INSIGHT

Trial Exam Paper

2009

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

A 100 mL solution of glucose, $C_6H_{12}O_6$, has a concentration of 75.0 g L^{-1}. The number of glucose molecules in the solution is

A. 0.0417

B. 0.417

C. **2.51×10^{22}**

D. 2.51×10^{23}

Answer is C.

Worked solution

- C is correct according to the steps below.

  Step 1: Determine the mass of glucose in the 100 mL solution.

  $$m(C_6H_{12}O_6) = \frac{100}{1000} \times 75.0$$
  $$= 7.50 \text{ g}$$

  Step 2: Determine the amount, in mol, of glucose molecules in the solution.

  $$n(C_6H_{12}O_6) = \frac{m}{M}$$
  $$= \frac{7.50}{(6 \times 12.0 + 12 \times 1.0 + 6 \times 16.0)}$$
  $$= \frac{7.50}{180}$$
  $$= 0.0417 \text{ mol}$$

  Step 3: Determine the number of glucose molecules in the solution.

  $$N(C_6H_{12}O_6) = n \times N_A$$
  $$= 0.0417 \times 6.02 \times 10^{23}$$
  $$= 2.51 \times 10^{22} \text{ molecules}$$

- A is incorrect because 0.0417 is the amount, in mol, of glucose molecules present. It needs to be multiplied by Avogadro's number to determine the actual number of glucose molecules present.
- B is incorrect because although the concentration of the solution is 75.0 g L^{-1}, the volume of the solution is only 100 mL, so the mass of glucose present in the solution is 7.50 g. Also, the amount, in mol, of glucose needs to be multiplied by Avogadro's number to determine the actual number of glucose molecules.
- D is incorrect because although the concentration of the solution is 75.0 g L^{-1}, the volume of the solution is only 100 mL, so the mass of glucose present in the solution is 7.50 g.

Questions 2 and 3 refer to the following information.

A sample of brick cleaner is diluted in a volumetric flask. Aliquots of the diluted solution are transferred to conical flasks, and a few drops of indicator are added to each. Then, each aliquot is titrated for hydrochloric acid content using a standard solution of sodium hydroxide.

Question 2

The term 'standard solution' refers to the fact that the sodium hydroxide solution

A. was prepared directly from a good primary standard.

B. has a concentration of 1.0 M.

C. was prepared using a volumetric flask.

D. **has an accurately known concentration.**

Answer is D.

Worked solution

- D is correct because a standard solution of any substance is one with an accurately known concentration, known to at least three significant figures.
- A is incorrect because sodium hydroxide is not a primary standard due to it absorbing water and reacting with carbon dioxide in the atmosphere.
- B is incorrect because a standard solution does not have a particular concentration, rather its concentration is accurately known to at least three significant figures.
- C is incorrect because the method of preparation does not determine whether a solution is a standard solution or not.

Tip

- *A standard solution of sodium hydroxide (and other substances that are not good primary standards) can be prepared using volumetric analysis, i.e. titration against another standard solution.*

Question 3

The best indicator for the analysis and the colour change observed is

	Indicator	**Colour change observed**
A.	**bromothymol blue**	**yellow to blue**
B.	bromothymol blue	blue to yellow
C.	thymol blue	red to yellow
D.	thymol blue	yellow to red

Answer is A.

Worked solution

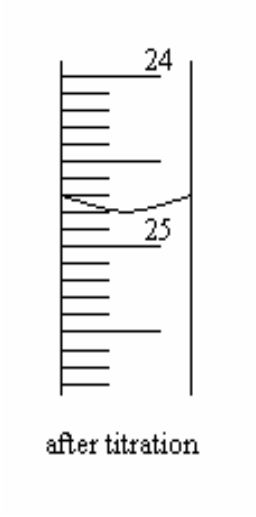
- A is correct because the reaction in this analysis is between a strong acid and a strong base, and so will have an equivalence point close to 7.0. From the VCE data book it can be found that bromothymol blue changes colour in the pH range 6.0 to 7.6, which matches the equivalence point much better than thymol blue, which has an endpoint in the range 1.2 to 2.8. The indicator is initially placed in the conical flask with the acid solution and so will start off as its acid colour (i.e. yellow). At its endpoint it will change to its base colour (i.e. blue).
- B is incorrect because although bromothymol blue is the correct choice of indicator, it is initially added to the conical flask with the acid, so will start off yellow. At its endpoint it will change to its base colour, which is blue.
- C is incorrect because the reaction in this analysis is between a strong acid and a strong base, and so will have an equivalence point close to 7.0. Bromothymol blue changes colour in the pH range 6.0 to 7.6, which matches the equivalence point much better than thymol blue, which has an endpoint in the range 1.2 to 2.8.
- D is incorrect because the reaction in this analysis is between a strong acid and a strong base, and so will have an equivalence point close to 7.0. Bromothymol blue changes colour in the pH range 6.0 to 7.6, which matches the equivalence point much better than thymol blue, which has an endpoint in the range 1.2 to 2.8. Also, it will start off as the acid colour in the conical flask and change to the base colour once its endpoint is reached.

Tip

- *Data about acid–base indicators, including their pH range, colour change and K_a values are included in the VCE data book.*

Question 4

An aliquot of 20.00 mL of 0.100 M CH_3COOH is placed in a conical flask. A solution of sodium hydroxide is aded to a burette. The initial volume of the burette was 8.40 mL. The diagram below shows the relevant section of the burette after the titration is complete.



The concentration, in mol L^{-1}, of the sodium hydroxide is

A. 0.0806
B. 0.119
C. **0.122**
D. unable to be determined from the information provided.

Answer is C.

Worked solution

- C is correct according to the steps below.

  Step 1: Determine the amount, in mol, of ethanoic acid in the conical flask.

  $n(CH_3COOH) = cV$

  $= 0.100 \times 0.02000$

  $= 0.00200$ mol

  Step 2: Write a balanced chemical equation to determine the mole ratio.

  $CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa\ (aq) + H_2O(l)$

  Step 3: Determine the amount, in mol, of NaOH in the titre.

  $n(NaOH) : n(CH_3COOH)$

  $1 : 1$

  $n(NaOH) = n(CH_3COOH)$

  $= 0.00200$ mol

Step 4: Determine the volume of the titre by reading the burette.

Initial volume = 8.40 mL

Final volume = 24.80 mL

Titre volume = 24.80 – 8.40

= 16.40 mL

Step 5: Determine the concentration of the sodium hydroxide.

$$c(\text{NaOH}) = \frac{n}{V}$$

$$= \frac{0.00200}{0.01640}$$

$$= 0.122 \text{ M}$$

- A is incorrect because the initial volume of the burette was 8.40 mL, so the titre volume is 24.80 – 8.40 = 16.40 mL.
- B is incorrect because the final burette reading is 24.80 mL, not 25.20 mL, so the titre volume is 24.80 – 8.40 = 16.40 mL.
- D is incorrect because there *is* sufficient data to answer this question. Although this reaction is between a weak acid and a strong base, the equivalence point will still be reached and indicated by the colour change (endpoint) of an appropriate indicator.

Question 5

The Hazelwood power station in the Latrobe Valley uses about 36 000 tonnes of coal each day. Coal contains 25.0% carbon by mass (1 tonne = 10^6 g). The volume of carbon dioxide, in L, released each day by the power station at 18°C and 1.03 atm is

A. 1.08×10^9

B. $\mathbf{1.74 \times 10^{10}}$

C. 6.98×10^{10}

D. 1.09×10^{11}

Answer is B.

Worked solution

- B is correct according to the steps below.

Step 1: Determine the mass of carbon in the coal burnt each day.

$m(\text{C})$ = 25.0% of 36 000

$$= \frac{25.0}{100} \times 36\,000$$

= 9000 tonnes

= 9000×10^6 g

Step 2: Determine the amount, in mol, of carbon burnt each day.

$$n(\text{C}) = \frac{m}{M}$$

$$= \frac{9000 \times 10^6}{12.0}$$

$$= 7.50 \times 10^8 \text{ mol}$$

Step 3: Determine the volume of carbon dioxide produced at the conditions specified.

$$V(\text{CO}_2) = \frac{nRT}{P}$$

$$= \frac{7.50 \times 10^8 \times 8.31 \times (18 + 273)}{(1.03 \times 101.3)}$$

$$= \frac{1.81 \times 10^{12}}{104}$$

$$= 1.74 \times 10^{10} \text{ L}$$

- A is incorrect because temperature must be expressed in K (kelvin) for use in the general gas equation.
- C is incorrect because only 25% of the mass of coal is carbon.
- D is incorrect because temperature must be expressed in K and pressure must be expressed in kPa for use in the general gas equation.

Tip

- *For use in the general gas equation, temperature must be expressed in K (kelvin) and pressure must be expressed in kPa. Numerical relationships to allow these conversions are listed in the data book.*

Question 6

Which of the following gases will occupy the biggest volume at STP?

A. 10.0 g of CO_2

B. 10.0 g of NO_2

C. 10.0 g of SO_2

D. **10.0 g of O_2**

Answer is D.

Worked solution

- D is correct because O_2 has the smallest molar mass of these gases, and so represents the largest number of mole for a mass of 10.0 g. The same amount, in mol, of different gases occupies the same volume under the same conditions. Hence, 10.0 g of O_2 with the biggest amount, in mol, of gas molecules will occupy the biggest volume. The volume by each gas can be calculated:

$$n(O_2) = \frac{m}{M}$$

$$= \frac{10.0}{2 \times 16.0}$$

$$= 0.313 \text{ mol}$$

$$V(O_2) = n \times V_M$$

$$= 0.313 \times 22.4$$

$$= 7.00 \text{ L}$$

- A is incorrect because the volume occupied by 10.0 g of CO_2 at STP is 5.09 L, which is less than the volume occupied by 10.0 g of O_2.
- B is incorrect because the volume occupied by 10.0 g of NO_2 at STP is 4.87 L, which is less than the volume occupied by 10.0 g of O_2.
- C is incorrect because the volume occupied by 10.0 g of SO_2 at STP is 3.49 L, which is less than the volume occupied by 10.0 g of O_2.

Question 7

A polymer is known to contain only carbon, hydrogen and chlorine. It contains 38.4% carbon and 4.84% hydrogen. The number of carbon atoms in the empirical formula is

A. 1

B. 2

C. 3

D. 4

Answer is B.

Worked solution

- B is correct according to the steps below.

  Step 1: Determine the mass of each element present in 100 g of the polymer.

  $m(\text{C}) = 38.4$ g

  $m(\text{H}) = 4.84$ g

  $m(\text{Cl}) = 100 - 38.4 - 4.84 = 56.8$ g

  Step 2: Calculate the amount, in mol, of each element present to determine a mole ratio.

  $$n(\text{C}) = \frac{m}{M} = \frac{38.4}{12.0} = 3.2 \text{ mol}$$

  $$n(\text{H}) = \frac{m}{M} = \frac{4.84}{1.0} = 4.84 \text{ mol}$$

  $$n(\text{Cl}) = \frac{m}{M} = \frac{56.8}{35.5} = 1.6 \text{ mol}$$

  Step 3: Divide each amount, in mol, by the smallest number to simplify the ratio.

  $$\frac{3.2}{1.6} = 2 \qquad \frac{4.84}{1.6} = 3 \qquad \frac{1.6}{1.6} = 1$$

  Step 4: Write the empirical formula.

  C_2H_3Cl

There are two carbon atoms in the empirical formula.

- A is incorrect because the simplest whole number ratio of C : H : Cl in the polymer requires more than one carbon atom.
- C is incorrect because the simplest whole number ratio of C : H : Cl in the polymer requires two carbon atoms.
- D is incorrect because the simplest whole number ratio of C : H : Cl in the polymer requires two carbon atoms.

Question 8

A volume of 30.0 mL of 0.10 M sulfuric acid (H_2SO_4) reacts with 30.0 mL of 0.10 M sodium hydroxide solution. The concentration of sulfate ions in the resultant solution, in M, is

A. 0.0

B. 0.0030

C. **0.050**

D. 0.10

Answer is C.

Worked solution

- C is correct because when sulfuric acid and sodium hydroxide react the sulfate ions are spectator ions and do not participate in the reaction. The amount, in mol, of sulfate ions present is the same before and after the reaction. However, the change in volume affects their concentration.

$n(H_2SO_4) = cV$

$= 0.10 \times 0.0300$

$= 0.0030$ mol

$n(SO_4^{2-}) = 0.0030$ mol

$c(SO_4^{2-})$ after the reaction $= \dfrac{n}{V}$

$= \dfrac{0.0030}{(0.0300 + 0.0300)}$

$= 0.050$ M

- A is incorrect because the sulfate ions are not consumed in the reaction because they are spectator ions. The amount, in mol, of sulfate ions present is the same before and after the reaction.
- B is incorrect because this is the amount, in mol, of sulfate ions present. It is not their concentration.
- D is incorrect because the total volume after the reaction is 30.0 + 30.0 = 60.0 mL. Although the amount, in mol, of sulfate ions remains the same, the concentration will change because the volume changes.

Question 9

A mixture of amino acids is analysed using thin layer chromatography. The amino acid serine moves 4.0 cm up the plate from the origin and has an R_f value of 0.76. The amino acid valine travels 3.0 cm up the plate from the origin. The R_f value of valine is

A. 0.25

B. **0.57**

C. 0.75

D. 2.28

Answer is B.

Worked solution

- B is correct. The R_f value of a component is calculated by:

$$R_f = \frac{\text{Distance travelled by component from origin}}{\text{Distance travelled by solvent front from origin}}$$

$$\text{For serine, } 0.76 = \frac{4.0}{\text{Distance travelled by solvent front from origin}}$$

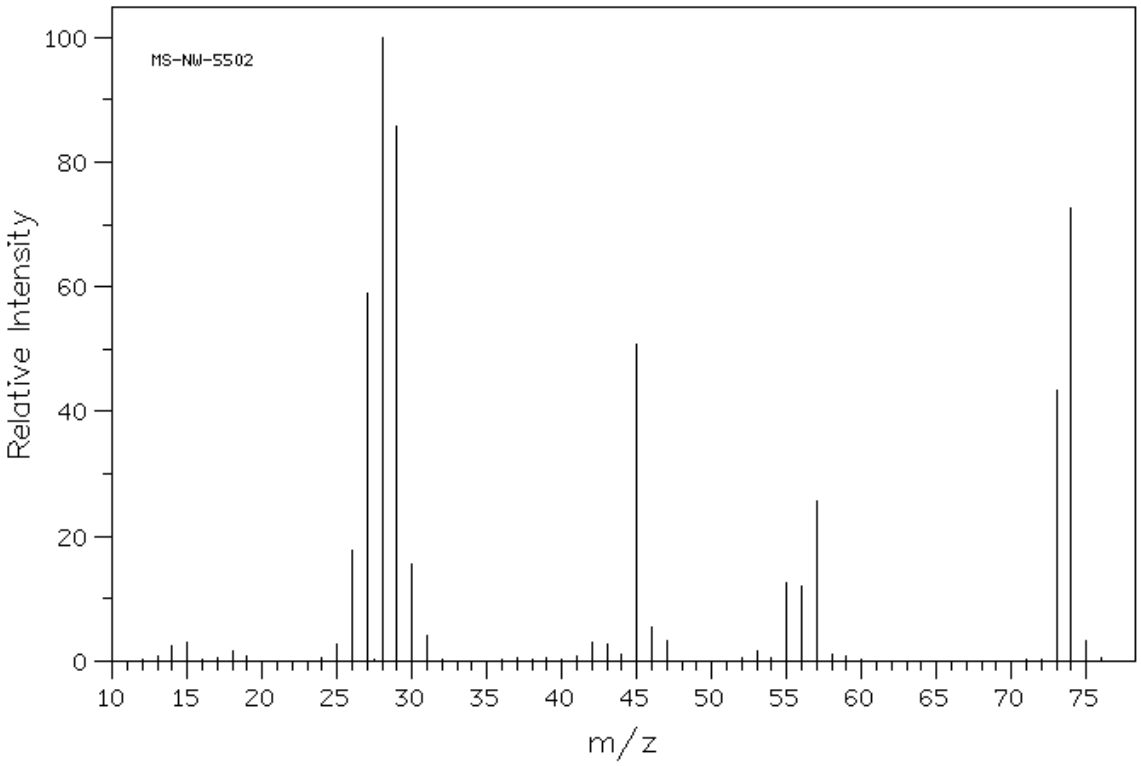
So, distance travelled by solvent front from origin = 5.3 cm

$$\text{For valine, } R_f = \frac{3.0}{5.3} = 0.57$$

- A is incorrect because $R_f = \frac{\text{Distance travelled by component from origin}}{\text{Distance travelled by solvent front from origin}}$
- C is incorrect because $R_f = \frac{\text{Distance travelled by component from origin}}{\text{Distance travelled by solvent front from origin}}$
- D is incorrect because the R_f value of a component always will be less than one because a component cannot travel further than the solvent front.

Question 10

The mass spectrum of propanoic acid is given below.



Source: http://riodb01.ibase.aist.go.jp/sdbs/cgi-bin/direct_frame_top.cgi

What fragment must have been lost from the molecular ion to account for the high peak at m/z 73?

A. **H**

B. H^+

C. H_2

D. H_2^+

Answer is A.

Worked solution

- A is correct. The formula of propanoic acid is CH_3CH_2COOH. This parent molecule has a relative molecular mass of 74, and so the parent molecular ion will occur at m/z 74. The molecular ion at m/z 73 has a relative molecular mass of 73, so the parent molecular ion must have lost a single H atom to form this ion. The ion showing a peak on the mass spectrum carries a positive charge. The fragment lost to form this ion is uncharged and, hence, does not show a corresponding peak on the spectrum.

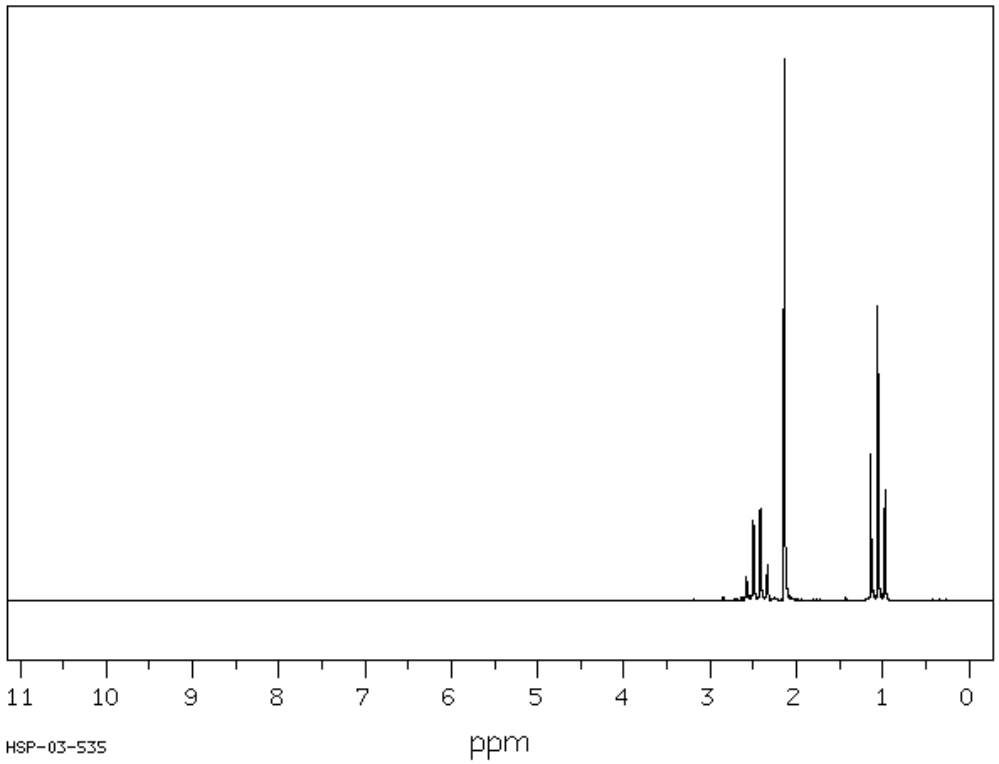
  $CH_3CH_2COOH^+ \rightarrow CH_3CH_2COO^+ + H$

  parent ion molecular ion

- B is incorrect because although the parent ion has lost a single H atom, it is an uncharged fragment, leaving the charged molecular ion to produce a peak on the mass spectrum. If an H^+ ion was lost from the parent molecular ion, it would leave a neutral molecule of mass 73, which would not show up on the mass spectrum.
  $CH_3CH_2COOH^+ \rightarrow H^+ + CH_3CH_2COO$
- C is incorrect because only one H atom was lost to form the molecular ion, as the parent molecular ion has a mass of 74 and the molecular ion has a mass of 73.
- D is incorrect because only one H atom was lost to form the molecular ion, as the parent molecular ion has a mass of 74 and the molecular ion has a mass of 73. Also, the fragment lost from a molecular ion has to be uncharged.

Question 11

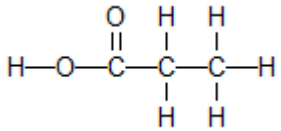
The ^{1}H nuclear magnetic resonance (NMR) spectrum of an unknown compound is shown below.



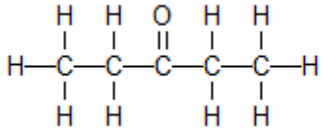
Source: http://riodb01.ibase.aist.go.jp/sdbs/cgi-bin/direct_frame_top.cgi

The structure of the compound could be

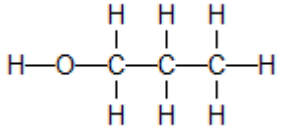
A.



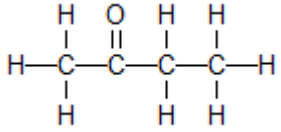
B.



C.



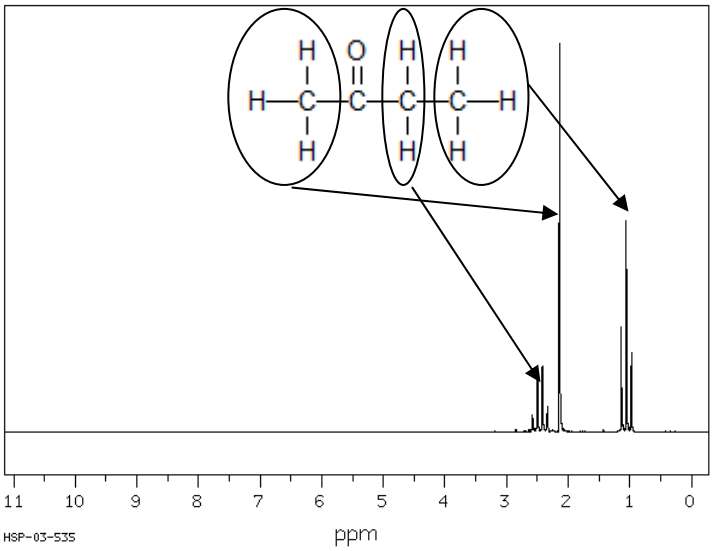
D.



Answer is D.

Worked solution

- D is correct. There are three different peaks on the spectra, indicating that there are three different hydrogen environments in the molecule. The peaks are formed by the different hydrogen atoms, as shown below.



- A is incorrect. Although there are three different hydrogen environments in this molecule, according to the VCE data book, the R–COO**H** atom has a chemical shift of 11.5 ppm. There is no peak at that shift in this spectrum, so it cannot represent this molecule.
- B is incorrect because there are only two different hydrogen environments in this molecule, meaning its ^{1}H NMR spectra would have only two main peaks.
- C is incorrect. There are four different hydrogen environments in this molecule, meaning its ^{1}H NMR spectra would have four main peaks.

Question 12

Aspirin is widely used for pain relief and to reduce fever. Which of the following statements regarding the synthesis of aspirin is **not** correct?

A. Aspirin can be formed by a reaction between the carboxyl group on one molecule and the hydroxyl group on another.

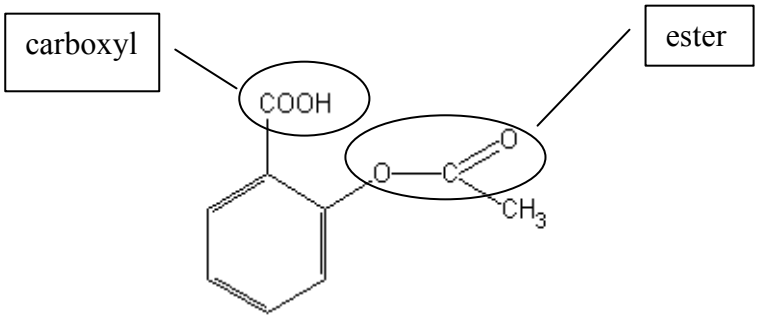
B. Aspirin contains carboxyl and ester functional groups.

C. Aspirin can be synthesised by a reaction between salicylic acid and ethanoic anhydride.

D. **The carboxyl functional group on salicylic acid is involved in the reaction with another molecule to form aspirin.**

Answer is D.

Worked solution



- D is the incorrect statement because it is the hydroxyl group on salicylic acid that reacts with ethanoic acid or ethanoic anhydride to form aspirin.
- A is correct because aspirin contains an ester functional group that forms when the hydroxyl group on salicylic acid reacts with the carboxyl group on ethanoic acid.
- B is correct because both of these functional groups are present in the aspirin molecule.
- C is correct. This pathway is fast and produces high yields.

Question 13

Which of the following statements about DNA is **not** correct?

A. DNA contains only the elements carbon, hydrogen, oxygen, nitrogen and phosphorous.

B. **A piece of double-stranded DNA, which is 50 base pairs in length and contains 20 thymine bases, will also contain 20 guanine bases.**

C. The bonding responsible for the primary structure of DNA is the same type of bonding as that responsible for the primary structure of proteins.

D. All DNA fragments are negatively charged.

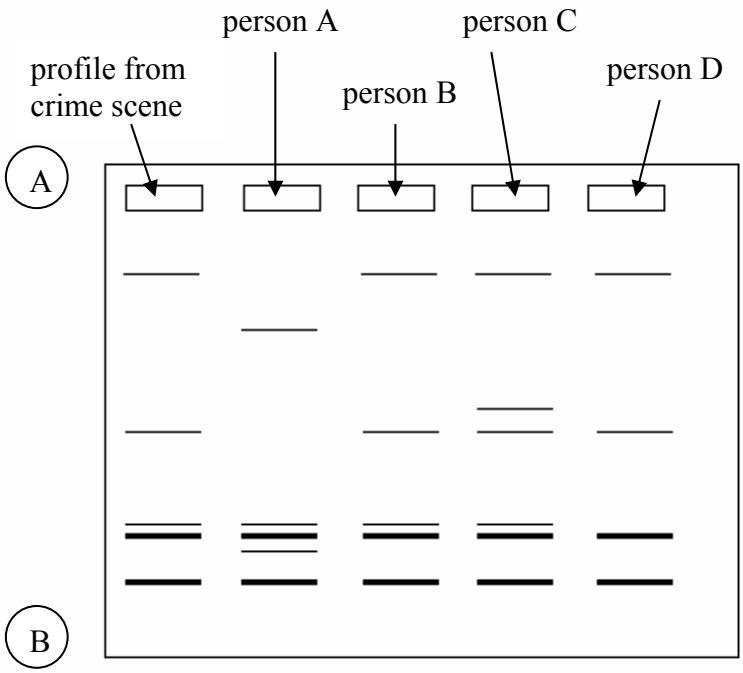
Answer is B.

Worked solution

- B is the incorrect statement because thymine pairs with adenine. If there are 20 thymine bases there will also be 20 adenine bases. The remaining 30 base pairs consist of an equal number of cytosine and guanine bases. Hence, there will be 30 guanine bases.
- A is correct because the deoxyribose sugar, the phosphate backbone and all of the nucleic acids contain only these elements.
- C is correct because the primary structure of both DNA and proteins is due to covalent bonding.
- D is correct because all DNA fragments are negatively charged due to the phosphate groups on the backbone of DNA.

Question 14

Gel electrophoresis can be used to separate DNA fragments in forensic chemistry. It can be used to obtain a DNA profile from hair left at a crime scene, which then can be compared to a number of suspects. One such analysis, using gel electrophoresis, is shown below.



Which of the following statements about the analysis is **not** correct?

A. The samples from persons B, C and D all contain at least one fragment with a higher molecular mass than any of the fragments in the sample from person A.

B. Person B is most likely to be the guilty individual.

C. The positive terminal of the power supply is connected to end B of the gel.

D. **The rate at which the DNA fragments in each sample move through the gel depends on their molecular mass and the number of positive charges present on each fragment.**

Answer is D.

Worked solution

- D is the incorrect statement because all DNA fragments carry a negative charge due to the phosphate groups on the sugar–phosphate backbone. The rate at which they travel through the gel is dependent only on molecular mass.
- A is a correct statement because in gel electrophoresis, the slowest moving fragments have the highest molecular mass. Persons B, C and D's slowest moving (i.e. highest molecular mass) fragment is slower and, hence, larger than the slowest moving (i.e. largest) fragment in the sample from person A.
- B is a correct statement because the profile from person B is an exact match to the profile from the crime scene.
- C is a correct statement because DNA fragments all carry a negative charge, so the far end of the gel is made positive so the DNA fragments are attracted to it.

Question 15

A triglyceride is formed by a reaction between glycerol and three myristic acid molecules. The molar mass of the triglyceride, in g mol^{-1}, will be

A. 504

B. **722**

C. 758

D. 776

Answer is B.

Worked solution

- B is correct. The formula of myristic acid is $C_{13}H_{27}COOH$.
  Its molar mass = $13 \times 12.0 + 27 \times 1.0 + 12.0 + 16.0 + 16.0 + 1.0 = 228$ g mol^{-1}.

  The molar mass of glycerol ($C_3H_8O_3$) is 92 g mol^{-1}.

  The formation of a triglyceride molecule from one glycerol and three myristic acid molecules is a condensation reaction that involves the formation of three ester linkages and the elimination of three water molecules. The molar mass of this triglyceride will be the molar mass of three myristic molecules plus one glycerol, less the molar mass of three water molecules; i.e. $(3 \times 228 + 92) - (3 \times 18.0) = 722$ g mol^{-1}.
- A is incorrect because a triglyceride contains three fatty acids and one glycerol molecule, not one fatty acid and three glycerol molecules.
- C is incorrect because three water molecules are eliminated in the formation of a triglyceride, not just one.
- D is incorrect because the formation of a triglyceride molecule from one glycerol and three myristic acid molecules is a condensation reaction that involves the formation of three ester linkages and the elimination of three water molecules. The mass of these three water molecules will be lost from the total molecule.

Question 16

A sample of an alkanol is placed in a cell and has infrared radiation passed through it. The difference in the radiation transmitted through the sample cell compared with a reference cell is due to energy being absorbed to

A. **move the molecule to a higher vibrational energy level.**

B. ionise and fragment the molecules.

C. promote an electron from a lower energy level to a higher energy level.

D. promote the nucleons to a higher spin level.

Answer is A.

Worked solution

- A is correct because infrared radiation can be absorbed by covalent bonds in a molecule as they bend and stretch, causing the overall molecule to move to a higher vibrational energy level.
- B is incorrect because it is in mass spectrometry that a high energy beam of electrons is fired at a molecule causing it to ionise and fragment.
- C is incorrect because there is not enough energy in infrared radiation to promote electrons from lower to higher energy levels. Heat and light can do this in flame tests and atomic absorption spectroscopy.
- D is incorrect because it is radio waves, not infrared radiation, that are used to promote nucleons in a magnetic field from low to high energy levels in nuclear magnetic resonance spectroscopy.

Question 17

An unknown organic molecule that is able to dissolve in water is thought to be an alkanol or a carboxylic acid. The analytical technique most suitable for identifying whether the organic molecule belongs to either of these homologous series is

A. nuclear magnetic resonance (NMR) spectroscopy.

B. UV-visible spectroscopy.

C. **infrared (IR) spectroscopy.**

D. mass spectroscopy.

Answer is C.

Worked solution

- C is correct because IR spectroscopy gives the most information about functional groups present in a molecule. Alkanols and carboxylic acids are different homologous series of organic molecules because they contain different functional groups.
- A is incorrect because although NMR spectroscopy provides information about carbon and hydrogen environments, it does not provide as much information about functional groups.
- B is incorrect because UV-visible spectroscopy is mainly used to provide quantitative information about inorganic compounds, as well as some organic compounds that absorb UV radiation.
- D is incorrect because mass spectroscopy is best used to determine the mass of an unknown compound and its fragments.

Question 18

Which of the following is the most unsaturated fatty acid?

A. linoleic acid

B. linolenic acid

C. arachidic acid

D. **arachidonic acid**

Answer is D.

Worked solution

- D is correct because arachidonic acid has the most carbon–carbon double bonds, making it the most unsaturated fatty acid. It has the formula $C_{19}H_{31}COOH$, so has four carbon–carbon double bonds.
- A is incorrect because linoleic acid, with the formula $C_{17}H_{31}COOH$, has two carbon–carbon double bonds.
- B is incorrect because linolenic acid, with the formula $C_{17}H_{29}COOH$, has three carbon–carbon double bonds.
- C is incorrect because arachidic acid, with the formula $C_{19}H_{39}COOH$, is saturated, meaning it has no carbon–carbon double bonds.

Tips

- *The molecular formulas of these compounds can be found in the VCE data book.*
- *The general formula of a saturated fatty acid will be $C_nH_{2n+1}COOH$. Every carbon–carbon double bond will result in two fewer hydrogen atoms than that specified in the general formula.*

Question 19

Fractional distillation can be used in the laboratory to separate a mixture of alkenes into components. Which of the following statements about fractional distillation is **not** correct?

A. The separation of components in fractional distillation is a physical process.

B. **The first component collected in the laboratory will have the highest molar mass.**

C. The last component collected in the laboratory will have the highest boiling temperature.

D. The order in which the components in this mixture are collected will depend on the strength of their dispersion forces.

Answer is B.

Worked solution

- B is the incorrect statement because the first component collected in the laboratory will be the most volatile component in the mixture, which in this case will be the alkene with the smallest molar mass.
- A is correct because the separation of components in a mixture is based on their boiling temperatures, which is a physical property.
- C is correct because the last component collected will be the least volatile. In a mixture of alkenes this will be the one with the largest molar mass and, therefore, the highest boiling temperature.
- D is correct because alkenes are non-polar substances, and so have only dispersion forces as the attraction between different molecules. It is the strength of the dispersion forces that will determine the boiling temperature of the alkenes in this mixture and so determine the order in which the components are collected.

Question 20

Correct functioning of an enzyme is dependent on its three-dimensional structure. If this structure is disrupted the protein will denature.

Which of the following changes could result in denaturation?

I The addition of a strong base.
II An increase in temperature.
III A decrease in temperature.

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

Answer is C.

Worked solution

- C is correct because both the addition of a strong base and an increase in temperature can disrupt the bonding responsible for the tertiary and secondary structure of the enzyme, changing the shape of the active site and rendering the enzyme inactive.
- A is incorrect because an increase in temperature also can denature the protein.
- B is incorrect because a decrease in temperature does not denature a protein. The rate of the reaction being catalysed by an enzyme may reduce due to decreased temperature, but the structure of the enzyme itself does not change. Also, addition of a strong base also can denature a protein.
- D is incorrect because a decrease in temperature does not denature a protein. The rate of the reaction being catalysed by an enzyme may reduce due to decreased temperature, but the structure of the enzyme itself does not change.

END OF SECTION A

SECTION B – Short-answer questions

Question 1

The concentration of iron(II) ions, $Fe^{2+}(aq)$, in a solution can be determined by volumetric analysis. Shown below is the method used in one such analysis to determine the iron(II) content of lawn fertiliser.

Method

- 16.80 g of lawn fertiliser is dissolved in water and the solution made up to 500.0 mL in a volumetric flask.
- Approximately 20 mL of 1 M sulfuric acid is added to three separate 20.00 mL samples of this solution.
- A 0.01000 M standard solution of potassium permanganate, $KMnO_4$, is used to titrate each of the samples. In this reaction, the iron(II) ions are oxidised to iron(III) ions and the purple permanganate ions are reduced to colourless manganese(II) ions.

The results of this analysis are shown below.

Results

Mass of lawn fertiliser = 16.80 g

Volume of volumetric flask = 500.0 mL

Volume of fertiliser solution in each sample = 20.00 mL

Sample	1	2	3
Titre volume (mL)	10.21	10.25	10.25

a. **i.** Determine the oxidation number of manganese in the permanganate ion.

Solution

+7

1 mark

Explanatory notes

The following oxidation number rules apply:

- Oxygen is always –2 (except in peroxides, when it is –1).
- The oxidation number of a single ion is equal to its valency.
- The sum of oxidation numbers in a charged ion must equal the charge on the ion.

For manganese in the permanganate ion:

- O has the oxidation number –2, and there are four oxygen atoms, so they contribute a total of –8.
- The sum of oxidation numbers in the ion must equal –1.

  (–8)

  –2

  MnO_4^-

  –1 = (–8) + oxidation number of Mn

  Oxidation number of Mn = +7

ii. Write a balanced half-equation for the reduction reaction that takes place in this analysis.

Solution

$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$

1 mark

Explanatory notes

- Reduction is the gain of electrons. The oxidation number (O.N.) of Mn in MnO_4^- is +7, the O.N. of Mn in Mn^{2+} is +2. Since the O.N. is decreasing, then the MnO_4^- to Mn^{2+} reaction must be a reduction reaction.

  Use the acronym KOHES for the steps needed to write the half-equation.

  K – Balance Key elements $MnO_4^- \rightarrow Mn^{2+}$

  O – Balance Oxygen by adding water $MnO_4^- \rightarrow Mn^{2+} + 4H_2O$

  H – Balance Hydrogen by adding H^+ ions $MnO_4^- + 8H^+ \rightarrow Mn^{2+} + 4H_2O$

  E – Balance charge by adding Electrons $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

  S – Add States $MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$

Tip

- *Always include states in your equations.*

iii. Write a balanced equation for the overall reaction that takes place in this analysis.

Solution

$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l) + 5Fe^{3+}(aq)$

2 marks

Mark allocation

- 1 mark for writing correct formulas for all of the species present.
- 1 mark for correctly balancing the equation; i.e. for correct coefficients.

Explanatory notes

- The oxidation reaction is $Fe^{2+} \rightarrow Fe^{3+} + e^-$, so must occur five times as often as the reduction reaction in order for the number of electrons lost and gained to be balanced.

b. Why is an indicator **not** required for this titration?

Solution

The permanganate ions are purple and the Mn^{2+} ion is colourless. A colourless solution will change to purple when slightly excess MnO_4^- has been added, without the addition of an extra indicator.

1 mark

c. Calculate

i. the amount, in mol, of $Fe^{2+}(aq)$ in the 500.0 mL volumetric flask.

Solution

$n(MnO_4^-)$ in average titre = cV

$$= 0.1000 \times \left(\frac{(0.01021 + 0.01025 + 0.01025)}{3} \right)$$
$$= 0.01000 \times 0.01024$$
$$= 1.024 \times 10^{-4} \text{ mol}$$

$n(Fe^{2+})$: $n(MnO_4^-)$

5 : 1

So, $n(Fe^{2+})$ in 20.00 mL $= 5 \times n(MnO_4^-)$

$= 5 \times 1.024 \times 10^{-4}$

$= 5.118 \times 10^{-4}$ mol

$n(Fe^{2+})$ in 500.0 mL $= \frac{500}{20} \times 5.118 \times 10^{-4}$

$= 0.01280$ mol

2 marks

Mark allocation

- 1 mark for correctly calculating $n(MnO_4^-)$ in the average titre.
- 1 mark for correctly calculating $n(Fe^{2+})$ in the 500.0 mL volumetric flask.

Explanatory notes

- A consequential mark can be earned if the first part is calculated incorrectly but the second part is calculated correctly. This is the case for all calculation questions throughout this paper. The same error should not be penalised twice.

Tip

- *This answer is expressed with four significant figures because the least precise piece of data given in the question has four significant figures.*

ii. the percentage, by mass, of iron(II) in the lawn fertiliser.

Solution

$m(Fe^{2+}) = n \times M$

$= 0.01280 \times 55.9$

$= 0.7153$ g

% by mass of iron in the fertiliser = $\frac{0.7153}{16.80} \times 100$

$= 4.258\%$

2 marks

Mark allocation

- 1 mark for correct calculation of mass of iron in the fertiliser sample.
- 1 mark for correct calculation of percentage by mass

d. Several actions that could occur during this analytical procedure are listed below (**A–D**).

i. For each action, indicate the likely effect on the calculated percentage of iron(II) ions in the fertiliser by placing a tick in the appropriate box.

Action	Calculated result would be too low	No effect on calculated result	Calculated result would be too high
A. The volumetric flask had been washed previously with distilled water, but not dried.			
B. A 25.00 mL pipette was unknowingly used instead of a 20.00 mL pipette.			
C. The mass of the fertiliser was recorded incorrectly. The recorded mass was 0.15 g less than the actual mass.			
D. The burette had been washed previously with distilled water only.			

Solution

Action	Calculated result would be too low	No effect on calculated result	Calculated result would be too high
A. The volumetric flask had been washed previously with distilled water, but not dried.		✓	
B. A 25.00 mL pipette was unknowingly used instead of a 20.00 mL pipette.			✓
C. The mass of the fertiliser was recorded incorrectly. The recorded mass was 0.15 g more than the actual mass.	✓		
D. The burette had been washed previously with distilled water only.			✓

4 marks

Mark allocation

- 1 mark for each correct tick.

Explanatory notes

- A. The volumetric flask should be washed with distilled water before use. It is used for making up a solution from a measured mass of fertiliser, so has distilled water added to it anyway.
- B. See part **ii** solution.
- C. If the recorded mass of fertiliser is more than the actual mass, then the calculated percentage mass of iron(II) ions will be lower than it should be. This is because the mass of iron(II) ions determined in the sample will be correct but the mass of fertiliser used in the percentage by mass calculation will be higher than it should be.
- D. Washing the burette with distilled water only will dilute the permanganate solution when it is added to the burette. More of it will be required to react with the fertiliser solution, making the calculated percentage by mass of iron higher than it should be.

ii. Explain your reasoning for the answer that you have given in the case of action **B**.

Solution

B. The sample of fertiliser solution in the conical flask will contain a greater amount of fertiliser than it should. This will require a greater volume of permanganate ions, making the mass of iron(II) ions in the fertiliser seem higher than it actually is.

1 mark
Total 4 + 1 + 4 + 5 = 14 marks

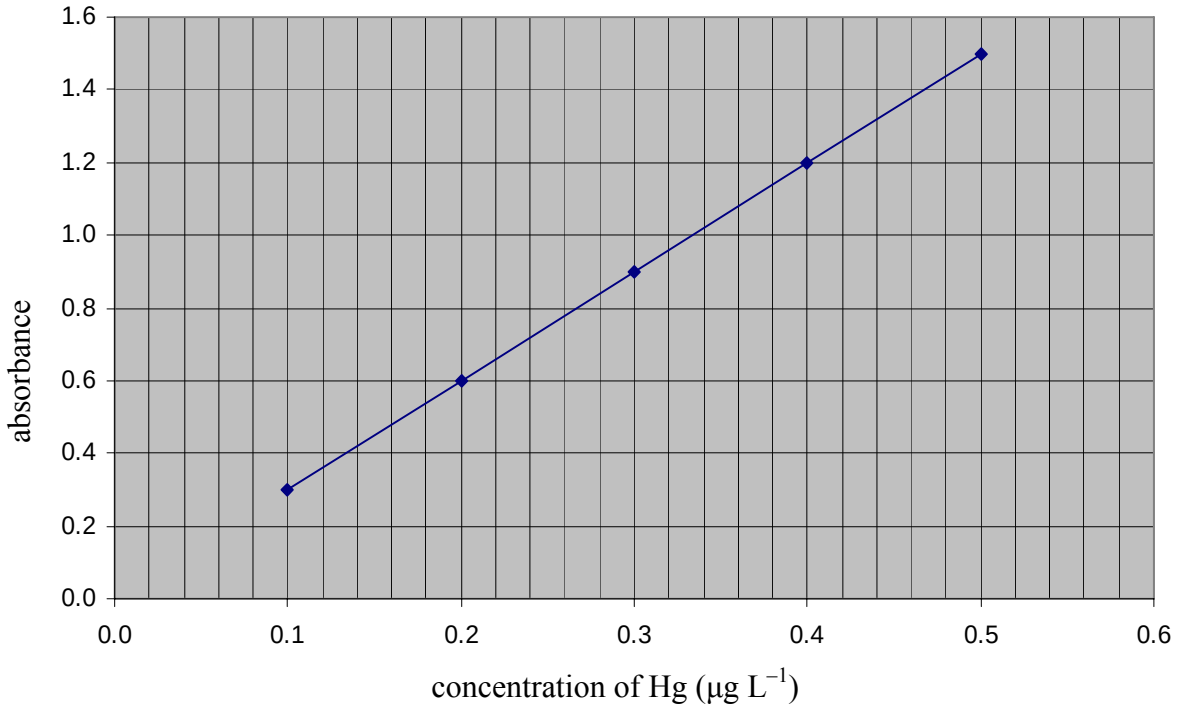
Question 2

Mercury poisoning is a disease in humans caused by excessively high exposure to mercury (Hg). Due to safety concerns, the mercury content of commercially traded shellfish that is intended for consumption by humans should not exceed 0.5 mg kg^{-1}. One way to determine the mercury content in shellfish is to analyse samples using atomic absorption spectroscopy (AAS).

A mass of 0.1373 g of freeze-dried sample of shellfish tissue is dissolved in 2.00 mL of nitric acid, heated for 3 hours at 125°C and transferred to a 500.0 mL volumetric flask, where it is made up to the mark with deionised water. A volume of 1.00 mL of this solution is then further diluted to 250.0 mL in a second volumetric flask. AAS is used to measure the absorbance of this solution, which is found to be 1.03.

Next, the absorbance of a series of Hg solutions of known concentration was measured using AAS and a calibration graph drawn.

Calibration graph



a. What is the concentration, in μg L^{-1}, of mercury in the 250.0 mL volumetric flask?

Solution

0.33–0.35 μg L^{-1}

1 mark

Explanatory notes

- The diluted solution in the 250.0 mL volumetric flask was directly analysed using AAS. Reading straight off the graph, an absorbance of 1.03 corresponds to a concentration somewhere in the range of 0.33–0.35 μg L^{-1}.

b. Calculate the mass, in mg, of mercury in the shellfish sample.

Solution

Concentration of Hg in the 250.0 mL flask = 0.34 μg L^{-1}

m(Hg) in the 250.0 mL flask = $\frac{250.0}{1000} \times 0.34 = 0.085$ μg

m(Hg) in the 500 mL flask = $\frac{500}{1.0} \times 0.085 = 43$ μg = 0.043 mg

So, m(Hg) in the shellfish sample = 0.043 mg

2 marks

Mark allocation

- 1 mark for correctly calculating m(Hg) in the 250.0 mL flask.
- 1 mark for correctly calculating m(Hg) in the shellfish sample.

c. Should this shellfish be traded commercially? Justify your answer.

Solution

No.

The 0.043 mg of mercury was obtained from a 0.1373 g sample of shellfish.

The concentration, in mg kg^{-1} = $\frac{1000}{0.1373} \times 0.043 = 310$ mg kg^{-1}

Therefore, the concentration of mercury in the shellfish exceeds the limit of 0.5 mg kg^{-1}.

3 marks

Mark allocation

- 1 mark for stating that the shellfish cannot be traded commercially.
- 1 mark for correctly calculating the mercury concentration as 310 mg kg^{-1}.
- 1 mark for stating that the shellfish concentration is above the legal limit.

d. **i.** What type of lamp would be used in the AAS for this analysis?

Solution

A mercury lamp.

1 mark

ii. Explain why this type of lamp is used.

Solution

It will emit the exact wavelength of light required for the mercury atoms to absorb.

1 mark
Total 1 + 2 + 3 + 2 = 8 marks

Question 3

A mixture of ethanol, 1-propanol and 1-butanol is analysed using gas chromatography (GC).

a. Predict which molecule will travel through the chromatography column at the fastest rate. Give a reason for your choice.

Solution

ethanol

It is the smallest molecule OR it has the lowest boiling temperature.

2 marks

Mark allocation

- 1 mark for ethanol.
- 1 mark for a correct reason.

Explanatory notes

- Ethanol, 1-propanol and 1-butanol are both alkanols, which are all polar molecules with hydrogen bonding between molecules. Hence, the differences in their boiling temperatures will be due only to differences in dispersion forces, which are due to differences in size. The smallest molecule has the weakest dispersion forces, and therefore has the lowest boiling temperature. As a result, it will travel at the fastest rate through a gas chromatography column.

b. Explain how gas chromatography can be used for qualitative analysis.

Solution

The retention time (R_t) of each component can be measured and compared to a set of standards.

1 mark

c. Explain how gas chromatography can be used for quantitative analysis.

Solution

The areas under each peak can be measured and analysed by establishing a calibration curve from a set of known standards.

1 mark

d. Predict which of the molecules in the mixture will show the greatest number of peaks in a ^{13}C NMR spectrum. Give a reason for your answer.

Solution

1-butanol

It has the greatest number of different carbon environments.

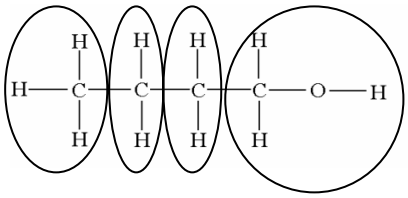
2 marks

Mark allocation

- 1 mark for 1-butanol.
- 1 mark for correct reason.

Explanatory notes

- In ^{13}C NMR, the number of peaks on the spectrum of a particular molecule corresponds to the number of different carbon environments in that molecule.
  In 1-butanol there are four different carbon environments, as shown below.



  Although there are two CH_2 groups in the middle of 1-butanol, they are different carbon environments because they are different distances from the highly electronegative oxygen in the hydroxyl functional group.

  1-Propanol has three different carbon environments, and ethanol has two different carbon environments.

Total 2 + 1 + 1 + 2 = 6 marks

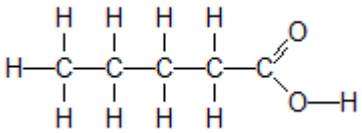
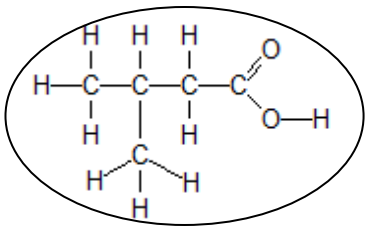
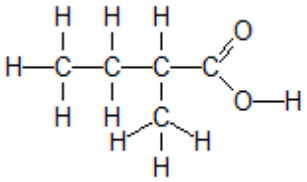
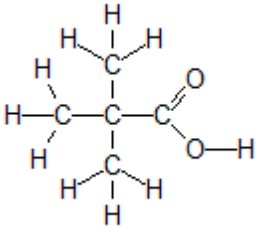
Question 4

A compound, X, is known to be a carboxylic acid of molecular formula $C_5H_{10}O_2$. The structure, which may or may not be branched, is unknown.

a. In the boxes below, draw the structures, showing **all** bonds, of the four possible carboxylic acids with the molecular formula $C_5H_{10}O_2$.

Carboxylic acid I	Carboxylic acid II
Carboxylic acid III	Carboxylic acid IV

Solution

Carboxylic acid I 	Carboxylic acid II 
Carboxylic acid III 	Carboxylic acid IV 

4 marks

Mark allocation

- 1 mark for each correct structure

Explanatory notes

- Isomers share the same molecular formula but have different structures.

Tip

- *When asked to draw structures make sure all bonds are shown, including full expansion of the carboxyl group.*

Compound X shows four peaks in the ^{1}H NMR spectrum and four peaks in the ^{13}C NMR spectrum.

b. What conclusions about the structure of X can be determined from this information?

Solution

Compound X contains four different hydrogen environments and four different carbon environments.

2 marks

Mark allocation

- 1 mark for four different H environments.
- 1 mark for four different C environments.

Explanatory notes

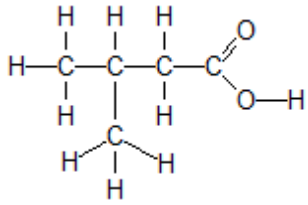
- The number of peaks in an NMR spectrum corresponds to the number of different environments that the element being analysed has in the structure of the molecule. It **does not** correspond to the actual number of atoms in each environment.

c. Identify compound X by

- circling the correct structure in part **i** that corresponds to compound X.
- writing the systematic name of compound X below.

Solution

The structure circled should be



3-methyl butanoic acid

2 marks

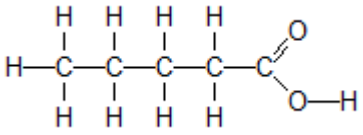
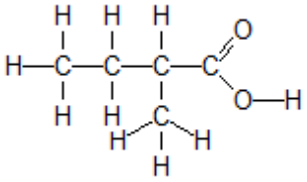
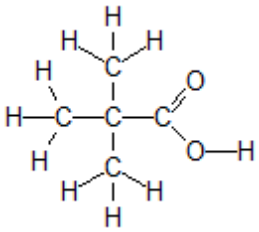
Mark allocation

- 1 mark for circling the correct structure.
- 1 mark for correct name.

(If an incorrect structure is circled but then named correctly, 1 mark should be awarded.)

Explanatory notes

- This is the only structure with four different hydrogen environments and four different carbon environments. The numbers of different environments for the other isomers are shown below.

Structure	Number of C environments	Number of H environments
	5	5
	5	5
	3	2

The correct structure is named as follows:

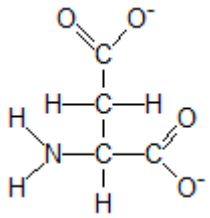
- It is a carboxylic acid with four carbons in the longest chain, so is butanoic acid. The carboxyl group is always located on the number one carbon.
- A methyl group branch is attached to the third carbon, starting counting from the end where the carboxyl group is.

Total 4 + 2 + 2 = 8 marks

Question 5

a. Draw the structure of the amino acid, aspartic acid, as it would exist in solution at pH 13. Show **all** bonds.

Solution



1 mark

Mark allocation

All bonds must be drawn clearly to receive the mark.

Explanatory notes

- A solution with pH 13 is a basic solution. The amino acid will act as an acid and donate all possible H^+ ions. This includes the one in the carboxyl group on the Z group.

Tip

- *The structures of all of the amino acids can be found in the VCE data book.*

b. What is the molecular formula of the amino acid, tyrosine?

Solution

$C_9H_{11}NO_3$

1 mark

Explanatory notes

- The Z group of tyrosine contains a phenol group, derived from the phenol ring, which has the formula C_6H_5OH. One fewer H atom is present in the overall structure since one of the H atoms from the phenol ring is lost when this ring is attached to the remainder of the amino acid molecule.

c. A tripeptide forms between two aspartic acids and one tyrosine.

i. How many different tripeptides could be possibly formed?

Solution

Three different tripeptides possible.

1 mark

Explanatory notes

- The possible structures can be summarised as

  H_2N-Asp-Tyr-Asp-COOH

  H_2N-Asp-Asp-Tyr-COOH

  H_2N-Tyr-Asp-Asp-COOH

ii. Name **all** of the functional groups that would be present on any of the tripeptides formed.

Solution

amine, carboxyl, hydroxyl, phenol, amide (or peptide) linkage

2 marks

Mark allocation

- Naming four correctly = 2 marks
- Naming two or three correct = 1 mark

Explanatory notes

- There will be an amine group ($–NH_2$) on one end of the tripeptide and a carboxyl group (–COOH) on the other end, as well as on the Z group of aspartic acid. There will be two amide (or peptide) linkages (–CONH–) formed within the tripeptide. Tyrosine has a phenol group, which is an –OH group attached to a benzene ring.

Proteins have different levels of structure.

d. i. Name the type of bonding responsible for the primary structure of a protein.

Solution

covalent

1 mark

ii. Name the type of bonding responsible for the secondary structure of a protein.

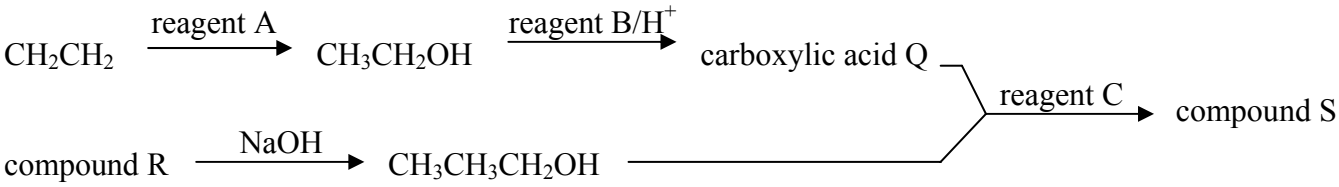
Solution

hydrogen

1 mark
Total 1 + 1 + 3 + 2 = 7 marks

Question 6

An ester can be produced using the partly completed reaction pathway shown below.



a. In the space provided below, give the formulas of reagents A, B and C.

reagent A

reagent B

reagent C

Solution

reagent A is H_2O.

reagent B is MnO_4^- or $Cr_2O_7^{2-}$ or $KMnO_4$ or $K_2Cr_2O_7$.

reagent C is $H_2SO_4(l)$.

3 marks

Mark allocation

- 1 mark per correct reagent.

Explanatory notes

- Reagent A, H_2O, is added across the double bond in an alkene (CH_2CH_2) to produce an alkanol (CH_3CH_2OH).
- Reagent B, MnO_4^- or $Cr_2O_7^{2-}$, is an oxidizing agent required to produce a carboxylic acid from an alkanol.
- Reagent C, H_2SO_4, when concentrated is a catalyst required to produce an ester from an alkanol and a carboxylic acid.

Tip

- *In these types of questions, always check if the names or formulas of substances are required and ensure the correct one is given.*

b. In the space provided below, give the systematic names of compounds Q and R.

compound Q

compound R

Solution

Compound Q is ethanoic acid.

Compound R is 1-chloropropane.

2 marks

Mark allocation

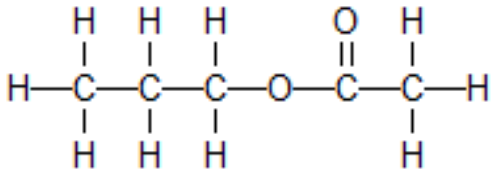
- 1 mark for each correct compound.

Explanatory notes

- Compound Q is a carboxylic acid produced from an alkanol with two carbon atoms, so must be ethanoic acid.
- Compound R reacted with NaOH to produce an alkanol. In this reaction, the hydroxyl functional group substitutes into the molecule in place of a chloro functional group. The chloro group must be located on the first of three carbon atoms, and so is named 1-chloropropane.

c. **i.** In the space below, draw the structure, showing **all** bonds, of compound S.

Solution



1 mark

ii. Give a systematic name for compound S.

Solution

propyl ethanoate

1 mark

Explanatory notes

When naming esters, the first part of the name is derived from the alkanol and the second part is derived from the carboxylic acid.

Total 3 + 2 + 2 = 7 marks

Question 7

Ethanol, biodiesel and biogas are all biochemical fuels.

a. What is the basis for classifying these fuels as 'biochemical' fuels?

Solution

They are all derived from biological renewable sources.

1 mark

Tip

- *'Plant materials' is also an acceptable answer.*

b. Write a balanced chemical reaction for the production of ethanol by the fermentation of glucose.

Solution

$C_6H_{12}O_6(aq) \rightarrow 2CH_3CH_2OH(aq) + 2CO_2(g)$

1 mark

Explanatory notes

- Enzymes catalyse this reaction. It is an anaerobic process, meaning it takes place in the absence of oxygen.

c. **i.** Give the name of the functional group present in ethanol.

Solution

hydroxyl

1 mark

Explanatory notes

Ethanol is an alkanol. All alkanols contain the hydroxyl (–OH) functional group.

Tip

- *Be careful to give the answer requested. In this case, the name of the functional group is requested. Simply giving the formula –OH would not earn the mark.*

ii. In which wavelength range, in cm^{-1}, would you expect this functional group to show a peak on an infrared absorption spectrum for ethanol?

Solution

3200–3550 cm^{-1}

1 mark

Explanatory notes

The characteristic range for infrared absorption, including the O–H in alkanols, is listed in the VCE data book.

Tip

- *Be careful to distinguish between the O–H in acids and the O–H in alcohols, as they absorb infrared radiation at different wavelengths.*

Total 1 + 1 + 2 = 4 marks

Question 8

A volume of 20.0 mL of 0.103 M NaCl(aq) was added to 15.0 mL of 0.855 M $AgNO_3$(aq). A reaction occurs according to the equation

$$NaCl(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + AgCl(s)$$

a. Calculate the mass of silver chloride you would expect to be precipitated from this reaction mixture.

Solution

$n(NaCl) = cV$

$= 0.103 \times 0.0200$

$= 2.06 \times 10^{-3}$ mol

$n(AgNO_3) = cV$

$= 0.855 \times 0.0150$

$= 1.28 \times 10^{-2}$ mol

$n(NaCl) : n(AgNO_3)$

1 : 1

So, $n(NaCl)$ is the limiting reagent.

$n(NaCl) : n(AgCl)$

1 : 1

So, $n(AgCl) = n(NaCl) = 2.06 \times 10^{-3}$ mol

$m(AgCl) = nM$

$= 2.06 \times 10^{-3} \times (107.9 + 35.5)$

$= 0.295$ g

2 marks

Mark allocation

- 1 mark for correctly determining that NaCl(aq) is the limiting reagent.
- 1 mark for correctly calculating $m(AgCl)$.

Explanatory notes

When data are given about the amount of both reagents in a reaction, the *limiting* reagent must be determined and used to predict the amount of product formed. The other reagent is in excess, so some will remain once the maximum amount of product has been produced.

b. Give **two** sources of experimental error that would cause the mass of the precipitate to be higher than it should be.

Solution

Two of:

Co-precipitation

Incomplete drying of the precipitate.

Incomplete washing of the precipitate.

The volume of NaCl(aq) added being higher than it should be.

2 marks

Mark allocation

- 1 mark for each correct source of experimental error.

Total 2 + 2 = 4 marks

END OF SOLUTIONS BOOK