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YEAR 12 *Trial Exam Paper*

2017

CHEMISTRY

Written examination

Worked solutions

This book presents:

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

SECTION A – Multiple-choice questions

Question 1

Answer: C

Worked solution

Option C is correct. Sugar cane is grown each year so it can be replenished within a reasonable time frame.

Option A is incorrect. Natural gas has finite reserves.

Option B is incorrect. Natural gas has finite reserves.

Option D is incorrect as the killing of whales is politically unpopular and stocks of whales would likely dwindle.

Question 2

Answer: A

Worked solution

Option A is correct. The data book quotes the combustion figure for butane to be 2880 kJ mol^{-1}.

The heat of combustion per gram will be = $\frac{2880}{58}$ = 49.7 kJ g^{-1}.

Option B is incorrect as this figure is the molar mass of butane.

Option C is incorrect as it gives the energy per mole, not per gram.

Option D is incorrect as the units are not kJ.

Question 3

Answer: B

Worked solution

Option B is correct: $n(\text{butane}) = \frac{1.16}{58} = 0.020$ mol

$$n(O_2) = \frac{13}{2} \times n(\text{butane}) = \frac{13 \times 0.02}{2} = 0.13 \text{ mol}$$

mass $O_2 = 0.13 \times 32 = 4.16$ g

Option A is incorrect as the figure does not take into account that oxygen gas exists as O_2.

Option C is incorrect as the figure is double the correct answer.

Option D is incorrect. It quotes the molar mass of oxygen atoms.

Question 4

Answer: D

Worked solution

Option D is correct. $n(CO_2) = 4 \times n(C_4H_{10})$.

$$V = \frac{nRT}{P} = \frac{0.08 \times 8.31 \times 1123}{500} = 1.49 \text{ L}$$

Option A is incorrect as pressure has been converted to Pa.

Option B is incorrect as the correct answer is 1.49.

Option C is incorrect as the number of moles of CO_2 is $4 \times n$(butane).

Question 5

Answer: B

Worked solution

Option B is correct. The value of ΔH is $-940 - (-50) = -890$ kJ mol^{-1}. From the heats of combustion in the data book, this matches methane as a fuel (889 kJ mol^{-1}).

Option A is incorrect as hydrogen has a different heat of combustion.

Option C is incorrect as methanol has a different heat of combustion.

Option D is incorrect as ethanol has a different heat of combustion.

Tip

- *This question is another example of how useful the data book is. The heat of combustion values for common fuels are included in a table in the data book. Be very familiar with its contents.*

Question 6

Answer: A

Worked solution

Option A is correct. The possible oxidants are Cu and water. Cu is the strongest reducing agent so it will react to form Cu^{2+} ions in solution.

Option B is incorrect. It is a reduction reaction that might occur at a cathode.

Option C is incorrect as Cu reacts in preference to water.

Option D is incorrect. It is the reaction that will occur at the cathode.

Question 7

Answer: C

Worked solution

Option C is correct. Cu^{2+} ions will form at the anode at the same rate they are converted to Cu metal at the cathode.

Option A is incorrect as it ignores the reaction at the cathode.

Option B is incorrect as the concentration of SO_4^{2-} concentration will not change.

Option D is incorrect as it ignores the anode reaction.

Question 8

Answer: C

Worked solution

Option C is correct. The reaction has to be oxidation to occur at the anode. Option C is correctly balanced. Note also that the half-equation in option C produces H^+ ions. This is consistent with the acidic conditions mentioned in the question.

Option A is incorrect. It is the reaction at the cathode.

Option B is incorrect as O^{2-} ions are not present.

Option D is incorrect as it is the overall equation for this cell.

Question 9

Answer: D

Worked solution

Option D is correct. The oxidation number of the manganese atoms is reduced from +4 to +2. For reduction, the electrons must be accepted and this is the case.

Option A is incorrect because it shows oxidation.

Option B is incorrect because hydrogen gas is not produced in the overall equation.

Option C is incorrect because it is a repeat of the overall equation.

Question 10

Answer: C

Worked solution

Option C is correct. The phrase 'continuous supply of fuel' suggests a fuel cell. Of the fuel cells listed, methane is the most likely to be obtained in a sustainable fashion. It is the main component of biogas.

Option A is incorrect. This lists the reactants for a secondary cell, not a fuel cell.

Option B is incorrect as aluminium is not considered a sustainable fuel, nor is it easy to produce as a continuous supply.

Option D is incorrect as butane is difficult to obtain in a sustainable fashion.

Question 11

Answer: A

Worked solution

Option A is correct. Liver contains an enzyme that catalyses this reaction. The effect of high temperature on an enzyme is to denature it, making it ineffective.

Option B is incorrect. Grinding the catalyst increases the surface area and consequently the reaction rate.

Option C is incorrect because a higher temperature will increase the rate of reaction when an inorganic catalyst is used.

Option D is incorrect because blending the liver will increase its surface area and its effectiveness.

Question 12

Answer: C

Worked solution

Option C is correct. The extra catalyst in experiment 2 will lead to a faster reaction but it will not change the volume of oxygen released. (The amount of H_2O_2 decomposing has not changed.)

Option A is incorrect. The amount of H_2O_2 decomposing in both experiments is the same.

Option B is incorrect. MnO_2 is not a reactant, it is a catalyst.

Option D is incorrect because the greater amount of catalyst in experiment 2 will lead to a faster rate.

Question 13

Answer: D

Worked solution

Option D is correct. The products of a reaction are always listed as the numerator in the equilibrium expression and the reactants as the denominator. The products will both have a coefficient of ½ in the balanced equation.

Option A is incorrect. The equation would need to be doubled for option A to be the correct answer.

Option B is incorrect because the equation is the wrong way around.

Option C is incorrect. The equation is both the wrong way around and double what it should be.

Question 14

Answer: D

Worked solution

Option D is correct. An increase in pressure will favour the products because the ratio of reactants to products is 4:2. This is an application of Le Chatelier's principle – that reactions partially oppose any change from equilibrium.

Option A is incorrect. An increase in temperature for an exothermic reaction will favour the reverse reaction.

Option B is incorrect. An increase in volume is the same as a decrease in pressure – this would favour the reverse reaction.

Option C is incorrect. The addition of a catalyst will not change the yield.

Question 15

Answer: D

Worked solution

Option D is correct. The –O-H (acid) absorption band will be around 3000 cm^{-1}. Propanal and propan-1-ol will not have this absorption.

Option A is incorrect. Propanal would also have this absorption.

Option B is incorrect. All three molecules will have a C–H absorption at 3000 cm^{-1}.

Option C is incorrect. A broad peak at 3300 cm^{-1} would suggest propan-1-ol.

Question 16

Answer: C

Worked solution

Option C is correct. Ionic bonds are part of the tertiary structure of a protein. They form between side chains of some amino acids.

Option A is incorrect because this is an ionic bond, not a hydrogen bond.

Option B is incorrect because the bond shown is an ionic bond.

Option D is incorrect because ionic bonds are not part of the primary structure of a protein.

Question 17

Answer: C

Worked solution

Option C is correct. The dot is used to indicate that the molecule is a free radical. The carbon-to-carbon double bonds make it an unsaturated fatty acid.

Option A is incorrect because the molecule is a fatty acid, not a triglyceride.

Option B is incorrect. The fatty acid is not saturated.

Option D is incorrect because the molecule is not a triglyceride.

Question 18

Answer: B

Worked solution

Option B is correct. Aspartame is more than 150 times sweeter than sucrose, hence the sweetness of soft drink B is less. The energy content of both sweeteners is similar but soft drink A has less sweetener in it.

Option A is incorrect because soft drink B will not be sweeter.

Option C is incorrect because the sweetness level is not similar.

Option D is incorrect because soft drink B is not sweeter.

Tip

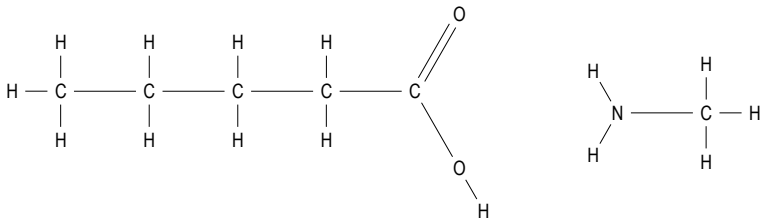
- *Aspartame is the only artificial sweetener named in the Study Design. Its structure is provided in the data book. Make sure you learn how it compares with simple sugars.*

Question 19

Answer: B

Worked solution

Option B is correct. An amide bond forms from the reaction between a carboxylic acid and an amine.



Option A is incorrect as the two functional groups are the wrong way around.

Option C is incorrect because methanamine is required, not ethanamine.

Option D is incorrect because methanamine is required, not ethanamine. Pentan-1-ol would also need to be pentanoic acid.

Tip

- *Amide bonds are an example of a functional bond that has been added in the new Chemistry Study Design. Students need to be aware that expectations for 2017 and beyond have changed; make sure you familiarise yourself with this new Study Design.*

Question 20

Answer: D

Worked solution

Option D is correct. Numbering for the molecule needs to start at the right-hand end as the hydroxyl functional group has highest priority. The methyl group is a 2-methyl and the alcohol is on the first carbon. The longest carbon chain in this molecule is four carbon atoms so it is a butane derivative.

Option A is incorrect as numbering of the molecule started on the left-hand end.

Option B is incorrect as the methyl group is omitted and the alcohol is listed on the wrong carbon atom.

Option C is incorrect as the numbering has started incorrectly from the left-hand end.

Tip

- *As per the Study Design, you must be able to provide the systematic names for molecules, like the one in this question.*

Question 21

Answer: A

Worked solution

Option A is correct. Triglycerides contain ester linkages. Hydrolysis breaks the ester bonds to form carboxyl groups and hydroxyl groups.

Option B is incorrect. Hydrolysis of proteins produces amine and carboxyl groups.

Option C is incorrect. Hydrolysis of carbohydrates produces hydroxyl groups.

Option D is incorrect. The products of hydrolysis of vitamins are varied and complex.

Question 22

Answer: A

Worked solution

Option A is correct. Amylopectin is slightly soluble in water, whereas amylose is insoluble. The cross-links in amylopectin limit the packing of the main molecule chains, exposing more –OH groups. Water is able to penetrate its structure more than the tightly packed structure of amylose.

Option B is incorrect. The lack of cross-links actually reduces the solubility of amylose.

Option C is incorrect because water cannot easily penetrate the amylose structure.

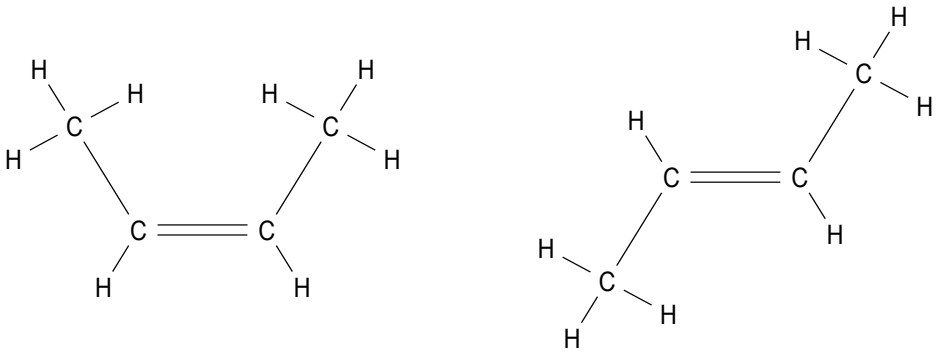
Option D is incorrect because amylopectin is more soluble in water.

Question 23

Answer: A

Worked solution

Option A is correct. The two isomers are drawn below.



Option B is incorrect because but-1-ene has only one structure.

Option C is incorrect because butane has no double bond to prevent the rotation of bonds.

Option D is incorrect because the molecule has no double bond to prevent the rotation of bonds.

Question 24

Answer: C

Worked solution

Option C is correct. Butan-1-ol is the larger molecule. It will have the longer retention time of 9.4 minutes. Propan-1-ol is more polar than butan-1-ol, hence it will spend more time in the polar solvent, leading to a lower retention time. The area of the second sample is one-third of the original, so the concentration will be one-third of the original.

Option A is incorrect because the second sample has only one component.

Option B is incorrect because the sample contains butan-1-ol.

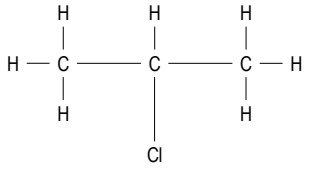
Option D is incorrect because the concentration in the second sample is less than that of the first.

Question 25

Answer: D

Worked solution

Option D is correct. From the structure of 2-chloropropane it can be seen that the middle proton has 6 neighbouring protons. These protons have the same environment. Using the n + 1 rule, the 6 protons will produce a septet.



Option A is incorrect because it should be a septet.

Option B is incorrect because it should be a septet.

Option C is incorrect as it should be a septet; 6 identical protons will produce n + 1 (6 + 1) peaks.

Tip

- *It is common to see a lack of clarity in the splitting patterns on NMR spectra. The degree to which hydrogen environments affect each other is low, meaning complex splitting patterns are often not as distinct as textbooks might suggest.*

Question 26

Answer: B

Worked solution

Option B is correct. The temperature is adjusted to 50 °C for each experiment – this is the controlled variable. The HCl concentration is the independent variable. The time for reaction is the dependent variable as it depends upon the HCl concentration.

Option A is incorrect as the dependent and independent variables are the wrong way around.

Option C is incorrect as the mass of $CaCO_3$ is not a variable.

Option D is incorrect as the time for the reaction is not controlled.

Question 27

Answer: B

Worked solution

Option B is correct. The results are all consistent, therefore they are precise. They do not match the tested value, however, so they are not accurate.

Option A is incorrect because the results are precise.

Option C is incorrect. The results do not match the tested value, so they are not accurate.

Option D is incorrect because the results are not accurate.

Question 28

Answer: D

Worked solution

Option D is correct.

$$CH_3COOH(aq) + KOH(aq) \rightarrow KCH_3COO(aq) + H_2O(l)$$

$n(\text{KOH}) = c \times V = 0.15 \times 0.012 = 0.0018 \text{ mol}$

$n(\text{KOH}) : n(\text{ethanoic acid}) = 1:1$

$n(\text{ethanoic acid}) = 0.0018 \text{ mol}$

$$c(\text{ethanoic acid}) = \frac{0.0018}{0.02} = 0.09 \text{ M}$$

$$c(\text{undiluted vinegar}) = 0.09 \times \frac{250}{10} = 2.25 \text{ M}$$

Option A is incorrect because the dilution factor has not been considered.

Option B is incorrect because the balanced equation does not have a 2:1 mole ratio.

Option C is incorrect because 2.25 M is the correct answer.

Question 29

Answer: A

Worked solution

Option A is correct. There might be other acids present, especially in fermented vinegars. These acids would have an effect on the titre.

Option B is incorrect as the burette should be rinsed with KOH.

Option C is incorrect as methyl orange is not suitable to use with weak acids.

Option D is incorrect. The calculations are not adjusted in any way just because the acid is a weak acid.

Question 30

Answer: B

Worked solution

Option B is correct.

Energy released by cashew = $m \times \Delta H = 1.80 \times 5.4 = 9.72$ kJ = 9720 J

ΔT for the calorimeter = $\frac{9720}{586}$ = 16.6 °C

Option A is incorrect because it is half of the correct value.

Option C is incorrect. The correct answer is 16.6.

Option D is incorrect because it is twice the correct answer.

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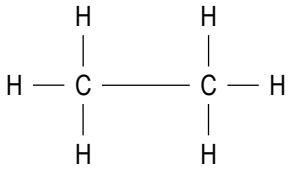
SECTION B

Question 1a.i.

Worked solution

Ethane

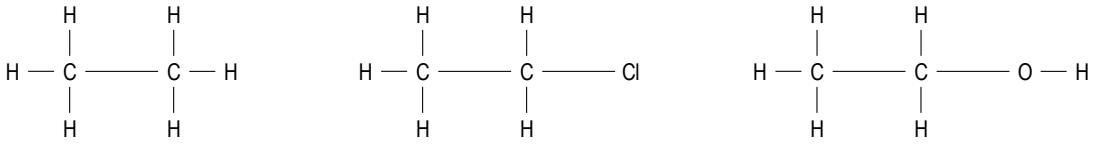


Mark allocation: 1 mark

- 1 mark for drawing AND naming ethane

Question 1a.ii.

Worked solution



$$\text{ethane} \xrightarrow{\text{UV/Cl}_2\text{(g)}} \text{chloroethane} \xrightarrow{\text{KOH(aq)}} \text{ethanol}$$

Mark allocation: 2 marks

- 1 mark for stating ethane is converted to chloroethane, then to ethanol
- 1 mark for reagents required – UV/Cl_2 for step 1 and KOH for step 2

Explanatory notes

Alkanes are relatively stable. Chlorine is often substituted first onto the alkane and the chlorine can then be replaced by an hydroxyl group. NaOH could be used for the final step instead of KOH.

Question 1a.iii.

Worked solution

No, petroleum is not a renewable fuel as it cannot be replenished easily.

Mark allocation: 1 mark

- 1 mark for answer of no and an explanation of petroleum not being renewable.

Tip

- *Students have a notion of what a renewable fuel is but often have difficulty expressing this notion. It is not correct to say it is 'recyclable' or that it is replaced immediately once used. A more satisfactory statement is that it can be replaced at a sustainable rate.*

Question 1b.i.

Worked solution

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

Mark allocation: 1 mark

- 1 mark for correctly balanced equation with states

Question 1b.ii.

Worked solution

Ethanol produced from sources such as sugar cane waste is considered renewable as the sugar crops are grown each year, providing the same raw material.

Mark allocation: 1 mark

- 1 mark for explaining the source can be replenished in a reasonable time frame

Explanatory notes

Fermentation takes glucose and converts it to ethanol and carbon dioxide. Fermentation occurs in anaerobic conditions (in the absence of oxygen) and is catalysed by yeast. The source of glucose can vary with the region; for example, potato peel is used in Ballarat at a small-scale plant for ethanol. Although CO_2 is consumed as plants grow, the use of bioethanol is not carbon neutral. The farm machinery used, the transport form used and other stages of processing all require the use of energy.

Question 1c.i.

Worked solution

$C_2H_6O(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

Mark allocation: 1 mark

- 1 mark for balanced equation and states (also allow C_2H_5OH)

Question 1c.ii.

Worked solution

$n(\text{ethanol}) = \frac{10000}{46} = 217.4 \text{ mol}$

$E = n \times$ heat of combustion $= 217.4 \times 1360 = 2.96 \times 10^5$ kJ

Mark allocation: 2 marks

- 1 mark for calculating the number of moles of ethanol
- 1 mark for calculating the amount of energy

Explanatory notes

Complete combustion produces CO_2 and H_2O. Balance the carbon atoms first, then the hydrogen atoms and, finally, the oxygen atoms.

10 kg of ethanol is 10 000 g. Calculate the number of moles of ethanol. The data book provides a figure of 1360 kJ for each mole of ethanol combusted.

Tip

- *You are expected to know how to write combustion equations. This year, for the first time, this expectation has been extended to include incomplete combustion. To balance equations for complete combustion, use the following process.*
  - *Balance the carbon atoms first:*
    $C_2H_6O(l) + O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$
  - *Balance the hydrogen atoms:*
    $C_2H_6O(l) + O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$
  - *Balance the oxygen atoms last:*
    $C_2H_6O(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

Question 1d.i.

Worked solution

$C_2H_6O(l) + 2O_2(g) \rightarrow 2CO(g) + 3H_2O(l)$

Mark allocation: 1 mark

- 1 mark for correctly balanced equation and states

Question 1d.ii.

Worked solution

T = 400 + 273 = 673 K

n(CO) = 2 × *n*(ethanol)

n(ethanol) = 217.4 (as per **Question 1c.ii.**)

$$V = \frac{nRT}{P} = \frac{2 \times 217.4 \times 8.31 \times 673}{400} = 6080 \text{ L}$$

Mark allocation: 2 marks

- 1 mark for correct conversion of temperature and pressure
- 1 mark for correct calculation of volume

Note: Consequential marking will be awarded if an incorrect value for *n*(ethanol) is used, as long as the method is correct.

Explanatory notes

Incomplete combustion can produce a range of products. Students must read the question carefully to see if it is explicit as to whether carbon or carbon monoxide is the main product.

The calculation of volume requires SI units of kelvin and kPa. The ideal gas equation can then be used to calculate the volume.

Question 2a.

Worked solution

i. anode $Zn(s) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^-$

ii. cathode $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$

Mark allocation: 2 marks

- 1 mark for a correct half-equation with states for anode
- 1 mark for a correct half-equation with states for cathode

Note: It is also correct for the coefficients in the cathode half-equation to be halved.

Explanatory notes

For a spontaneous reaction, oxygen reacts with zinc metal. The second half-equation must be reversed to show it is zinc reacting. The reaction of oxygen is reduction, which will occur at the cathode. Oxidation occurs at the anode.

Question 2b.i.

Worked solution

$2Zn(s) + O_2(g) \rightarrow 2ZnO(s)$

Mark allocation: 1 mark

- 1 mark for a correctly balanced equation with states included

Explanatory notes

The overall equation is obtained by combining the two half-equations. The zinc half-equation is doubled to balance the number of electrons. It is convention to multiply through by 2 to have all whole-number coefficients.

Question 2b.ii.

Worked solution

$0.34 - (-1.25) = 1.59 \text{ V}$

Mark allocation: 1 mark

- 1 mark for correct answer of 1.59 V

Explanatory notes

The cell voltage is the difference between the potentials of the two half-equations. The lower potential is subtracted from the higher potential to calculate the difference.

Question 2c.i.

Worked solution

Zinc is relatively abundant.

Oxygen can be obtained from air.

Mark allocation: 2 marks

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

Explanatory notes

The zinc–air cell is inexpensive because the reactants are cheap and abundant. Oxygen can be obtained from the air and zinc is mined in many different countries. Graphite electrodes are also inexpensive.

Question 2c.ii.

Worked solution

Fuel cells rely on a continuous supply of reactants – changing the zinc electrode is like a continuous supply of zinc and there is a continuous supply of air.

Mark allocation: 1 mark

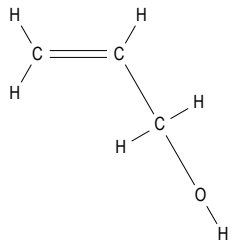
- 1 mark for discussion around a continuous supply of reactants

Explanatory notes

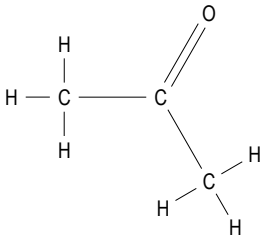
This cell is equivalent to a fuel cell in that it can run indefinitely if zinc is continually replaced. It is not recharged.

Question 3a.

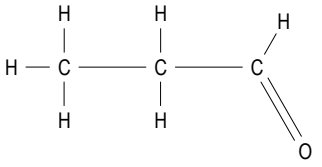
Worked solution



prop-2-en-1-ol



propan-2-one



propanal

Mark allocation: 3 marks

- 1 mark for each correct structure AND correct name (up to 3 marks)

Note: There might be other possible answers that match this molecular formula.

Explanatory notes

Three possibilities are provided above. The number of hydrogen atoms makes it unlikely that the molecule is an alcohol, unless it also has a carbon-to-carbon double bond.

Question 3b.i.

Worked solution

m/z ratio = 29

Mark allocation: 1 mark

- 1 mark for answer of 29

Question 3b.ii.

Worked solution

$CH_3CH_2^+$ and CHO^+

Mark allocation: 2 marks

- 1 mark for each correct answer (up to 2 marks)
  $CH_3CH_2^+$ can be shown as $C_2H_5^+$

Note: Answer must have a positive charge to receive a mark.

Explanatory notes

The fragment must have a mass of 29 g/mol and be part of the molecular formula C_3H_6O.

Question 3c.i.

Worked solution

No, there is no broad peak around 3300 cm^{-1}.

Mark allocation: 1 mark

- 1 mark for the answer no with a valid explanation, mentioning the broad peak around 3300 cm^{-1}

Explanatory notes

An –O-H group will show on infrared spectra as a broad peak around 3300 cm^{-1}. This spectrum does not have this peak.

Question 3c.ii.

Worked solution

Yes, strong absorption around 1700 cm^{-1}.

Mark allocation: 1 mark

- 1 mark for the answer yes with a valid explanation, mentioning the absorption around 1700 cm^{-1}

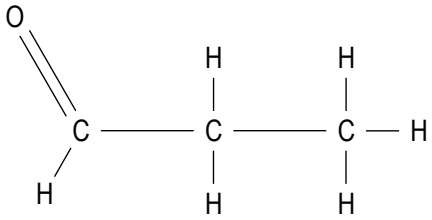
Explanatory notes

A C=O group will show on infrared spectra as a peak around 1700 cm^{-1}. This spectrum has this peak.

Question 3d.

Worked solution

The molecule in question is propanal.



Propanal should have three different hydrogen environments, a quintet and two triplets. The shift of 9.8 matches that of an aldehyde (– CHO).

Mark allocation: 2 marks

- 1 mark for the correct choice of propanal
- 1 mark for valid explanation that refers to the hydrogen environments

Explanatory notes

Propanal has three different hydrogen environments. The –CHO peak will have a shift of 9.8 (from the data book) and it will be a triplet because it has two neighbouring protons. The middle carbon has four neighbouring hydrogen atoms, hence it will be split into five. (It is actually an uneven split as the neighbouring protons are not equivalent, but this is beyond the VCE course). The methyl group on the end will be split into a triplet because it has two neighbouring protons.

Tip

- *Be specific when deducing chemical structures from spectral data. Quote the exact expected wavelength or shift when referring to a particular functional group. It is often helpful to draw the molecule itself and annotate the structure.*

Question 4a.

Worked solution

$C_2H_2O_4(aq) + 2NaOH(aq) \rightarrow Na_2C_2O_4(aq) + 2H_2O(l)$

Mark allocation: 1 mark

- 1 mark for a correctly balanced equation

Note: Oxalic acid could be written as HOOCCOOH.

Explanatory notes

The structure of oxalic acid is shown. The student needs to recognise that it will be diprotic; that is, the balanced equation will require 2 moles of NaOH. An acid and a base react to form a salt and water.

Question 4b.i.

Worked solution

$n(\text{NaOH}) = c \times V = 0.12 \times 0.02 = 0.00240$ mol

Mark allocation: 1 mark

- 1 mark for correct calculation of moles

Explanatory notes

The concentration and volume of NaOH are both known, so the number of moles can be calculated as the starting point.

Question 4b.ii.

Worked solution

$n(\text{oxalic acid}) = \frac{1}{2}n(\text{NaOH}) = \frac{1}{2} \times 0.0024 = 0.00120$ mol

Mark allocation: 1 mark

- 1 mark for halving the number of moles of NaOH

Note: Consequential marking will apply with this question. If the student did not realise oxalic acid is diprotic then they can still obtain full marks for subsequent questions if their answers are out by a factor of 2.

Explanatory notes

The number of moles of oxalic acid will be half the number of moles of NaOH, from the balanced equation.

Question 4b.iii.

Worked solution

n(oxalic acid) in the volumetric flask = n(titration) × $\frac{250}{14.8}$

$$= 0.0012 \times \frac{250}{14.8} = 0.0203 \text{ mol}$$

m(oxalic acid) = $n \times M$ = 0.0203 × 90.0 = 1.82 g

Mark allocation: 2 marks

- 1 mark for applying a dilution factor correctly
- 1 mark for calculating the mass

Note: There are alternative ways of reaching the correct answer. Award 2 marks for the correct answer if the working is valid.

Explanatory notes

The number of moles of oxalic acid in the volumetric flask is greater than the number of moles in the titre. The ratio of volumes is 250:14.8.

Question 4b.iv.

Worked solution

The % (m/m) of oxalic acid = $\frac{1.82 \times 100}{2.46}$ = 74.2%

Mark allocation: 1 mark

- 1 mark for the correct calculation of % (m/m) of oxalic acid

Question 5a.

Worked solution

i. $C_6H_{12}O_2$

ii. C_3H_6O

Mark allocation: 2 marks

- 1 mark for correct molecular formula
- 1 mark for correct empirical formula

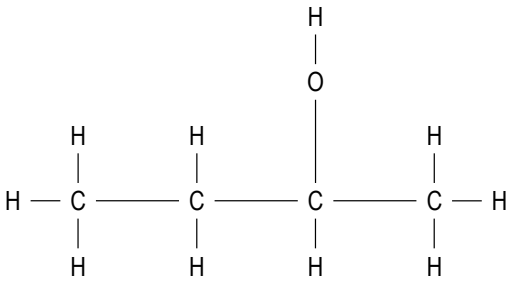
Explanatory notes

The molecular formula can be determined by adding the atoms of each element. Alternatively, saturated esters will have twice as many hydrogen atoms as carbon atoms.

The molecular formula can be halved to obtain the empirical formula.

Question 5b.i.

Worked solution

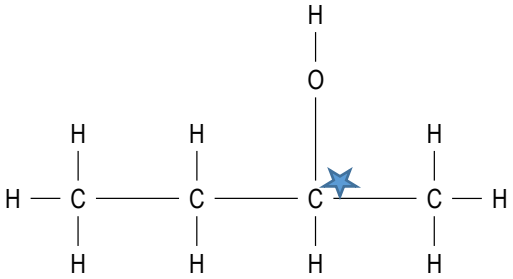


Mark allocation: 1 mark

- 1 mark for structure of butan-2-ol drawn correctly

Question 5b.ii.

Worked solution



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Mark allocation: 1 mark

- 1 mark for asterisk on the correct carbon

Tip

- *The identification of a chiral centre is one of the new concepts in the Study Design. A chiral centre has four different functional groups attached to it.*

Question 5b.iii.

Worked solution

butan-2-ol

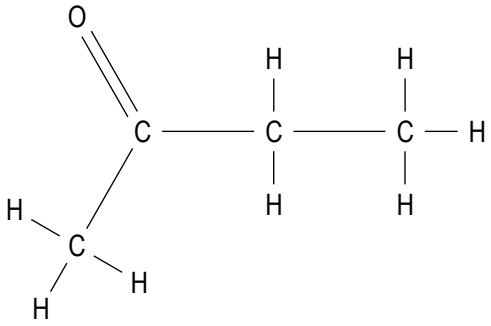
Mark allocation: 1 mark

- 1 mark for butan-2-ol

Note: Butanol is not an acceptable answer. 2-butanol is acceptable but is not the preferred representation.

Question 5b.iv.

Worked solution



Mark allocation: 1 mark

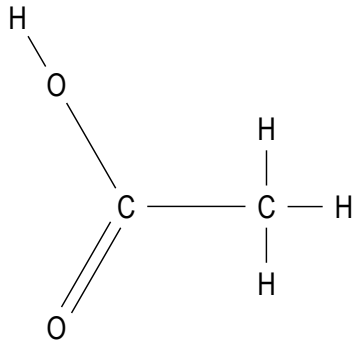
- 1 mark for correct structure (butan-2-one)

Explanatory notes

Hydrolysis of an ester will produce an alcohol and a carboxylic acid. The alcohol is butan-2-ol. This is a secondary alcohol that can be oxidised to a ketone.

Question 5c.i.

Worked solution



Mark allocation: 1 mark

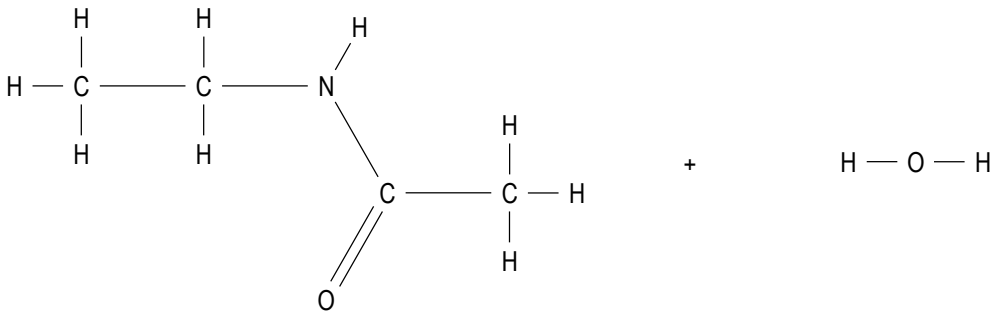
- 1 mark for drawing ethanoic acid correctly

Explanatory notes

The monoprotic carboxylic acid formed contains two carbon atoms; therefore, it will be ethanoic acid.

Question 5c.ii.

Worked solution



Mark allocation: 2 marks

- 1 mark for drawing the amide shown
- 1 mark for drawing water

Explanatory notes

The reaction between a carboxylic acid and an amine is a condensation reaction that forms the amide drawn and also water.

Question 6a.

Worked solution

$CH_4(g)$	+	$H_2O(g)$	⇄	$CO(g)$	+	$3H_2(g)$	
2		1.8		0		0	Start
2 – 0.24		1.8 – 0.24		0.24		0.24 × 3	Equilibrium

$$K = \frac{[CO][H_2]^3}{[CH_4][H_2O]} = \frac{0.24 \times 0.72^3}{1.76 \times 1.56} = 0.033 \text{ M}^2$$

Mark allocation: 3 marks

- 1 mark for determining the equilibrium concentrations of the species present
- 1 mark for correct equilibrium expression
- 1 mark for the correct answer and units

Explanatory notes

The amounts of methane and steam given are not equilibrium values. During the reaction, 0.24 mol of CO forms.

Therefore, the amount of H_2 formed is three times that (i.e. 3 × 0.24 = 0.72 mol).

The amounts of CH_4 and H_2O at equilibrium are 0.24 mol less than their original values. In the new Study Design, units for *K* are required.

Question 6b.i.

Worked solution

K is unchanged because the temperature is unchanged.

Mark allocation: 1 mark

- 1 mark for stating that *K* is unchanged

Question 6b.ii.

Worked solution

The amount of CO will be less because the increase in pressure favours the back reaction.

Mark allocation: 1 mark

- 1 mark for stating that the amount of CO is less

Question 6b.iii.

Worked solution

The concentration of CO will be greater because the decrease in volume increases the concentration.

Mark allocation: 1 mark

- 1 mark for stating that the concentration of CO is increased

Explanatory notes

The concentration of CO has increased even though the back reaction is favoured. This is because of the effect of the volume being halved. When the volume is halved, the pressure is doubled and this outweighs subsequent adjustments.

Question 6b.iv.

Worked solution

The rate of the forward reaction will be greater because the decrease in volume will lead to more collisions.

Mark allocation: 1 mark

- 1 mark for stating that rate is increased

Explanatory notes

The rate of both the forward and back reactions increases equally when the volume is halved. This is due to an increase in the number of collisions.

Question 6c.

Worked solution

$CO(g) + 3H_2(g) \rightleftarrows CH_4(g) + H_2O(g)$

Mark allocation: 1 mark

- 1 mark for supplying the reverse equation of the original equation supplied

Explanatory notes

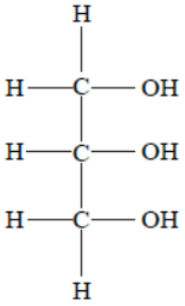
The value of *K* given in **part c.** is the reciprocal of the original *K* value. This tells you that the original equation has been reversed.

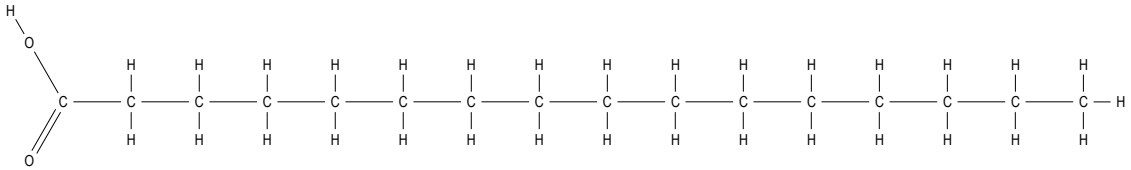
When the volume is halved, the system will respond by moving in the direction that involves fewer particles. There are two reactant particles compared to four product particles, so the reverse reaction is favoured:

$CH_4(g) + H_2O(g) \rightleftarrows CO(g) + 3H_2(g)$

Question 7a.i.

Worked solution





Mark allocation: 2 marks

- 1 mark for the structure of glycerol
- 1 mark for the structure of the fatty acid

Question 7a.ii.

Worked solution

Most digestion of fats and oils occurs in the small intestine. Fats and oils are non-polar, so do not break down to any great extent in the stomach. The presence of emulsifiers in the large intestine leads to the breakdown of fats.

Mark allocation: 2 marks

- 1 mark for large intestine
- 1 mark for mentioning the non-polar nature of fats and oils

Explanatory notes

Triglycerides are formed from a reaction between glycerol and fatty acids. Hydrolysis reverses this reaction, re-forming the glycerol and fatty acids. The fatty acids in this particular triglyceride are all the same.

Question 7b.i.

Worked solution

$CH_3(CH_2)_{14}COOCH_3$

Mark allocation: 1 mark

- 1 mark for the semi-structural formula of biodiesel

Explanatory notes

Biodiesel is an ester, in this case between methanol and the fatty acid drawn earlier. The fatty acid has 16 carbon atoms and the methanol adds one more.

Question 7b.ii.

Worked solution

$2C_{17}H_{34}O_2(l) + 49O_2(g) \rightarrow 34CO_2(g) + 34H_2O(g)$

Mark allocation: 2 marks

- 1 mark for the correct formulas of reactants
- 1 mark for correctly balanced equation with correct states

Explanatory notes

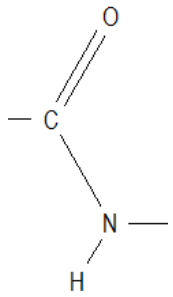
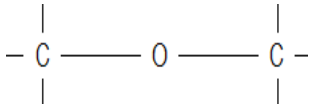
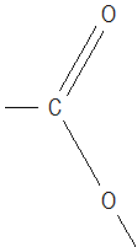
Complete combustion of the biodiesel will form CO_2 and H_2O. Be systematic – balance the carbon atoms first, then the hydrogen atoms and, finally, the oxygen atoms.

Tip

- *Students often find it frustrating deciding what state an organic chemical should be assigned in a chemical equation. In this question, biodiesel is shown as a liquid (l) and not aqueous. Fuels will usually perform poorly if they contain water. However, glucose solutions that are used to produce ethanol in fermentation will be aqueous solutions.*

Question 8a.

Worked solution

Macronutrient	Draw the bond broken during hydrolysis	Name of product(s) of hydrolysis
protein		amino acids
carbohydrate		glucose
triglyceride		glycerol and fatty acids

Mark allocation: 6 marks

- 1 mark for each box filled in correctly, as shown above (up to 6 marks)

Explanatory notes

Proteins: The amide bond is broken to form the amino acids that proteins are built from.

Carbohydrates: The glycosidic bonds are broken to form monosaccharide molecules.

Triglycerides: The ester bonds are broken to form glycerol and fatty acids.

Question 8b.i.

Worked solution

No, D group vitamins are insoluble in water due to a lack of polar hydroxyl bonds.

Mark allocation: 1 mark

- 1 mark for explaining that a lack of hydroxyl groups makes vitamin D insoluble in water

Question 8b.ii.

Worked solution

No, humans do not need a regular intake of Vitamin D. Fat-soluble vitamins do not need to be taken regularly as they can be stored for long periods in the body in fat tissue.

Mark allocation: 1 mark

- 1 mark for explaining that fat-soluble vitamins can be stored in the body for long periods

Explanatory notes

Vitamins are either fat soluble or water soluble. Those with several hydroxyl groups per molecule will be soluble in water due to the dipoles of the hydroxyl groups. Since the body stores fat-soluble vitamins in fat tissues, regular intake is not essential.

Question 8c.

Worked solution

The sugar in fruit is mainly fructose. This does not readily form glucose, so the GI value is low.

Mark allocation: 1 mark

- 1 mark for stating that fructose is the main sugar present rather than glucose

Explanatory notes

The GI index refers to the glucose concentration in blood. Since fructose is the main sugar in fruit, the fruit will taste sweet but will not have a high GI value.

Question 9a.

Worked solution

The positive sodium ions will move towards the negative electrode and the negative chloride ions will move towards the positive electrode.

Mark allocation: 2 marks

- 1 mark for stating that the particles are sodium ions and chlorine ions
- 1 mark for correctly explaining the direction of flow of the ions

Explanatory notes

Once the NaCl melts, the ions are free to move. Negative ions will move towards the positive electrode (anode) and positive ions will move towards the negative electrode (cathode).

Question 9b.

Worked solution

i. anode $2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$

ii. cathode $Na^+(l) + e^- \rightarrow Na(l)$

Mark allocation: 2 marks

- 1 mark for correct half-equation (states must be correct)
- 1 mark for correct half-equation (states must be correct)

Explanatory notes

Chloride ions are oxidised to chlorine gas at the anode. Sodium ions form sodium metal at the cathode. Both half-equations can be obtained from the data book.

Question 9c.

Worked solution

$2Na^+(l) + 2Cl^-(l) \rightarrow 2Na(l) + Cl_2(g)$

Mark allocation: 1 mark

- 1 mark for correct equation and states (accept 2NaCl(l))

Explanatory notes

The overall equation is obtained by adding together the two half-equations. The sodium half-equation needs to be multiplied by 2 to balance the electrons.

Question 9d.

Worked solution

Chlorine gas has a pungent odour and is harmful to inhale.

Producing very reactive liquid sodium and chlorine gas in proximity to each other is dangerous, especially at high temperatures.

Mark allocation: 2 marks

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

Explanatory notes

Both elements produced are dangerous. Chlorine is a toxic gas and liquid sodium is very reactive.

Question 9e.

Worked solution

$n(\text{e}) = 2n(\text{Cl}_2) = 2 \times 0.46 = 0.92$ mol

$Q = n(\text{e}) \times 96\,500 = 0.92 \times 96\,500 = 88\,800$ C

$t = \dfrac{Q}{i} = \dfrac{88\,800}{5.62} = 15\,800$ s (or 4.39 h)

Mark allocation: 3 marks

- 1 mark for correct number of moles
- 1 mark for calculation of charge
- 1 mark for correct calculation of time

Explanatory notes

The gas produced is chlorine. It takes two electrons to produce one chlorine molecule, therefore, the number of mole of chlorine is half the number of mole of electrons.

The charge required is calculated from the formula $Q = n(\text{e}) \times 96\,500$ and time is calculated by rearranging the formula $Q = It$.

Question 10a.

Worked solution

Error 1: The concentration of the three solutions is not the same. The electrochemical series assumes concentrations of 1.0 M, so all three cells should have the same concentration.

Error 2: The temperature may not have been constant if the experiments were performed over a series of days. The temperature of the laboratory should be regulated or the cells tested all at the same time.

Note: Other possible answers include consideration of the purity of solutions, the nature of the salt bridges used or the need to run multiple experiments. It is not appropriate to say the results are wrong because the order of reactivity does not match that of the electrochemical series. The results are as shown – it is up to students to identify errors.

Mark allocation: 4 marks

- 1 mark for each valid error (up to 2 marks)
- 1 mark for subsequent explanation of how to fix each error (up to 2 marks)

Explanatory notes

The electrochemical series is prepared under standard conditions. The temperature used is always 25 °C, the concentration is 1.0 M and the pressure of any gases is at 1 atm. Each cell needs to be constructed under these standard conditions.

Question 10b.

Worked solution

$Cu^{2+}(aq) + 2e^- \rightleftarrows Cu$ voltage 0.59 V

$Co^{2+}(aq) + 2e^- \rightleftarrows Co$ voltage –0.03 V

Mark allocation: 2 marks

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

Explanatory notes

From the data book:

The difference in voltage between nickel and copper is = 0.34 – (–0.25) = 0.59.

The difference in voltage between nickel and cobalt is = –0.28 – (–0.25) = –0.03.

Tip

- *The emphasis on experimental design is very strong in the new course. Expect this style of question whereby there is a long description of an experimental procedure and you are asked to comment on the validity of the procedure.*

Question 11a.i.

Worked solution

$E = 4.18 \times 900 \times (24.4 - 18.8) = 21\ 100$ J = 21.1 kJ

Mark allocation: 2 marks

- 1 mark for using correct formula and temperature change
- 1 mark for the correct answer and units

Explanatory notes

The energy required to heat the water is given by the formula $E = 4.18 \times m \times \Delta T$.

The units will be joules.

Question 11a.ii.

Worked solution

$$\Delta H = \frac{E}{m} = \frac{21100}{3.782 - 1.122} = 7920 \text{ J g}^{-1} = 7.92 \text{ kJ g}^{-1}$$

Mark allocation: 1 mark

- 1 mark for the correct answer

Explanatory notes

To obtain the heat of combustion per gram, the energy obtained needs to be divided by the mass of biscuit burnt.

Question 11b.

Worked solution

Possible modifications:

- Put a lid on the beaker.
- Wrap the beaker in insulation.
- Change from using a beaker to using a bomb calorimeter.
- Use a metal can.

Mark allocation: 3 marks

- 1 mark for each valid design change listed (up to 3 marks)

Explanatory notes

The heat losses from using an open glass beaker will be high. The design needs to be changed to limit these losses. A lid and insulation are obvious changes.

END OF WORKED SOLUTIONS