UNIT 3 CHEMISTRY 2006
WRITTEN EXAMINATION 1 - SOLUTIONS

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SECTION A – MULTIPLE CHOICE QUESTIONS

QUESTION 1 Answer is A

$$n(H_3PO_4) = \frac{m}{M} = \frac{5.00}{97.934} = 0.05105\ mol$$

One molecule of H_3PO_4 will form 4 ions: 3 of H^+ and 1 of PO_4^{3-}.

$$Number\ Ions = 6.023\times10^{23}\times0.051034\times4$$

QUESTION 2 Answer is C

Never add concentrations (only mole and particle numbers may be added). To find the concentration of the new solution, students need to calculate the total number of mole of nitrate ions and then divide by the new volume.

For KOH: $n(NO_3^-) = n(KOH) = cV = 1.00\times0.100 = 0.100\ mol$

For $Ca(NO_3)$: $n(NO_3^-) = 2\times n(Ca(NO_3)_2) = 2\times cV = 2\times1.00\times0.100 = 0.200\ mol$

$$n(NO_3^-)_{Total} = 0.100 + 0.200 = 0.300\ mol$$

$$c = \frac{n}{V} = \frac{0.300}{0.200} = 1.50\ M$$

QUESTION 3 Answer is B

A Oxidation number of oxygen in $Cr_2O_7^{2-}$ is -2.
B Oxidation number of oxygen in HOF is 0.
C Oxidation number of oxygen in H_2SO_4 is -2.
D Oxidation number of oxygen in H_2O_2 is -1.

QUESTION 4 Answer is D

QUESTION 5 Answer is B

QUESTION 6 Answer is C

Note: Lead sulfate, lead chloride and lead hydroxide are not soluble in water.

QUESTION 7 Answer is A

The pH at neutralisation depends upon the relative strengths of the acid and base. If the strengths are approximately equal, the pH at the equivalence point will be approximately 7. If the acid is of greater strength than the base, the pH at the equivalence point will be acidic.

As the pH at the equivalence point of the given titration is alkaline, the base must be of greater strength than the acid. The answer is therefore A.

QUESTION 8 Answer is C

Limiting Reactant is CO.

As the reaction is occurring at constant temperature and pressure, mole ratios may be used as volume ratios.

From mole ratios: $2\,vols\,CO \rightarrow 2\,vols\,CO_2$

$$\therefore 100\,cm^3\ CO \rightarrow 100\,cm^3\ CO_2$$

As only $50\,cm^3$ of O_2 are consumed during the reaction, there will be $50\,cm^3$ of O_2 remaining.

Final $V = 100 + 50 = 150\ cm^3$

QUESTION 9 Answer is C

$$\Delta H = H_P - H_R = -220 - (-390) = +170\ kJ / mol$$

QUESTION 10 Answer is C

$$E_A = H_f - H_i = -170 - -220 = 50\ kJ / mol$$

Note: Activation energies **must** always be positive (this is an energy requiring event).

QUESTION 11 Answer is D

Observe mole ratios and their impact on concentration changes!

QUESTION 12 Answer is B

As the concentrations all increased simultaneously, the volume of the container was decreased at the 5 minute mark.

As the value of K changed, the temperature was not held constant.

$$K = \frac{[SO_3]^2}{[O_2][SO_2]^2}$$

At 5 minutes: $K = \frac{(0.7)^2}{(1.4)(0.2)^2} = 8.75$

At 15 minutes: $K = \frac{(1.35)^2}{(1.46)(0.35)^2} = 10.2$

QUESTION 13 Answer is D

Both carboxylic acids and alcohols will dissociate in water to produce H^+.

The larger K_a value for ethanoic acid indicates that the position of equilibrium for the dissociation of ethanoic acid is further to the right than for ethanol. Therefore, ethanoic acid releases protons more readily and is more acidic than ethanol. Answer is B or D.

As more H^+ is produced, the solution becomes more acidic, hence the pH decreases. Therefore, the pH of ethanol will be higher than that of ethanoic acid. The answer is D.

QUESTION 14 Answer is A

$NaOH$ is a base and will hence react with H^+. Decreasing the concentration of H^+ will cause both equilibria to shift to the right. The amount of Br_2 will decrease and hence the colour of the solution will fade.

All other answers increase the concentration of one or more of the products, hence favouring a net back reaction, which will cause the colour of the solution to darken.

QUESTION 15 Answer is C

Separation is based on boiling points. The larger the molecule, the greater the net strength of dispersion forces that exist between molecules, therefore, the higher the boiling point.

QUESTION 16 Answer is A

As this reaction is an addition polymerisation reaction – monomers need to be unsaturated (an alkene).

QUESTION 17 Answer is B

QUESTION 18 Answer is D

H_2SO_4 exhibits acidic, oxidising and dehydrating properties.

QUESTION 19 Answer is A

QUESTION 20 Answer is A

Oxygen is used as a reactant in the first two stages (the burner and converter).

SECTION B – SHORT ANSWER QUESTIONS

QUESTION 1

a. (i) When the absorbance (i.e. concentration of iodine) stopped changing i.e. at 150 seconds. *(1 mark)*

(ii) At 150 minutes, absorbance is 0.1.
Read the corresponding concentration off the standard curve.
Concentration is 0.20 M when the system reaches equilibrium. *(1 mark)*

b. (i) $K_c = \dfrac{\left[C_6H_6O_{6(aq)}\right]\left[HI_{(aq)}\right]^2}{\left[C_6H_8O_{6(aq)}\right]\left[I_{2(aq)}\right]}\ M$

(ii) As equimolar amounts of vitamin C and iodine were initially added to the reaction mixture, upon mixing, the initial concentrations would be equal. Due to the stoichiometry of the reaction, the equilibrium concentrations would also be equal.

$\left[C_6H_8O_{6(aq)}\right] = \left[I_{2(aq)}\right] = 0.20\ M$

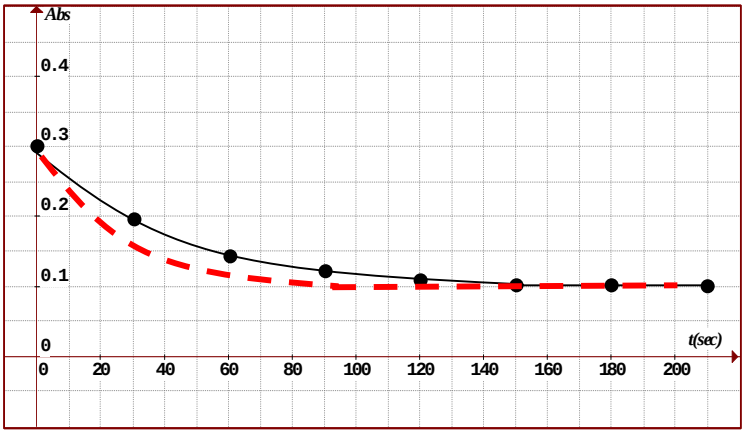
$$3.125 = \frac{\left[C_6H_6O_{6(aq)}\right]\left[HI_{(aq)}\right]^2}{0.20 \times 0.20}$$

As $\left[HI_{(aq)}\right] = 2\left[C_6H_6O_{6(aq)}\right]$

$$3.125 = \frac{\left[C_6H_6O_{6(aq)}\right]^3}{0.20 \times 0.20}$$

$\left[C_6H_6O_{6(aq)}\right]^3 = 0.125\ M$
$C_6H_6O_{6(aq)} = 0.50\ M$ *(3 marks)*

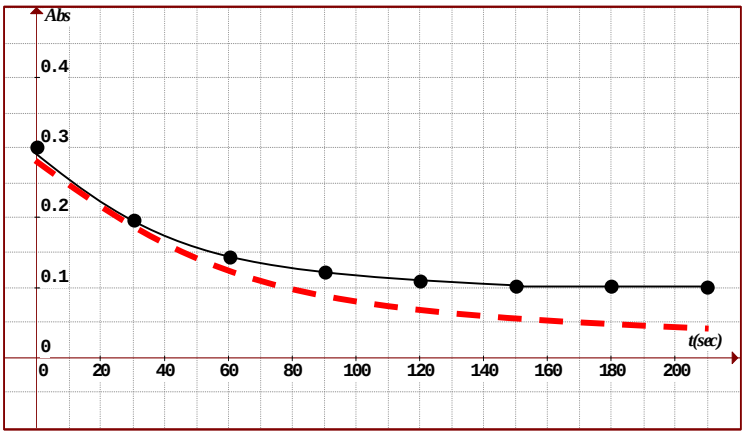
c. (i) Answer is the graph with the broken line.



(2 marks)

The curve must start at the point (0, 0.3) and end at the same absorbance value as the given graph. This final absorbance (0.1 units) must be achieved earlier i.e. the steepness of the initial part of the curve must be higher.

c. (ii) Answer is the graph with the broken line.



(2 marks)

The curve must start at the point (0, 0.3) and end at a lower absorbance value than the given graph.

Note: As product is removed, the position of equilibrium will shift further to the right. More of the reactants will be consumed, therefore, the concentration of iodine will decrease. The corresponding absorbance will also decrease.

QUESTION 2

a. (i) Circle oxygen *(1 mark).*

Oxygen cannot be used as the carrier gas in GLC as it can readily react with the molecules that need to be separated. The carrier gas must be inert under the conditions it is being used. *(1 mark)*

(ii) The temperature must be strictly controlled as fluctuations will alter the strength of the interparticle bonds and hence the volatility of each molecule. This will alter R_T values. *(1 mark)*

Note: As the temperature increases - the net strength of interparticle bonds between molecules will decrease, volatility will increase, and hence R_T values will decrease.

b. Butane: C_4H_{10} = Peak B

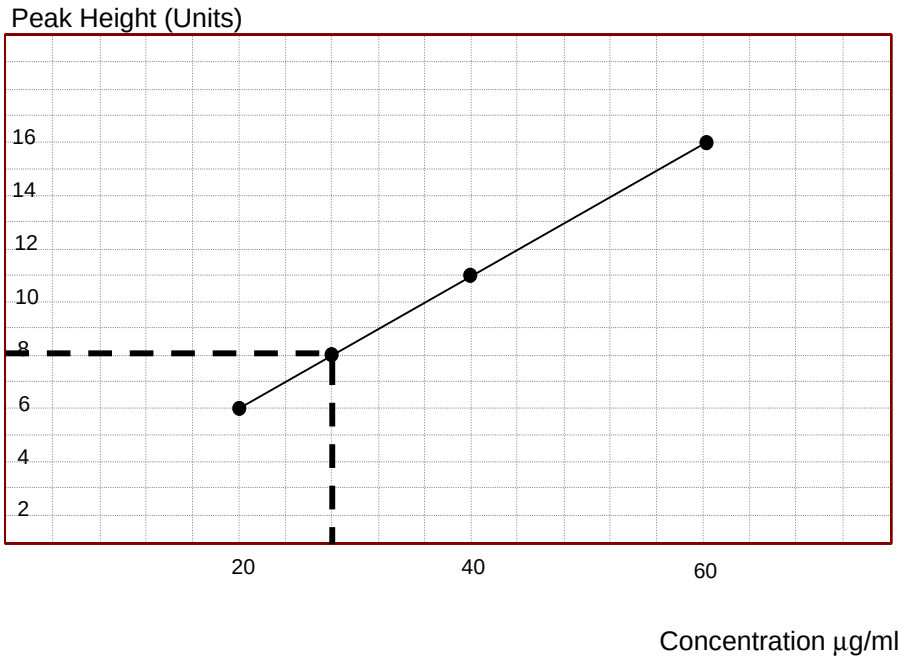
Butanoic acid: $C_4H_8O_2$ = Peak D

Butanol: $C_4H_{10}O$ = Peak C

Butene: C_4H_8 = Peak A *(0.5 marks per correct answer)*

Explanation: The more polar the molecule, the stronger the interparticle bonding, hence the lower the volatility. The less volatile a molecule, the longer the retention time. *(1 mark)*

c. (i)



(1 mark)

Students may also plot a graph of the actual height of the peaks in mm or cm as a function of concentration.

Concentration ($\mu g / ml$)	Peak Height (Units)
20	5
40	10
60	15
Unknown	7

(ii) Concentration of butanol in the unknown sample is $28\ \mu g / ml$. *(1 mark).*

(iii) $28\ \mu g / ml = 28\ \mu g / g$ (Assume that the density of the solution is $1\ g / ml$).

$\downarrow$

$28 \times 1 \times 10^6\ \mu g / 1 \times 10^6\ g$

$\downarrow$

$28 g / 1 \times 10^6\ g = 28\ ppm$

(2 marks)

QUESTION 3

a. $Mg(OH)_{2(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + 2H_2O_{(l)}$ *(1 mark)*

b. (i) Average titre = $\dfrac{22.60 + 22.70 + 22.80}{3} = 22.70\ ml$ *(1 mark)*

Student must use the volumes of the 3 concordant results.
Otherwise – no marks are to be awarded.

(ii) $n = cV = 0.350 \times 0.02270 = 0.007945 = 0.00795\ mol$ *(1 mark)*

(iii) $n(NaOH) = n(HCl) = 0.007945 = 0.00795\ mol$ *(1 mark)*

(iv) $n(HCl)_{reacted} = n(HCl)_{initial} - n(HCl)_{used\ in\ titration}$

$= (0.200 \times 0.050) - 0.007945 = 0.002055 = 0.00206\ mol$ *(2 marks)*

(v) $n\left(Mg(OH)_2\right) = \dfrac{1}{2} \times n(HCl) = \dfrac{1}{2} \times 0.002055 = 0.0010275\ mol$

$m\left(Mg(OH)_2\right) = n \times M = 0.0010275 \times 58.312 = 0.05992\ g$ *(1 mark)*

$\%\, Mg(OH)_2 = \dfrac{m(Mg(OH)_2)}{m(sample)} \times 100 = \dfrac{0.05992}{0.750} \times 100 = 7.9887 = 7.99\%$ *(1 mark)*

c. (i) Percentage by mass will be lower *(1 mark).*

(ii) $\%Mg(OH)_2$ will be lower than the true value *(1 mark).*

Note: To neutralise the excess HCl, a greater volume of $NaOH$ would need to be delivered from the burette.

$n(NaOH)$ calculated will be higher than true value.
$\therefore n(HCl)$ calculated in excess will be higher than the true value.
$\therefore n(HCl)$ calculated to have reacted with $Mg(OH)_2$ will be lower than the true value.

$\therefore n\left(Mg(OH)_2\right)$ calculated to be present will be lower than the true value.

$\therefore \%Mg(OH)_2$ will be lower than the true value.

QUESTION 4

a. Circle addition and hydration *(0.5 marks for each correct answer).*

b. (i) As the value of K decreases as temperature increases, a net back reaction is occurring. This would occur if the forward reaction is exothermic. *(1 mark)*

(ii) Higher pressures. *(1 mark)*
Low temperatures. *(1 mark)*

c. (i) $C_3H_{8(g)} \rightarrow CH_{4(g)} + C_2H_{4(g)}$ *(1 mark)*
$C_3H_{8(g)} \rightarrow H_{2(g)} + C_3H_{6(g)}$ *(1 mark)*

(ii) Alkenes are produced due to insufficient quantities of H_2 being available to saturate all double covalent C-C bonds. *(1 mark)*

d. React a known amount and volume of ethane and ethene with a known amount (and volume) of $Br_{2(aq)}$, which is red-brown in colour *(1 mark).* Measure the rate at which $Br_{2(aq)}$ disappears (or monitor the change in colour). *(1 mark)*

Ethene: $C_2H_{4(g)} + Br_{2(g)} \rightarrow C_2H_4Br_{2(g)}$ *(1 mark)*

As the alkenes are more reactive than their corresponding alkane (due to the presence of the double bond), the rate at which Br_2 disappears will be higher in the reaction involving the alkene. The colour of the alkene mixture will therefore fade at a faster rate. *(1 mark)*

QUESTION 5

a. (i) Circle the COO in $CH_3COOCH_2CH_2CH_2CH_{3(l)}$ *(1 mark)*

(ii) Butyl ethanoate *(1 mark).*

b. (i) $CH_3COOH_{(l)} + CH_3CH_2CH_2CH_2OH_{(l)} \overset{H_2SO_4}{\rightleftharpoons} CH_3COOCH_2CH_2CH_2CH_{3(l)} + H_2O_{(l)}$

Ethanoic acid Butanol

2 marks

(ii) The acid removes water *(1 mark)*, shifting the position of equilibrium to the right, favouring the production of ester. In this manner, the yield of ester is improved. *(1 mark)*

(iii) An excess of water would favour the reverse reaction, decreasing the yield of ester. *(1 mark)*

QUESTION 6

(a) In neutral water, $[OH^-] = [H^+] = 10^{-6.60}\,M$ *(1 mark)*

(b) $K_w = \left[H_3O^+_{(aq)}\right]\left[OH^-_{(aq)}\right] = 10^{-6.60} \times 10^{-6.60} = 10^{-13.2}\,M^2$ *(1 mark)*

(c) $[OH^-] = [NaOH] = 0.0040\ M$

$$[H^+] = \frac{10^{-13.2}}{[OH^-]} = \frac{10^{-13.2}}{0.0040} = 1.5774 \times 10^{-11}\,M$$

$$pH = -\log_{10}[H^+] = -\log_{10}(1.5774 \times 10^{-11}) = 10.8$$ *(2 marks)*

QUESTION 7

a. (i) Decrease *(1 mark)*

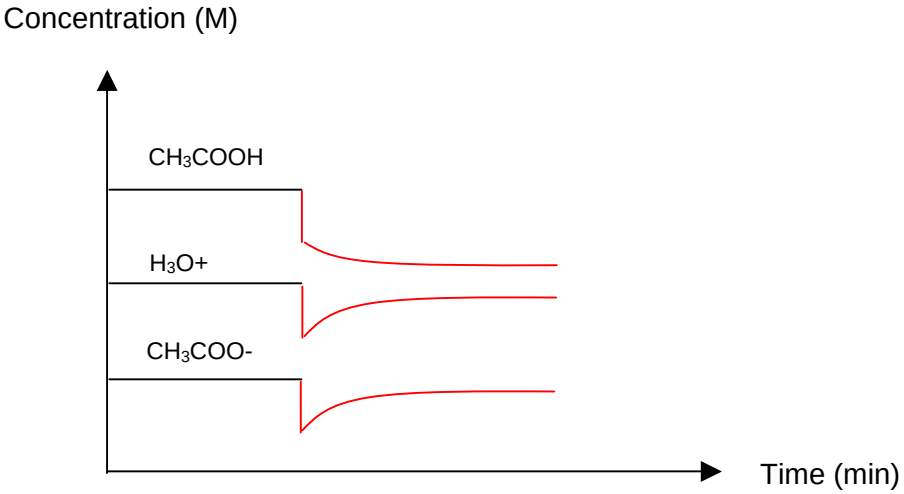
A net forward reaction occurs (i.e. the forward reaction occurs to a greater extent than the back reaction), however, as the number of reactant particles has decreased, the number of effective collisions have decreased, hence the forward reaction rate has decreased.

(ii) Lower *(1 mark)*

Dilution favours the reaction that will increase the number of mole of particles. A net forward reaction occurs, hence the amount of CH_3COO^- increases. However, the concentration once equilibrium is re-established will be lower than in the previous equilibrium mixture.

When the system is diluted, the concentration of every species in the reaction mixture will decrease instantaneously. As the net forward reaction occurs, $[CH_3COO^-]$ increases, but never returns to its previous value.

Note: As the concentration of water liquid in aqueous solutions remains relatively constant, we ignore water in equilibrium considerations.



(iii) Higher *(1 mark)*

Adding a base will decrease the concentration of H_3O^+, therefore, a net forward reaction will occur. As the forward reaction is exothermic, the temperature will increase.

b. $CH_3COOH_{(aq)} + H_2O_{(l)} \Leftrightarrow H_3O^+_{(aq)} + CH_3COO^-_{(aq)}$

$$K_a = \frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH]}\ M$$

Assume: $[CH_3COOH]_{eq} = [CH_3COOH]_{initial} = 0.10\ M$

Assume: $[CH_3COO^-]_{eq} = [H_3O^+]_{eq}$

$$\therefore K_a = \frac{[H_3O^+]^2}{0.1}$$

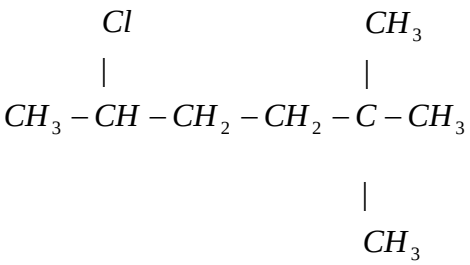
Percentage hydrolysis of CH_3COOH is 1.30%, therefore:

$$[H_3O^+] = \frac{1.30}{100} \times 0.10 = 0.0013\ M$$

$$K_a = \frac{[H_3O^+]^2}{0.1} = \frac{(0.0013)^2}{0.1} = 1.69 \times 10^{-5}\ M$$ *(3 marks)*

QUESTION 8

a. (i)



(1 mark)

(ii) 3,4-dimethyl-2-hexene *(1 mark)*

b. $Cr_2O^{2-}_{7(aq)} + 14H^+_{(aq)} + 6e^- \rightarrow 2Cr^{3+}_{(aq)} + 7H_2O_{(l)}$ *(1 mark)*

$CH_3CH_2OH_{(aq)} + H_2O_{(l)} \rightarrow CH_3COOH_{(aq)} + 4H^+_{(aq)} + 4e^-$ *(1 mark)*

Multiply equation 1 by 2 and equation 2 by 3 and then add.

$$2Cr_2O^{2-}_{7(aq)} + 3CH_3CH_2OH_{(aq)} + 16H^+_{(aq)} \rightarrow 4Cr^{3+}_{(aq)} + 3CH_3COOH_{(aq)} + 11H_2O_{(l)}$$

(1 mark)

c. (i) $\%C = \frac{12}{44} \times 100 = 27.273 = 27.3\ \%$ *(1 mark)*

(ii) Assuming that all the C in the organic molecule is converted to CO_2:

$m(C) = \frac{27.273}{100} \times 1.32 = 0.3600 = 0.360\ g$ *(1 mark)*

(iii) $m(O) = 0.900 - 0.360 - 0.0560 = 0.484\ g$ *(1 mark)*

(iv)

	C	:	H	:	O
Find n	$\frac{0.360}{12}$	:	$\frac{0.0560}{1}$	:	$\frac{0.484}{15.99}$
Simplify	0.03	:	0.0560	:	0.03
Divide by smallest ratio	1	:	1.87	:	1

The empirical formula of the compound is CH_2O. *(2 marks)*

(v) $PV = nRT$

$n = \frac{PV}{RT} = \frac{1.25 \times 10^2 \times 0.484}{8.31 \times (273 + 179)} = 0.016107\ mol$ *(1 mark)*

$n = \frac{m}{M}$

$\therefore M = \frac{m}{n} = \frac{2.90}{0.016107} = 180.046\ g/mol$ *(1 mark)*

$M(CH_2O) = 30\ g/mol$

Therefore, 6 units of CH_2O exist in the molecule. Therefore, the molecular formula is $C_6H_{12}O_6$. *(1 mark)*