INSIGHT

Year 12 *Trial Exam Paper*

2012
CHEMISTRY
Written examination 1

Solutions Book

This book presents:

- correct solutions with full working
- explanatory notes
- mark allocations
- tips and guidelines

SECTION A – Multiple-choice questions

Question 1

Which of the following statements are examples of a quantitative analysis?

I Watermelon contains 92% water by mass.

II A chocolate bar contains 7.45 g of fat.

III A sample of breakfast cereal contains iron.

A. I and III only
B. **I and II only**
C. II and III only
D. I, II and III

Answer is B

Worked solution

- Examples I and II give the amount of one substance present in another substance, meaning they are examples of quantitative analysis. Example III gives the contents of an impure sample, not an analysis of the amount of a component in the sample.
- B is correct.
- A, C and D are incorrect.

Question 2

A 1.00 M standard solution of sodium hydroxide is used to analyse the concentration of hydrochloric acid in brick cleaner. The sodium hydroxide is called a standard solution because:

I sodium hydroxide is a good primary standard

II the concentration of the solution is accurately known

III the concentration of the solution is 1.00 M.

A. I and II only

B. **II only**

C. I and III only

D. I, II and III

Answer is B

Worked solution

- B is correct because II is the only correct statement. The definition of a standard solution is a solution that has an accurately known concentration.
- A is incorrect because statement I is not correct. Sodium hydroxide is not a good primary standard as it can absorb water and react with carbon dioxide in the air.
- C is incorrect because statement III is not correct. The concentration of a standard solution does not have to be 1.00 M. It can be any concentration as long as it is accurately known.
- D is incorrect because statements I and III are not correct statements.

Tip

A standard solution is a solution that has an ***accurately known*** *concentration. A standard solution does not have to be prepared from a primary standard. Its concentration can be determined by titrating it against another standard solution.*

Questions 3 and 4 refer to the following information.

10.0 g of hydrogen sulfide reacts with 15.0 g of sulfur dioxide in a sealed 4.0 L container under standard laboratory conditions according to the following equation:

$$2H_2S(g) + SO_2(g) \rightarrow 2H_2O(l) + 3S(s)$$

Question 3

The mass of sulfur produced, in g, is

A. 6.27
B. **14.1**
C. 22.5
D. 42.3

Answer is B

Worked solution

- B is correct according to the following steps:

Step 1: Determine the excess reactant.

$$n(H_2S) = \frac{m}{M} = \frac{10.0}{34.1}$$
$$= 0.293 \text{ mol}$$

$$n(SO_2) = \frac{m}{M} = \frac{15.0}{64.1} = 0.234 \text{ mol}$$

$$\frac{0.293}{2} = 0.147$$

H_2S is the limiting reactant

Step 2: Determine the mass of S produced.

$$n(H_2S) : n(S)$$
$$2 : 3$$

$$\text{So } n(S) = \frac{3}{2} \times n(H_2S)$$
$$= \frac{3}{2} \times 0.293$$
$$= 0.440 \text{ mol}$$

$$m(S) = nM = 0.440 \times 32.1 = 14.1 \text{ g}$$

- A is incorrect because the ratio $n(H_2S) : n(S)$ is 2 : 3, not 3 : 2. The amount of S produced is determined by $n(S) = \frac{3}{2} \times n(H_2S)$.
- C is incorrect because H_2S, not SO_2, is the limiting reactant.
- D is incorrect because the molar mass of sulfur is 32.1 g mol^{-1} and is used for the value, M, in $n = \frac{m}{M}$. The coefficient of 3 is not relevant to the molar mass used.

Question 4

The volume of gas, in L, remaining in the container after the reaction is complete is

A. 1.9
B. 2.1
C. **4.0**
D. 5.2

Answer is C

Worked solution

- C is correct because the kinetic molecular theory tells us that gases fill all available space. Any amount of gas in a sealed 4.0 L container will occupy the full 4.0 L volume.
- A and B are incorrect because a gas cannot take up less volume than the container that it is in.
- D is incorrect because a gas cannot have a larger volume than the container it is sealed in.

Question 5

10.0 g of aspirin, $C_9H_8O_4$, is produced from a reaction between salicylic acid and ethanoic anhydride. The mass, in g, of ethanoic acid produced in this reaction and needing to be removed before the aspirin can be put into tablet form is

A. 1.67
B. 3.33
C. 6.67
D. 10.0

Answer is B

Worked solution

- B is correct because 1 mole of ethanoic acid is produced for every mole of aspirin produced in this reaction.

$$\begin{aligned} n(C_9H_8O_4) &= \frac{m}{M} \\ &= \frac{10.0}{180} \\ &= 0.0556 \text{ mol} \\ n(CH_3COOH) &= 0.0556 \text{ mol} \\ n(CH_3COOH) &= nM \\ &= 0.0556 \times 60 \\ &= 3.33 \text{ g} \end{aligned}$$

- A is incorrect because the ratio of ethanoic acid to aspirin produced is 1 : 1, not 1 : 2.
- D is incorrect because the ratio of ethanoic acid to aspirin produced is 1 : 1, not 2 : 1.
- C is incorrect because the ratio of ethanoic acid to aspirin produced is a 1 : 1 mole ratio, not a mass ratio.

Section A - continued

Question 6

To each of three samples of a solution, a different acid–base indicator is added. The following colours are observed.

Indicator	Colour
Phenol red	yellow
Methyl red	yellow
Bromophenol blue	blue

The pH of the solution could be

A. 5.5
B. **6.5**
C. 7.5
D. 8.5

Answer is B

Worked solution

- B is correct according to the following interpretation of the acid–base indicators table in the data booklet:
  - The colour of phenol red indicates the pH is less than 6.8.
  - The colour of the methyl red indicates the pH is above 6.3.
  - The colour of the bromophenol blue indicates the pH is above 4.6.

  pH 6.5 is the only alternative that meets this criteria.
- A is incorrect because the colour of methyl red in a pH 5.5 solution will be intermediate between red and yellow.
- C is incorrect because the colour phenol red in a pH 7.5 solution will be intermediate between yellow and red.
- D is incorrect because the colour phenol red in a pH 8.5 solution will be red.

Question 7

The reactants used for the fastest and best yielding synthesis of aspirin are:

I ethanoic acid

II ethanoic anhydride

III salicylic acid.

A. I and II only

B. I and III only

C. **II and III only**

D. I, II and III

Answer is C

Worked solution

- C is correct because the reaction between salicylic acid and ethanoic anhydride is the fastest and best yielding.
- A is incorrect because ethanoic acid and ethanoic anhydride do not react together to produce aspirin.
- B is incorrect because the reaction between ethanoic acid and salicylic acid is slow and has a low yield.
- D is incorrect because ethanoic acid is not involved in the fastest, best-yielding reaction.

Question 8

Consider the following equation:

$$2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$$

In this reaction

A. H_2O_2 is undergoing oxidation only.

B. H_2O_2 is undergoing reduction only.

C. **H_2O_2 is undergoing both reduction and oxidation.**

D. H_2O_2 is not undergoing either reduction or oxidation.

Answer is C

Worked solution

- C is correct according to the changes in oxidation number of O:
  - In hydrogen peroxide, the oxidation number O = –1.
  - In water, the oxidation number of O = –2.
  - In oxygen gas, a free element, the oxidation number of O = 0.

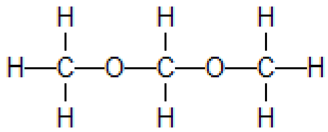
  The oxidation number of O changes from –1 in H_2O_2 to –2 in H_2O and 0 in O_2. It has both increased and decreased, meaning H_2O_2 has undergone both oxidation and reduction.
- A is incorrect because the oxidation number of O changes from –1 in H_2O_2 to –2 in H_2O, meaning H_2O_2 is also undergoing reduction.
- B is incorrect because the oxidation number of O changes from –1 in H_2O_2 to 0 in O_2, meaning H_2O_2 is also undergoing oxidation.

Tip

While O is usually assigned oxidation number –2, it is important to remember the exception that in peroxides O takes the oxidation number of –1. Also, some students forget that all free elements, including O_2 (and H_2) are assigned an oxidation number of 0. Similarly, while H is usually assigned oxidation number +1, we also remember the exception that in metal hydrides, such as NaH, H takes the oxidation number of –1.

Question 9

Consider the following molecular structure.



The number of peaks and peak splitting that would be observed when this molecule was subject to high resolution ^{1}H NMR is

	Number of peaks	Peak splitting
A.	2	One peak split into a triplet, one peak split into a quartet
B.	**2**	**No splitting evident**
C.	3	One peak split into a triplet, two peaks each split into a quartet
D.	3	One peak split into a doublet, two peaks each split into a triplet

Answer is B

Worked solution

- In high-resolution ^{1}H NMR, the pattern of peaks and splits is according to:
  - Each non-equivalent H environment produces its own major peak.
  - Each major peak is split according to the formula *n* + 1 where *n* is the number of H atoms on the neighbouring atom.
- B is correct because the given molecular formula contains two chemically distinct hydrogen environments. 6 H atoms are in $-CH_3$ and 2 H atoms are in $-CH_2$, so there will be two peaks on the spectrum. The neighbouring atom to both the $-CH_3$ and $-CH_2$ groups is an O with no H atoms attached, so no splitting will be evident.
- A is incorrect because an O atom is the neighbouring atom to both types of H environments, so no splitting is evident.
- C and D are incorrect because there will only be two peaks. The $-CH_3$ groups at either end of the molecule are chemically equivalent environments.

Question 10

Which of the following correctly describes the types of particles that absorb energy in the different spectroscopic techniques of UV–visible spectroscopy, ^{13}C nuclear magnetic resonance spectroscopy and infrared spectroscopy?

	UV–visible spectroscopy	**^{13}C NMR spectroscopy**	**Infrared spectroscopy**
A.	molecules	protons	positive ions
B.	molecules	nucleons	molecules
C.	electrons	protons	positive ions
D.	**electrons**	**nucleons**	**molecules**

Answer is D

Worked solution

- D is correct.
- A is incorrect because all three options are incorrect. It is electrons, not molecules, in UV–visible spectroscopy that absorb energy to move to higher energy levels. In ^{13}C NMR spectroscopy it is nucleons, not protons, that absorb radiowaves. Also, in IR spectroscopy it is the covalent bonds in molecules that absorb infrared radiation.
- B is incorrect because in UV–visible spectroscopy it is electrons, not molecules, that absorb energy to move to higher energy levels.
- C is incorrect because in ^{13}C NMR spectroscopy it is nucleons, not protons, that absorb radiowaves. Also, in IR spectroscopy it is the covalent bonds in molecules that absorb infrared radiation.

Question 11

Which of the following compounds contains the highest percentage by mass of oxygen?

A. Propyl propanoate

B. 1-propanol

C. **Propanoic acid**

D. 1-aminopropane

Answer is C

Worked solution

- The formula of each compound can be used to calculate the percentage by mass of oxygen:

Propyl propanoate is $CH_3CH_2COOCH_2CH_2CH_3$

$$\text{\% by mass of O} = \frac{\text{mass of O in 1 mol}}{\text{molar mass of molecule}} \times 100$$
$$= \frac{32.0}{116} \times 100$$
$$= 27.6\%$$

1-propanol is $CH_3CH_2CH_2OH$

$$\text{\% by mass of O} = \frac{\text{mass of O in 1 mol}}{\text{molar mass of molecule}} \times 100$$
$$= \frac{16.0}{60.0} \times 100$$

Propanoic acid is CH_3CH_2COOH

$$\text{\% by mass of O} = \frac{\text{mass of O in 1 mol}}{\text{molar mass of molecule}} \times 100$$
$$= \frac{32.0}{74.0} \times 100$$
$$= 43.2\%$$

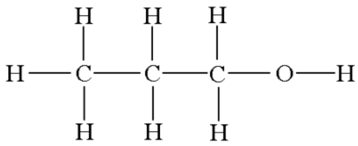
1-aminopropane is $NH_2CH_2CH_2CH_3$

There is no oxygen in the compound.

- C is correct.
- A, B and D are incorrect.

Question 12

Propene is reacted with substance X to produce the following structure.



The name of substance X is:

A. methanol

B. sodium hydroxide

C. ethanol

D. **water**

Answer is D

Worked solution

- Propanol is produced by an addition reaction of propene.
- D is correct because an alkanol is produced from an alkene by adding H_2O across the double bond.
- A is incorrect because propene will not react with methanol to produce propanol.
- B is incorrect because sodium hydroxide is not used in an addition reaction with an alkene.
- C is incorrect because propene will not react with ethanol to produce propanol.

Question 13

Which of the following gives the correct systematic name of a compound that is an isomer of heptane?

A. 1-methylhexane
B. 2,3-dimethylbutane
C. 3-methylheptane
D. **2-methylhexane**

Answer is D

Worked solution

- D is correct because 2-methylhexane is $CH_3CH_2CH_2CH_2CH(CH_3)CH_3$ so has a molecular formula C_7H_{16}. It has exactly the same number and type of atoms as heptane, C_7H_{16}.
- A is incorrect because 1-methylhexane is not a correct systematic name of a compound. An alkyl branch can never be attached to the first carbon in a longest chain because it would always become part of the longest chain.
- B is incorrect because 2,3-dimethylbutane is $CH_3CH(CH_3)CH(CH_3)CH_3$ so has a molecular formula C_6H_{14}. It is not an isomer of heptane, C_7H_{16}.
- C is incorrect because 3-methylheptane is $CH_3CH_2CH(CH_3)CH_2CH_2CH_2CH_3$ so has a molecular formula C_8H_{18}. It is not an isomer of heptane, C_7H_{16}.

Question 14

Ethyl butanoate, $CH_3CH_2OOCCH_2CH_2CH_3$, is used in pineapple flavouring. The formulas for the molecules that react to produce ethyl butanoate are

A. CH_3COOH and $CH_3CH_2CH_2CH_2OH$
B. CH_3CH_2COOH and $CH_3CH_2CH_2OH$
C. CH_3CH_2OH and CH_3CH_2COOH
D. **$CH_3CH_2CH_2COOH$ and CH_3CH_2OH**

Answer is D

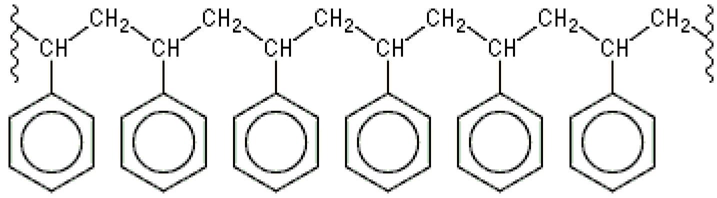
Worked solution

- The naming convention of esters tells us that ethyl butanoate is made from ethanol and butanoic acid.
- D is correct because $CH_3CH_2CH_2COOH$ is butanoic acid and CH_3CH_2OH is ethanol.
- A is incorrect because the molecules are ethanoic acid and butanol.
- B is incorrect because the molecules are propanol and propanoic acid.
- C is incorrect because although ethanol is one of the molecules, the other is propanoic acid.

Section A - continued

Question 15

A section of the structure of polystyrene can be represented by the following formula.



polystyrene

Compared to the percentage by mass of carbon in the polymer, the percentage by mass of carbon in the monomer styrene, from which it is formed, is:

A. **equal**
B. less
C. greater
D. unable to be determined from the information given.

Answer is A

Worked solution

- A is correct because in the addition polymerisation reaction used to produce polystyrene from styrene monomers, no atoms are eliminated or added, so the percentage by mass of each element will remain the same.
- B, C and D are incorrect.

Question 16

Which of the following molecules is produced when a triglyceride containing no carbon–carbon double bonds undergoes hydrolysis?

A. CH_3CH_2OH

B. $C_6H_{12}O_6$

C. $\mathbf{C_{11}H_{23}COOH}$

D. $C_{19}H_{31}COOH$

Answer is C

Worked solution

- The products of the hydrolysis (reaction with water) of a triglyceride are glycerol, $C_3H_8O_3$, and three fatty acids.
- C is correct because $C_{11}H_{23}COOH$ is a saturated fatty acid, meaning it contains no carbon–carbon double bonds.
- A is incorrect because CH_3CH_2OH is an alkanol, not glycerol or a fatty acid.
- B is incorrect because $C_6H_{12}O_6$ is glucose, not glycerol or a fatty acid.
- D is incorrect because although $C_{19}H_{31}COOH$ is a fatty acid, it is unsaturated, meaning it contains carbon–carbon double bonds.

Tip

A saturated fatty acid has the general formula $C_nH_{2n+1}COOH$. If the number of H atoms is less than 2n + 1, it indicates a carbon–carbon double bond is present. Every 2 hydrogen atoms lower than 2n + 1 indicates one double bond.

Question 17

The mass, in g, of bromine that will react with 0.010 mol of oleic acid is

A. 1.6
B. 3.2
C. 0.020
D. 0.010

Answer is A

Worked solution

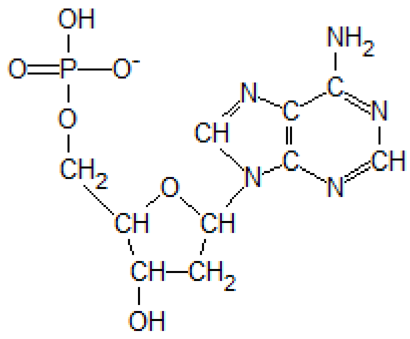
- Bromine, Br_2, is used to indicate unsaturation in molecules because a Br_2 molecule will react with a double bond in an addition reaction. One Br_2 molecule will react with each double bond in a molecule
- A is correct because the formula of oleic acid is $C_{17}H_{33}COOH$, indicating one carbon–carbon double bond is present. It will react with bromine in a 1:1 ratio, meaning 0.010 mol of oleic acid reacts with 0.010 mol of bromine.

$$\begin{aligned} m(\mathrm{Br_2}) &= nM \\ &= 0.010 \times (2 \times 79.9) \\ &= 1.6 \text{ g} \end{aligned}$$

- B is incorrect because there is only 1 double bond in oleic acid, not 2, so it reacts in a 1:1 ratio with bromine, not 1:2.
- C is incorrect because this is the amount, in mol, of bromine required, not its mass.
- D is incorrect because there is only 1 double bond in oleic acid, not 2, so it reacts in a 1:1 ratio with bromine, not 1:2. Also, 0.020 would be the amount, in mol, not the mass.

Question 18

Consider the following structure of a nucleotide.



The name of the base that would form hydrogen bonds with this nucleotide in a complementary strand of DNA is:

A. adenine

B. cytosine

C. guanine

D. **thymine**

Answer is D

Worked solution

- D is correct because this nucleotide contains the base adenine, which always pairs with thymine on the complementary strand in DNA.
- A is incorrect because the base in this nucleotide is adenine and it does not pair with itself.
- B and C are incorrect because cytosine and guanine always pair with each other on complementary strands in DNA.

Question 19

A chemist uses fractional distillation to separate a mixture of water, ethanol, propanol and ethylpropanoate. The first fraction collected will contain mostly

A. water

B. **ethanol**

C. propanol

D. ethylpropanoate

Answer is B

Worked solution

- The first fraction collected in fractional distillation is always the one with the lowest boiling point.
- B is correct because ethanol has the lowest boiling point of the molecules listed.
- A, C and D are incorrect because water, propanol and ethylpropanoate all have a higher boiling temperature than ethanol.

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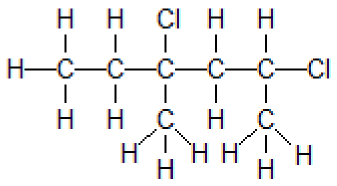
Question 20

Consider the following molecule.

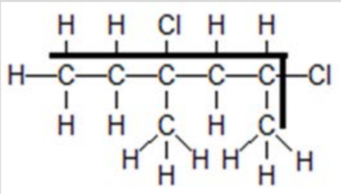


The systematic name of this molecule is

A. 3,5-dichloro-3,5-dimethylpentane
B. 1,3-dichloro-1,3-dimethylpentane
C. 3,5-dichloro-3-methylhexane
D. **2,4-dichloro-4-methylhexane**

Answer is D

- The molecule is a hexane. The numbering of carbons starts at the end a chloro group is closest to, which in this case is the carbon on the right of the page. There is a chloro group on carbon 2, a methyl group on carbon 4 and a chloro group also on carbon 4.



- A and B are incorrect because the longest chain is 6 carbons long (shown above), making the parent molecule hexane, not pentane.
- C is incorrect because the numbering of the carbon atoms begins at the end the functional group is closest to. This is the chloro group that is closest to the carbon on the left of the molecule as drawn on the page.

END OF SECTION A

END OF SECTION A

SECTION B – Short-answer questions

Question 1

Below are the molecular formulas of a number of important organic molecules.

A. $C_6H_{12}O_6$	**B.** $C_3H_8O_3$	**C.** $C_5H_{10}O_4$
D. $C_{18}H_{32}O_{16}$	**E.** H_2NCH_2COOH	**F.** $C_{15}H_{31}COOH$
G. $H_2NCH(CH_2SH)COOH$	**H.** $C_{15}H_{29}COOH$	**I.** $CH_3CH_2CH_2COOCH_3$

In each of the following questions, circle the letter or letters that correspond to the compound/s in the table. The same letter may be used in more than one response.

a. Which molecule could be involved in determining the tertiary structure of a protein?

A B C D E F G H I

1 mark

Solution

G

Explanatory notes

- G is a semistructural formula of the amino acid cysteine. The Z group of cysteine can form disulfide bonds in a protein, which contributes to its tertiary structure.

b. Which molecule is a trisaccharide?

A B C D E F G H I

1 mark

Solution

D

Explanatory notes

- A trisaccharide is made of three sugars. This particular trisaccharide is formed when three glucose molecules, $C_6H_{12}O_6$, react in two condensation reactions. Each condensation reaction eliminates a water molecule.

Section B – continued

c. Which **two** molecules are produced by condensation reactions?

A **B** **C** **D** **E** **F** **G** **H** **I**

2 marks

Solution

D and I

Explanatory notes

- D is a trisaccharide formed when three glucose molecules, $C_6H_{12}O_6$, react in two condensation reactions. I is an ester formed when an alkanol and carboxylic acid react in a condensation reaction.

Mark allocation

- 1 mark for D
- 1 mark for I

d. Which molecule is produced when a nucleotide undergoes hydrolysis?

A **B** **C** **D** **E** **F** **G** **H** **I**

1 mark

Solution

C

Explanatory notes

- C is a deoxyribose sugar. When a nucleotide is hydrolysed, it will produce a base, deoxyribose and a phosphate group.

e. Which molecule is glycerol?

A **B** **C** **D** **E** **F** **G** **H** **I**

1 mark

Solution

B

f. Which **two** molecules could be monomers for the process of condensation polymerisation to form a polypeptide?

A **B** **C** **D** **E** **F** **G** **H** **I**

2 marks
Total 8 marks

Solution

E and G

Explanatory notes

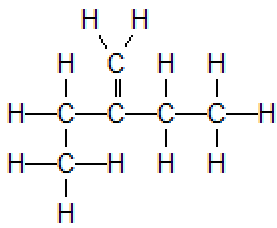
- E and G are both amino acids. They each contain an amino group as well as a carboxy group.

Mark allocation

- 1 mark for E
- 1 mark for G

Question 2

Consider the following molecule.



a. What is the systematic name of this molecule?

1 mark

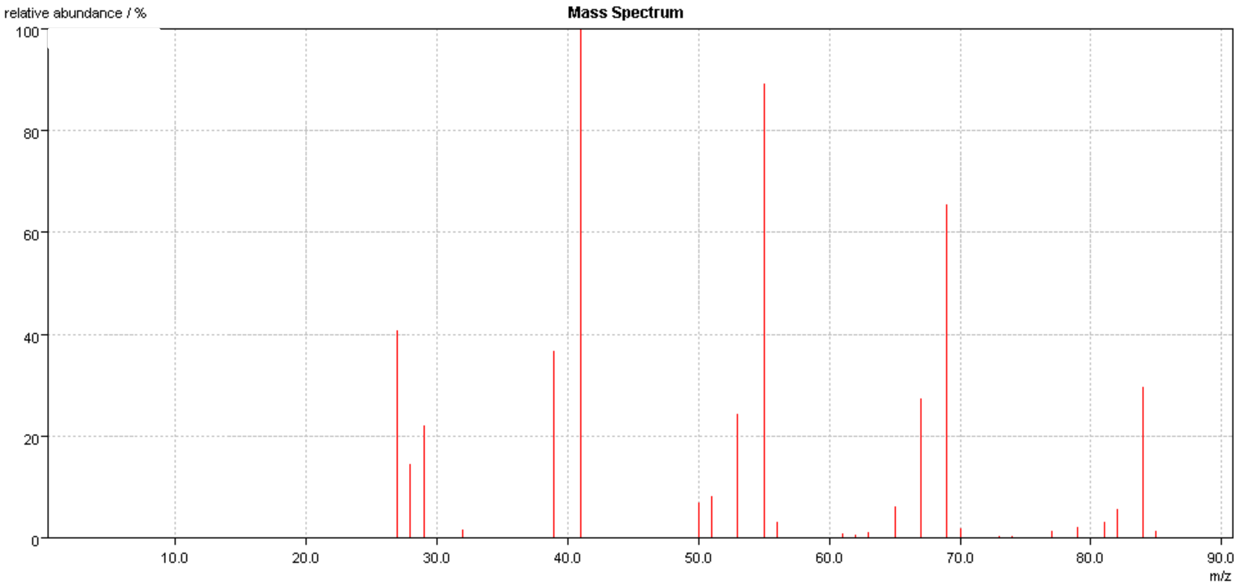
Solution

2-ethylbut-1-ene

Explanatory notes

- The longest chain must contain the double carbon–carbon bond, making it 4 carbon atoms long so the base molecule is a butene. The double bond is located between carbon atoms 1 and 2, making the base molecule but-1-ene. There is an ethyl group attached to the second carbon atom.

b. The mass spectrum of this compound is shown below.

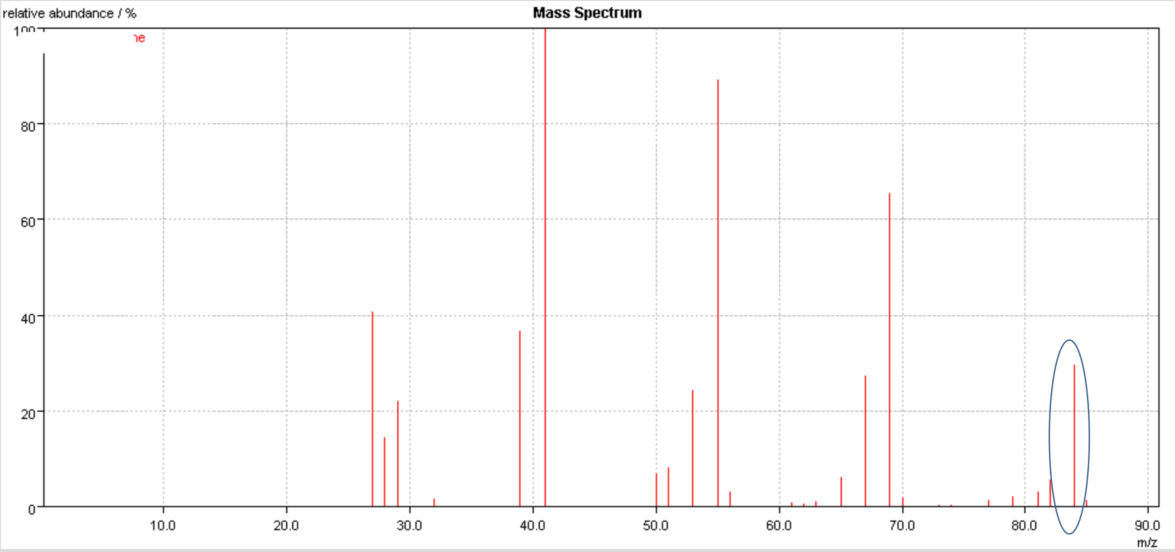


Source: Royal Society of Chemistry http://www.le.ac.uk/spectraschool/

i. Circle the peak due to the parent molecular ion on the graph above.

1 mark

Solution



Explanatory notes

- The molecular formula of the molecule is C_6H_{12}, giving it a molar mass of 84.0 g mol^{-1}. The parent molecular ion is the ion formed by the intact molecule before any fragmentation occurs.

ii. Give the formula of the species that produces the peak at *m*/*z* = 84.0.

1 mark

Solution

$C_6H_{12}^{+}$

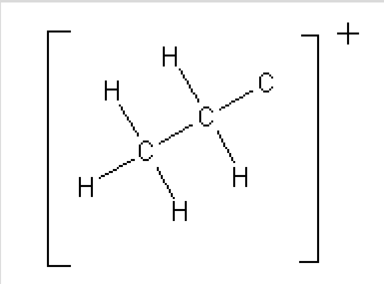
Explanatory notes

- The species that produces the peak at *m/z* = 84.0 has a mass of 84.0 g mol^{-1} so must be the parent molecular ion. As it is an ion, the species must carry a valence of +1.

iii. Draw the structure of the species that produces the base peak on the mass spectrum above.

1 mark

Solution



Explanatory notes

- The base peak is the peak present in the greatest abundance and assigned 100 on the spectrum. In the spectrum above, it has a mass of 41.0 g mol^{-1}. This indicates a fragment consisting of 3 carbon atoms and 5 hydrogen atoms.

iv. Give the *m*/*z* of the peak that would be produced by the species that experiences the greatest deflection in the mass spectrometer.

1 mark

1 + 1 + 1 + 1 = 4 marks

Solution

27

Explanatory notes

- The species that has the smallest *m/z* ratio will experience the greatest deflection in the mass spectrometer.

c. This molecule can also be analysed by NMR spectroscopy.

i. How many peaks would be visible in a low-resolution ^{1}H NMR spectrum of this compound?

1 mark

Solution

3

Explanatory notes

- There are three chemically different hydrogen environments: $–CH_3$, $–CH_2–$ and $=CH_2$.

ii. How many peaks would be visible in a ^{13}C NMR spectrum of this compound? Explain your answer.

2 marks
1 + 2 = 3 marks

Solution

4 peaks

There are four different carbon environments in the molecule.

Explanatory notes

- The four carbon environments are $–CH_3$, $–CH_2–$, –C–, $=CH_2$.

Mark allocation

- 1 mark for 4 peaks.
- 1 mark for explaining it is due to the number of different carbon environments.

d. **i**. Draw the structure of an isomer of this molecule

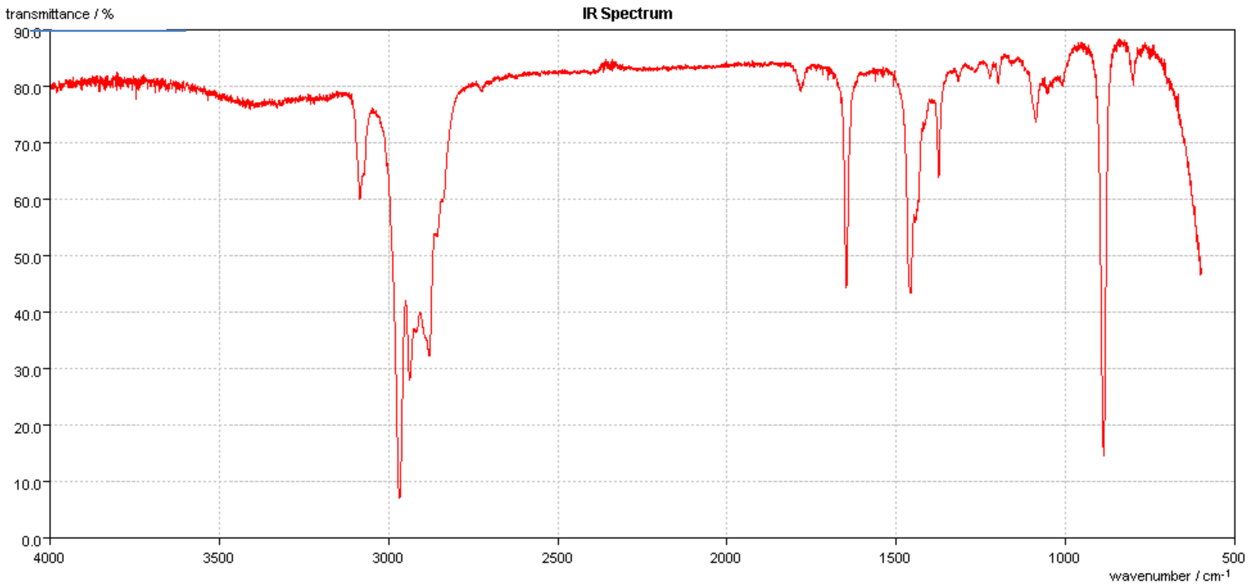
1 mark

Solution

A number of different structures would be acceptable. These include the molecules hex-1-ene, hex-2-ene, hex-3-ene, 2-methylpent-1-ene, 2-methylpent-2-ene, 3-methylpent-1-ene, 3-methylpent-2-ene, 2-ethylbut-2-ene.

Section B – continued

The IR spectrum of the molecule is shown below.



Source: Royal Society of Chemistry *http://www.le.ac.uk/spectraschool/*

d. **ii.** Explain how this IR spectrum could be used to distinguish between the molecule and the isomer you have drawn in **part i.**

2 marks
1 + 2 = 3 marks
Total 11 marks

Solution

The fingerprint region which is the section below 1000 cm^{-1} is unique for different molecules.

Mark allocation

- 1 mark for indicating the uniqueness of the fingerprint region
- 1 mark for indicating the fingerprint region is the section below 1000 cm^{-1}.

Question 3

Quantitative analysis of ethanol can be performed using different techniques. These include volumetric analysis and gas chromatography.

a. Briefly explain the principles of chromatography.

3 marks

Solution

The substance to be analysed is dissolved in a solvent called the mobile phase. The mobile phase then carries the substance along a stationary phase. As it travels along the stationary phase, the components in the mixture adsorb and desorb to different extents. A substance that adsorbs strongly to the stationary phase will move more slowly than a substance that adsorbs less strongly.

Mark allocation

- 1 mark for the substance being analysed being dissolved in the mobile phase.
- 1 mark for the mobile phase carrying the substance along the stationary phase.
- 1 mark for the substance or components adsorbing and desorbing to the stationary phase.

b. Briefly explain the principles of volumetric analysis.

3 marks

Solution

The amount, in mol, of a substance being analysed is determined by measuring the volume of the substance required to react with a measured volume of a solution of known concentration.

Mark allocation

- 1 mark for indicating that the amount, in mol, of a substance is determined.
- 1 mark for a measured volume of the substance being reacted with.
- 1 mark for a measured volume of a solution of known concentration.

c. Assuming you have full access to all of the equipment and materials needed to perform either technique, describe two considerations for choosing one technique over the other.

2 marks
Total 8 marks

Solution

Any two of:

- state of the sample
- accuracy required
- cost
- chemical nature of the sample
- size of the sample available for testing
- time available
- availability of equipment

Mark allocation

- 1 mark for each reasonable consideration.

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Section B – continued

Question 4

A particular barium halide exists as the hydrated salt $BaX_2.2H_2O$, where X is the halogen. The identity of X can be determined by using gravimetric analysis to determine the barium content of the salt.

A 0.4560 g sample of the halide is dissolved in 200.0 mL of deionised water. Excess sulfuric acid is added to the solution, which is then heated and boiled for 45 minutes. A white precipitate of barium sulfate forms. The precipitate is filtered, washed several times with deionised water and thoroughly dried. The mass of the precipitate is found to be 0.4360 g.

a. Determine the identity of X.

4 marks

Solution

$$n(\text{BaSO}_4) = \frac{m}{M} = \frac{0.4360}{233.4} = 0.001\,868 \text{ mol}$$

$$n(\text{Ba}) = 0.001\,868 \text{ mol because there is one Ba}^{2+} \text{ ion in BaSO}_4$$

$$n(\text{BaX}_2.2\text{H}_2\text{O}) = 0.001\,868 \text{ mol because there is one Ba}^{2+} \text{ ion in BaSO}_4$$

$$M(\text{BaX}_2.2\text{H}_2\text{O}) = \frac{m}{n} = \frac{0.4560}{0.001\,868} = 244.1 \text{ g mol}^{-1}$$

$$M(\text{X}) = M(\text{BaX}_2.2\text{H}_2\text{O}) - M(\text{other components of the molecule}) = 244.1 - 173.3 = 70.81$$

$$M(\text{X}) = 35.41$$

X is Cl

Mark allocation

- 1 mark for the amount, in mol, of the precipitate $BaSO_4$ being 0.001 868 mol.
- 1 mark for $n(BaX_2.2H_2O)$ = 0.001 868 mol.
- 1 mark for correctly determining the molar mass of $BaX_2.2H_2O$ as 244.1 g mol^{-1}.
- 1 mark for identifying X as Cl.

b. Briefly outline a way in which you could experimentally confirm that there are two H_2O molecules in the formula for the hydrated salt identified in **part a**.

2 marks
Total 6 marks

Solution

Take a sample of the salt and weigh it. Heat it in an oven to over 100°C, cool it and then reweigh it. Repeat the heating and cooling until constant mass is achieved. Use the mass of water lost and the mass of the remaining solid to determine the mole ratio of water to salt in the formula.

Mark allocation

- 1 mark for heating to over 100^{o} C
- 1 mark for indicating the need to repeat the heating and weighing until constant mass is achieved.

Question 5

Plants need nitrogen to produce proteins required for growth and development. Consequently lawn fertilisers contain nitrogen to promote fast and healthy growth of plants. The nitrogen in fertilisers that is present as ammonium ions can be analysed by a back titration.

A student weighed 1.34 g of finely ground fertiliser and then carefully transferred it to a 250 mL volumetric flask. Deionised water was added to dissolve the fertiliser and the solution was made up to the calibration line. A 20.00 mL pipette was used to deliver aliquots of the fertiliser solution to three 250 mL conical flasks. To each flask was added a 20.00 mL aliquot of 0.535 M sodium hydroxide solution as well as 50.00 mL of deionised water. Each mixture was boiled for about 10 minutes until vapour at the neck of the flask no longer turned red litmus paper blue. Two drops of methyl red indicator was then added to each flask, and the flasks were titrated with 0.987 M hydrochloric acid until the endpoint was reached. The three titre volumes were found to be 10.12 mL, 10.18 mL and 9.98 mL.

The equation for the reaction of sodium hydroxide and hydrochloric acid is:

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

a. **i.** Justify why methyl red was used as the indicator for this reaction.

2 marks

Solution

The endpoint of methyl red indicator closely matches the equivalence point of the reaction.

Mark allocation

- 1 mark for endpoint of indicator.
- 1 mark for equivalence point of reaction.

ii. What colour change would have been observed to indicate the endpoint of the reaction?

1 mark

2 + 1 = 3 marks

Solution

Yellow to red

Explanatory notes

- Methyl red is red in an acid and yellow in a base. The solution in the conical flasks is sodium hydroxide, meaning the indicator will start yellow and turn red as hydrochloric acid is added.

b. Suggest one reason why a back titration was chosen to analyse the amount of nitrogen in the form of ammonium ions.

1 mark

Solution

Ammonium ions are a weak acid and would not produce a sharp enough endpoint if directly titrated with a base.

c. **i**. Write an ionic equation for the reaction between the ammonium ions and sodium hydroxide.

1 mark

Solution

$NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$

ii. Explain why red litmus paper was used to test the vapours at the neck of the conical flask.

2 marks

1 + 2 = 3 marks

Solution

The ammonia gas produced in the reaction will turn the paper blue. When paper held at the neck of the flask stops changing colour, it is an indication the reaction is complete.

Mark allocation

- 1 mark for describing that ammonia gas changes the colour of the paper.
- 1 mark for explaining it is used to indicate when the reaction is complete.

d. **i.** Determine the average titre of hydrochloric acid.

1 mark

Solution

$$\frac{10.12+10.18+9.98}{3}=10.09 \text{ mL}$$

ii. Determine the amount, in mol, of sodium hydroxide that reacted with fertiliser solution in the conical flask.

3 marks

Solution

$$n(\text{HCl}) = cV$$
$$= 0.987 \times 10.09 \times 10^{-3}$$
$$= 9.96 \times 10^{-3} \text{ mol}$$
$$n(\text{NaOH}) \text{ in excess} = \frac{1}{1} \times 9.96 \times 10^{-3} = 9.96 \times 10^{-3}$$
$$n(\text{NaOH initially added}) = cV$$
$$= 0.535 \times 20.00 \times 10^{-3}$$
$$= 0.0107 \text{ mol}$$
$$n(\text{NaOH reacted}) = 0.0107 - 9.96 \times 10^{-3}$$
$$= 7.40 \times 10^{-4} \text{ mol}$$

Mark allocation

- 1 mark for n(HCl) in the average titre.
- 1 mark for n(NaOH) in excess = 9.96×10^{-3}.
- 1 mark for n(NaOH reacted) = n(NaOH initially added) – n(NaOH in excess).

iii. Calculate the percentage by mass of nitrogen in the sample of fertiliser. Give your answer with the appropriate number of significant figures.

5 marks
1 + 3 + 5 = 9 marks
Total 16 marks

Solution

$$n(\text{NaOH}) : n(\text{NH}_4^+) \text{ is } 1:1$$

$$\text{so } n(\text{NH}_4^+) \text{ in 20.00 mL aliquot} = 7.40 \times 10^{-4} \text{ mol}$$

$$n(\text{NH}_4^+) \text{ in 250 mL flask} = \frac{250}{20.00} \times 7.40 \times 10^{-4}$$

$$= 0.009\ 25 \text{ mol}$$

$$n(\text{N}) = 0.009\ 25 \text{ mol}$$

$$m(\text{N}) = nM$$

$$= 0.009\ 25 \times 14.0$$

$$= 0.130 \text{ g}$$

$$\%\text{ mass of N in fertiliser sample} = \frac{0.130}{1.34} \times 100$$

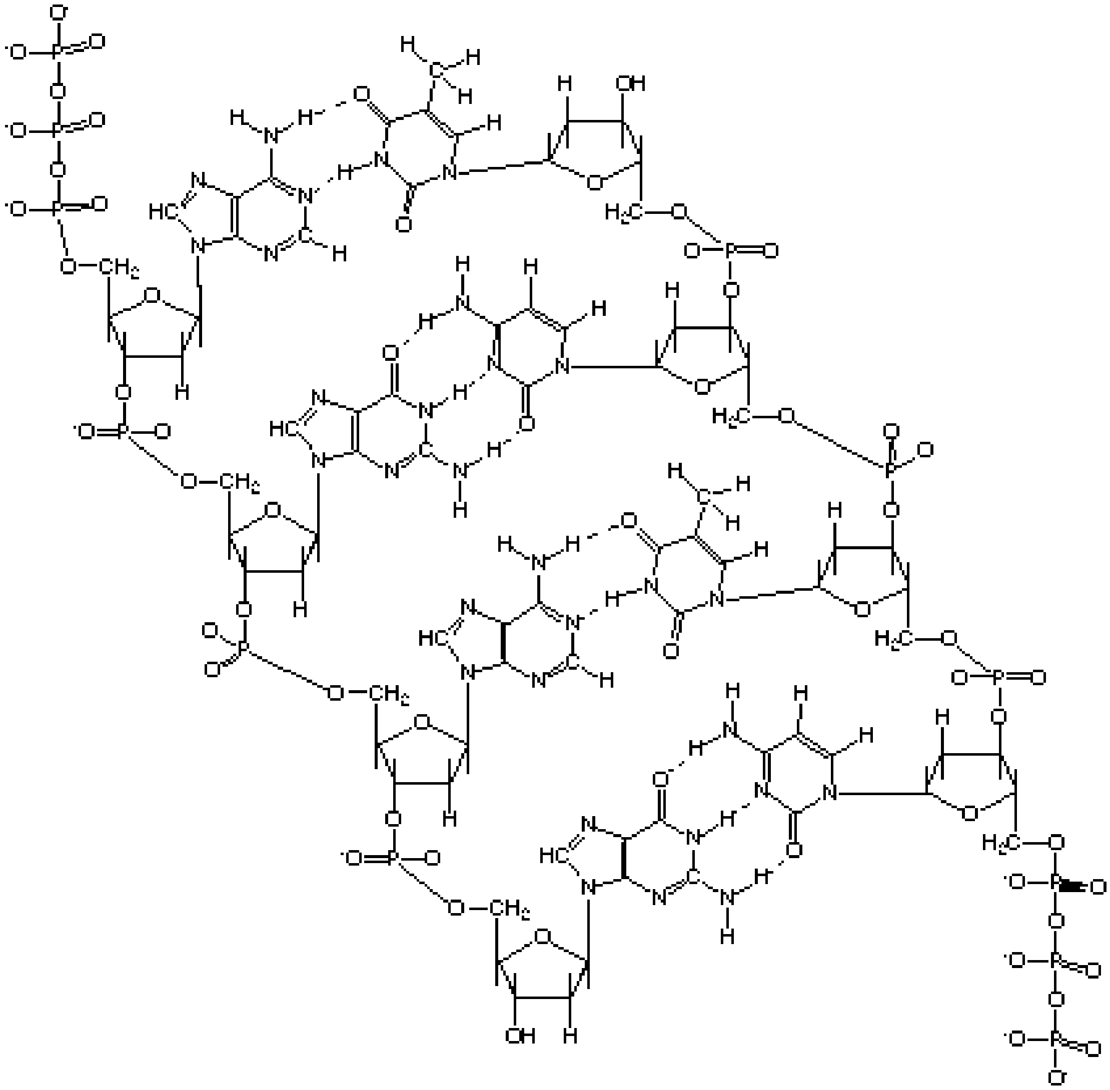
$$= 9.70\%$$

Mark allocation

- 1 mark for correct calculation of NH_4^+ in 20.00 mL aliquot.
- 1 mark for correct calculation of NH_4^+ in volumetric flask.
- 1 mark for correct calculation of mass of nitrogen in the fertiliser.
- 1 mark for correct calculation of percentage by mass of nitrogen.
- 1 mark for showing 3 significant figures in the final answer.

Question 6

Shown below is a section of a DNA molecule.



Source: MIT Biology Hypertextbook
http://202.114.65.51/fzjx/wsw/website/mit/lm/nucleicacids/dna.html

a. On the diagram above:

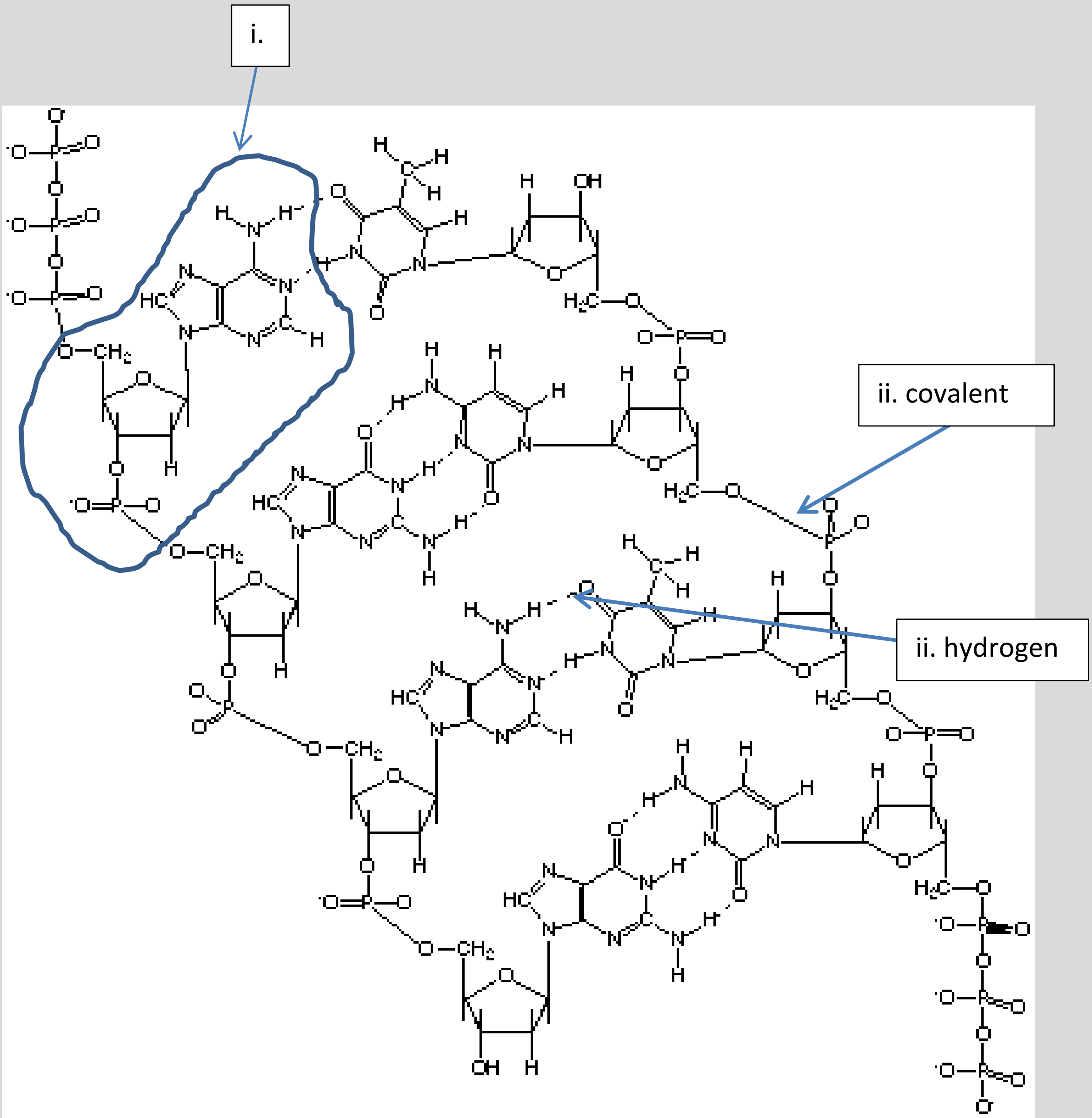
i. Circle a nucleotide that contains an adenine base.

1 mark

ii. Clearly label and name the two major types of bonding present in the molecule.

2 marks

Solution



Mark allocation

- In part ii. both the name and a clear label are required for each mark.

1 + 2 = 3 marks

b. What type of chemical reaction is responsible for the joining of single nucleotides into a long chain?

1 mark

Solution

Condensation (polymerisation)

Total 4 marks

Question 7

a. Consider a section of a polypeptide that contains the following three amino acids:

–Gly–Leu–Ser–

i. Describe a way in which this section of the polypeptide may contribute to the tertiary structure of a protein.

1 mark

Solution

The serine Z group contains an –OH group that could hydrogen bond to an OH group on other parts of the polypeptide.

ii. Describe a way in which this section of the polypeptide may contribute to the secondary structure of a protein.

1 mark

Total 2 marks

Solution

The CONH linkage between different amino acids can hydrogen bond to neighbouring CONH linkages, causing the chain to twist or bend.

b. Give the name of the link that holds amino acids together in a polypeptide.

1 mark

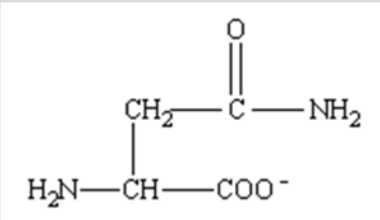
Solution

Peptide or amide

c. Draw the structure of asparagine in a solution of pH 11.

1 mark

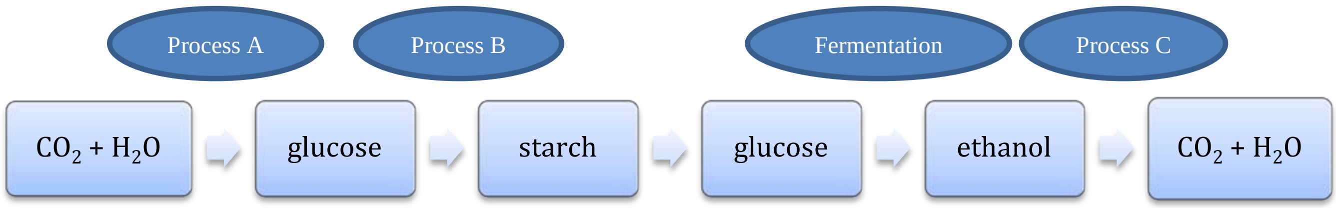
Solution



Total 4 marks

Question 8

Biochemical fuels are fuels derived from plant materials. The flowchart below represents steps in the production and use of ethanol, a biochemical fuel.



a. Give the name of processes A and B

2 marks

Solution

Process A – photosynthesis
Process B – condensation polymerisation

b. Write a balanced equation for the fermentation reaction.

1 mark

Solution

$C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$

c. Write a balanced chemical equation for process C.

2 marks

Solution

$C_2H_5OH(l \text{ or } g) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g \text{ or } l)$

Mark allocation

- 1 mark for correct species and balanced equation.
- 1 mark for correct state symbols. Ethanol must not be (aq) in the combustion reaction.

d. Biodiesel is another example of a biochemical fuel. What type of biochemical molecules is biodiesel a mix of?

1 mark

Solution

Esters or methyl esters

Total 6 marks

END OF SOLUTIONS BOOK