CHEMISTRY

Units 3 & 4 – Written examination

2014 Trial Examination

SOLUTIONS

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

Question 1

Answer: D

Explanation:

The half equation for the reaction is $Al^{3+} + 3e \rightarrow Al$. Therefore the number of electrons is three times the number of aluminium atoms. $3 \times 0.12 = 0.36$

Question 2

Answer: B

Explanation:

In all redox cells oxidation occurs at the anode. In the case of electrolysis the anode is positive.

Question 3

Answer: C

Explanation:

The diagram shows magnesium being oxidized to magnesium ions and sulfur being reduced. From the electrochemical series this could occur as a spontaneous galvanic cell.

Question 4

Answer: C

Explanation:

Aluminium will not deposit from an aqueous solution hence C is correct.
Ag^{+} will have the same number of mole as the electrons.
Cu^{2+} will have half the number of mole of the electrons.

Question 5

Answer: C

Explanation:

In this cell, Cl_2 will react with Mn(s). Cl_2 forming Cl^{-} is a reduction reaction, hence will occur at the cathode. Mn(s) reaction is an oxidation reaction and it will occur at the anode.

Question 6

Answer: B

Explanation:

$2SO_2 + 2e \rightarrow S_2O_4^{2-}$ is a balanced reduction reaction. Reduction occurs at the cathode.

Question 7

Answer: D

Explanation:

In SO_2, the sulfur is +4. In $S_2O_4^{2-}$, the charge on sulfur is +3

Question 8

Answer: A

Explanation:

Bioethanol can be produced from renewable plant matter at a sustainable rate. All other options are non-renewable.

Question 9

Answer: C

Explanation:

The highest pH refers to the weakest acid. From the Data Book, the weakest acid listed is hypobromous acid.

Question 10

Answer: A

Explanation:

At both temperatures, there are some reactants with enough energy to overcome the activation energy. The graph at 100 ^{o}C however, is higher than the graph of 50 ^{o}C at the activation energy. This means there are more particles at 100 ^{o}C with sufficient energy to react.

Question 11

Answer: D

Explanation:

To obtain the reaction $H_2O(g) \rightarrow H_2O(s)$ the first equation supplied needs to be reversed and then the two equations added together;

$H_2O(l) \rightarrow H_2O(s) \quad \Delta H = -6.0 \text{ kJ mol}^{-1}$
$H_2O(g) \rightarrow H_2O(l) \quad \Delta H = -44.0 \text{ kJ mol}^{-1}$

ΔH will therefore be $-6 + -44 = -50 \text{ kJ mol}^{-1}$

Question 12

Answer: A

Explanation:

Compared to the first equation, the second has been reversed then doubled. This leads to K being the reciprocal of the first value and then squared.

$K = \frac{1}{24.2^2} = 0.00171$

Question 13

Answer: C

Explanation:

In pure water, the $[H_3O^+] = [OH^-] = 10^{-6.8}$
$pH = -\log 10^{-6.8} = 6.8$

Question 14

Answer: A

Explanation:

The pH curve is of the reaction between a weak base and a strong acid, which would have an equivalence point occurring below pH of 7. Sodium carbonate and nitric acid are the only examples of weak base and strong acid on the list of alternatives.

Question 15

Answer: D

Explanation:

The question is answered by looking up each hydrogen atoms shift in the data book. The alkanes have a low shift and carboxylic acids have very high shifts.

Question 16

Answer: A

Explanation:

The graph shows two reactants and one product. The product concentration grows at the same rate one of the reactants is used up, so they must share the same coefficient in the reaction (2NO $2NO_2$). The other reactant drops at half the rate of the first, so its coefficient must be half of the other reactant (2NO + O_2)

$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$

Question 17

Answer: D

Explanation:

In reactions involving weak bases the concentration of water is so much greater than any other species that it is assumed to be a constant (of the order of 55 M). After water, benzoic acid would be the next in terms of concentration as weak acids do not donate a high percentage of protons.

Question 18

Answer: B

Explanation:

The base shown is thymine. Thymine has hydrogen bonding at two sites and these will be 2 and 3.

Question 19

Answer: D

Explanation:

Glucose has a molecular formula of $C_6H_{12}O_6$ as does fructose. Ethanoic acid is $C_2H_4O_2$. The empirical formula of these three molecules is CH_2O.

Question 20

Answer: D

Explanation:

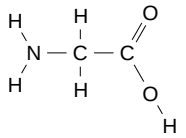
The alkanol section of this molecule is ethanol and the acid section is methanoic acid, hence the ester is ethyl methanoate.

Question 21

Answer: C

Explanation:

Glycine has an amine group and a carboxyl group. The carboxyl group can react with a base and the amine group can react with an acid.



Question 22

Answer: A

Explanation:

Use of the Data Book shows the three amino acids as leucine, glycine and serine

Question 23

Answer: C

Explanation:

Option C is the formation of an ester through a condensation reaction. This does not involve any changes in oxidation states.

Question 24

Answer: B

Explanation:

The spectrum is of ethanol. The absorption trough at 3300 cm^{-1} indicates the presence of an – O – H group for al alcohol. The absence of a peak around 1750cm^{-1} also rules out ethanoic acid.

Question 25

Answer: C

Explanation:

n(HCl start) = 0.2 x 1 = 0.2 mol
n(HCl after reaction) = 0.1 mol
c = $\frac{n}{V} = \frac{0.1}{0.3}$ = 0.33 M => pH = -log 0.33 = 0.48

Question 26

Answer: A

Explanation:

Benzoic acid is a weak acid, therefore the solution will be acidic. The pH however will be greater than 2.8 so the indicator will be yellow in colour (see Data Book). (if the pH is calculated using the K_a value, the pH for this ionisation is 3.1).

Question 27

Answer: D

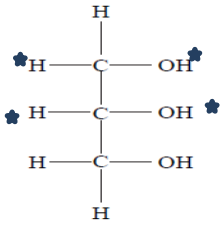
Explanation:

A monounsaturated molecule has one double bond. Its formula is evident as $C_nH_{2n-2}O_2$

Question 28

Answer: B

Explanation:
Glycerol has 4 different environments, marked with an *



Question 29

Answer: C

Explanation:

n(Ca) = $\frac{8}{40.1} = 0.1995$ mol

n(HCl) = 2n(Ca) = 0.399 mol

$c = \frac{n}{V} = \frac{0.399}{0.4} = 1.0\ M$

Question 30

Answer: B

Explanation:

n(C)=$\frac{2}{12} = 0.166$

n(H) = 10/4 n(C) = 10 x 0.166/4 = 0.417

mass = 0.417 g

SECTION B : Short-answer questions

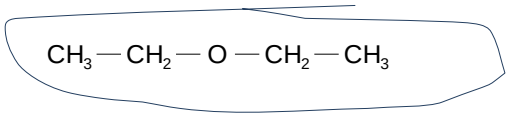
Question 1 (10 marks)

a. **i** Example: glucose sucrose starch
1 mark

ii. Molecular formula: $C_6H_{12}O_6$ * : $C_{12}H_{22}O_{11}$ *
2 marks

iii. Structural isomer : fructose/galactose 1 mark

b. 1 mark



c. **i**. pepsin is close to its optimum reaction rate* while trypsin does not function at this pH*
2 marks

ii. The tertiary and secondary structures of the enzyme are destroyed. The enzyme loses its particular 3-D shape. Its primary structure however, is still intact.
1 mark

iii. The mass of the individual amino acids will be greater than the mass of the protein.* When hydrolysis occurs, water is added back onto the molecules. 19999 water molecules would be needed to allow hydrolysis * 2 marks

Question 2 (10 marks)

a. **i**. $SO_2(g) + 2H_2O(l) \rightarrow 4H^+(aq) + 2e + SO_4^{2-}(aq)$ 1 mark

ii. $I_2(aq) + 2e \rightarrow 2I^-(aq)$ 1 mark

b. +4 to + 6
1 mark

c. **i**. $n(I_2) = c \times V = 0.0062 \times 0.0132 = 8.18 \times 10^{-5}$ mol *
$n(SO_2) = n(I_2) = 8.18 \times 10^{-5}$

$c = \frac{8.18 \times 10-5}{0.02} = 0.00409$ M *

2 marks

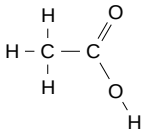
ii. 0.00409 mol per litre = 0.00409 x 64 = 0.262 g L^{-1} = 262 mg L^{-1}

1 mark

c. $CH_3CH_2OH(aq) + H_2O(l) \rightarrow CH_3COOH(aq) + 4e + 4H^+(aq)$ 1 mark

d. 1 mark

i. 2



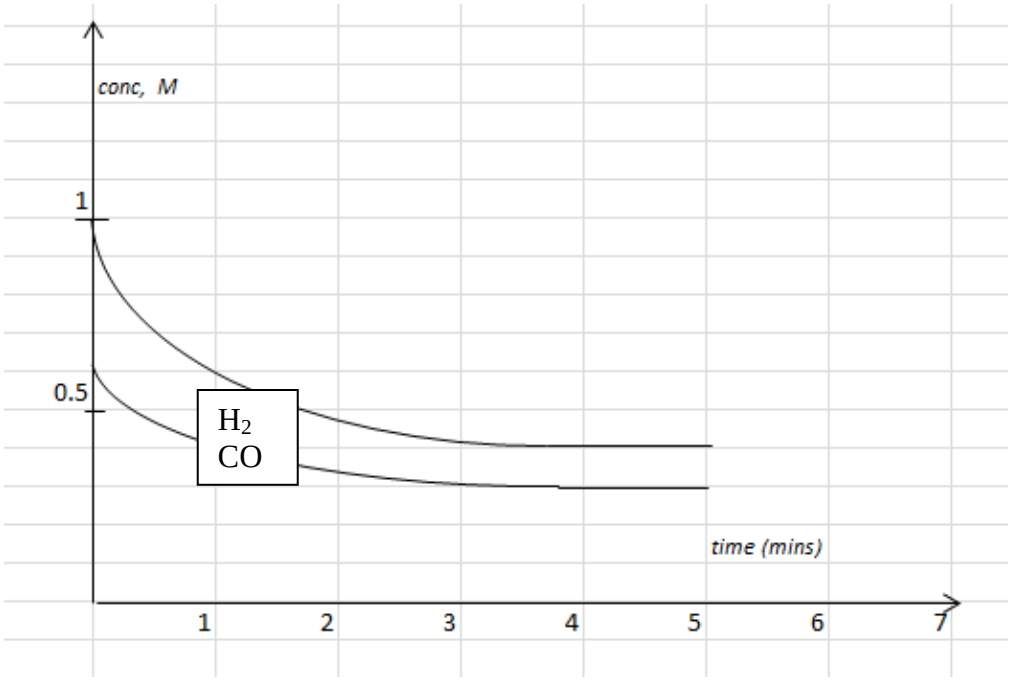
ii. Splitting does not occur if hydrogen is attached to an oxygen atom. The other hydrogen atoms in the methyl group do not have any hydrogen atom neighbours. 1 mark

iii. The carboxyl group hydrogen atom has a very large shift of about 11 ppm.

1 mark

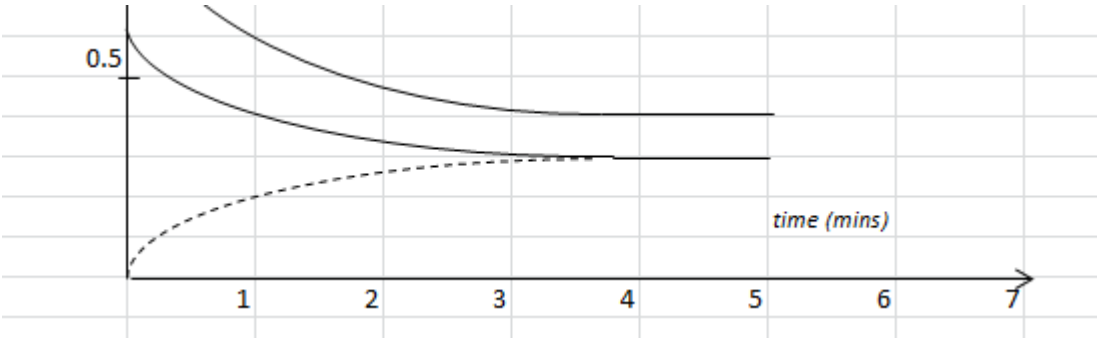
Question 3 (10 marks)

a.



i. See graph: H_2 drops at twice the rate of CO from balanced equation ** 2 marks

ii. Methanol starts at zero and rises at the same rate CO drops – dashed line below



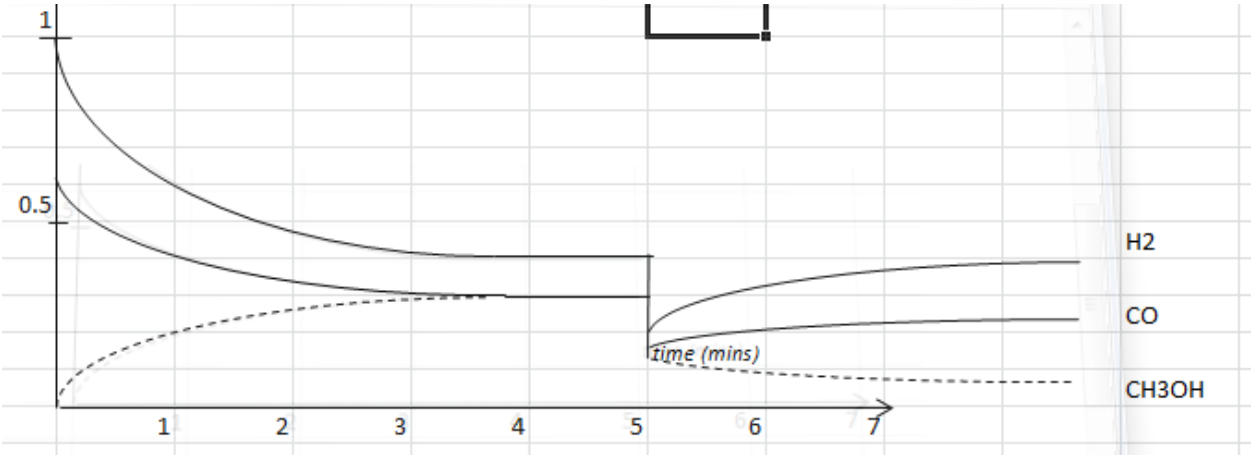
1 mark

b. **i.** $K = \frac{[CH3OH]}{[CO][H2]^2}$ * 2 marks

$= \frac{0.3}{0.3\ x 0.4^2} = 6.25\ M^{-2}$ *

ii. $c = 0.3$ => $n = c\ x\ V = 0.3$ x 2 = 0.6 mol 1 mark

c. **i.** each concentration is halved. Keep in mind that the concentration drop is not the same for each chemical – the graph should show the values halving. 2 marks



ii. system will move to the left, creating more particles*. The concentration of carbon monoxide and hydrogen will increase* 2 marks

Question 4 (6 marks)

a. **i**. methyl propanoate 1 mark

ii. C_2H_4O 1 mark

b. **i**. $C_4H_8O_2(l) + H_2O(l) \rightarrow CH_4O(aq) + C_3H_6O_2(aq)$ 1 mark

ii. $2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$

1 mark

iii. ΔH for methanol is -725 kJ mol^{-1} *
ΔH per g = 725/32 = 22.7 kJ g^{-1} *

2 marks

Question 5 (7 marks)

a. Cell contents: KCl(aq) * 3 marks

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

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

b. Metal will be deposited in the $CuCl_2$ solution. *
$Q = It$ = 2.55 x 20 x 60 = 3060 C *

$n(e) = \frac{3060}{96500} = 0.0317\ mol$ *
$n(Cu)$ = ½ $n(e)$ = 0.0159 mol

mass = 0.0159 x 63.5 = 1.00 g *

4 marks

Question 6 (9 marks)

a. **i**. $Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$ 1 mark

ii. As this cell discharges the sulfuric acid reacts. Therefore the pH will rise as the cell discharges. 1 mark

iii. A secondary cell can be recharged but a primary cell is disposed of once flat.

1 mark

iv. Lead is very heavy hence the vehicle is heavy*. Lead is neither abundant nor completely safe to handle.*

2 marks

b. $PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e$ 1 mark

c. **i**. anode: $Na \rightarrow Na^+ + e$
cathode: $3S + 2e \rightarrow S_3^{2-}$

2 marks

ii. Sodium reacts very vigorously with water, especially at 300 ^{0}C.

1 mark

Question 7 (12 marks)

a. **i**. Mass of chlorine = 3.6 – 1.65 – 0.322 = 1.628 g 1 mark

ii. $\frac{1.65}{12} : \frac{0.322}{1} : \frac{1.628}{35.5}$ = 0.138:0.322:0.0459 * = 3:7:1 $=C_3H_7Cl$ 2 marks

b. **i**. Chlorine has two isotopes, ^{35}Cl and ^{37}Cl. There is a peak present for each isotope.

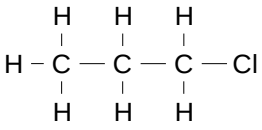
1 mark

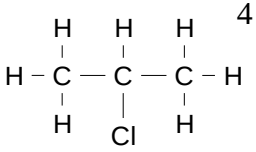
ii. 63 is 15 less than 78. This is probably the removal of a methyl group, CH_3.

1 mark

iii. Molecular formula of the compound matches empirical formula C_3H_7Cl 1 mark

c. 4 marks

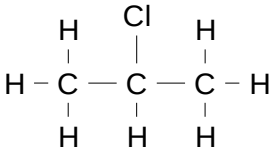




Isomer 1: 1-chloropropane** Isomer 2: 2-chloropropane**

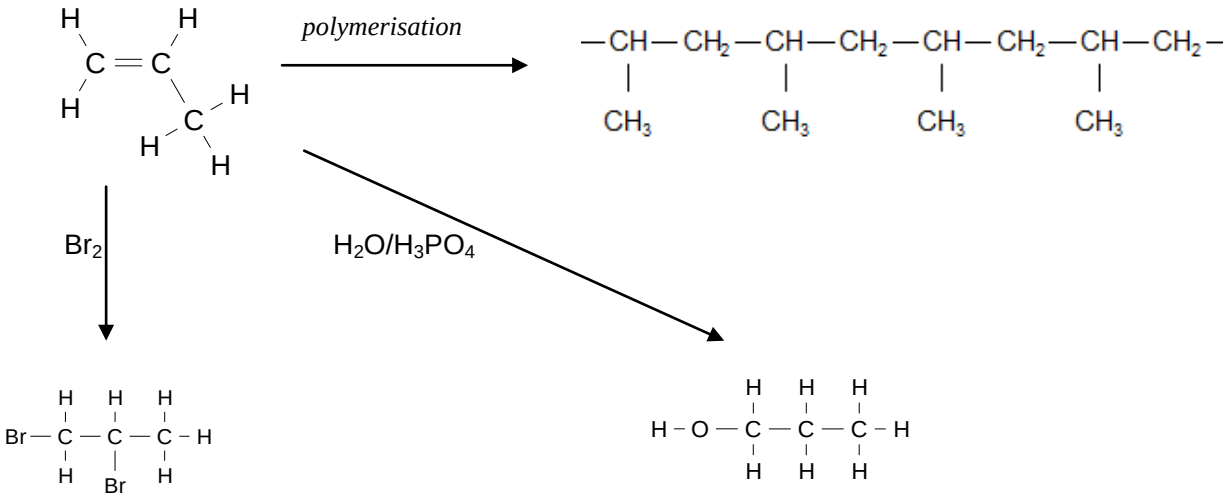
d. molecule is 2-chloropropane* as it has two different hydrogen environments. One environment is shown on the spectra as a doublet (one H neighbour) and the other as a septet (six H neighbours).*.

2 marks



Question 8 (9 marks)

a.



i. Propene is a hydrocarbon. It has no significant dipoles to lead to any polarity. It is non- polar, hence low in solubility in water . 1 mark

ii. Again, the lack of dipoles means that the forces between molecules are dispersion forces only. They are weak and the boiling point is low. 1 mark

b. See diagram 1 mark

c. **i**. See diagram 1 mark

ii. A 'bromine test' is a test for whether a molecule is saturated or not*. Bromine is brown in colour. If a double or triple bond is present, it will react and the brown colour disappears.* 2 marks

d. **i**. See diagram. (could also be 2-propanol)

ii. Several possible answers. Molecule B will react with dichromate to form a carboxylic acid. Molecule B will have an absorption band around 3200 cm^{-1} where the -O –H absorbs. (1 mark method, 1 mark why method works)

2 marks

Question 9 (7 marks)

a. HMe and Me^- have different colours, therefore the position of equilibrium can be monitored by the colour. 1 mark

b. $[H_3O^+]$ is increased*. This favours the back reaction and produces the red colour*. 2 marks

c. The OH^- reacts with H_3O^+. This lowers the $[H_3O^+]$*. This favours the forward reaction and produces the orange colour.* 2 marks

d. $K_a = \frac{[H3O+][Me-]}{[HMe]} = 2 \times 10^{-4}$ * 2 marks

Since [HMe] = [Me^-] at transition, $K_a = 2 \times 10^{-4}$

pH = $-\log(2 \times 10^{-4}) = 3.7$ *

Question 10 (7 marks)

a. **i.** *n*(ethanol) = $\frac{1.5}{46} = 0.0326\ mol$ * 2 marks

$E = 1364 \times 0.0326 = 44.5$ kJ *

ii. CF = $\frac{energy}{\Delta T} = \frac{44.5}{8.9} = 5.00$ kJ $^0C^{-1}$ 1 mark

b. $E = CF \times \Delta T = 5 \times 0.87 = 4.35$ kJ *

n(Na) = $\frac{0.145}{23} = 0.00630$ mol *

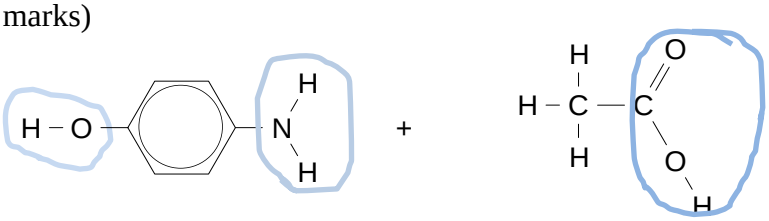
Energy/mole = $\frac{4.35}{0.00630} = 690$ kJ mol^{-1}

$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$ *

$\Delta H = -1380$ kJ mol^{-1} *

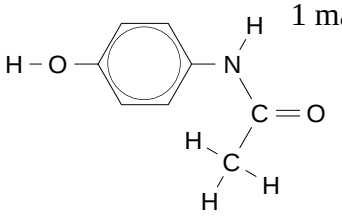
4 marks

Question 11 (6 marks)



a. In order: hydroxyl, amine and carboxyl 3 marks

b. i. 1 mark



ii. What other molecule is formed when paracetamol is formed? Water 1 mark

iii. Benzene: molecular formula is C_6H_6 1 mark