write ionic equations for the reactions that take place during electrolysis at each electrode.
(2 marks)

e For each of the cases below, state two properties of aluminium that make it suitable for use as

i cooking pans
(1 mark)

ii overhead electric cables.
(1 mark)

f Aluminium is higher in the reactivity series than iron, yet reacts more slowly with dilute hydrochloric acid at room temperature. Explain this.
(2 marks)

2 Several monomers are produced by the oil industry and used in polymer manufacture. Examples include propene, styrene and vinyl chloride.

a Draw the structural formula of propene.
(1 mark)

b Isotactic polypropene has a regular structure, while atactic polypropene does not.

i Draw the structure of isotactic polypropene, showing a chain of at least six carbon atoms.

ii State and explain how its properties differ from those of atactic polypropene.
(4 marks)

3 **a** State the essential chemical process in the extraction of iron and aluminium.
(1 mark)

b Using iron and aluminium as examples, discuss the major factor that determines the ease of extraction of metals.
(2 marks)

4 Iron is produced in a blast furnace.

a **i** State the name and formula of the main impurity in iron ore.
(2 marks)

ii Name the raw material used to remove the impurity. Show with equations how the impurity is removed.
(3 marks)

b State the process used to extract aluminium on an industrial scale and write equations for the reactions involved.
(3 marks)

c Explain the use of cryolite in the production of aluminium, other than cost.
(2 marks)

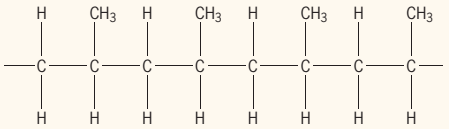
5 **a** State one source of iron used in industry, other than iron ores.
(1 mark)

b Identify one ore of iron and two other raw materials needed to produce iron in the blast furnace.
(3 marks)

c **i** Explain why iron from the blast furnace is not as suitable as steel for making many objects.
(2 marks)

ii Outline how iron from the blast furnace is converted to steel.
(1 mark)

6 The diagram below represents a section of a polymer.



a **i** Draw the structure of the monomer from which this polymer is manufactured.
(1 mark)

ii Polymers A and B both have the structure shown above, but the average chain length is much greater in A than in B. Suggest two physical properties that would be different for A and B.

(2 marks)

iii Polymers A and B both have isotactic structures. Polymer C is manufactured from the same monomer but is not isotactic. State the name used to describe this different structure and outline how the structure differs.

(2 marks)

b Polymers have replaced more traditional materials such as metal and wood. Suggest one polymer property, different in each case, that makes polymers more suitable than metal and wood.

(2 marks)

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7 a Traditionally, the raw materials for the production of iron are iron ore, coke, limestone and preheated air. Iron oxides are reduced in a blast furnace by both carbon and carbon monoxide to form iron. Give the equation for the reduction of iron(III) oxide by carbon monoxide.

(1 mark)

b In many modern blast furnaces, hydrocarbons, (such as methane) are also added to the preheated air. This produces carbon monoxide and hydrogen. The hydrogen formed can also act as a reducing agent. Give the equation for the reduction of magnetite, by hydrogen.

(1 mark)

c The iron produced in the blast furnace is known as 'pig iron'. It contains about 5% carbon, together with small amounts of other elements such as phosphorus and silicon.

Explain the chemical principles behind the conversion of iron into steel using the basic oxygen converter.

(6 marks)

d State one element that must be added to the basic oxygen converter to produce stainless steel rather than ordinary steel.

(1 mark)

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Total (SL): 50 marks

Higher level questions

8 Polyethene is the most commonly used synthetic polymer. It is produced in low-density and high-density forms.

a Identify which form has the higher melting point. Explain by reference to its structure and bonding.

(4 marks)

b Describe how the properties of two named polymers can be modified by adding a different substance in each case.

(4 marks)

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9 a Compare the different processes used to manufacture low-density and high-density polyethene, by referring to reaction conditions, the name of the catalyst and the type of reaction mechanism.

(4 marks)

b The basis of the chlor-alkali industry is the manufacture of chlorine and sodium hydroxide from brine.

i Write half-equations for the reaction taking place at each electrode in both the diaphragm cell and the mercury cell.

(3 marks)

ii Identify the material used for the diaphragm and describe its function.

(3 marks)

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10 The manufacture of low-density polyethene involves a free-radical mechanism in which the species RO· takes part.

a List the names of the three stages common to free-radical mechanisms.

(2 marks)

b Identify a source of the species RO·.

(1 mark)

c Write an equation to show how RO· reacts with a molecule of ethene.

(1 mark)

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Total (HL): 72 marks

Chapter 4 Review questions

Standard level questions

1 Outline the stages involved in the research, development and testing of new pharmaceutical products.

2 Describe the most likely method of administration of a medicine that is intended to help a patient to breathe more easily.

3 Describe the difference between intravenous and intramuscular injections and describe one advantage and one disadvantage of each type of injection.

4 Describe how a side-effect could become the main effect of a drug.

5 Explain what is meant by the term *tolerance*.

6 Describe the relative toxicity of two drugs, A and B, if drug B has a higher LD_{50} than drug A.

7 Write an equation for the neutralization of hydrochloric acid in the stomach by:

a calcium carbonate

b aluminium hydroxide

c magnesium oxide.

8 Describe the method of action of a strong analgesic.

9 Explain why heroin is rejected for use by the medical profession.

10 State the name of one functional group that is common to aspirin, acetaminophen and ibuprofen.

11 List three short-term effects and three long-term effects of alcohol (ethanol) use.

12 Outline at least two examples of the synergistic effect of using ethanol and other drugs, such as aspirin.

13 **a** Describe the colour change that occurs in a positive test for ethanol using a breathalyser containing potassium dichromate(VI) crystals.

b Write a half equation for the reaction that the dichromate ions undergo in the breathalyser, in the presence of ethanol.

c Write a half-equation for the reaction that the ethanol from a user's breath undergoes in the breathalyser.

14 Name two commonly used depressants other than ethanol.

15 **a** Name the hormone mimicked by amphetamines.

b Describe the function of that hormone and hence describe the effect of amphetamines on the body.

16 Describe:

a three short-term effects of smoking tobacco

b three long-term effects of smoking tobacco.

17 Draw the general structure of penicillin and label:

a the β-lactam ring

b the position at which the side-chain bonds.

18 Explain why it is important to finish a course of penicillin, even if you are feeling quite well.

19 Explain why a virus cannot reproduce on its own.

20 Explain why it is difficult to effectively treat AIDS with antiviral drugs.

Higher level questions

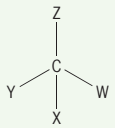
HL

21 Two types of stereoisomerism are geometric isomerism and optical isomerism. State the name of an anti-cancer drug that exhibits:

a geometric isomerism

b optical isomerism.

22 Some drug molecules contain a structure that can be represented as shown.



a Draw the structure that is the mirror image of the one shown.

b State the term that is used to describe two molecules that are mirror images of each other, as you have drawn.

23 Identify, giving a reason for your choice, which of acetaminophen (paracetamol) or ibuprofen exists as optical isomers.

24 **a** Explain how the term *racemic mixture* relates to drug synthesis and why it can be a troublesome issue.

b Outline the method of drug synthesis that is used to overcome the possibility of preparing a racemic mixture.

25 Explain the role of robotics in combinatorial chemistry.

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Chapter 4 Test

Standard level questions

1 It takes many years to introduce a new drug onto the market.

a Explain the purpose of making many structural modifications to a drug in the research stage.

(1 mark)

b Explain the meaning of these terms:

i The LD_{50} test

(1 mark)

ii The placebo effect

(1 mark)

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2 Antacids can be taken for indigestion caused by excess acidity.

a Identify the substance responsible for the low pH value of the liquid in the human stomach.

(1 mark)

b Two active ingredients in antacids are $Mg(OH)_2$ and $NaHCO_3$. Write an equation to show how each ingredient can relieve indigestion.

(2 marks)

c Three antacid preparations contain 0.01 mol of one of the following—$Mg(OH)_2$, $Al(OH)_3$ and $NaHCO_3$. Identify the most effective antacid. Give a reason for your choice, with reference to the formula of the antacid.

(2 marks)

d Give **two** reasons why alginates are included in many antacids.

(2 marks)

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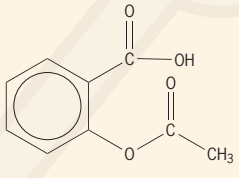
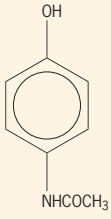
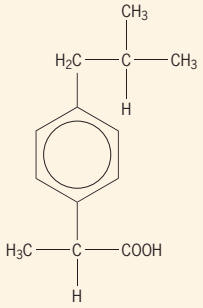
3 The structures of some analgesics are shown. Refer to these structures when answering parts **b** and **c** of this question.



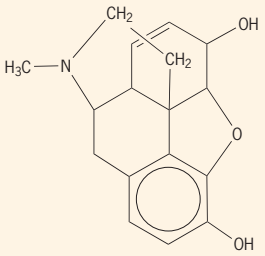
aspirin



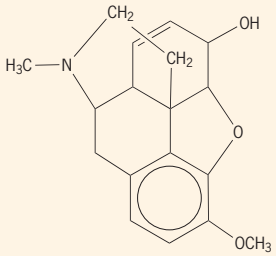
paracetamol (acetaminophen)



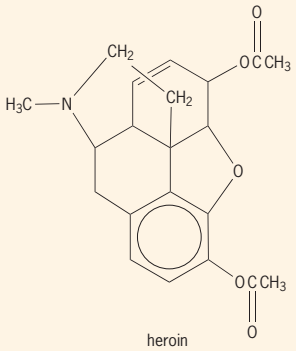
ibuprofen



morphine



codeine



heroin

a Explain the difference in the method of action of mild analgesics and strong analgesics.

(2 marks)

b State the name of the nitrogen-containing functional group in each of the following molecules.

Paracetamol Heroin

(2 marks)

c Naturally occurring morphine can be converted into synthetic heroin by reaction with ethanoic acid. Identify the **group** in the morphine molecule that reacts with ethanoic acid, the name of the **type of reaction** and the **other product** of the reaction.

(3 marks)

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4 **a** Ethanol in the human body can be detected in several ways.

i Explain how the breathalyser works and describe its colour change in a positive result.

(2 marks)

ii Explain how alcohol is detected using an intoximeter.

(2 marks)

b Identify three compounds that are classified as depressants.

(2 marks)

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5 a i List the three different ways in which drugs can be injected into the body.

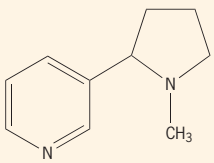
ii Predict, giving a reason, which of the three methods will result in the drug having the most rapid effect.

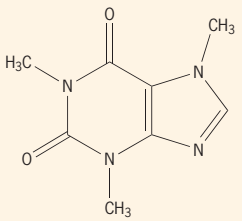
(4 marks)

b State what is meant by tolerance towards a drug and explain why it is potentially dangerous.

(2 marks)

6 Caffeine and nicotine are two stimulants whose structures are below.





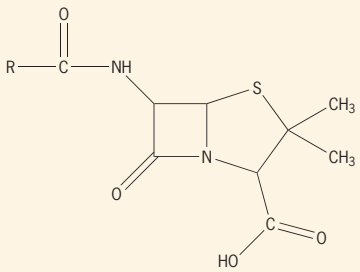
a Describe two similarities in their structures, not including the presence of double bonds, methyl groups and nitrogen atoms.

(2 marks)

b Discuss the problems associated with nicotine consumption, distinguishing between short-term and long-term effects.

(6 marks)

7 Penicillins are molecules that can kill harmful micro-organisms. Their general structure is shown below.



a State the type of micro-organism killed by penicillins and explain how they do this.

(4 marks)

b Explain the effect of overprescription of penicillins.

(3 marks)

8 a State **two** differences between viruses and bacteria.

(2 marks)

b Suggest how acyclovir acts as an antiviral drug.

(2 marks)

c Describe **two** ways in which an antiviral drug can prevent HIV from interacting with human cells.

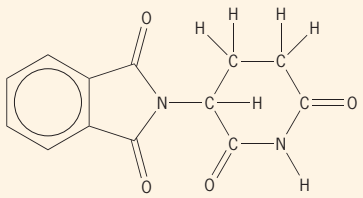
(2 marks)

Total (SL): 50 marks

Higher level questions

HL

9 a The structure of the drug thalidomide is as follows:



i Identify the chiral carbon atom in the structure of thalidomide using an asterisk (*).

(1 mark)

ii State the effect of each of the **two** isomers of thalidomide in human beings.

(2 marks)

b The compound *cis*-platin is an example of an inorganic complex that has an isomer.

i Draw the structures of *cis*-platin and its isomer.

(1 mark)

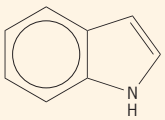
ii State with a reason the type of isomerism shown by *cis*-platin in **b i**.

(1 mark)

iii Identify the isomer that has an important pharmacological effect and state the name of the disease it treats.

(1 mark)

c Indole is an example of an amine.



i State whether the amine group in indole is primary, secondary or tertiary.

(1 mark)

ii Identify **two** mind-altering drugs that have the indole ring structure.

(1 mark)

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10 a Describe how chiral auxiliaries can be used to synthesize only the desired enantiomeric form of a drug from a non-chiral starting compound. Explain why it is important to use only the desired enantiomeric form of a drug and state an example of what can happen if a racemic mixture is used.

(5 marks)

b Explain the importance of the beta-lactam ring action of penicillin.

(3 marks)

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11 Discuss the arguments for and against the legalization of cannabis.

(4 marks)

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Total (HL): 70 marks

Chapter 5 Review questions

Standard level questions

1 Describe the state of the environment if humans did not exist on Earth.

2 Describe both the natural and anthropogenic sources of CO, NO_x, SO_x, particulates and VOCs in the atmosphere.

3 Evaluate the use of catalytic converters as a means to reduce air pollution.

4 Compare the use of alkaline scrubbers and fluidized beds as a means to reduce the emission of SO_2.

5 Describe the problem associated with using lean-burn engines as a way to reduce air pollution.

6 Explain why particulates are one of the least examined causes of air pollution. Describe what can be done to stop particulates entering our atmosphere. Comment on whether or not this solution will stop all particulates from entering the atmosphere.

7 Research and evaluate whether or not 'sick building syndrome' is an actual medical condition.

8 Describe the origin of acid deposition. State who is to blame—humans or nature?

9 Discuss the environmental effects of acid deposition and possible methods of counteracting them.

10 Explain how the death of Scandinavian forests can be blamed on pollution from UK power stations.

11 Give an equation for the reaction of acid deposition with marble statues.

12 The use of internal combustion engines in cars is a leading cause of pollution that results in acid deposition.

- **a** Give an equation that shows the formation of NO in an engine and give the resulting equation for the formation of its corresponding acid in the atmosphere.
- **b** Give the equation for the gas that results if this same engine is fitted with a catalytic converter.
- **c** Explain how the catalytic converter causes a reduction in acid deposition.

13 Describe the greenhouse effect in terms of radiation of different wavelengths.

14 Comment on the reality of climate change linked to the greenhouse effect.

15 Discuss the impact that methane gas and carbon dioxide gas have on the greenhouse effect.

16 Identify the group of countries (developing or developed) that are the most responsible for contributions to the greenhouse effect. Explain what should be done about these countries.

17 Describe the link between wavelength and ozone depletion and formation.

18 Discuss the advantages and disadvantages of using hydrocarbons and hydrofluorocarbons as alternatives to CFCs.

19 Explain how the use of phosphates in detergents can lead to eutrophication.

20 Power stations often use local water supplies for cooling purposes. Comment on this practice.

21 Explain the link between BOD and the health of a water source.

22 Outline the nature of primary treatment of waste water and list the main pollutants removed during this stage of waste water treatment.

23 Outline the nature of secondary treatment of waste water and list the main pollutants removed during this stage of waste water treatment.

24 Heavy metals are some of the most harmful water pollutants. State how these pollutants are removed and give one environmental and one health effect of each specific heavy metal.

25 Compare reverse osmosis and distillation, the two main methods of obtaining fresh water from sea water.

26 Discuss salinization, nutrient degradation and soil pollution as causes of soil degradation.

27 Comment on how SOM levels can be increased.

28 List the most common soil organic pollutants and give their sources.

29 Outline and compare the various methods for waste disposal.

30 Comment on why it is important to participate in recycling programs.

31 Discuss whether or not recycling is a viable means of waste reduction.

Higher level questions

32 Describe the relationship between ozone and CFCs, giving appropriate equations.

33 Explain why we should be concerned by the destruction of the ozone layer, especially if we live in the far north or the far south of our planet.

34 Describe the chemical that is most responsible for the formation of photochemical smog.

35 Describe the ideal atmospheric and geographical conditions for the formation of photochemical smog.

36 State the mechanisms for the formation of the secondary components of smog—aldehydes and peroxyacylnitrates.

37 Describe the involvement of hydroxyl radicals in the formation of acid deposition.

38 Discuss the link between electrochemistry and the involvement of ammonia in acid deposition.

39 Discuss the physical, biological and chemical functions of SOM.

40 Explain the role that lime plays in the maintenance of a suitable soil pH.

41 Write the expressions and give the units for the solubility products of

a bismuth sulfide

b silver chromate.

42 Calculate how many grams of ZnS will dissolve in 0.250 dm^3 of water. The K_{sp} value for ZnS is 1.6×10^{-24}.

43 Calculate the minimum concentration of AgCl that dissolves in a 0.20 mol dm^3 solution of NaCl. The K_{sp} value for AgCl is 1.6×10^{-10}.

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Weblinks are available on the Companion Website to support learning and research related to this chapter.

Chapter 5 Test

Standard level questions

1 Carbon monoxide and sulfur oxides are air pollutants. For each one

a Identify a major human activity responsible for its formation.

b Write an equation showing its formation.

c Describe one harmful effect on the human health.

d Describe one method of decreasing its formation, other than by using alternatives to fossil fuels.

(8 marks)

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2 **a** Use equations to show how ozone undergoes natural depletion in the atmosphere.

(2 marks)

b Identify one pollutant that contributes to the lowering of the ozone concentration in the upper atmosphere. State a source of the pollutant identified.

(2 marks)

c Fluorocarbons and hydrofluorocarbons are now considered as alternatives to some ozone-depleting pollutants. Outline one advantage and one disadvantage of the use of these alternatives.

(2 marks)

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3 **a** Explain, with the help of an equation, why rain is naturally acidic.

(2 marks)

b Catalytic converters are used in motor vehicles to reduce the emissions of acidic gases.

i Give an equation to show the formation of nitrogen(II) oxide in a motor vehicle and identify the acid it forms in the atmosphere.

(2 marks)

ii Nitrogen(II) oxide reacts with carbon monoxide in a catalytic converter to produce harmless substances. Deduce the equation for this reaction.

(2 marks)

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4 The term greenhouse effect is used to describe a natural process for keeping the average temperature of the Earth's surface nearly constant.

a Describe the greenhouse effect in terms of radiations of different wavelengths.

(4 marks)

b Water vapour acts as a greenhouse gas. State the main natural and man-made sources of water vapour in the atmosphere.

(2 marks)

c Two students disagreed about whether carbon dioxide or methane was more important as a greenhouse gas.

i State one reason why carbon dioxide could be considered more important than methane as a greenhouse gas.

(1 mark)

ii State one reason why methane could be considered more important than carbon dioxide as a greenhouse gas.

(1 mark)

d Discuss the effects of global warming on the Earth.

(4 marks)

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5 The demand for drinking water continues to be a problem for the world. About 97% of all the water on the planet is present in the seas and oceans and most of the rest is in ice caps or glaciers.

a One method used to provide drinking water from sea water is reverse osmosis, which uses a partially permeable (semipermeable) membrane.

i Outline the terms *osmosis* and *partially permeable membrane*.

(2 marks)

ii Explain the technique of reverse osmosis used to produce drinking water from sea water.

(3 marks)

b Water that allows marine life to flourish needs a high concentration of dissolved oxygen. Several factors can alter the oxygen concentration.

i State how an increase in temperature affects the oxygen concentration.

(1 mark)

ii Eutrophication is a process that decreases the oxygen concentration of water. Explain how the accidental release of nitrates into a river can cause eutrophication.

(2 marks)

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6 Discuss salinization, nutrient depletion and soil pollution as causes of soil degradation.

(6 marks)

7 Compare the storage and disposal methods for both low-level and high-level radioactive waste.

(4 marks)

Total (SL): 50 marks

Higher level questions

8 a State and explain, using equations, the term cation-exchange capacity (CEC).

(4 marks)

b Explain, using equations, how cation-exchange capacity is affected by acidic and basic soils.

(5 marks)

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9 a Describe the main source of photochemical smog and its main component.

(2 marks)

b Explain how the formation of thermal inversions may increase the effect of pollution.

(2 marks)

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10 Ozone depletion in the upper atmosphere poses a threat to living organisms.

a Describe, with the help of balanced equations, the ozone–oxygen system that existed in the upper atmosphere before its disturbance by human activities. In your answer describe the role of light in this process and discuss the importance of wavelength in the reactions involved.

(5 marks)

b Discuss the role of chlorofluorocarbons (CFCs) in the process of ozone depletion. Your answer should include a description of the mechanism and an explanation as to why a small amount of CFCs has such a large effect on the ozone layer.

(5 marks)

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Total (HL): 73 marks

Chapter 6 Review questions

Standard level questions

1 Comment on the following statement: 'Food is what you put in your mouth and nutrients are what your body soaks up from the food.' Discuss the validity of this statement.

2 Describe the general chemical reaction that occurs when a triester is formed.

3 Draw the lipid structure that results when you combine a glycerol molecule with a molecule of dodecanoic acid ($CH_3(CH_2)_{10}COOH$) and two molecules of tetracosanoic acid ($CH_3(CH_2)_{22}COOH$).

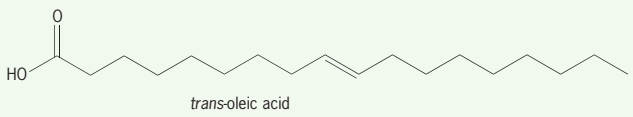
4 Describe the components that constitute a monosaccharide and explain how monosaccharides are related to disaccharides and polysaccharides.

5 Describe the general structure of a 2-amino acid and explain how these chemicals combine to form proteins.

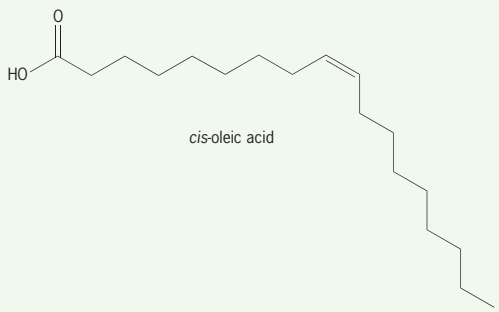
6 Give the general structure of a fatty acid.

7 Describe the difference in structure between saturated and unsaturated fatty acids.

8 Explain which of the molecules below will have the higher melting point.



trans-oleic acid



cis-oleic acid

9 Explain the difference between fats and oils in terms of their physical states and their melting points.

10 Explain why saturated fats are more stable than unsaturated fats, and describe the four possible reactions that unsaturated fats can undergo.

11 The conversion of liquid oils to semi-hard fats by the addition of hydrogen to the unsaturated double bonds was invented by English chemist William Norman in 1901. Comment on the importance of this process if you had a career as a baker. Comment on the issues associated with this process if you had a career as a dietician.

12 Explain why a food's shelf life would be important to the following stakeholders:

a Consumers

b Manufacturers

c Shop owners

13 You have recently been hired as the quality-control officer for a newly developed food production business that specializes in the manufacture of various food products. Describe the factors that you would have to be concerned with that may affect the shelf life of your products.

14 Compare the processes of hydrolytic and oxidative rancidity of fats.

15 Describe the traditional methods used by different cultures to extend the shelf life of foods. Compare these traditional methods of preservation with modern means of minimizing the rate of rancidity in food.

16 Food was once to be found only in the kitchen; now its domain has spread into the chemistry laboratory. One area that has been developing quickly in food chemistry is the development of synthetic antioxidants that can extend the shelf life of various foods. Compare the use of natural and synthetic antioxidants in foods today.

17 Explain why tomatoes appear red and carrots appear orange and blueberries appear blue.

18 Describe the range of colours, the sources of and the factors affecting the colour stability of these naturally occurring pigments: anthocyanins, carotenoids, chlorophyll and heme.

19 Comment on the following statement: 'Some scientific studies have shown that when children consume foods that contain certain synthetic colourants the occurrence of hyperactivity increases.'

20 Compare the two processes of non-enzymatic browning and caramelization that cause the browning of food.

21 Explain why the debate on genetically modified food has grown in recent years even though farmers have been modifying their crops for generations.

22 Discuss the benefits and concerns of using genetically modified foods.

23 Distinguish between suspensions, emulsions and foams in food. State two examples of each type of dispersed system.

24 When making an oil and vinegar vinaigrette, mustard is often used to improve the taste and to act as an emulsifier. Explain the importance of mustard as an emulsifier in the vinaigrette.

Higher level questions

25 Auto-oxidation is responsible for the loss of flavour in foods such as butter. During the first step of this type of rancidity, a metal catalyst or light is required. Explain why this is so.

26 Describe the steps in the free-radical chain mechanisms that occur during the four steps (initiation, propagation, peroxide decomposition and termination) of oxidative rancidity.

27 List the functional groups that are common to these free radical antioxidants: BHA, BHT, TBHQ and tocopherols.

28 Explain how EDTA, ascorbic acid and carotenoids can act as antioxidants.

29 Compare the different conventions used for naming the different enantiomeric forms: D and L system, R and S system and (+) and (–) system.

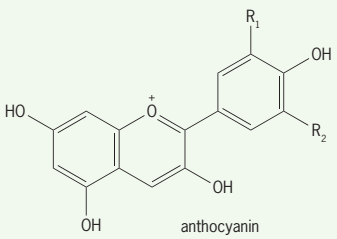
30 Explain how the conventions used for naming the different enantiomeric forms are important in the study of food chemistry.

31 Explain why stereoisomerism is important in determining authenticity in the food industry.

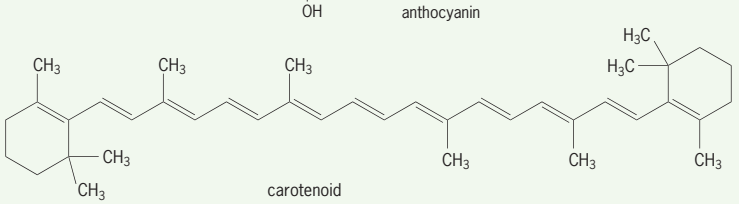
32 Explain the importance of stereoisomerism in amino acids and sugars.

33 Compare the similarities and differences in the structures of these natural pigments: anthocyanins, carotenoids, chlorophyll and heme.

34 By examining the structures of anthocyanin and carotenoid below, deduce whether these molecules are water- or fat-soluble.



anthocyanin



carotenoid

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Weblinks are available on the Companion Website to support learning and research related to this chapter.

Chapter 6 Test

Standard level questions

1 Polypeptides and proteins are formed by the condensation reactions of amino acids.

a Give the general structural formula of a 2-amino acid.

(1 mark)

b Give the structural formula of the dipeptide formed by the reaction of alanine and glycine. State the other substance formed during this reaction.

(2 marks)

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2 Fats and oils can be described as esters of glycerol, $C_3H_8O_3$.

a Draw the structure of glycerol.

(1 mark)

b Glycerol can react with three molecules of stearic acid, $C_{17}H_{35}COOH$, to form a triglyceride. Deduce the number of carbon atoms in one molecule of this triglyceride.

(1 mark)

c A triglyceride is also formed in the reaction between glycerol and three molecules of oleic acid, $C_{17}H_{33}COOH$. State and explain which of the two triglycerides (the one formed from stearic acid or the one formed from oleic acid) has the higher melting point.

(3 marks)

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3 **a** State how genetically modified food differs from unmodified food.

(1 mark)

b List **two** benefits and **two** concerns of using genetically modified crops.

(4 marks)

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4 **a** **i** Explain the meaning of shelf life.

(1 mark)

ii State two properties which are affected when food has exceeded its shelf life.

(2 marks)

b Discuss one way, different in each case, in which each of the following factors affect the shelf life and quality of food.

- Water content
- pH change
- Light

(3 marks)

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5 Compare the two processes of non-enzymatic browning (Maillard reaction) and caramelization that cause browning of food, in terms of the following.

a An example of one food affected

- Maillard reaction
- Caramelization

(2 marks)

b The chemical composition of food affected

- Maillard reaction
- Caramelization

(2 marks)

c The factors that increase the rate of browning

- Maillard reaction
- Caramelization

(2 marks)

d Features of the product

- Maillard reaction
- Caramelization

(2 marks)

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6 **a** Describe dispersed systems in food.

(1 mark)

b Distinguish between the following types of dispersed systems.

- Suspension
- Emulsion
- Foam

(3 marks)

c Lecithin is an example of a natural emulsifier. State one feature that enables lecithin to act as an emulsifier and describe its action.

(2 marks)

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7 List the main features of a lipid, a carbohydrate and a protein.

(3 marks)

8 **a** Distinguish between a dye and a pigment.

(1 mark)

b Explain the occurrence of colour in naturally occurring pigments.

(1 mark)

c List a source for the following naturally occurring pigments: anthocyanins and chlorophyll.

(2 marks)

Total (SL): 40 marks

Higher level questions

HL

9 Describe the steps in the free-radical chain mechanism occurring during the oxidative rancidity, ensuring that you give the appropriate chemical equations.

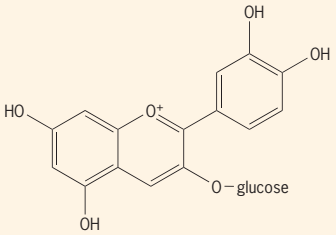
(8 marks)

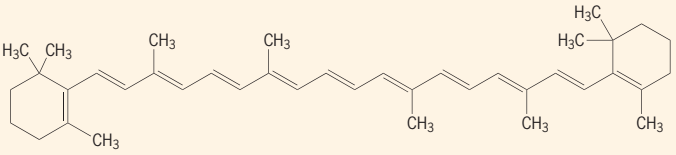
10 Distinguish between the three main types of antioxidants and give an example of each.

(6 marks)

11 Examine the structures below and explain whether the compounds are water-soluble or fat-soluble.

(4 marks)





12 Distinguish between the properties of the different enantiomeric forms of stereoisomers that can be found in various foods.

(2 marks)

Total (HL): 60 marks

Chapter 7 Review questions

Standard level questions

1 With the aid of examples, explain the meaning of each of the following.

- **a** Nucleophile
- **b** Electrophile
- **c** Carbocation
- **d** Grignard reagent
- **e** An unsymmetrical alkene

2 Draw diagrams to illustrate each of the following.

- **a** A cyanohydrin
- **b** An alkoxide ion
- **c** A substituted phenol
- **d** A hydrazone
- **e** Two resonance structures for benzene

3 An organic compound with molecular formula C_3H_6 reacts with hydrogen chloride to form two organic products, both with molecular formula C_3H_7Cl. The yield of one product is much greater than that of the other.

- **a** Draw structural formulas for the organic compound C_3H_6 and for the two organic products C_3H_7Cl.
- **b** Name the type of reaction occurring to produce the two organic products C_3H_7Cl.
- **c** In terms of the mechanism of the reaction, explain why the yields of the two products are not the same.

4 Write equations for the reaction between:

- **a** butanal and hydrogen cyanide
- **b** methanal and ethylmagnesium bromide
- **c** butanone and hydrogen cyanide
- **d** but-2-ene and bromine
- **e** 1-bromopentane and magnesium

5 **a** Name the reaction type for the reaction of ethanal with hydrogen cyanide.

- **b** Draw a mechanism for the reaction of ethanal with hydrogen cyanide.
- **c** Draw the structure of the compound formed when the product from the reaction of ethanal with hydrogen cyanide is hydrolysed.

6 An organic compound of molecular formula C_4H_8O reacted with 2,4-dinitrophenylhydrazine to form an orange precipitate.

- **a** Draw the structural formula of the functional group that is responsible for the reaction.
- **b** Draw two possible structures for the organic compound.
- **c** Draw a mechanism for the addition of hydrogen cyanide to one of the compounds drawn in part **b**.
- **d** Explain why the reaction between 2,4-dinitrophenylhydrazine and the compound is useful in deciding which of the compounds drawn in part **b** is correct.

7 Identify the reagent and reaction type used to convert:

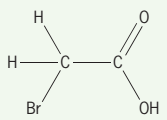
- **a** butanone to 2-hydroxybutan-2-nitrile
- **b** ethene to 1,2-dibromoethane
- **c** ethylmagnesium bromide to ethane
- **d** chloroethane to ethylmagnesium chloride
- **e** propylmagnesium bromide to butanoic acid

8 Cyclohexene reacts with hydrogen to form cyclohexane.

$C_6H_{10} + H_2 \rightarrow C_6H_{12}$ $\quad \Delta H = -120 \text{ kJ mol}^{-1}$

- **a** Calculate the expected heat of hydrogenation of benzene, assuming its structure to be 1,3,5-cyclohexatriene.
- **b** Explain why the experimental value differs from the value calculated in part **a**.
- **c** Discuss the bonding and structure present in benzene.

9 Consider molecules P–S.



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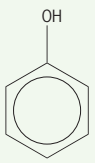

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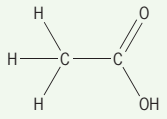

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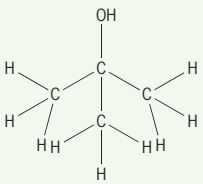


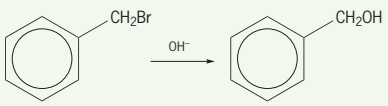
S

- **a** Place the molecules in order of increasing acidity, clearly stating which is the most acidic.
- **b** Explain your choices in part **a**.

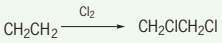
10 For each reaction below, state the reaction type. Choose from the following list:

- Electrophilic addition
- Elimination
- Nucleophilic addition
- Nucleophilic substitution

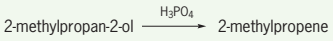
a



b



c



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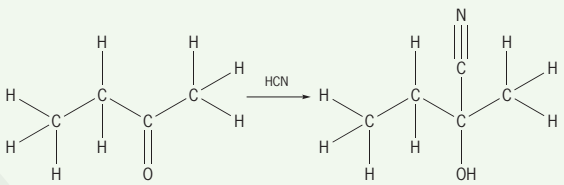


11 Explain why:

a aminoethane is more basic than ammonia

b 2,4,6-trinitrophenol is more acidic than phenol.

12 Consider molecules W–Z.

W **X**

Y **Z**

a Place the molecules in order of increasing basicity, clearly stating which is the most basic.

b Explain your choices in part **a**.

13 State the type of reaction that takes place when:

a propene reacts with hydrogen chloride to form 2-chloropropane

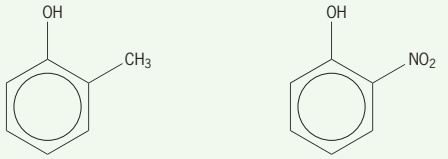
b propanal reacts with hydrogen cyanide to form 2-hydroxybutanenitrile

c ICl reacts with 2-methylpropene

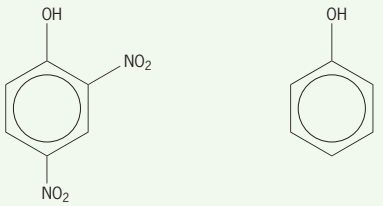
d hexanone reacts with 2,4-dinitrophenylhydrazine in aqueous solution

e bromomethylbenzene reacts to form phenylmethanol.

14 Consider molecules K–N.



K **L**



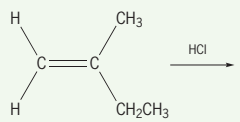
M **N**

a Place the molecules in order of increasing acidity, clearly stating which is the most acidic.

b Explain your choices in part **a**.

15 Predict the major product in each of the following reactions. Explain your choices.

a



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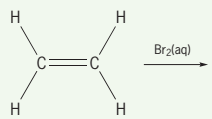


16 Draw the mechanism of each of the following reactions using 'curly arrows' to show the movement of pairs of electrons.

a Hydrogen cyanide reacts with ethanal to form 2-hydroxypropanenitrile.

b ICl is added to 2-butene.

c Bromomethyl benzene reacts with hydroxide ion.

d Propan-1-ol undergoes acid catalysed dehydration.

17 Draw possible two-step reaction pathways for the synthesis of the following compounds from the given starting compounds. Include structural formulas, and any inorganic reagents and conditions needed for the pathway.

a 2-Hydroxy-2-methylbutanoic acid from butanone

b Propanone from propene

c Ethanoic acid from bromomethane

d 3-Methyl-3-hydroxypentane from butanone and 1-bromoethane

e 2,2-Dimethylbutanoic acid from 2-bromo-2-methylbutane

Higher level questions

18 Draw diagrams and give the names of compounds to illustrate each of the following.

a An acyl chloride containing four carbon atoms

b An acid anhydride containing six carbon atoms

c An ester containing four carbon atoms

d A substituted amide containing five carbon atoms

19 Write equations using structural formulas for the:

a mononitration of toluene ($C_6H_5CH_3$)

b preparation of propanoic acid using propanoic anhydride

c reaction of methylbenzene with chlorine in the presence of an aluminium chloride catalyst

d production of methyl ethanoate from ethanoyl chloride.

20 Identify the reagent and catalyst used to convert:

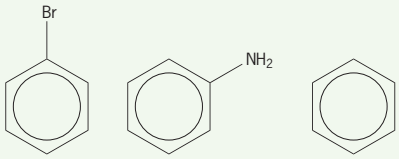
a propanoyl chloride to propanamide

b benzene to ethylbenzene

c ethanoic anhydride to *N*,*N*-dimethylethanamide

d benzene to phenylethanone.

21 Consider molecules J, K, L below.



J **K** **L**

a List the molecules in order of increasing reactivity towards reaction with chlorine.

b Explain your choices in part **a**.

22 Draw possible reaction pathways of no more than two steps for the synthesis of the following compounds from the given starting compounds. Include structural formulas, and any inorganic reagents and conditions needed for the pathway.

a Methanoic acid from methanoyl chloride

b 2-Nitromethylbenzene from benzene

c *meta*-Bromonitrobenzene from benzene

d 2,4,6-Trichlorophenol from phenol

23 Methylbenzene, $C_6H_5CH_3$, reacts with Cl_2 to form different products depending on the conditions used.

a Consider the reaction of $C_6H_5CH_3$ and Cl_2 in ultraviolet light.

i Name the type of reaction occurring.

ii Draw a structural formula for the product C_7H_7Cl.

iii What is the role of the ultraviolet light?

b Consider the reaction of $C_6H_5CH_3$ and Cl_2 in the presence of aluminium chloride.

i Name the type of reaction occurring.

ii Draw a structural formula for the product C_7H_7Cl.

iii Explain the role of the aluminium chloride.

24 Bromine can react with benzene by an electrophilic substitution mechanism.

a Write the equation for the formation of bromobenzene from benzene.

b State the conditions used for this reaction.

c Show how the electrophile in the reaction is formed.

d Draw a mechanism for the reaction.

25 Draw the mechanism of each of the following reactions using 'curly arrows' to show the movement of pairs of electrons.

a Methanol reacts with ethanoyl chloride

b Benzene reacts with methanoyl chloride

c Phenol reacts with a mixture of concentrated nitric and sulfuric acids.

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Weblinks are available on the Companion Website to support learning and research related to this chapter.

Chapter 7 Test

Standard level questions

1 Butan-2-ol can be converted to but-2-ene.

a State the reagent used for this conversion and identify the type of reaction.

(2 marks)

b Give the mechanism for the reaction. Use curly arrows to represent the movement of electron pairs.

(3 marks)

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2 On being reacted separately with HBr, 2-methylbut-1-ene and 2-methylbut-2-ene produce the same major product but different minor products.

a Draw the structural formula of the major product and explain why it is formed in terms of the stability and structure of the organic intermediate.

(4 marks)

b Draw the structural formulas of the two minor products.

(2 marks)

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3 When hydrogen cyanide reacts with an aldehyde or a ketone the product molecule has one more carbon atom.

a Give a mechanism for the reaction of hydrogen cyanide with propanone.

(4 marks)

b Write an equation for the acid hydrolysis of this product. State the two functional groups in the organic product.

(2 marks)

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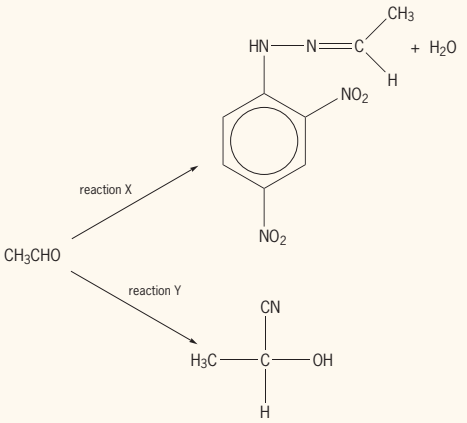
4 Two reactions of ethanal are shown.



a **i** State the type of reaction for:

X

Y

(2 marks)

ii Give the structure of the compound formed when reaction X is carried out using the alkanal of formula C_6H_5CHO instead of ethanal.

(1 mark)

b State the reagent used for reaction X and explain how this reaction can be used for the identification of individual alkanals and alkanones.

(4 marks)

c Explain why reaction Y is useful in organic synthesis and give the structure of the compound formed when the product of reaction Y is hydrolysed. Explain why the product of this reaction exists in different forms.

(3 marks)

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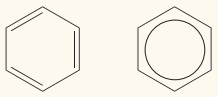
5 The structure of benzene can be represented in two ways.



structure A structure B

a Use information from the IB Data Booklet © IBO 2007 to explain why structure B is used instead of structure A.

(2 marks)

b The enthalpy changes for the hydrogenation of cyclohexane and benzene are as follows:

$C_6H_{10} + H_2 \rightarrow C_6H_{12}$ $\Delta H = -120$ kJ mol^{-1}

$C_6H_6 + 3H_2 \rightarrow C_6H_{12}$ $\Delta H = -210$ kJ mol^{-1}

Explain how this information can be used to support the statement that structure B is more stable than structure A.

(3 marks)

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6 Samples of $C_6H_5CHClCH_3$ and C_6H_5Cl are warmed separately with aqueous sodium hydroxide. State, with a reason, whether $C_6H_5CHClCH_3$ or C_6H_5Cl would react more slowly.

(2 marks)

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7 The IB Data Booklet © IBO 2007 contains pK_a values for organic compounds.

a Write an equation for the dissociation of 2-nitrophenol in aqueous solution. Explain with reference to its structure and this equation why 2-nitrophenol is a stronger acid than phenol.

(2 marks)

b Write an equation to show how methylamine acts as a base in aqueous solution. Explain with reference to its structure and this equation why dimethylamine is a stronger base than methylamine.

(3 marks)

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8 The strength of an organic acid can be considered in terms of the breaking of the O–H bond in the molecule.

a State how the strength of an acid is related to the dissociation constant, K_a, of the acid, and to its pK_a value.

(2 marks)

b By referring to their structures, explain the difference in the acid strengths of ethanol and phenol.

(2 marks)

c Use the IB Data Booklet © IBO 2007 to find the pK_a values of the following acids. State how the presence of substituents in carboxylic acids affects their acid strengths. For each pair, explain the difference in acid strength by referring to the substituents.

- Ethanoic acid and propanoic acid
- Chloroethanoic acid and dichloroethanoic acid
- Chloroethanoic acid and fluoroethanoic acid

(5 marks)

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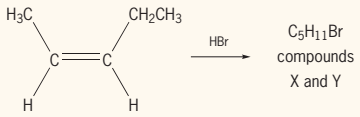
9 *This question concerns the reaction shown in the diagram below.*



Markovnikov's rule is sometimes useful in predicting the major product in this type of reaction. Explain why this rule cannot be used to predict whether X or Y would be the major product.

(2 marks)

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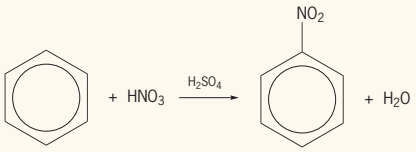
Total (SL): 50 marks

Higher level questions

HL

10 Benzene reacts with a mixture of concentrated nitric acid and concentrated sulfuric acid at 50°C to form nitrobenzene according to the equation:



a Name the mechanism by which this reaction proceeds.

(1 mark)

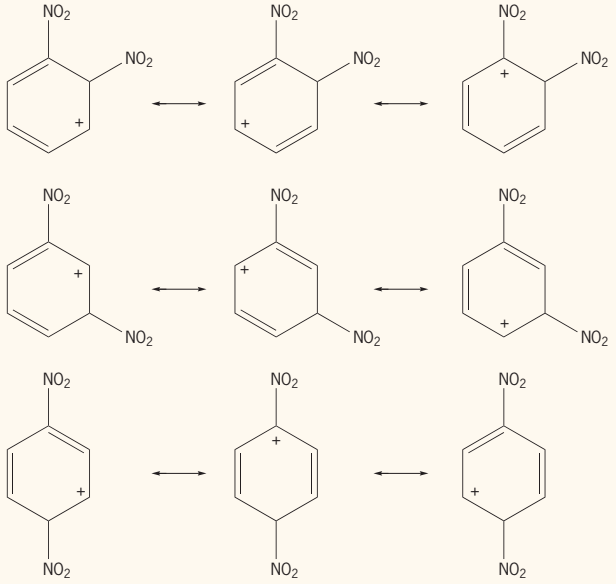
b What is the initial role of the sulfuric acid when it functions as a catalyst in this reaction?

(1 mark)

c The product, nitrobenzene, can be further nitrated with a mixture of concentrated nitric acid and sulfuric acid, but the temperature needs to be increased to 100°C. Explain why nitrobenzene is less reactive towards nitration than benzene.

(2 marks)

d The further nitration of nitrobenzene can take place in the 2-, 3- or 4- position. The structures of the possible intermediate carbocations are given below:



i State what is meant by the term *resonance hybrid*.

(1 mark)

ii Explain why the major product in the reaction is 1,3-dinitrobenzene rather than 1,2-dinitrobenzene or 1,4-dinitrobenzene.

(2 marks)

11 A student prepared a sample of compound Y from benzene as follows:

$$C_6H_6 \rightarrow C_6H_5CH_2CH_3 \rightarrow C_6H_5CHClCH_3$$

X Y

a **i** The first step was the conversion of benzene to compound X, using chloroethane as the reagent and aluminium chloride as a catalyst. Write the equation for the reaction and give equations for the mechanism.

(5 marks)

ii Name the type of mechanism that occurs in the second step when X is converted to Y.

(1 mark)

12 Explain why the nitration of methylbenzene is faster than the nitration of benzene.

(2 marks)

13 The compound CH_3CH_2COCl reacts rapidly with water. State the name of the organic product and write equations to show the mechanism of the reaction.

(5 marks)

Total (HL): 70 marks