CHEMISTRY

Written examination

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2015 Trial Examination

SOLUTIONS

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

Question 1

Answer: A

Explanation:

The answer comes from a combination of $PV=nRT$ and $n = \frac{m}{M}$

⇨ $\frac{m}{M} = \frac{PV}{RT}$

⇨ $m = \frac{PVM}{RT}$

Question 2

Answer: D

Explanation:

Each answer has to be tested to see which has the greater number of mole;
A: n = 44.8/36.5 < 2 mol
B: $n = c \times V$ = 1.2 x 1 = 1.2 mol
C: $n = c \times V$ = 0.5 x 2 = 1.0 mol
D: $n = V/22.4$ = 44.8/22.4 = 2 mol

Question 3

Answer: C

Explanation:

With a non-polar solvent, a non-polar component will travel through the column very quickly. The non-polar components will dissolve in the solvent and spend little time on the stationary phase. Component A is the first to emerge from the column so it will be the most non-polar component.

Question 4

Answer: C

Explanation:

Component A moves well in this solvent, as both are non-polar. Therefore it will have the highest R_f value of the three components.

Question 5

Answer: A

Explanation:

An absorbance of 0.51 corresponds to a concentration of 6 mg L^{-1}. Since the sample is a 100 mL one, not 1000 mL, the mass will be 0.6 mg.

$0.6 \text{ mg} = 6 \times 10^{-4} \text{ g}$

Question 6

Answer: B

Explanation:

Atomic absorption spectroscopy measures the radiation absorbed by a sample. A sample will absorb energy when electrons are excited from the ground state. (Be aware that atomic absorption is not caused by electrons returning from the excited state).

Question 7

Answer: B

Explanation:

The number of mole of carbon has to be used for this calculation as it is the scarce reagent in this reaction.
$n(\text{Al}) = \frac{4}{3} \times 0.72 = 0.96$ mol

Question 8

Answer: D

Explanation:

$n(\text{C}) = \frac{36}{12} = 3mol = n(CO_2)$

$V = n \times 24.5 = 73.5$ L

Question 9

Answer: A

Explanation:

Phosphoric acid is triprotic so will only need one third the volume of NaOH, which is 6.66 mL. Both hydrochloric acid and ethanoic acid are monoprotic so will require the same volume as NaOH. It is not relevant in a titration that ethanoic acid is a weak acid.

Question 10

Answer: D

Explanation:

Mass carbon in 1 tonne of brown coal = $1000000 \times \frac{24}{100} = 240000$ g
$n(\text{C}) = \frac{240000}{12} = 20000$ mol
$n(CO_2)$ formed = $n(\text{C}) = 20000$ mol
$mass(CO_2) = 20000 \times 44 = 880000$ g

Question 11

Answer: B

Explanation:

n(NaOH) = $c \times V$ = 0.01× 0.1 =0.001 mol
n(HCl) = $c \times V$ = 0.01× 0.3 =0.003 mol
n(HCl remaining) = 0.002 mol in 20 mL

$c(\text{HCl}) = \frac{0.002}{0.02} = 0.1$ M

pH = 1

Question 12

Answer: C

Explanation:

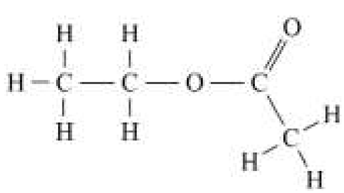
The correct half equation for this reaction will be:
$CH_3CH_2OH(aq) + H_2O(l) \rightarrow CH_3COOH(aq) + 4H^+(aq) + 4e^-$

The other half equations are all correctly balanced.

Question 13

Answer: D

Explanation:



Ethyl ethanoate is shown – it has four carbon atoms and each has a unique environment. There are three different hydrogen environments.

Question 14

Answer: C

Explanation:

Fatty acids have two oxygen atoms so the molecular formula is probably $C_{18}H_{32}O_2$. A saturated fatty acid will have the formula $C_nH_{2n+1}COOH$. In this case, the fatty acid would have 36 hydrogen atoms if it was saturated. As it has 4 less than that it must have two carbon to carbon double bonds.

Question 15

Answer: B

Explanation:

When the volume is decreased, the green intensity increases. The volume decrease favours the forward reaction, as there are less product molecules than reactants. This will reduce the green intensity but the net change in green intensity is still an increase over the original value.

Question 16

Answer: D

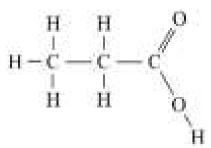
Explanation:

The temperature is increased and the amount of chlorine increases. As chlorine is a reactant then the temperature increase has led to a drop in the value of K. This is consistent with an exothermic reaction.

Question 17

Answer: C

Explanation:

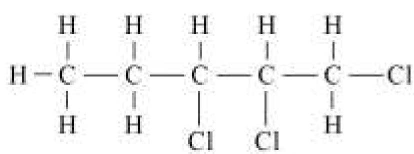


Like ethanoic acid, propanoic acid can be formed from the oxidation of the equivalent alkanol, in this case propan-1-ol. None of the other options are correct.

Question 18

Answer: A

Explanation:



Numbering should start from the right hand end. This will give 1,2,3- trichloropentane making A the correct answer.

Question 19

Answer: B

Explanation:

The molecule shown is the base cytosine. It forms three hydrogen bonds and these are at the sites 2, 3 and 4.

Question 20

Answer: D

Explanation:

The molecule shown contains a carboxyl group on the right hand end and an amine and amide group close to each other in the middle. It does not contain an ester or a hydroxyl group.

Question 21

Answer: A

Explanation:

When a reaction is reversed, the sign of the value of ΔH changes (it becomes positive) and the numerical value of K becomes the reciprocal of the original value (1/5.6 = 0.18).

Question 22

Answer: A

Explanation:

Commercial production of electricity from nuclear sources involves nuclear fission. In nuclear fission, large nuclei are split, releasing neutrons that can further split more nuclei. Large amounts of energy are released as thermal energy in this process.

Question 23

Answer: D

Explanation:

n(ethanol) = $\frac{0.46}{46}$ = 0.01 mol

energy released (from Data Book) = $0.01 \times 1364 = 13.64$ kJ = 1.36×10^4 Joule

Question 24

Answer: B

Explanation:

$E = shc \times mass \times \Delta T$ where shc = specific heat capacity

$750 = x \times 80 \times 3.9$

$x = 750/312 = 2.40$

Question 25

Answer: B

Explanation:

The relevant half-equations are

$I_2(s) + 2e^- \rightarrow 2I^-(aq)$
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$

Iodine will react with zinc metal. The zinc will be oxidised to zinc ions at the anode which is the negative electrode.

Question 26

Answer: A

Explanation:

The question states that the cell is using an alkaline electrolyte, so OH^- ions will be present and not H^+ ions. The carbon in methane will form carbon dioxide, meaning the balanced half equation will be :

$CH_4(g) + 8OH^-(aq) \rightarrow CO_2(g) + 6H_2O(g) + 8e^-$

This is oxidation, which will occur at the anode.

Question 27

Answer: D

Explanation:

Methane is produced from biomass from the action of anaerobic bacteria. Biomass can be obtained from sewerage, food scraps and other organic waste. Fermentation is not a correct answer as it produces ethanol. Coal as a fuel is not a sustainable resource.

Question 28

Answer: D

Explanation:

This is electrolysis of an aqueous solution so the relevant half equations are;

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow \underline{2H_2O(l)}$
$\underline{Ag^+}(aq) + e^- \rightarrow Ag(s)$
$\underline{2H_2O(l)} + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

The strongest oxidant, Ag^+, will react with the strongest reductant, $H_2O(l)$
The silver ions are reduced and water is oxidised to oxygen gas at the anode.
Therefore oxygen gas is produced at the positive electrode.

Question 29

Answer: C

Explanation:

Using the working from question 28, silver metal is produced in a reduction reaction, which will occur at the negative cathode.

Question 30

Answer: D

Explanation:

$Q = It = 8.4 \times 12 \times 60 = 6048$ C

$n(e) = \frac{6048}{96500} = 0.0627$ mol $= n(Ag)$

$mass(Ag) = n \times M = 0.0627 \times 107.9 = 6.77$ g

SECTION B : Short-answer questions

Question 1 (9 marks)

a. **i**. To increase the reaction rate by liberating tartaric acid from grapes 1 mark

ii. Several possible answers but main one is the assumption that tartaric acid is the only acid present at significant levels. 1 mark

b. **i**. $H_2Ta(aq) + 2NaOH(aq) \rightarrow Na_2Ta(aq) + 2H_2O(l)$ 1 mark

ii. $2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$ 1 mark

c. **i**. $n(H_2SO_4) = c \times V = 0.12 \times 0.0146 = 0.00175$ mol 1 mark

ii. n(NaOH start) = $c \times V = 0.1 \times 0.04 = 0.00400$ mol 1 mark

iii. n(NaOH left over) = $2\, n(H_2SO_4) = 2 \times 0.00175 = 0.00350$ mol 2 marks

n(NaOH reacting with tartaric acid) = 0.004 – 0.00350 = 0.000496 mol*

n(tartaric acid) = ½ n(NaOH) = ½ × 0.000496 = 0.000248 mol

$mass = n \times M$ =0.000248 × 150 = 0.0372 g *

iv. % mass tartaric acid = $\frac{0.0372 \; x \; 100}{2.60}$ = 1.43 % 1 mark

Question 2 (4 marks)

a. What is the oxidation number of nitrogen in; 2 marks

- NO_3^- +5 (x + -6) = -1 => x = +5
- NH_4^+? -3 (x + 4) = +1 => x = -3

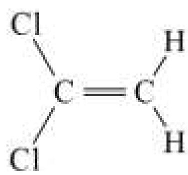
b. $NO_3^-(aq) + 10H^+(aq) + 8e^- \rightarrow NH_4^+(aq) + 3H_2O(l)$ 1 mark

c. $NH_4^+(aq) + H_2O(l) \rightleftarrows NH_3(aq) + H_3O^+(aq)$ 1 mark

Question 3 (11 marks)

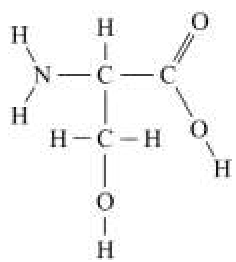
a.

i. 1 mark



ii. 1,1-dichloroethene 1 mark

b. **i**. 2 marks



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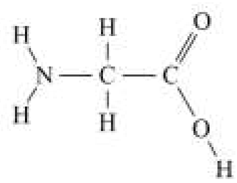

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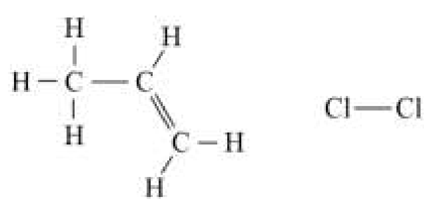
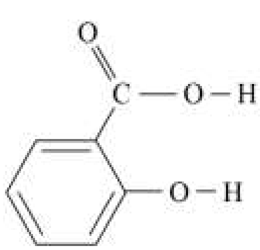
ii. Molecule A: serine * Molecule B: glycine * 2 marks

c. **i**. 2 marks



ii. Addition. 1 mark

d. 2 marks



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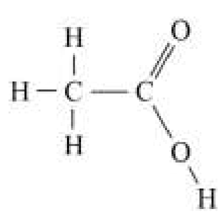

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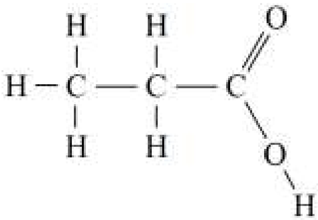
Question 4 (11 marks)

a. 1 mark



b. **i**. $C_3H_6O_2 + e^- \rightarrow C_3H_6O_2^+ + 2e^-$ 1 mark

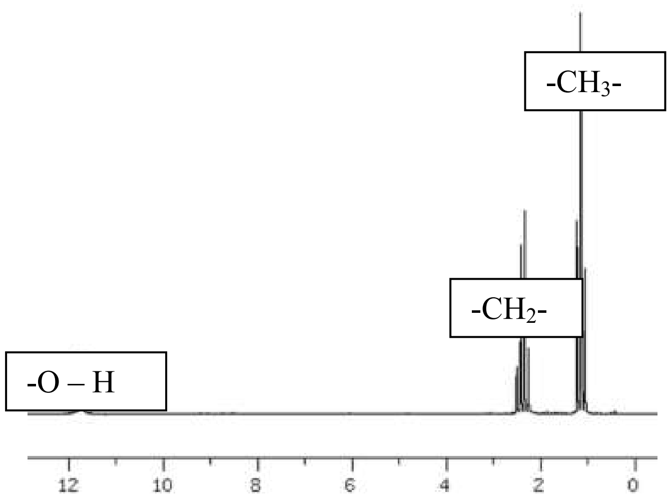
ii. Perhaps $COOH^+$ 1 mark

c. 2 marks

- Peak at 2500-3300 cm^{-1} O – H (acid)
- Peak at 1680-1750 cm^{-1} C = O

d. **i**.

3 marks



ii. 2.4 ppm quartet as group is beside – CH_3 n + 1 rule gives quartet 2 marks

1.1 ppm triplet as group is beside -CH_2 n+1 rule gives triplet

iii. 1:2:3 (from left to right) 1 mark

Question 5 (9 marks)

a. **i**. Glucose will be soluble due to the presence of so many O – H bonds. These bonds are highly polar and will lead to hydrogen bonds forming between water and glucose.

1 mark

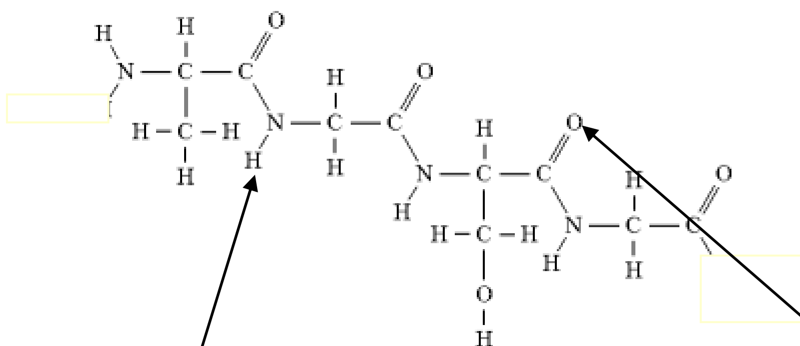
ii. Ether or glycosidic. 1 mark

iii. One of starch, cellulose or glycogen. 1 mark

iv. $C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$ 1 mark

v. $C_6H_{12}O_6(aq) \rightarrow 2C_2H_6O(aq) + 2CO_2(g)$ 1 mark

b.



i. The secondary structure is the result of hydrogen bonding between one part of the chain and another part.* The hydrogen bonds form as a result of dipoles between positive charges on hydrogen atoms attached to nitrogen atoms and negative charges on oxygen atoms attached to carbon atoms.*

2 marks

ii. The difference in the amino acids is the -R group. In glycine and alanine, the R group is an alkyl group that is non-polar and low in solubility*. In serine, a significant dipole exists, so the solubility in water will be higher*.

2 marks

Question 6 (10 marks)

a. **i.** 1 mark

$K = \frac{[CO_2][H2]^4}{[CH4][H2O]^2}$

ii.

	$CH_4(g)$	+ $2H_2O(g)$	⇄ $CO_2(g)$	+ $4H_2(g)$
Initial	1	1.4	0	0
Equilibrium	1-0.22 0.78 *	1.4 – 0.44 0.96*	0.22	0.88* (as 4 times CO_2)

3 marks

iii. $K = \frac{(0.22)(0.88^4)}{(0.78)(0.96^2)}$ * $= \frac{0.132}{0.719}$ $= 0.18\ M^2$ * 2 marks

b. Answer True or False to each of the following. 4 marks

Statement	True or False
If 4 mol of methane is added to steam in a reactor and the amount of methane changes to 3 mol over time, the amount of carbon dioxide formed will be 1 mol.	True (1 mol of methane will form 1 mol CO_2)
1 mol of carbon dioxide and 1 mol of hydrogen gas are added to an empty reactor. No reaction will occur as they are both products.	False (It is a reversible reaction)
1 mol of methane is added to 10 mol of steam in an empty reactor. When equilibrium is reached the methane will be all gone as it is very much the scarce reagent.	False (In a reversible reaction, some reactant will remain)
If 4 mol of methane and 8 mol of steam are added to an empty reactor, 4 mol of carbon dioxide will form.	False (not all the methane will react)

Question 7 (11 marks)

a. **i.** pH =1 for HCl 1 mark

ii. $Ka = \frac{[H3O+][F-]}{[HF]}$ => $7.6 \times 10^{-4} = \frac{X \times X}{0.1}$ *

$X = \sqrt{(0.1 \times 7.6 \times 10^{-4})} = 0.0087$ *

$pH = -\log 0.0087 = 2.1$ *

3 marks

iii. NH_4^+ 3 marks

$Ka = \frac{[H3O+][NH3]}{[NH4+]}$ => $5.6 \times 10^{-10} = \frac{X \times X}{0.1}$ *

$X = \sqrt{(0.1 \times 5.6 \times 10^{-10})} = 0.0000075$ *

pH = -log0.0000075 = 5.1 *

b. **i**. $[H_3O^+] = 10^{-6.8} = 1.6 \times 10^{-7}$M
1 mark

ii. $K_w = 10^{-6.8} \times 10^{-6.8} = 10^{-13.6} = 2.5 \times 10^{-14}$M
1 mark

iii. $H_2O(l) + H_2O(l) \rightleftarrows H_3O^+(aq) + OH^-(aq)$ 1 mark

iv. The self-ionisation must be endothermic. An increase in temperature led to an increase in K_w, which is consistent with an endothermic reaction. 1 mark

Question 8 (8 marks)

a. **i**. The value of ΔT will be lower than that of a well insulated calorimeter. 1 mark

ii. The calibration factor will be higher than that of a well-insulated calorimeter. 1 mark

b. **i**. $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$ 1 mark

ii. The number of mole of HCl must be used as it is the limiting reagent in this experiment.
1 mark

c. **i**. The value of ΔT will be lower than it should be as more water is being heated. 1 mark

ii. the value of ΔH will be lower than it should be as a result of the low ΔT 1 mark

d. $n(\text{ethanol}) = \frac{0.552}{46} = 0.012$ mol

$E = n \times 1364 = 0.012 \times 1364 = 16.368$ kJ = 16368 J *

$\Delta T = E/CF = 16368/684 = 23.9\ ^0C$ * 2 marks

Question 9 (8 marks)

a. V^{3+}, V^{2+}, V^{5+} (in VO_2^+), V^{4+} (in VO^{2+}) ½ mark each 2 marks

b. i. $VO_2^+(aq) + 2H^+(aq) + V^{2+}(aq) \rightarrow VO^{2+}(aq) + V^{3+}(aq) + H_2O(l)$ 1 mark

ii. 1.26 V 1 mark

iii. The left hand side is the negative electrode and the right hand side the positive 1 mark

c. **i**. $VO^{2+}(aq) + V^{3+}(aq) + H_2O(l) \rightarrow VO_2^+(aq) + 2H^+(aq) + V^{2+}(aq)$ 1 mark

ii. Voltage must be greater than 1.26 V for recharging to occur. 1 mark

iii. A secondary cell is a cell that can be recharged. A power supply can be applied that reverses the discharge equation, reforming the reactants. 1 mark

Question 10 (9 marks)

a. Cell A: Molten KCl 2 marks

- the cathode: $K^+(l) + e^- \rightarrow K(l)$
- the anode: $2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$

b. Cell B: Dilute KCl solution 2 marks

- the cathode: $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$
- the anode: $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

c. Cell C: 4.0 M KCl solution 2 marks

i.

- the cathode: $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$
- the anode: $2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$

ii. $Q = It = 3.4 \times 25 \times 60 = 5100$ C* 3 marks

$n(\text{e}) = \frac{5100}{96500} = 0.0528$ mol

$n(H_2) = ½\ n(e^-) = 0.0528 \times 0.5 = 0.0264$ mol*

$volume(\text{ H}_2) = \frac{nRT}{P} = \frac{0.0264 \times 8.31 \times 297}{105} = 0.62 \text{ L}$

Question 11 (4 marks)

$n(SO_2) = \frac{3.700}{64.1} = 0.0577$ mol *

$n(S) = n(SO_2) = 0.0577$ mol

mass (sulphur in compound) = 0.0577 × 32.1 = 1.853 g

mass (iron in compound) = 4.000 – 1.853 = 2.147 g *

empirical formula = $\frac{2.147}{55.8} : \frac{1.853}{32.1}$ = 0.0384 : 0.0577 * = 1:1.5 = 2:3

Empirical formula is Fe_2S_3 *