YEAR 12 *Trial Exam Paper*

2019

CHEMISTRY

Written examination

Worked solutions

This book includes:

- correct solutions, with full working
- explanatory notes
- mark allocations
- tips.

Question 1

Answer: C

Explanatory notes

Option A is not the most accurate answer. Renewable fuels such as biodiesel will not be used at the exact rate they are produced.

Option B is incorrect. For example, there is a limit to the amount of canola that can be grown or waste sugar cane that can be processed.

Option C is correct. A fuel is considered to be renewable when it is possible to replenish amounts of the fuel used in a reasonable period of time. The growing of a crop of canola for biodiesel is an example of the fuel being replenished but not instantaneously.

Option D is incorrect. Fuels are not recyclable in the way that a plastic product might be.

Question 2

Answer: A

Explanatory notes

Option A is correct.

The amount of energy is 200×10^{15} J or 200×10^{12} kJ.

The amount of energy released by each gram of methane is 55.6 kJ, therefore the mass required is

$$\frac{200 \times 10^{12}}{55.6} = 3.6 \times 10^{12} \text{ g.}$$

Option B is incorrect, as the data book energy values are in grams, not kilograms.

Option C is incorrect, as the data book energy values are listed in kJ.

Option D is incorrect, as the correct answer is 3.6×10^{12} g.

Tip

- *Don't forget to reference the provided data book. There will be many instances throughout the exam when a value, structure, half-equation or a formula can be sourced from this book.*

Question 3

Answer: D

Explanatory notes

Option A is incorrect, as a molecule of octane has twice as many carbon atoms as that of butane but the number of bonds in the molecule is not double. The combustion table in the data book can be used to confirm this.

Option B is incorrect, as 1 g of butane releases more energy than 1 g of octane. The values are provided in the data book.

Option C is incorrect, as this trend is the opposite to the correct answer.

Option D is correct, as the bond energy of C–H bonds is greater than that of C–C bonds. The energy density decreases as the length of the molecule increases and the carbon-to-hydrogen ratio increases.

Question 4

Answer: B

Explanatory notes

Option A is incorrect, as three methanol molecules are also required if biodiesel is to form.

Option B is correct. Each triglyceride contains three fatty acid chains. When the triglyceride is hydrolysed, the three ester bonds break to form glycerol and three molecules of fatty acid. Each fatty acid molecule then reacts with a methanol molecule to form a biodiesel molecule.

Option C is incorrect, as three methanol molecules are required, not one.

Option D is incorrect, as three molecules of biodiesel are formed, not one.

Tip

- *You might find the large structures involved in biodiesel structures difficult to understand; however, the topic is an important one, especially as triglycerides are also covered in the food section of the course. You should rote learn the process of producing biodiesel from a triglyceride.*

Question 5

Answer: B

Explanatory notes

Option A is incorrect, as each mole of methane would react with 2 moles of oxygen.

Option B is correct, as the ratio of fuel to O_2 is 0.08:0.28 or 1:3.5. Each fuel listed needs to be tested to see which balanced equation matches this ratio. Ethane provides a matching equation: $C_2H_6(g) + 3.5O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

Option C is incorrect, as each mole of ethanol would react with 3 moles of oxygen.

Option D is incorrect, as each mole of butane would react with 6.5 moles of oxygen.

Tip

- *Remember, you are expected to be able to write combustion equations. This expectation includes the writing of equations for incomplete combustion. To balance equations for complete combustion, use the following process:*
  - *Balance the carbon atoms:* $CH_4(g) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$
  - *Balance the hydrogen atoms:* $CH_4(g) + O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$
  - *Balance the oxygen atoms last:* $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

Question 6

Answer: D

Explanatory notes

Option A is incorrect. The energy density does not depend on temperature.

Option B is incorrect. The magnitude of the activation energy will not make a difference of this magnitude.

Option C is incorrect. Even when both cars are similarly tuned, the diesel car will still travel a significant distance further.

Option D is correct. Methane is supplied as a gas and its density is much lower than that of diesel. The mass of methane in the 50 litre tank will be significantly less than that of diesel.

Tip

- *Recent exams have had an expectation of some general knowledge. Examples include that submarines need to operate very quietly and that Mars is further from the Sun than is Earth. In this case, option D offers you a suggestion of a low density fuel that is plausible with the data given.*

Question 7

Answer: C

Explanatory notes

Option A is incorrect. As this is a reversible reaction, the relative amounts of NOCl and Cl_2 will depend on the temperature of the system.

Option B is incorrect. As this is a reversible reaction, the relative amounts of NOCl and NO will depend on the temperature of the system.

Option C is correct, as the ratio between NO and Cl_2 in the balanced equation is 2:1. The amount of NO formed will be double that of the chlorine.

Option D is incorrect, as the mole ratio is 2:1, not 1:2.

Question 8

Answer: C

Explanatory notes

Option A is incorrect.

Option B is incorrect.

Option C is correct.

$K = \frac{[NO]^2[Cl_2]}{[NOCl]^2} = \frac{x^2 x}{x^2} = 0.2$, where x = concentration of each compound.

$x = 0.2$ M

Option D is incorrect.

Question 9

Answer: D

Explanatory notes

Option A is incorrect, as 890 needs to be subtracted from –200.

Option B is incorrect, as the initial value is –200, not +200 kJ mol^{-1}.

Option C is incorrect, as the initial value has not been used.

Option D is correct. From the data book, the molar heat of combustion of methane is listed as –890 kJ mol^{-1}. For this value to be consistent with the –200 value on the axis, the enthalpy of the products must be (–200 – 890) = –1090 kJ mol^{-1}.

Tip

- *When you see a heat of combustion question, consider whether the data book can help you.*

Question 10

Answer: D

Explanatory notes

Option A is incorrect, as it is close to the reciprocal.

Option B is incorrect, as the concentrations are not equal.

Option C is incorrect, as the [HI] has not been squared.

Option D is correct.

[HI] from graph is 1.25 M.

[HI] dropped by 0.75 $\Rightarrow$ $[I_2]$ and $[H_2]$ = $\frac{1}{2}$ [HI] = 0.375 M

$$K = \frac{[H_2][I_2]}{[HI]^2} = \frac{0.375 \times 0.375}{1.25^2} = 0.090$$

Question 11

Answer: A

Explanatory notes

Option A is correct. Oxygen will always be the reactant at the cathode (where the reduction reaction occurs) in a fuel cell and the electrolyte is alkaline. The OH^- ions formed are consistent with the electrolyte.

Option B is incorrect, as the electrolyte is not acidic.

Option C is incorrect, as the reaction is in an aqueous environment.

Option D is incorrect, as this is the oxidation reaction that will occur at the anode.

Question 12

Answer: B

Explanatory notes

Option A is incorrect, as the lithium electrode will lose mass.

Option B is correct, as electrons are produced at the lithium anode, and they will flow through to the cathode.

Option C is incorrect, as the pH will increase if further OH^- ions are formed.

Option D is incorrect, the mass change is not the same as the mole ratio.

Tip

- *It is common for the examiners to use an example of a new galvanic cell. Although the cell will be unfamiliar, you should be able to apply the skills you have learned to write the equations for the cell.*
- *It is an expectation that you can analyse the galvanic cell that can be constructed from any two half-cells shown on the electrochemical series in the data book. 'Analyse' means write half-equations and predict the direction of electron flow and the polarity.*

Question 13

Answer: C

Explanatory notes

Option A is incorrect.

Option B is incorrect.

Option C is correct.

$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

Experiment 1: $n(CaCO_3)$ is approximately 0.01 mol $\left(\frac{1}{100}\right)$.

$$n(HCl) = c \times V = 0.02 \times 1 = 0.02 \text{ mol}$$

For experiment 1, the reactants are in the stoichiometric ratio of 1:2,

$n(CaCO_3) = \frac{1}{2}\, n(HCl)$. When the mass of $CaCO_3$ is doubled in experiment 2, the initial rate of reaction is higher because more collisions will occur. The volume of gas evolved will end up being unchanged as the HCl is the limiting reagent.

Option D is incorrect, as the HCl is limiting the total volume of gas evolved.

Question 14

Answer: C

Explanatory notes

Option A is incorrect, as water will not react in cell 1.

Option B is incorrect, as water does not react in cell 1 but it does in cell 2.

Option C is correct. In cell 1, copper ions are the strongest oxidising agent and bromide ions are the strongest reducing agent. Copper metal and bromine gas will form. In cell 2, water is both the strongest oxidising agent and the strongest reducing agent. It will form oxygen and hydrogen gases.

Option D is incorrect, as hydrogen forms at the cathode and oxygen at the anode in cell 2.

Question 15

Answer: B

Explanatory notes

Option A is incorrect, as 5 moles of hydrogen forms but oxygen gas will also form.

Option B is correct, as no gases are formed in the left cell. In the right cell, 5 moles of hydrogen gas and 2.5 moles of oxygen will form. This gives a total of 7.5 moles.

$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ (ratio of gas to electrons is 1:2 = 5 mol)

$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$ (ratio of gas to electrons is 1:4 = 2.5 mol)

Option C is incorrect, as the number of moles of gas is too high.

Option D is incorrect, as the number of moles of gas is too high.

Question 16

Answer: D

Explanatory notes

Option A is incorrect, as the molecule cannot be an alkane. An alkane will not have an empirical formula of CH_2.

Option B is incorrect, as ethene has only one carbon environment.

Option C is incorrect, as but-1-ene has four carbon environments.

Option D is correct. But-2-ene has an empirical formula of CH_2 and two carbon environments, and it undergoes an addition reaction with chlorine gas.

Question 17

Answer: B

Explanatory notes

Option A is incorrect. This molecule is not acidic.

Option B is correct. The bromine test indicates the molecule is unsaturated (i.e. contains a carbon-to-carbon double or triple bond). The NaOH addition test shows the molecule is an acid and the dichromate addition test rules out the presence of an alcohol group.

Option C is incorrect, as butan-1-ol would not react with bromine or NaOH.

Option D is incorrect, as this molecule would not react with bromine.

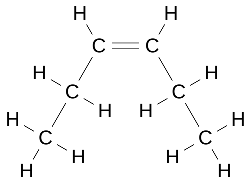
Question 18

Answer: B

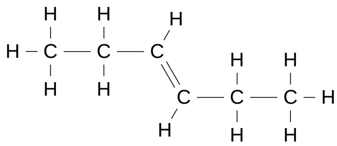
Explanatory notes

Option A is incorrect, as the first carbon atom has two hydrogen atoms on it.

Option B is correct, as shown in the two geometric isomers of hex-3-ene drawn below.



cis-hex-3-ene



trans-hex-3-ene

Option C is incorrect, as the first carbon atom has identical chlorine atoms.

Option D is incorrect, as the carbon-to-carbon double bond needs to be on the second carbon atom to match the positions of the two chlorine atoms.

Tip

- *For an alkene to have geometric isomers, each carbon on the double bond must be bonded to different functional groups. For example, the left carbon on the double bond of the molecule above is bonded to an H atom and to a CH_3CH_2 .*

Question 19

Answer: D

Explanatory notes

Option A is incorrect, as it is a skeletal diagram of ethyl butanoate.

Option B is incorrect, as the diagram is of butanoic acid and the convention used is not correct. An example of a skeletal diagram can be found in the data book.

Option C is incorrect, as it is an ester but has a branch on it.

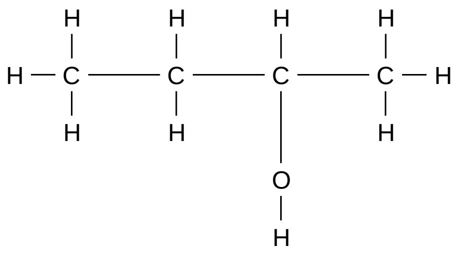
Option D is correct, as the left end of the molecule is the ethanoate and the right end has four vertices, matching a butyl group.

Question 20

Answer: A

Explanatory notes

Option A is correct. Butan-2-ol is drawn below. It has five different hydrogen environments and four carbon environments.



Option B is incorrect, as 2-chlorobutane will have only four hydrogen environments.

Option C is incorrect, as pentane has three different hydrogen environments.

Option D is incorrect, as pentan-1-ol has six different hydrogen environments.

Question 21

Answer: D

Explanatory notes

Option A is incorrect, as butanoic acid is relatively polar.

Option B is incorrect, as butan-1-ol is polar.

Option C is incorrect, as butane is non-polar but it is a smaller molecule than hexane.

Option D is correct. Ethanol is a polar solvent. The stationary phase will be non-polar. Polar molecules will move through this column faster than non-polar molecules of a similar size. Hexane is the largest non-polar alternative; hence, it will have the highest retention time.

Question 22

Answer: C

Explanatory notes

Option A is incorrect, as ethanal would have a parent molecular ion with an m/z ratio of 44, not 88, as shown on the spectrum.

Option B is incorrect, as ethanol would have a parent molecular ion with an m/z ratio of 46, not 88, as shown on the spectrum.

Option C is correct. The parent molecular ion has an m/z peak of 88. This makes the molecular formula double that of the empirical formula of C_2H_4O (i.e. $C_4H_8O_2$). Butanoic acid is the only alternative matching this formula. The small m/z peak on the spectrum at 89, is probably due to an isotope of one of the elements and can be disregarded. A molar mass of 89 g mol^{-1} would not be consistent with the empirical formula.

Option D is incorrect, as the molecular formula of butan-1-ol is not $C_4H_8O_2$.

Question 23

Answer: B

Explanatory notes

Option A is incorrect, as the mole ratio is not 1:1.

Option B is correct.

$n(Cr_2O_7^{2-}) = c \times V = 0.3 \times 0.2 = 0.06$ mol

$n(CH_3CH_2OH) = \frac{3}{2} \times n(Cr_2O_7^{2-})$

$n(CH_3CH_2OH) = \frac{3}{2} \times 0.06 = 0.09$ mol

$c(CH_3CH_2OH) = \frac{n}{V} = \frac{0.09}{0.45} = 0.20$ M

Option C is incorrect, as the concentration is too high.

Option D is incorrect, as the mole ratio has not been applied correctly.

Question 24

Answer: D

Explanatory notes

Option A is incorrect, as vitamins are smaller structures than the one given.

Option B is incorrect, as carbohydrates do not contain sulfur or nitrogen.

Option C is incorrect, as starch will not contain sulfur or nitrogen.

Option D is correct. The size of the molecule suggests it is a polymer, such as a carbohydrate or protein. The presence of nitrogen and sulfur makes it likely to be a protein.

Question 25

Answer: B

Explanatory notes

Option A is incorrect, as the question asks for different amino acids.

Option B is correct, as this molecule is formed from the reaction between glycine and alanine.

Option C is incorrect, as the first part of the molecule is not an α-amino acid.

Option D is incorrect, as the first part of the molecule is not an α-amino acid.

Question 26

Answer: A

Explanatory notes

Option A is correct, as linolenic acid has a carbon-to-carbon double bond on the third carbon from the methyl group end of the fatty acid.

Option B is incorrect, as the carbon-to-carbon double bond is not on the third carbon.

Option C is incorrect, as it is saturated.

Option D is incorrect, as the carbon-to-carbon double bond is not on the third carbon.

Tip

- *The fatty acids referenced in questions are usually taken from the data book. Make sure you check whether the question is about the fatty acid or the triglyceride formed from the fatty acid.*

Question 27

Answer: D

Explanatory notes

Option A is incorrect, as the presence of hydroxyl groups is not restricted to vitamins.

Option B is incorrect, as it refers to enzymes rather than vitamins.

Option C is incorrect, as nearly all vitamins have to be included in our diets because we do not synthesise them.

Option D is correct. Vitamins are chemically different but are deemed to be molecules that are essential to the human body and nutrition but are not generally synthesised in the body.

Question 28

Answer: C

Explanatory notes

Option A is incorrect, as this is a systematic error.

Option B is incorrect, as spillage is a mistake.

Option C is correct. As the sun emerges occasionally, the room temperature might fluctuate slightly and in an unpredictable fashion.

Option D is incorrect, as this is a mistake.

Question 29

Answer: B

Explanatory notes

Option A is incorrect, as the time used was only one minute, not four.

Option B is correct.

CF = $\frac{VIt}{\Delta T} = \frac{5.4 \times 3.6 \times 4 \times 60}{4}$ = 1170 J °C^{-1}

Option C is incorrect.

Option D is incorrect, as it is out by a factor of 4.

Question 30

Answer: C

Explanatory notes

Option A is incorrect.

Option B is incorrect, as the temperature change has not been used and the units are wrong.

Option C is correct.

Energy = CF × ΔT = 1170 × 6.8 = 7960 J

Heat of combustion $= \frac{\text{energy}}{\text{mass}} = \frac{7960}{1.42} = 5600 \text{ J g}^{-1} = 5.60 \text{ kJ g}^{-1}$

Option D is incorrect.

SECTION B

Question 1a.i.

Worked solution

100 kPa = 0.987 atm $\Rightarrow$ 11.5 atm = $\dfrac{11.5 \times 100}{0.987}$ = 1170 kPa

Explanatory notes

The conversion figure for atm to kPa is provided in the data book.

Mark allocation: 1 mark

- 1 mark for correct conversion

Question 1a.ii.

Worked solution

C_3H_8(l) + 3.5O_2(g) → 3CO(g) + 4H_2O(l) or

2C_3H_8(l) + 7O_2(g) → 6CO(g) + 8H_2O(l)

Explanatory notes

Incomplete combustion produces CO and H_2O. Balance the carbon first, then the hydrogen and finally the oxygen.

Mark allocation: 1 mark

- 1 mark for a correctly balanced equation with states

Question 1b.

Worked solution

S(s) + O_2(g) → SO_2(g)

Explanatory notes

Sulfur burning in oxygen will form the pollutant sulfur dioxide, SO_2.

Mark allocation: 1 mark

- 1 mark for a correctly balanced equation with states

Question 1c.i.

Worked solution

$m = d \times V = 0.495 \times 24\,000$

$= 11\,900$ g or 11.9 kg

Explanatory notes

The mass is calculated from the density and volume provided.

Mark allocation: 1 mark

- 1 mark for the calculation of the mass

Question 1c.ii.

Worked solution

Energy released = 11 900 × 50.5 = 600 000 kJ = 6.0×10^5 kJ

Explanatory notes

The energy is calculated from the number of grams multiplied by the energy per gram.

Mark allocations: 1 mark

- 1 mark for calculation of energy released using the energy density value given in the data book

Question 1c.iii.

Worked solution

$$n(C_3H_8) = \frac{11\,900}{44} = 270 \text{ mol}$$

$n(CO_2) = 3n(C_3H_8) = 810$ mol

$$V = \frac{810 \times 8.31 \times 693}{220} = 2.12 \times 10^4 \text{ L}$$

Explanatory notes

The ideal gas equation is used to calculate the volume of gas produced. Keep in mind that the number of moles of CO_2 is three times the number of moles of propane.

Mark allocation: 2 marks

- 1 mark for calculating number of moles of CO_2
- 1 mark for correct answer and units

Tip

- *There are aspects to the Chemistry course that are highly likely to appear on the exam, so you should focus on these areas. Examiners value the skill to complete stoichiometry, and this is one of the few topics that provides an opportunity to assess this skill.*

Question 2a.

Worked solution

	Similarity	Difference
primary galvanic cell compared to a fuel cell	*Electrons flow from anode to cathode.*	*A fuel cell requires a constant supply of fuel.*
methane gas in a portable generator compared to a methane fuel cell	*The overall reaction in both is the same.*	*Potential energy is converted directly to electrical energy in the fuel cell but not the generator; or fuel cells are usually smaller.*
a hydrogen–oxygen fuel cell compared to a cell used to produce sodium from sodium chloride	*Both require an electrolyte; or both require a continuous supply of reactant.*	*The fuel cell produces energy, whereas the sodium cell requires energy.*

Explanatory notes

Fuel cells generate electrical energy but they require a constant supply of reactants. In a generator, the thermal energy released from the combustion of methane is used to generate electricity. In a fuel cell, potential energy in methane is converted directly to electrical energy. The production of sodium is conducted in an electrolytic cell. The polarity is reversed in an electrolytic cell.

Marking allocation: 6 marks

- 1 mark for each cell with a correct response (up to 6 marks)

Note: There will be more than one possible answer for each cell.

Tip

- *Read questions like this carefully to ensure that you are clear on which comparison the examiner is looking for. For example, the fact that a fuel cell requires a continuous supply of fuel is relevant in a comparison to other galvanic cells but it is not a relevant difference with an electrolytic cell.*

Question 2b.

Worked solution

Energy transferred to water = 568 × 4.18 × 8.2 = 19 500 J = 19.5 kJ

Theoretical energy available from 1.80 g of ethanol = 1.8 × 29.6 = 53.3 kJ

Percentage efficiency of the burner is $\frac{19.5 \times 100}{53.3}$ = 36.5%

Explanatory notes

The energy transferred to the water can be calculated because the mass of water and the temperature change are known. Formula is $q = mc\Delta T$. The energy density figure from the data book can be used to calculate the theoretical amount of energy released by the fuel. The percentage efficiency can then be calculated from these two figures.

Marking allocation: 3 marks

- 1 mark for calculation of energy transfer to water
- 1 mark for theoretical energy amount
- 1 mark for efficiency calculation

Question 2c.i.

Worked solution

$CH_3COOH(aq) + 2H_2O(l) \rightarrow 2CO_2 + 8H^+(aq) + 8e^-$

Explanatory notes

For the ethanoic acid half-equation, balance the carbon atoms first, then the oxygen atoms, then hydrogen and finally the charge.

Mark allocation: 1 mark

- 1 mark for a correct half-equation

Question 2c.ii.

Worked solution

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$

Explanatory notes

The half-equation for oxygen is listed as 1.23 V on the electrochemical series (see the data book).

Mark allocation: 1 mark

- 1 mark for a correct half-equation

Question 2c.iii.

Worked solution

$CH_3COOH(aq) + 2O_2(g) \rightarrow 2CO_2 + 2H_2O(l)$

Explanatory notes

The oxygen half-equation must be doubled before it is added to the ethanoic acid half-equation in order to balance the electrons.

Mark allocation: 1 mark

- 1 mark for a balanced overall equation

Question 3a.i.

Worked solution

The molecular formula will be the same as the empirical formula, C_3H_7ON. The parent molecular ion has an m/z value of 73, matching the molar mass of C_3H_7ON.

Explanatory notes

The parent molecular ion provides a likely relative molecular mass. The value of 73 is consistent with the empirical formula C_3H_7ON. There is a small peak at 74 but this would be due to the presence of an isotope.

Mark allocation: 1 mark

- 1 mark for C_3H_7ON

Question 3a.ii.

Worked solution

29: $C_2H_5^+$

44: $CONH_2^+$

Explanatory notes

An m/z of 29 often corresponds to an ethyl branch, $CH_3CH_2^+$.

An m/z peak of 44 could be $CONH_2^+$.

Mark allocation: 2 marks

- 1 mark for $C_2H_5^+$, $CH_3CH_2^+$, CHO^+ or another other valid answer of 29
- 1 mark for $CONH_2^+$ or another valid answer of 44

Note: The positive signs must be included.

Question 3b.

Worked solution

Absorption wavelength	Likely bond responsible
3350	N–H
1680	C=O

Explanatory notes

Reference to the data book is required to answer this question. The presence of nitrogen in the molecule makes an N–H bond very likely. (It is worth noting the shape of the double peak on this infra-red spectrum indicates an $N–H_2$ bond.) The presence of oxygen makes a C=O bond similarly likely.

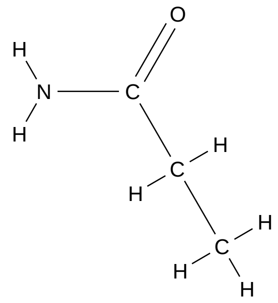
Mark allocation: 2 marks

- 1 mark for each correct wavelength and bond (up to 2 marks)

Note: Another possible answer is C–H around 3000 cm^{-1}.

Question 3c.i.

Worked solution



Explanatory notes

The molecular formula and the presence of a C=O and N–H bond suggest the molecule is an amide. The simplest amide possible is the primary one that is shown above.

Mark allocation: 1 mark

- 1 mark for the amide drawn

Note: There is another amide structure possible ($CH_3CONHCH_3$).

Question 3c.ii.

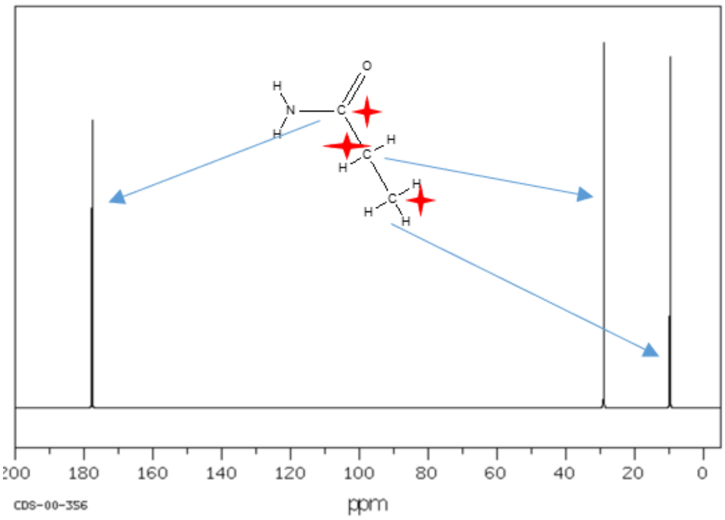
Worked solution

The molecule drawn has three carbon environments, which are marked with asterisks. This matches the three peaks on the ^{13}C NMR. The shifts of each carbon atom can be matched to the peaks on the ^{13}C NMR.

Shift 9: CH_3

Shift 30: $–CH_2–$

Shift 178: CO



Explanatory notes

This question is best answered with an annotated sketch of the molecule and a discussion of the environments and shifts.

Mark allocation: 3 marks

- 1 mark for matching three peaks to the molecular structure
- 1 mark for matching a shift listed in the data book to the molecule
- 1 mark for matching a second shift listed in the data book to the molecule

Tip

- *It is acceptable to use sketches and annotated diagrams in your responses. Point form answers are also acceptable.*

Question 4a.i.

Worked solution

Ethane is reacted with chlorine gas with UV light as a catalyst, to produce chloroethane.

Chloroethane is reacted with ammonia, NH_3, to form ethanamine.

Explanatory notes

Alkanes are relatively non-reactive, so it is common to first use chlorine to replace one of the hydrogen atoms. This is a substitution reaction that also produces HCl.

Mark allocation: 2 marks

- 1 mark for outlining chloroethane as the first stage
- 1 mark for reacting chloroethane with ammonia

Question 4a.ii.

Worked solution

$HCl(aq) + C_2H_5NH_2(aq) \rightarrow C_2H_5NH_3^+(aq) + Cl^-(aq)$

Explanatory notes

HCl acts as an acid, donating a proton to the ethanamine.

Mark allocation: 1 mark

- 1 mark for a correct equation

Question 4b.

Worked solution

Phenolphthalein is a poor choice of indicator for this reaction. The titration is between a strong acid and a weak base, so the indicator should be one that changes at a low pH. It is this poor choice that means the indicator is probably changing colour too early and the transition point is hard to discern.

Explanatory notes

For a titration between a strong acid and a weak base, an indicator like methyl orange (which changes at a low pH) should be used. If phenolphthalein is used, it will start to change colour before the equivalence point and the transition from pink to colourless will be difficult to judge. The titre obtained will likely be lower than it should be.

Mark allocation: 2 marks

- 1 mark for identifying the poor choice of indicator as the problem
- 1 mark for valid comment on the effect of this choice

Tip

- *The percentage of descriptive questions in Section B of the exam has increased and the percentage of numerical questions has decreased. Your ability to express your thoughts clearly and to use the correct terminology is therefore important.*

Question 4c.

Worked solution

Average titre is 15.57 mL.

$n(\text{HCl}) = c \times V = 0.01557 \times 0.012 = 0.000187$ mol

$n(\text{ethanamine}) = n(\text{HCl}) = 0.000187$ mol

$c(\text{ethanamine}) = \frac{0.000187}{0.02} = 0.0934$ M

Explanatory notes

The mole ratio between the acid and the base is 1:1. There was no dilution of the solution so determining the concentration of ethanamine is a standard calculation.

Mark allocation: 3 marks

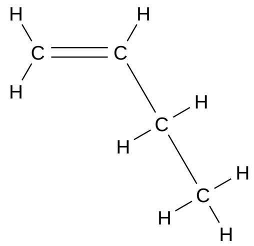
- 1 mark for averaging the titres
- 1 mark for calculating the number of moles of ethanamine
- 1 mark for the concentration of ethanamine

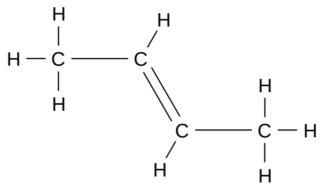
Tip

- *Titrations and emission volumes are the two parts of the course that lend themselves to stoichiometry questions. In the case of titrations, the data will usually refer to organic acids and bases, such as ethanoic acid or ethanamine.*

Question 5a.

Worked solution





Explanatory notes

The reagents H_3PO_4/H_2O will react with alkenes to form alcohol molecules. Either but-1-ene or but-2-ene will form butan-2-ol. (Butan-1-ol might also form and would need to be separated from butan-2-ol.)

Mark allocation: 2 marks

- 1 mark for each correct structure (up to 2 marks)

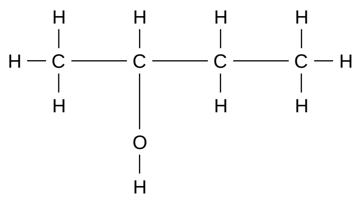
Note: The order of the two compounds does not matter.

Tip

- *Organic pathways appear on nearly every exam. It is important to memorise the appropriate reagents and catalysts.*

Question 5b.i.

Worked solution



Mark allocation: 1 mark

- 1 mark for the correct structure

Question 5b.ii.

Worked solution

butan-2-ol

Explanatory notes

Ketones form from secondary alcohols, so compound C must be butan-2-ol rather than butan-1-ol.

Mark allocation: 1 mark

- 1 mark for correct name

Question 5c.

Worked solution

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

Explanatory notes

Balance oxygen atoms first, then hydrogen, and finally the charge in order to obtain the half-equation given.

Mark allocation: 1 mark

- 1 mark for a correct half-equation

Tip

- *You should be well versed in writing half-equations for the reaction of ethanol, dichromate ions ($Cr_2O_7^{2-}$) and permanganate ions (MnO_4^-). These three chemicals are often examined.*

Question 5d.

Worked solution

pentane, butan-2-one, butan-2-ol

Explanatory notes

Generally, alcohol molecules will have significantly higher boiling points than alkanes with a similar number of carbon atoms, due to the presence of highly electronegative elements such as oxygen. Alcohols generally have a higher boiling point than equivalent ketones because they can form hydrogen bonds, whereas ketones cannot.

Mark allocation: 1 mark

- 1 mark for the correct ranking

Question 6a.

Worked solution

Anode: $2F^-(l) \rightarrow F_2(g) + 2e^-$

Cathode: $2H^+(l) + 2e^- \rightarrow H_2(g)$

Overall equation: $2H^+(l) + 2F^-(l) \rightarrow H_2(g) + F_2(g)$

Explanatory notes

It is not obvious that KHF_2 will produce hydrogen and fluorine gases. However, the question states that a gas is produced at each electrode. Therefore, it is expected that you will deduce that these are the only possible reactions. Fluoride ions are oxidised to fluorine gas and hydrogen ions are reduced to hydrogen gas.

Mark allocation: 3 marks

- 1 mark for each correct equation (up to 3 marks)

Question 6b.

Worked solution

to keep the gases produced apart as they might react vigorously

Explanatory notes

Hydrogen and fluorine react vigorously to form hydrogen fluoride. The danger is heightened because of the high temperatures used.

Mark allocation: 1 mark

- 1 mark for stating that the gaseous products need to be kept apart

Question 6c.

Worked solution

Anode: $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

Cathode: $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

Explanatory notes

In an aqueous solution, water is present. Water is a stronger oxidising agent than potassium ions, and water is a stronger reducing agent than fluoride ions, so water reacts at both electrodes. The water half-equations can be found on the electrochemical series.

Mark allocation: 2 marks

- 1 mark for each correct equation (up to 2 marks)

Question 6d.

Worked solution

$Q = It = 50.8 \times 12 \times 60 \times 60 = 2.19 \times 10^6$ C

$n(\text{e}) = \dfrac{2.19 \times 10^6}{96\,500} = 22.7$ mol

$n(\text{H}_2) = \dfrac{1}{2}\,n(\text{e}) = 11.4$ mol

$V = \dfrac{nRT}{P} = \dfrac{11.4 \times 8.31 \times 1113}{185} = 568 \text{ L}$

Explanatory notes

Use the current and time to calculate the charge. The charge on one mole of electrons is 96 500 C. This value is used to calculate the number of moles of electrons transferred. The ideal gas equation is used to calculate the volume of gas.

Mark allocation: 3 marks

- 1 mark for correct calculation of the charge
- 1 mark for correctly calculating number of moles of hydrogen
- 1 mark for correct volume calculation

Question 7a.

Worked solution

Compound	NH_3	HNO_3
Oxidation number	–3	+5

Explanatory notes

NH_3: If hydrogen has an oxidation number of +1, then nitrogen will be –3.

NO_3^-: If oxygen is –2, then nitrogen will be +5.

Mark allocation: 2 marks

- 1 mark for each correct oxidation number (up to 2 marks)

Tip

- *To work out the oxidation states, remember the following rules:*
  - *oxygen will usually have a charge of –2*
  - *hydrogen will usually have a charge of +1*
  - *an element such as Cl_2 will have an oxidation state of zero*
  - *the periodic table can be used for many elements like calcium (all Group 2 elements are +2), chlorine (all Group 17 elements are –1) etc.*

Question 7b.

Worked solution

Reaction	**Effect of pressure increase**
1	If favours forward reaction, as the ratio of reactant molecules to product is 4:2. Moving in the forward direction will oppose the pressure increase.
2	If favours reverse reaction, as the ratio of reactant molecules to product is 9:10. Moving in the reverse direction will oppose the pressure increase.

Explanatory notes

Equilibrium mixtures oppose any change. This is explained by Le Chatelier's principle: when the pressure increases, the reaction will move towards the side with the least particles.
The coefficients in the balanced equations must be compared. In reaction 1, there are fewer products, so the reaction moves forward. Reaction 2 has fewer reactants, so the reverse reaction is favoured.

Mark allocation: 4 marks

- Reaction 1:
  - 1 mark for forward reaction
  - 1 mark for reason why (i.e. reactant and product ratio)
- Reaction 2:
  - 1 mark for reverse reaction
  - 1 mark for reason why (i.e. reactant and product ratio)

Question 7c.

Worked solution

	Effect of temperature increase
Rate of reaction	The temperature increase will lead to more collisions and a higher proportion of successful collisions, which means there will be an increased rate.
Yield of ammonia	The reaction is exothermic. For an exothermic reaction, a temperature increase will lead to a drop in the value of *K*, meaning the reverse reaction is favoured and the yield of ammonia drops.

Explanatory notes

An increase in temperature means particles are moving faster. There will be more collisions and a higher proportion of successful collisions. Reaction 1 is exothermic. An increase in temperature of any exothermic reaction results in a decrease in the value of the equilibrium constant, *K*. This means the reverse reaction is favoured and the yield drops.

Mark allocation: 2 marks

- 1 mark for stating the rate increases and giving a reason why
- 1 mark for stating the yield drops for the reason that it is an exothermic reaction

Question 8a.i.

Worked solution

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

Explanatory notes

Glucose ferments to ethanol and carbon dioxide. This reaction occurs in the presence of yeast under anaerobic conditions.

Mark allocation: 1 mark

- 1 mark for a correct equation

Note: There are alternative ways of writing the formulas of these molecules.

Tip

- *It is expected that you can write the equation for fermentation without any prompting. Remember that the state of glucose will be aqueous.*

Question 8a.ii.

Worked solution

$C_{12}H_{22}O_{11}(aq) + H_2O(l) \rightarrow C_6H_{12}O_6(aq) + C_6H_{12}O_6(aq)$

glucose fructose

Explanatory notes

The hydrolysis of sucrose produces glucose and fructose – both have the same molecular formula. The structure of each molecule can be found in the data book.

Mark allocation: 1 mark

- 1 mark for a correct equation

Note: There are alternative ways of writing the formulas of these molecules.

Question 8a.iii.

Worked solution

$C_{17}H_{35}COOH + CH_3CH_2OH \rightarrow C_{17}H_{35}COOCH_2CH_3 + H_2O$

Explanatory notes

Stearic acid and ethanol will form a biodiesel ester and water.

Mark allocation: 1 mark

- 1 mark for a correct equation

Note: There are alternative ways of writing the formulas of these molecules.

Question 8b.

Worked solution

$n(Br_2) = \dfrac{166}{159.8} = 1.04$ mol

Ratio of Br_2 to fatty acid = 1.04:0.26 = 4:1

The molecule has four carbon-to-carbon double bonds, so it could be arachidonic acid.

Explanatory notes

Bromine can undergo additional reactions over carbon-to-carbon double bonds. If the ratio of bromine to fatty acid is 4:1, there must be four carbon-to-carbon double bonds in each molecule. Arachidonic acid is the only fatty acid in the data book with four double bonds.

Mark allocation: 2 marks

- 2 marks for identifying arachidonic acid

  Note: No working needs to be shown. If you do not identify the acid but calculate a 1:4 ratio, then 1 mark will be awarded.

Tip

- *You must be able to use the molecular formula of a fatty acid to predict the amount of carbon-to-carbon double bonds.*

Question 8c.

Worked solution

From the data book, each gram of carbohydrate produces 16 kJ of energy.

If the energy produced is 46 kJ, then the mass is $\dfrac{46}{16} = 2.88$ g

$c = \dfrac{2.88}{0.2} = 14 \text{ g L}^{-1}$

Explanatory notes

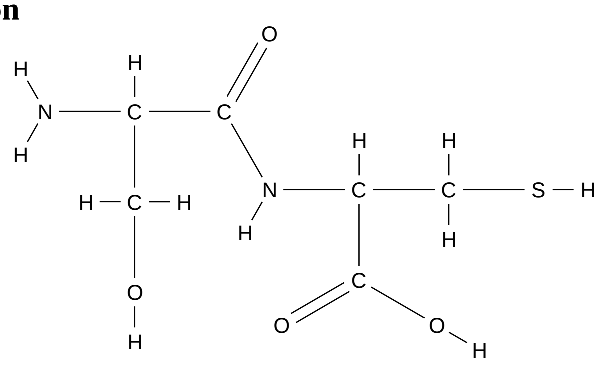
The data book lists the energy content of carbohydrates as 16 kJ g^{-1}. The mass of sucrose consumed by the athlete is 2.88 g. The solution has a volume of 200 mL, so the concentration is 14 g L^{-1}.

Mark allocation: 2 marks

- 1 mark for the mass of sucrose
- 1 mark for correctly calculating the concentration

Question 8d.i.

Worked solution



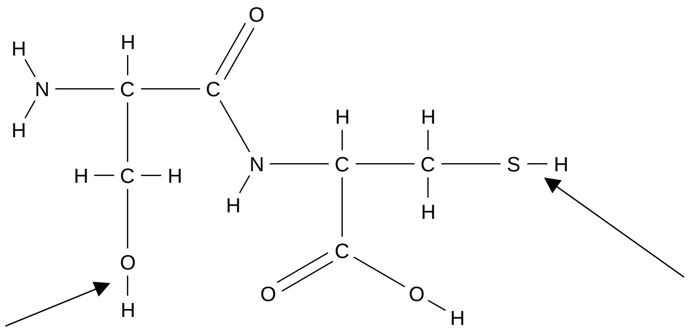
Mark allocation: 1 mark

- 1 mark for the structure of a dipeptide

Note: The order of the two amino acids could be reversed.

Question 8d.ii.

Worked solution



The –OH can lead to hydrogen bonds with other parts of the protein.

The –SH can form a covalent disulfide bond with another –SH containing amino acid.

Explanatory notes

The tertiary structure of the protein is determined by the –R groups on the amino acids. The hydroxyl groups lead to hydrogen bonding.

Mark allocation: 2 marks

- 1 mark for –OH linked to hydrogen bonds
- 1 mark for –SH linked to covalent disulfide bonds

Question 9a.i.

Worked solution

A glycosidic bond (also known as an ether bond) joins the glucose and galactose molecules in lactose.

Explanatory notes

Lactose is an example of a disaccharide. Saccharides are joined by C–O–C bonds, known as glycosidic linkages.

Mark allocation: 1 mark

- 1 mark for stating either glycosidic or ether bond

Question 9a.ii.

Worked solution

Lactose is soluble due to the presence of many polar hydroxyl groups that can form hydrogen bonds with water.

Explanatory notes

The presence of several –OH groups in lactose will enable it to form hydrogen bonds with water, making it relatively soluble.

Mark allocation: 1 mark

- 1 mark for stating soluble

Question 9a.iii.

Worked solution

The aim of a low-kilojoule diet is to decrease the energy content of the food. Aspartame has a similar energy density to that of lactose and other sugars but far less of it is required to achieve the same level of sweetness. The energy content of a low-kilojoule food is reduced because of the lower amounts of sweetener needed.

Explanatory notes

Aspartame has a similar energy density to that of sucrose and other sugars. The energy densities of most monosaccharides and disaccharides are very similar. Diet foods use aspartame because far lower levels of sweetener are required to achieve the same level of sweetness.

Mark allocation: 2 marks

- 1 mark for awareness that aspartame and lactose have a similar energy density
- 1 mark for recognition that the level of sweetness of aspartame is far higher than that of lactose

Tip

- *You should rote learn a comparison of aspartame and sucrose.*

Question 9b.i.

Worked solution

lock-and-key model

Mark allocation: 1 mark

- 1 mark for lock-and-key

Question 9b.ii.

Worked solution

Enzymes are very specific to the molecules they catalyse. The stereoisomers of lactose will have different shapes. It is likely that lactase will be effective on only one form of lactose.

Explanatory notes

Lactase is an enzyme. Enzymes bond with a substrate that has a very particular shape. As both forms of lactose are stereoisomers, their shape must be different. It is likely that lactase will not be effective on one of the isomers.

Mark allocation: 1 mark

- 1 mark for stating that enzymes often work on one type of isomer only

Question 9b.iii.

Worked solution

Heating lactase will denature it, changing its tertiary structure. It is unlikely to work as a catalyst after being heated.

Explanatory notes

When enzymes are heated, they will denature. 80 °C is a relatively high temperature for an enzyme. When enzymes denature, they lose their unique shape and no longer function as a catalyst.

Mark allocation: 1 mark

- 1 mark for reference to denaturing and loss of effectiveness

Question 9c.i.

Worked solution

A person who is lactose intolerant cannot break down lactose in the early stages of digestion. The lactose reaches the large intestine, where it causes bloating. This condition occurs because the person's digestive system does not produce the lactase required to break down lactose.

Explanatory notes

In most people, lactose is broken down to glucose and galactose before it reaches the large intestine. When a person does not have lactase in their digestive system, this breakdown will not occur and lactose passes to the large intestine. It ferments there, forming gases that lead to discomfort.

Mark allocation: 2 marks

- 1 mark for describing the effect of undigested lactose
- 1 mark for linking this to a lack of lactase

Question 9c.ii.

Worked solution

The person can take lactase tablets, or remove lactose from their diet.

Explanatory notes

Various solutions for a person who is lactose intolerant include taking lactase tablets and avoiding dairy.

Mark allocation: 1 mark

- 1 mark for a valid solution

Question 10a.

Worked solution

Independent variable: the type of alcohol

Dependent variable: the energy released or temperature change

Controlled variable: the duration of burning (or the burner used)

Explanatory notes

The energy released depends on the fuel used. The experimental set-up is a controlled variable and the time allowed for the fuel to burn is also controlled.

Mark allocation: 3 marks

- 1 mark for each correct response (up to 3 marks)

Tip

- *Expect the exam to have a question of this nature; that is, an analysis of an experiment's design and derived data. A discussion of variables, hypotheses and errors is likely to be included.*

Question 10b.

Worked solution

The use of ΔT on the vertical axis will show the same trend that would be shown by energy released. Although it can be used to judge whether the hypothesis is correct or not, it does not show the actual amount of energy each fuel releases.

Explanatory notes

As energy released = $m \times 4.18 \times \Delta T$, energy and change in temperature are directly proportional and will show the same trend. However, it would be more relevant to the experiment to use energy released.

Mark allocation: 2 marks

- 1 mark for stating that it shows the same trend as energy released
- 1 mark for stating that is not as informative as showing energy released

Question 10c.

Worked solution

In theory this should not matter. It takes the same amount of energy to cause the same temperature change, independent of the starting temperature. In practice, however, if the apparatus is poorly insulated, then the heat loss from a very hot apparatus will be greater.

Explanatory notes

An understanding of specific heat capacity suggests that the starting temperature will not matter. The energy released depends on the temperature change, not the actual temperature. As the difference in temperature between the apparatus and the room increases, however, the degree of heat loss will also increase.

Mark allocation: 2 marks

- 1 mark for the theoretical impact of this decision
- 1 mark for the practical impact

Question 10d.

Worked solution

The conclusion is not valid because the analysis of the experiment's results is flawed.
The graph is comparing the energy released per gram of fuel rather than the energy released per mole.

Explanatory notes

At no point has the student brought 'mole' into their calculations. If they weighed the burner before and after, then they would have a mass change to use to calculate the energy released per mole. The student's analysis is closer to that of a comparison of the energy released per gram of fuel, rather than comparing energy released per mole.

Mark allocation: 2 marks

- 1 mark for stating the conclusion is flawed
- 1 mark for a valid reason

Question 10e.

Worked solution

Improvement 1: Use a new wick for each fuel.

Improvement 2: For each fuel, weigh the burner before and after the experiment. It cannot be assumed that burning each fuel for 2 minutes will lead to the same mass change.

Explanatory notes

The experimental design could be improved in several ways. Some suggestions are listed below.

- If the same wick is reused, then some of the previous fuel is burnt for the first part of each trial.
- The burner should be weighed for mass comparisons.
- It would be better to allow the water to cool each time.
- Multiple tests could be run.

Mark allocation: 2 marks

- 1 mark for each valid improvement (up to 2 marks)

Note: There are several possible answers.

END OF WORKED SOLUTIONS