CHEMISTRY

Units 3&4 - Written examination

2018 Trial Examination

SOLUTIONS

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

Question 1

Answer: D

Explanation:

Biogas is formed in anaerobic conditions. A significant amount of CO_2 will be generated at the same time.

Question 2

Answer: C

Explanation:

The ratio of fuel to CO_2 is 1:4. This will match butane as its molecules have 4 carbon atoms that will form 4 molecules of CO_2.

Question 3

Answer: C

Explanation:

$$V = \frac{nRT}{P} = \frac{2 \times 8.31 \times 308}{100} = 51 \text{ L}$$

Question 4

Answer: A

Explanation:

octane: $10 \times 47.9 = 479$ kJ
butane: $9 \times 49.7 = 447$ kJ
methane: $8 \times 55.6 = 445$ kJ
ethanol: $0.2 \times 1360 = 272$ kJ

Question 5

Answer: A

Explanation:

The equation for the reaction is
$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$
As the reaction proceeds, the amount of HCl left decreases. The pH will rise and approach 7 if the zinc is in excess.

Question 6

Answer: B

Explanation:

Butane. From the graph, the value of ΔH is -5 760 kJ mol^{-1}. Taking into account the balanced equation, this value will match that of butane in the Data book.
$2C_4H_{10}(l) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$

Question 7

Answer: D

Explanation:

An increase in temperature will favour the forward reaction as it is endothermic. The removal of oxygen will favour the forward reaction replacing the oxygen. A decrease in volume will increase the concentration of all species. The system will oppose this by moving in the reverse direction but the concentration will remain greater than it was.

Question 8

Answer: B

Explanation:

The value of *K* is relatively high. Such a high value will only be obtained if the concentration of HI is considerably greater than that of the reactants.

Question 9

Answer: B

Explanation:

The expression for *K* is $2SO_3(g) \rightleftarrows 2SO_2(g) + O_2(g)$
Since the reverse reaction is asked for, the equation is $2SO_2(g) + O_2(g) \rightleftarrows 2SO_3(g)$

Question 10

Answer: C

Explanation:

Fe^{2+} is reduced to Fe, making it the oxidant. It oxidises lithium atoms to lithium ions.

Question 11

Answer: C

Explanation:

Metal A is lower on the E^0 series than silver.
Metal A is lower on the E^0 series than lead.
Metal A is higher on the E^0 series than aluminium.
Metal A is lower on the E^0 series than nickel => Manganese

Question 12

Answer: A

Explanation:

In a hydrogen fuel cell, hydrogen reacts to form hydrogen ions. This is oxidation. The electrons released reduce oxygen gas to oxygen ions.

Question 13

Answer: A

Explanation:

Oxidation occurs at the anode. The anode reaction is the oxidation of hydrogen atoms. This requires electrons and water is formed.

Question 14

Answer: D

Explanation:

The deposit at the cathode is of copper metal and the gas at the anode is oxygen gas (matching the electrolysis of aqueous $CuCl_2$

Question 15

Answer: C

Explanation:

$n(\text{Cu}) = \dfrac{3.17}{63.5} = 0.050$ mol
$n(\text{Ag}) = 2 = 0.05 \times 2 = 0.10$ mol

mass = $0.10 \times 108 = 10.8$ g

Question 16

Answer: B

Explanation:

Oxygen gas is formed from water at the positive electrode of both cells.
$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$
$n(O_2)$ in Cu cell = ½ n(Cu) = 0.025
$n(O_2)$ in Ag cell = ¼ n(Cu) = 0.025

Total $n(O_2) = 0.025 + 0.025 = 0.05$ mol

Question 17

Answer: A

Explanation:

The half-equation for the permanganate ion is
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$
When this is compared to the $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$ half-equation a ratio of 1:5 is evident.

Question 18

Answer: D

Explanation:

The two molecules in option D can be superimposed. A good check for geometric isomers is to look for a carbon atom having different groups on it.

Question 19

Answer: A

Explanation:

Molecule A is a tertiary alcohol. A tertiary alcohol will not be oxidised.

Question 20

Answer: B

Explanation:

The first molecule has a carbon-to-carbon double bond on the second carbon = but-2-ene
The second molecule has an amine group on the second carbon
The third molecule is an ester formed from ethanol and methanoic acid.

Question 21

Answer: **B**

Explanation:

The spectrum shows three different hydrogen environments, one a singlet due to the –OH, one a doublet from the two methyl groups and one a septet due to the six hydrogen atoms near the middle hydrogen atom.

Question 22

Answer: D

Explanation:

There is a broad absorption around 3000 cm^{-1} due to the –OH (acid) and an absorption at 1750 due to the –C=O

Question 23

Answer: C

Explanation:

The amino acids can be identified from the Data book as glutamic acid, lysine and serine.

Question 24

Answer: A

Explanation:

The molecule shown can be identified as lactose from the Data book. It can be hydrolysed to glucose and galactose.

Question 25

Answer: C

Explanation:

Basmati rice has a higher proportion of amylose than other rices. Amylose is less water soluble, and slower digesting, than amylopectin.

Question 26

Answer: B

Explanation:

Vitamin D has a low solubility in water. It can be stored in fat tissue for long periods.

Question 27

Answer: A

Explanation:

Arginine contains an amine group as part of its R group. This acts as a base in the same way that ammonia does.

Question 28

Answer: B

Explanation:

Oleic acid has a molar mass of 282 g mol^{-1}. The formula is in the Data book.

Question 29

Answer: D

Explanation:

$E = 0.015 \times 1360 = 20.4$ kJ

$CF = \frac{20.4}{12.4} = 1.60$ kJ $^0C^{-1} = 1640$ J $^0C^{-1}$

Question 30

Answer: B

Explanation:

$E = 1640 \times 4.8 = 7870$ J

Heat of combustion = $\frac{7870}{1.4} = 5\ 620$ J g^{-1}

SECTION B – Short answer questions
*An * indicates the allocation of 1 mark*

Question 1 (9 marks)

a. **i**. Choose from – natural gas deposits, biogas generators, distillation of crude oil.

ii. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

iii. $E = 120\,000 \times 10^6 \times 55.6 = 1.2 \times 10^{11} \times 55.6 = 6.67 \times 10^{12}$ kJ

1 + 1 + 1 = 3 marks

b. **i**. The burning gas releases energy. Hot air expands, acting to move the compressor and to turn a turbine to generate electricity.

ii. Two of: thermal energy gas to thermal energy steam. Thermal energy to mechanical energy. Mechanical energy to electrical energy

iii. $V = \frac{nRT}{P} = \frac{1 \times 8.31 \times 357}{100}$ ** = 29.7 L *

1 + 2 + 3 = 6 marks

Question 2 (14 marks)

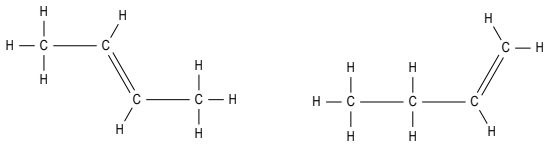
a.

i. 56 g mol^{-1}

ii. C_4H_8

iii. $C_3H_5^+$

iv.

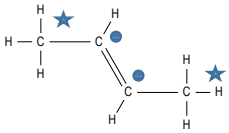


Structure 1: but-2-ene Structure 2: but-1-ene

1 + 1 + 1 + 2 = 5 marks

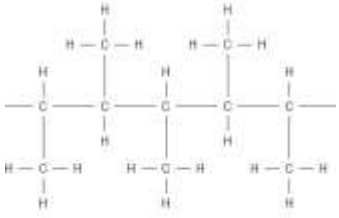
b. **i**. 2 hydrogen enviroments

ii. Molecule is but-2-ene as it has two different H environments as shown on the diagram



1 + 2 = 3 marks

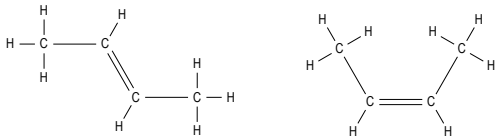
c.



1 mark

d. **i**. Geometric isomers have the same molecular formula but have a different spatial arrangement that prevents them being superimposed. In particular, geometric isomers are often formed by a lack of rotation around carbon-to-carbon double bonds.

ii.



Isomer 1: trans-but-2-ene Isomer 2: cis but-2-ene

1 + 2 = 3 marks

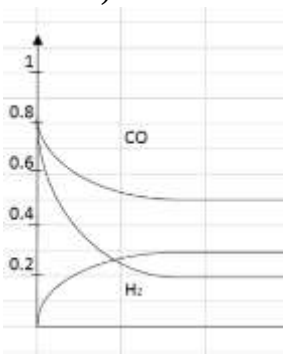
e. **i**. Reddish bromine solution will go colourless when added to unsaturated organic compounds.

ii. $C_4H_8(l) + Br_2(l) \rightarrow C_4H_8Br_2(l)$

1 + 1 = 2 marks

Question 3 (11 marks)

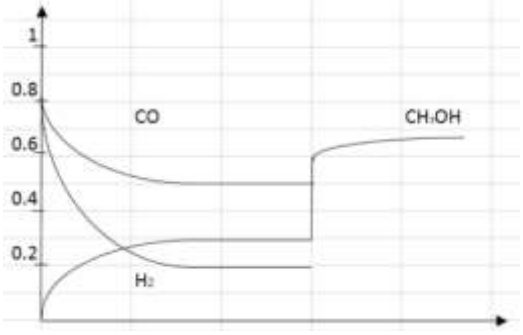
a. **i**.



ii. $K = \frac{[CH_3OH]}{[CO][H_2]^2} = \frac{0.3}{0.5 \times 0.2^2} = 15\ M^{-2}$ One mark each step in calculation

2 + 3 = 5 marks

b.



1 1 + 1 = 2 marks

c. i. the value of *K* drops as the reaction is exothermic
ii. the amount of methanol drops as the back reaction is favoured

1 + 1 = 2 marks

d. **i**. $2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$
ii. $E = 22.7 \times 1000000 = 2.27 \times 10^7$ kJ

1 + 1 = 2 marks

Question 4 (6 marks)

a. **i**. Lithium has a low mass and it is the strongest reductant of all.
ii. Lithium reacts violently with water or lithium batteries are dangerous when swallowed

2 + 1 = 3 marks

b. **i**. anode: $Li \rightarrow Li^+ + e^-$
cathode: $2SOCl_2 + 4e^- \rightarrow 4Cl^- + SO_2 + S$

ii. The cell produces 3.6 V and the value for the lithium half-cell is 3.04 therefore voltage will be -3.04 - -3.6 = +0.56 V

2 + 1 = 3 marks

Question 5 (11 marks)

a. **i**. Magnesium ions are stronger oxidants than potassium and sodium ions, therefore they react with the Cl^- ions. *
$Cl_2(g) + 2e^- \rightarrow \underline{2Cl^-}(l)$
$\underline{Mg}^{2+}(l) + 2e^- \rightarrow Mg(l)$
$Na^+(l) + e^- \rightarrow Na(l)$
$K^+(l) + e^- \rightarrow K(l)$ * for evidence

ii. In an aqueous solution water will react before magnesium ions, producing hydrogen gas*
$\underline{2H_2O}(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$
$\underline{Mg}^{2+}(aq) + 2e^- \rightarrow Mg(s)$ *

2 + 2 = 4 marks

b. Two reasons from: producing reactive magnesium and chlorine gases at close proximity, high temperature materials. High electrical currents.

2 marks

c. anode: $2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$ cathode: $Mg^{2+} + 2e^- \rightarrow Mg(l)$

2 marks

d. $Q = It = 180\,000 \times 24 \times 60 \times 60 = 1.56 \times 10^{10}$ C *

$n(\text{e}) = \dfrac{1.56 \times 10^{10}}{96500} = 1.62 \times 10^{5}$

$n(\text{Mg}) = 8.06 \times 10^{4}$ mol *

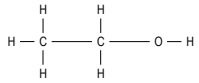
mass = $8.06 \times 10^{4} \times 24.3 = 1\,960$ kg *

3 marks

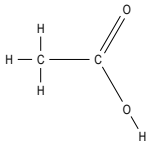
Question 6 (10 marks)

a. $CH_3CH_2OCOCH_2CH_3$

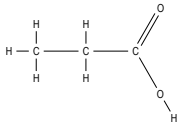
1 mark

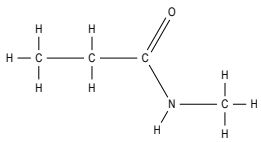
b. i. 

ii. $C_6H_{12}O_6(aq) \rightarrow 2C_2H_6O(aq) + 2CO_2(g)$

iii. 

1+ 1 + 1 = 3 marks

d. i. 

ii. H-O-H 

1 + 2 = 3 marks

e. $n(\text{NaOH}) = 0.025 \times 0.5 = 0.0125$ mol *

$n(\text{propanoic acid}) = 0.0125$ mol *

$c = \dfrac{n}{V} = \dfrac{0.0125}{0.005} = 2.5$ M *

3 marks

Question 7 (10 marks)

a. Oxidation half-equation: $H_2O_2(l) \rightarrow 2e^- + 2H^+(aq) + O_2(g)$

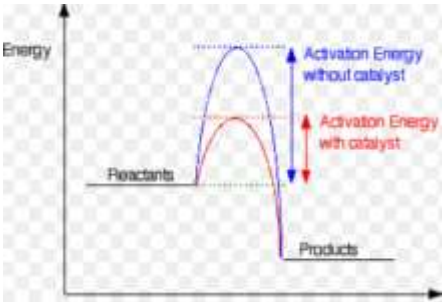
Reduction half-equation: $H_2O_2(l) + 2H^+(aq) + 2e^- \rightarrow 2H_2O(l)$

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

-1 to -2 (O^- to O^{2-})

1 + 1 + + 1 = 4 marks

b.



2 marks

c. **i**. MnO_2 will be more effective at 75 ^{0}C. *It is an inorganic catalyst that will not denature with heat like an enzyme will.*

ii. Both catalysts provide an alternative reaction pathway with lower activation energy*. Both catalysts should be unchanged in the reaction*.

2+ 2 = 4 marks

Question 8 (13 marks)

a. **i**. oleic acid

ii. ethanol

1 + 1 = 2 marks

b. **i**. Melting point of this biodiesel molecule will be higher than that of petrodiesel – (longer molecule, more dipoles.)

ii. Viscosity of this biodiesel molecule will be less than one formed from arachidic acid and the same alcohol. Its hydrocarbon chain is shorter and it has a carbon-to-carbon double bond that places a kink in the chain and limits tight packing.

1 + 2 = 3 marks

c. **i**. $3(C_{18}H_{34}O_2) + C_3H_8O_3 - 3H_2O = C_{57}H_{104}O_6$

ii. $0.34 \times 37 = 12.6$ kJ

iii. $Q = 4.18 \times m \times \Delta T = 12600$*

$\Delta T = 12600/(4.18 \times 150) = 20.1$ final T = 21.6 + 20.1 = 41.7 ^{0}C*

2 + 1 + 2 = 5 marks

d. **i**. The carbon atom adjacent to the carbon-to-carbon double bond is a likely point of breakdown.

ii. Store in an airtight*, dark container away from light*.

1 + 2 = 3 marks

Question 9 (7 marks)

a. The structure is of amylopectin, a form of starch. It has α–glucose particles as the building blocks.* They are connected by glycosidic bonds. Every 20-24th glucose particle, there is a crosslink, also a glycosidic covalent bond*. (These are 1,6 linkages). The molecule is slightly soluble in water as it does not pack together as tightly as amylose or cellulose.* It is digested by humans through the use of enzymes. Higher GI than amylose. *

4 marks

b. amylase and maltase

2 marks

c. Amylopectin will hydrolyse fairly readily, releasing glucose quickly. It is the quick release of glucose that makes it high GI.

1 mark

Question 10 (9 marks)

a. $CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$ 1 mark

b. 4 marks: 1 mark for each box of the table

Issue	Why is it a problem?
The volumetric flask has not been used properly. It should be made up to the mark and not have 20 mL added to 230 mL.	20 mL added to 230 mL of water will not necessarily give 250 mL. Some liquids are miscible in each other. All concentration calculations will be subsequently affected.
Methyl red is not an appropriate indicator for a weak acid/ strong base titration.	The endpoint will occur earlier than it should, leading to a low result for the ethanoic acid calculation.

c. Run 1 titre is omitted as it is not concordant. Mean titre from other runs is 22.0 mL. *

$n(NaOH) = 0.15 \times 0.022 = 0.0033$ mol

$n(CH_3COOH) = 0.0033$ mol *

$c(\text{diluted}) = \frac{0.0033}{0.02} = 0.165$ M *

$c(\text{ethanoic acid}) = \frac{0.165 \times 250}{20} = 2.06$ M * 4 marks