

CHEMISTRY

Units 3&4 – Written examination



2022 Trial Examination

SOLUTIONS

SECTION A: Multiple-choice questions (1 mark each)

Question 1

Answer: C

Explanation:

Using the data booklet, the enthalpy of methane is -890 kJ mol^{-1} . Therefore, in order to calculate the amount of energy, the mole of CH_4 needs to be calculated first.

$$n(\text{CH}_4) = m/M$$

$$n = 1/16 = 0.0625$$

1 mole of CH_4 released 890 kJ.

$$890 \times 0.0625 = 55.6 \text{ kJ} \quad \text{or } 1 \times 55.6 = 55.6 \text{ kJ}$$

Question 2

Answer: D

Explanation:

$$n(\text{CH}_4) = 4.16/16 = 0.26 \text{ mol}$$

$$n(\text{O}_2) = 2 \times 0.26 = 0.52 \text{ mol}$$

$$m(\text{O}_2) = 0.52 \times 32 = 16.64 \text{ g}$$

Question 3

Answer: A

Explanation:

Using the gas equation of $PV = nRT$.

$n(\text{CH}_4) = m/M$

$n = 4.26/16 = 0.266 \text{ mol}$

$n(\text{H}_2\text{O}) = 2 \times 0.266 = 0.53 \text{ mol}$

$V = (0.53 \times 8.31 \times 723)/200 = 15.92 \text{ L}$

Question 4

Answer: A

Explanation:

Coal is burnt to produce electrical energy and stores chemical energy prior to combustion.

Thermal energy is released as a result of the reaction to allow the mechanical turbine to move and generate electricity.

Question 5

Answer: D

Explanation:

Coal, oil (petrodiesel), and natural gas are not renewable energy sources and limited in the amount left. Therefore, sugar cane is the only sustaining (re-planted) energy source that can be considered the most sustainable.

Question 6

Answer: C

Explanation:

Biodiesel chains are longer than petrodiesel chains and due to the additional C-O bonds, biodiesel is more viscous.

Question 7

Answer: A

Explanation:

Fuels are substances that react with oxygen and release energy. Combustion reactions are exothermic due to the large of heat energy released.

Question 8

Answer: B

Explanation:

Only those cations higher on the electrochemical series than Pb^{2+} will be reduced by lead.

Question 9

Answer: C

Explanation:

The reverse reaction is endothermic, hence a positive enthalpy value. D – represented the activation energy, A – the exothermic reaction, and B – the activation energy for the exothermic reaction.

Question 10

Answer: A

Explanation:

The combustion reaction of ethane is $2\text{C}_2\text{H}_6 + 7\text{O}_2 \rightarrow 4\text{CO}_2 + 6\text{H}_2\text{O}$. Therefore, the concentration units would be 10 molecules for products/9 molecules for the reactants leaving the concentration to M to the power of one.

Question 11

Answer: C

Explanation:

A – Has electrons remaining in the overall equation which is incorrect.

B – Unbalanced number of carbon atoms

C – The only balanced equation

D – Is unbalanced with the number of sodium atoms

Question 12

Answer: D

Explanation:

If the electrode is damaged or unable to discharge the sodium carbonate effectively. This means less reactant will remain to be used for futures recharges. Decreasing battery life, performance, and amount of future charge that can be held.

Question 13

Answer: A

Explanation:

A primary alcohol is where the carbon atoms of the -OH group is attached to only one single alkyl group.

B – tertiary alcohol

C – secondary alcohol

D – secondary alcohol

Question 14

Answer: D

Explanation:

When solving the molecular formula for each molecule it can be realised that each contains four carbons, eight hydrogen, and two oxygen atoms.

Question 15

Answer: C

Explanation:

An alcohol reacting to form a carboxylic acid on an IR spectroscopy will form a new C=O peak at about 1700cm^{-1} as this bond does not exist in pentanol.

Question 16

Answer: D

Explanation:

B – does not follow the formula of an alkane due to the number of double bonds

C – three double bonds therefore must have less than 34 hydrogens

D – has the correct number of hydrogen and carbons

Question 17

Answer: C

Explanation:

The double bonds located at carbon positions 9 and 12 are on opposing sides to the functional group making them trans bonds.

Question 18

Answer: B

Explanation:

Whilst ethyl butanoate has six carbons, the -COO- bond does not contain any hydrogens. Whilst the remaining five carbon atoms are all attached to hydrogens.

Question 19

Answer: A

Explanation:

As calcium hypochlorite is a basic solution, the indicator will begin pink prior to becoming colourless. The solution will not begin acidic and reach the end point.

Question 20

Answer: B

Explanation:

$$n(\text{HCl}) = 0.5 \times 0.025 = 0.0125 \text{ mol}$$

$$n(\text{calcium hypochlorite}) = 0.0125/4 = 0.0031 \text{ mol}$$

$$V = 250 / 20.07 = 12.46 \quad \text{*average of three concordant titres}$$

$$n(\text{calcium hypochlorite in beaker}) = 12.46 \times 0.0031 = 0.0386 \text{ mol}$$

$$m(\text{calcium hypochlorite}) = n \times M$$

$$m(\text{calcium hypochlorite}) = 0.0386 \times 143$$

$$m(\text{calcium hypochlorite}) = 5.52 \text{ g}$$

Question 21

Answer: C

Explanation:

For correct volumetric analysis, equipment should only be rinsed with the substance that is soon to be used in that specific equipment. As the 250 mL beaker is to be filled up with deionised water once the base has been added, this will not impact the concentration. Rinsing with acid or base would increase the amount of unmeasured substance leading to a variant end point.

Question 22

Answer: B

Explanation:

A condensation reaction produces water molecules, whilst a hydrolysis reaction requires water molecules. As a result, when this triglyceride undergoes hydrolysis, glycerol and a fatty acid would be produced.

Question 23

Answer: D

Explanation:

Vitamin D is not soluble in water unlike the other molecules that contain polar bonds. Vitamin D is a fat soluble molecule.

Question 24

Answer: C

Explanation:

The GI content is higher in potatoes, milk, and nuts because these products all contain sugars with glucose. Unlikely fruit which is a high percentage of fructose a monosaccharide that does not contain glucose.

Question 25

Answer: C

Explanation:

A catalyst does not impact the direction of the forwards or backwards reaction just the rate of the reaction. Therefore, the endothermic and exothermic reactions will be impacted proportionally the same.

Question 26

Answer: A

Explanation:

Energy released by the almond = $m \times \Delta H = 1.8 \times 7.2 = 12.96 \text{ kJ} = 12,960 \text{ J}$

$\Delta T = \text{energy/calibration factor}$

$\Delta T = 12960/678$

$\Delta T = 19.12^\circ\text{C}$

Question 27

Answer: D

Explanation:

This is a systemic error due to the calibration error with instrumentation that is being consistently used for the experiment. The calibration factor will be higher due to increased amount of water in the vessel.

Question 28

Answer: C

Explanation:

The temperature is required to be kept at the same temperature. Meanwhile the strength of smell is what is being measured as the dependent variable and the size of the carboxylic acid the independent variable.

Question 29

Answer: B

Explanation:

An omega-3 fatty acid is where the double bond occurs on the third carbon atom. Using the data booklet this can be seen as linolenic acid, unlike the other three fatty acids whose double bonds occur on various other carbon atoms.

Question 30

Answer: A

Explanation:

Fuel cells follow the principles of a galvanic cell in converting chemical energy to electrical energy for electricity to be used. The reactants are continuously supplied to the cell for the spontaneous reaction to continue occurring.

SECTION B: Short-answer questions**Question 1** (10 marks)

- a. Propane is a non-polar molecular with weak dispersion forces requiring less energy to break the weaker intermolecular bonds apart hence a lower melting point. Whereas ethanol is a polar substance with hydrogen bonding and requires more energy to break the stronger intermolecular bonds apart hence a high melting point.

2 marks

- b. Propane volume: 60% of 50 L = 30 L
Butane volume: 40% of 50 L = 20 L
Propane mass = density x volume = $0.493 \times 30,000^* = 14,790$ g
Butane mass = density x volume = $0.573 \times 20,000^* = 11,460$ g

*The volume needs to be in mL to match the units of density. One mark for correct calculations of propane and one mark for correct calculations

2 marks

- c. Energy released by propane = $50.5 \times 17,190 = 8.68 \times 10^5$ kJ
Energy released by butane = $49.7 \times 9,860 = 4.90 \times 10^5$ kJ
Total energy released of 50 L of LPG = $8.68 \times 10^5 + 4.90 \times 10^5 = 1.36 \times 10^6$ kJ

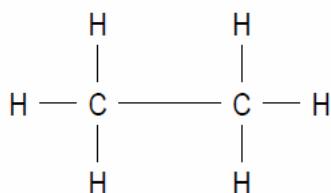
One mark for correct calculations of energy released of propane and butane. One mark for correct addition of the two fuels.

2 marks

- i. A possible molecule student could draw is ethane. One mark for naming ethane and one mark for drawing correctly ethane.

d.

Ethane

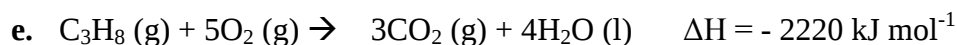


2 marks

ii. E10, sourced from a sugar cane is renewable biofuel and sustainable due to crops being resown when needed. Whereas E10, sourced from coal is not considered a renewable fuel as it cannot be replenished easily and there is a finite amount of coal.

One mark for the discussion of sugar cane source and one mark for coal discussion source.

2 marks



Water can be listed as a liquid or gas state. One mark was awarded to a correct balanced equation including states and one mark was awarded to enthalpy value being completed.

2 marks

f. $n (\text{propane}) = m/M = 17190/44 = 390.68 \text{ mol}$
 $n (\text{butane}) = n/M = 170.0 \text{ mol}$

The balanced equation for the combustion of butane is $2\text{C}_4\text{H}_{10} + 13\text{O}_2 \rightarrow 8\text{CO}_2 + 10\text{H}_2\text{O}$

$n (\text{CO}_2) \text{ from propane} = 3 \times n (\text{propane}) = 510 \text{ mol}$
 $n (\text{CO}_2) \text{ from butane} = 13/2 \times n (\text{butane}) = 1,105 \text{ mol}$

Total $n (\text{CO}_2) = 1105 + 510 = 1615 \text{ mol}$

$PV = nRT$
 $V = (1615 \times 8.31 \times 623)/102$
 $V = 8.20 \times 10^4 \text{ L}$

One mark was awarded to the correct calculation of moles of propane and butane. One mark awarded to the correct mole ratios. One mark for the mole of CO_2 of propane and butane calculated. One mark awarded for the correct volume calculation.

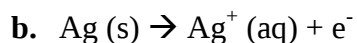
4 marks

Question 2 (8 marks)

- a. Cathode: spoon Polarity: negative
 Anode: silver electrode Polarity: positive

One mark was awarded to correct naming of the anode and cathode. One mark was for the correct polarity of the cathode and anode.

2 marks



1 mark

c. One mark for each general response is awarded:

- The battery required for the reaction to occur. As electricity is needed for the chemical reaction.
- Discussion of polarity, a galvanic cell the cathode is positive and anode is negative.
- A spontaneous reaction will not occur for an electrolytic cell, however, galvanic cells derive their energy from spontaneous redox reactions.

2 Marks

d. $Q = I \times t = 50 \times (70 \times 60) = 2.1 \times 10^5 \text{ C}$

$n(e^-) = Q/F = 2.1 \times 10^5 / 96500 = 2.18 \text{ mol}$

The cathode reaction is $\text{Ag}^+ + e^- \rightarrow \text{Ag}$ 1:1 ratio of $n(\text{Ag}) : n(e^-)$

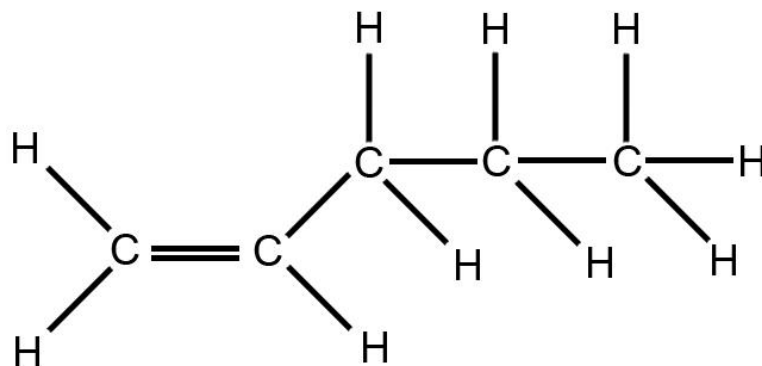
$m(\text{Ag}) = n \times M = 2.18 \times 107.9 = 235 \text{ g}$

Time is recorded in seconds. One mark was awarded to correct calculation of charge. One mark was awarded to correct calculation of mole. One mark was awarded to the correct amount of mass.

3 marks

Question 3 (12 marks)

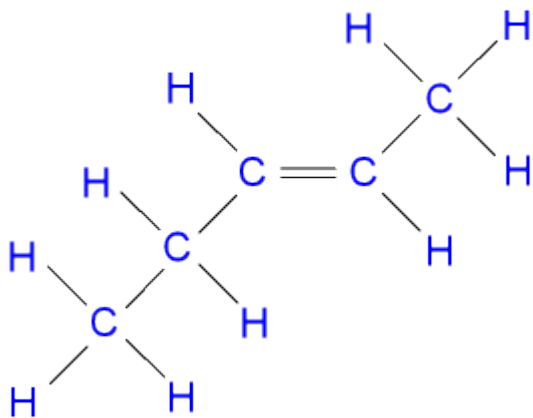
a.



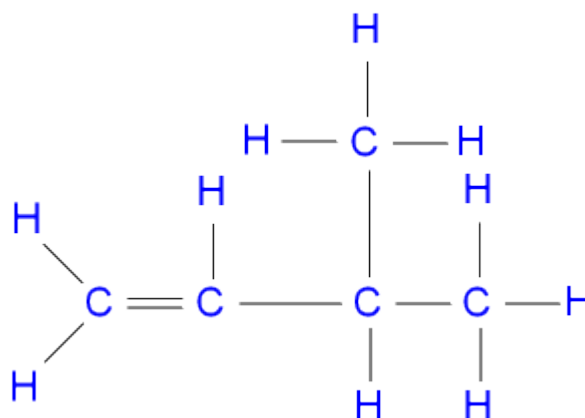
1 mark

b. Four possible structures:

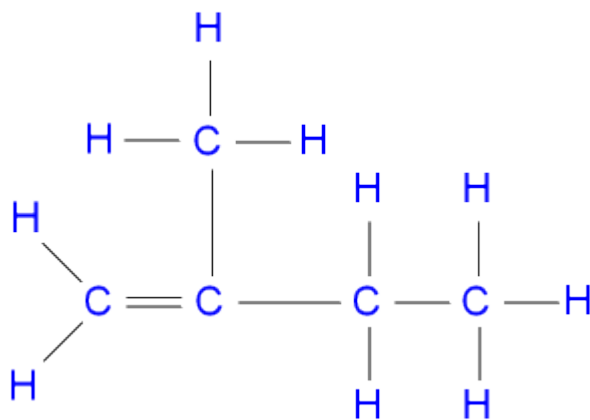
Pent-2-ene



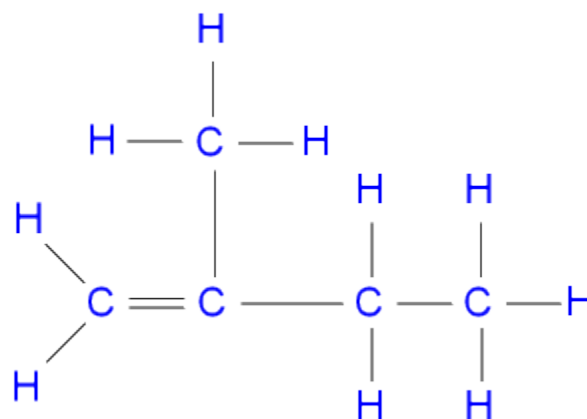
2-methylbut-1-ene



3-methylbut-1-ene



2-methylbut-2-ene



2 marks

c. H_2O (water) and H_3PO_4 catalyst

1 mark

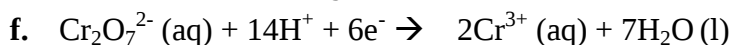
d. Pentanol

1 mark

e.

Semi-structural formula: $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH}$

2 marks



One mark was awarded to correctly balanced equation. One mark was awarded to correct states.

g. Name: Ethyl pentanoate*

Class of compounds: Ester*

2 marks

Question 4 (9 marks)

a. $K_c = [\text{NOCl}]^2 / [\text{NO}]^2 [\text{Cl}_2]$

1 mark

b. This is an endothermic reaction* as the enthalpy value for this reaction is positive and energy is absorbed from the environment. *

2 marks

c. Increasing the temperature will result in an increase in rate of nitrosyl chloride being produced*.

Increase in temperature increases the average kinetic energy of all molecules, leading to increased number of collisions*.

Increase in temperature will also lead to more collisions that are successful as collisions occur with greater energy.*

Referring to only Le Chatelier's principle is not addressing collision theory.

3 marks

d. Following Le Chatelier's principle, yield could be improved by the following points:

- increasing the temperature. This will cause the forward reaction to occur increasing the amount of nitrosyl chloride produced. *
- increasing the pressure. This will favour the side with few molecules, in this reaction causing a forward reaction to occur and increase the amount of nitrosyl chloride produced. *

Explaining the improvement was necessary to obtain full marks for each point.

2 marks

e. $K_c = [\text{NOCl}]^2 / [\text{NO}]^2 [\text{Cl}_2]$ at 35°C $K_c = 3.2 \times 10^2$

$x = \text{Cl}_2$ and $2x = \text{NO}$

$320 = [0.72]^2 / [2x]^2 [x]$

$320 = 0.1296/x^3$

$x^3 = 4.0 \times 10^{-4}$

$x = 0.074 \text{ M}^{-1}$

One mark was awarded to correct arrangement of the equilibrium expression. One mark awarded for the correct input into the expression and calculation. One mark was awarded for the final answer and correct units.

f. Helium, an inert gas will cause no change*.

There are more collisions due to additional particles but not successful collision since inert gases do not affect equilibrium. *

2 marks

Question 5 (12 marks)

a. i. One conclusion is the peak at 2950cm^{-1} on the IR spectrum that indicates a O-H bond of an acid.*

Another conclusion is the peak at 1800cm^{-1} on the IR spectrum that indicates a C=O bond.

For full marks students need to discuss the wave number with a comment about a possible bond.

2 marks

ii. Any of the following correct comments about IR spectrum are accepted:

- Molecules absorb frequencies of light that are characteristic of the structure of the molecule
- Different covalent bonds absorb IR radiation within a range of frequencies allowing functional groups to be identified
- The region prior to 1400cm^{-1} is the fingerprint region due to the unique spectrum below this region.

Other correct statements about the principles of IR spectroscopy are accepted.

1 mark

b. The ion located at m/z of $57 = \text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2^+$

The ion located m/z of $43 = \text{CH}_2\text{COOH}^+$

The positive charge is required for both peaks because all peaks are ions.

2 marks

c. Hydrogen carbon X = 2-methyl butanoic acid*

The C NMR data supports the name of this molecule due to 2-methyl butanoic acid having five carbon environments. *

The H NMR data supports as there were listed five hydrogen environments, the CH_3 , CH, (CH_3) , CH_2 , and OH environments. *

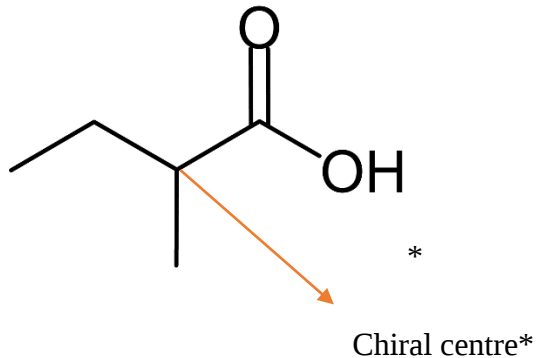
The IR spectrum identified a C=O bond and O-H bond which is the carboxylic acid functional group. *

The mass spectrometry data peaks align with 2-methyl butanoic acid as the $-\text{COOH}$ fragment caused the 57 m/z value and the $-\text{CH}_3\text{CH}_2(\text{CH}_3)$ fragment caused the 43 m/z value.*

For full marks students are required to identify how each analytical technique supports the name of the molecular identified. Components of the molecule should be listed as evidence.

5 marks

d. 2-methyl butanoic acid



2 marks

Question 6 (7 marks)

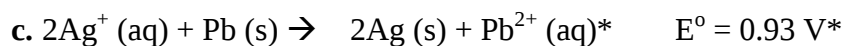
- a. Oxidation: $\text{Pb (s)} \rightarrow \text{Pb}^{2+} \text{ (aq)} + 2\text{e}^- *$
 Reduction: $\text{Ag}^+ \text{ (aq)} + \text{e}^- \rightarrow \text{Ag (s)} *$

2 marks

- b. Reductant = Lead or Pb* this is because the oxidation number change is 0 to +2 resulting in a loss of electrons.*
 Oxidant = $\text{Ag}^+ *$ this is because the oxidation number change is +1 to 0 resulting in a gain of electrons. *

Marks are not awarded to Ag/Silver being the oxidant and the student to include the change in oxidation number for each species to obtain full marks.

4 marks



2 marks

- d. Electron flow is from the anode (lead electrode) to the cathode (silver electrode).

1 mark

- e. A salt bridge is necessary in a galvanic cell to keep the charge flowing through the cell. Without a salt bridge the electrons would build up at the anode and the reaction would stop occurring.*

K^+ ions would move towards the cathode and Cl^- ions would move towards the anode.

2 marks

- f. A spontaneous reaction would not occur.*

This is because gold is located above in the electrochemical series and is a more suitable oxidant in this reaction, not a suitable reductant if it were solid were to react with silver.*

2 marks

Question 7 (14 marks)

- a. The process of SCG being converted to biodiesel proposes a number of environmental impacts as a petroleum refinery which emits large amounts of fossil fuels is being used in the process. Using these refineries is not sustainable given non-renewable energy sources are being used and could be causing environmental damage depending on the source of the fossil fuel. This process could be improved significantly by using an energy source that is sustainable and carbon neutral. This would allow the production of biodiesel to be continually used for a period of time with minimal environmental impact and limited carbon emissions. The process of combustion of SCG to water and carbon dioxide proposes the risks of emitting CO_2 a greenhouse gas as a product. Additionally, water is being produced so this could be recycled back through the plant or used for other benefits.

Marks were allocated based on addressing:

- Discussion of fossil fuel source for SCG to become biodiesel
- The sustainability/environmental impact of this process
- Improving this process to make sustainable
- Discussion of releasing of CO_2 for the combustion of SCG
- The sustainability/environmental/risks impact of this process

5 marks

- b. $q = m \times C \times \Delta T$

$$q = 600 \times 4.18 \times 31 = 77,748 \text{ J energy absorbed by the water or } 77.748 \text{ kJ}^*$$

$$\Delta m = \Delta m_{\text{initial}} - \Delta m_{\text{final}} = 20.67 - 8.67 = 12 \text{ g}^*$$

$$E = q/\Delta m = 77.748/12$$

$$E = 6.5 \text{ kJ g}^{-1} *$$

3 marks

- c. Glucose* and fructose* are the two monosaccharides that contribute to sucrose.
- d. The two amino acids are lysine* and histidine*. 2 marks
- e. During hydrolysis the covalent bonds are broken down to the primary structure.*
During denaturation the breakdown of hydrogen bonds occurs at the secondary structure.*

Students could also comment on denaturation about the tertiary structure breaking down for various bond types.

2 marks

Enzymes have a specific shape and therefore lactase would not be effective at breaking down sucrose. The substrate specific nature of enzymes often means lactase is suitable for one reaction pathway.

One mark was awarded to saying that lactase would not be effective with supporting evidence.

1 mark