

2013 UNIT 3/4 EXAM SOLUTIONS

Penalties : the usual ones!

* max^m 1 mark off if incorrect numbers of significant figures are given* max^m 1 mark off if symbols of state are omitted

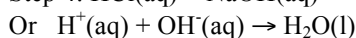
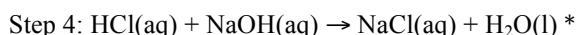
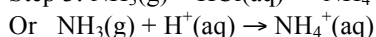
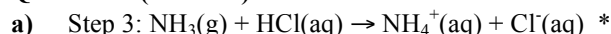
* 1 mark off each time a unit is omitted from answer that requires a unit

SECTION A [30 × 1 = 30]

- | | | | | | | | | | |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1. D | 2. C | 3. A | 4. D | 5. D | 6. B | 7. A | 8. D | 9. C | 10. A |
| 11. A | 12. D | 13. D | 14. D | 15. B | 16. A | 17. B | 18. C | 19. C | 20. D |
| 21. B | 22. C | 23. A | 24. B | 25. C | 26. B | 27. A | 28. C | 29. B | 30. A |

SECTION B [total = 95] * = 1 mark

Question 1 (9 marks)



- b) $n(\text{HCl})$ reacted with $\text{NH}_3(\text{g}) = n(\text{HCl})$ supplied – $n(\text{HCl})$ in excess
 $= n(\text{HCl})$ supplied – $n(\text{NaOH}) = 0.100 \times 100 \times 10^{-3} - 0.200 \times 31.4 \times 10^{-3}$ *

$$= 0.0100 - 0.00628$$

$$= 0.00372 \text{ mol} \text{ * (3 sig fig)}$$

- c)
- $n(\text{N})$
- in sample =
- $n(\text{NH}_3)$
- produced =
- $n(\text{HCl})$
- reacting with
- $\text{NH}_3 = 0.00372 \text{ mol}$

$$m(\text{N}) \text{ in sample} = 0.00372 \times 14.0 = 0.0521 \text{ g} \text{ *}$$

- d) % N =
- $[m(\text{N}) / m(\text{sample})] \times 100 = (0.052 / 5.152) \times 100$

$$= 1.01 \% \text{ * (3 sig figs)}$$

- e)
- $K_a = 5.8 \times 10^{-10}$
- Data Book Table 12

$$K_a = [\text{B}(\text{OH})_4^-][\text{H}^+] / [\text{H}_3\text{BO}_3] = 5.8 \times 10^{-10} = [\text{H}^+]^2 / 0.647$$

$$[\text{H}^+]^2 = 5.8 \times 10^{-10} \times 0.647 \text{ * } = [\text{H}^+] = \sqrt{(5.8 \times 10^{-10} \times 0.647)} = 1.94 \times 10^{-5} \text{ M} \text{ *}$$

$$\text{pH} = -\log_{10}(1.94 \times 10^{-5}) = 4.7 \text{ * (2 sig fig)}$$

Question 2 (8 marks)

- a) The identity of each peak could be established by *running a sample of each alkanol* through the column and *noting the retention time*. *
- b) 1 mark for recognising the overlap of ethanol and 2-methylpropanol peaks, that could create problems if 2-methylpropanol is in wine sample
- c) retention time around 7.2. * 1-pentanol is the next alkanol in the homologous series * and the retention time seems to be increasing by a little over 1 with each member of the
 - 1 mark for nominating a retention time around 7 (should be between 7 and 7.5)
 - 1 mark for linking the retention time to the position of the alkanol in the homologous series
- d) 1-butanol and 2-methylpropanol are structural isomers * but their retention times are quite different. * This suggests that this technique might have the potential to separate structural isomers.
- e) If the concentration is doubled, the area under the peak (peak height is not sufficient) should be doubled. *
- f) At a higher temperature, the retention times of each alkanol should be shorter. * The order of peaks will be the same.

Question 3 (9 marks)

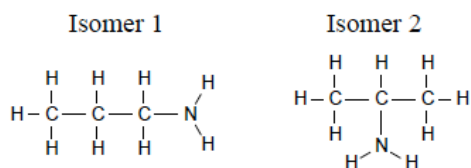
- a) (i) Mass of hydrogen = $2.800 - 1.710 - 0.664 = 0.426 \text{ g}^*$
 (ii) $\text{EF} = \frac{1.71}{12} : \frac{0.664}{14} : \frac{0.426}{1} = 0.142 : 0.0474 : 0.426 = 3 : 1 : 9$ *

$$\text{EF} = \text{C}_3\text{H}_9\text{N} \text{ *}$$

- b) (i) The base peak has a value of 29 *

- (ii) The parent molecular ion has a mass of 59. This matches the empirical formula of $\text{C}_3\text{H}_9\text{N}$. Therefore, the empirical formula and the molecular formula are both $\text{C}_3\text{H}_9\text{N}$. *

c)



Isomer 1: 1-aminopropane (or propan-1-amine)*

Isomer 2: 2-aminopropane (or propan-2-amine)*

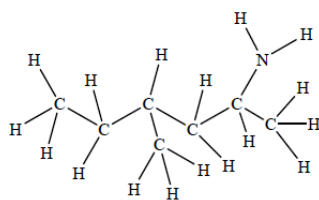
1 mark for each structure with its correct name.

c) The molecule is 2-aminopropane. *

It has three different hydrogen environments* in its structure and this matches the NMR shown.
 1-aminopropane would have four different hydrogen environments.
 (The NMR spectrum is incorrect as the triplet should be a doublet. Assigning the peaks was not part of the answer)

Question 4 (14 marks)

a) 1 mark for correct structure, all bonds MUST be shown to obtain the mark

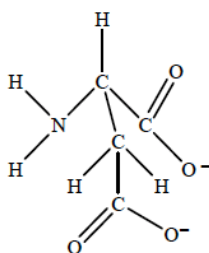


b) Amino acids contain a carboxyl –COOH functional group as well as an amino group.

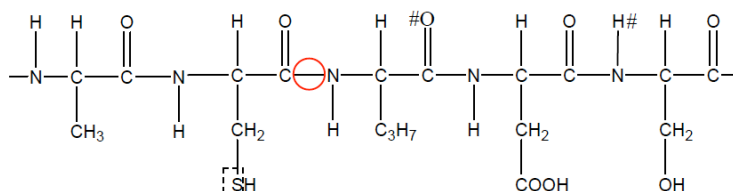
DMMA molecules do not have carboxyl groups. *

c) 2-aminopropanoic acid *

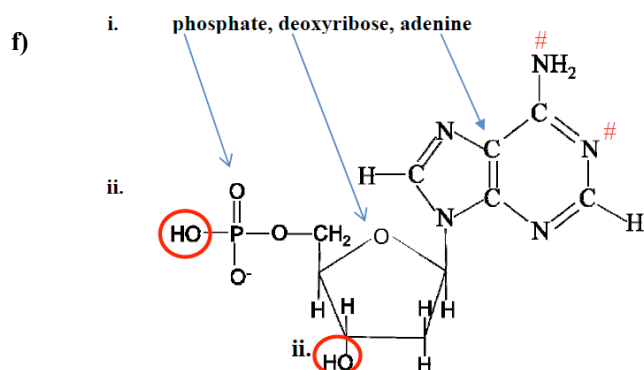
d) * all bonds MUST be shown and both –COOH groups deprotonated



e)

i. * for any C-N bond. (the **bond** not the entire peptide group needed to be circled)ii. * for an 'O' on one peptide group AND an 'H' on a different peptide group.

iii. *for the 'S' atom.



Names of all species were available from the data booklet

i. ** for all three correct, [* for two correct]

ii. * for both 'OH' groups circled. Also accept POOH.

iii. * for both the N and the NH₂ on the right hand side of the nitrogen base (adenine).

No marks if the H on the C-H is asterisked.

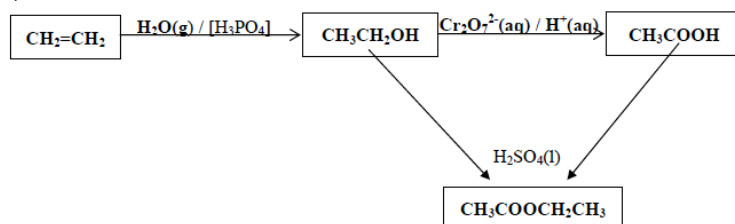
g) Adenine-Thymine (A-T) pairs have only two sites for hydrogen bonding. * The *greater* the proportion of C-G (cytosine-guanine) base pairs, the *stronger* the attraction between the strands.

Question 5 (13 marks)

a) The two peaks are in the absorption band 1670-1750 cm⁻¹ (Data Book) and are caused by the **two** C=O groups * in the molecule. The peaks are centered at slightly different wavenumbers because of the different bonding environments in the caffeine molecule; one C=O is between two N atoms whilst the other C=O is between one C and one N atom. *

b) There are eight peaks and there are 8 'different' carbon atoms * in the caffeine molecule. Each C atom has a different bonding environment (looking through the whole molecule) *

c)



Two marks ** for the four correct semi-structural formulae; one mark if two or three correct.

One mark * for H₂O(g) / [H₃PO₄] (H₂O has to be (g) because it is steam)

One mark * Cr₂O₇²⁻(aq) / H⁺(aq) (no mark if **not** acidic conditions)

One mark * H₂SO₄(l) (no mark if no or aq state) *

e) CH₃CH₂OH(l) + CH₃COOH(l) $\rightleftharpoons$ CH₃COOCH₂CH₃(l) + H₂O(l) *
Correct states and equilibrium arrows necessary for the mark (no half mark!)
H₂SO₄(l) as catalyst needed

f) i. Because the forward reaction is endothermic, the yield of ethyl ethanoate will be increased. *

The higher temperature will increase the rate of reaction. *

ii. Ethanol is volatile and very flammable and should not be used near a naked flame.

There would be a high risk of explosion. *

(Ethanoic acid is also flammable)

Question 6 (18 marks)

- a) The radioactive hydrogen will participate in the equilibrium, i.e. it will react with iodine at the same rate that HI will be broken down.*

Radioactive HI should be detected as the forward and reverse reactions will continue even though there is no evident concentration change.*

b) $K = [\text{HI}]^2 / [\text{H}_2] [\text{I}_2] = (0.04)^2 / (0.09)(0.06) = 0.3$ (1SF)

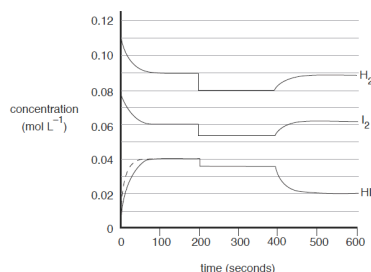
- c) As the gaseous concentrations decreased, the volume of the equilibrium container was increased. *
The concentration of H_2 decreased from 0.090 M to 0.080 M, so the volume was increased by a factor of 9/8. * (magnitude has to be given to obtain full mark)

- d) i. lower *

- ii. The concentrations of the reactants increase and the concentration of the product decreases. *

In the concentration fraction, the numerator is smaller and the denominator is larger, resulting in a smaller value of **K**.

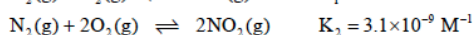
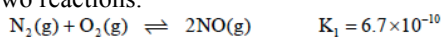
- e) Drawing on graph should show equilibrium concentration of 0.040 M being reached earlier.



f) i. $\Delta H = \Delta H_1 + \Delta H_2 = -180 + 66 = -114 \text{ kJ mol}^{-1}$

ii. $K = [\text{NO}_2]^2 / [\text{NO}]^2 [\text{O}_2]$ *

- iii. The equilibrium constant for the reaction can be obtained from the equilibrium constants for other two reactions.



$$\frac{[\text{NO}]^2}{[\text{N}_2][\text{O}_2]} = 6.7 \times 10^{-10}$$

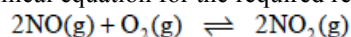
$$\frac{[\text{NO}_2]^2}{[\text{N}_2][\text{O}_2]^2} = 3.1 \times 10^{-9}$$

$$K = \frac{[\text{NO}_2]^2}{[\text{NO}]^2 [\text{O}_2]} = \frac{[\text{NO}_2]^2}{[\text{N}_2][\text{O}_2]^2} \cdot \frac{[\text{N}_2][\text{O}_2]}{[\text{NO}]^2} \quad (1 \text{ mark})$$

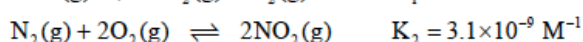
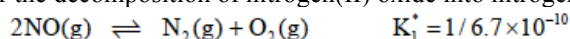
$$K = \frac{[\text{NO}_2]^2}{[\text{NO}]^2 [\text{O}_2]} = 3.1 \times 10^{-9} / 6.7 \times 10^{-10} = 4.6 \text{ M}^{-1} \quad (1 \text{ mark})$$

Alternative solution:

The chemical equation for the required reaction is:



Since the starting material in this reaction is nitrogen(II) oxide then the chemical equation and equilibrium constant for the decomposition of nitrogen(II) oxide into nitrogen and oxygen will be



The equilibrium constant for this reaction will be the product of the two equilibrium constants, K_1^* and K_2 above.

$$K = \frac{[\text{NO}_2]^2}{[\text{NO}]^2 [\text{O}_2]} = 3.1 \times 10^{-9} \times (1 / 6.7 \times 10^{-10}) = 4.6 \text{ M}^{-1}$$

iv. The rates of the two reactions would be expected to be slow because both reactions involve *breaking the nitrogen-nitrogen triple bond* $\frac{1}{2}$ * which would *require a large amount of energy* $\frac{1}{2}$ * Therefore the activation energies for these reactions would be large.

v. 1 mark for correct energy level of reactants and product (reactants higher energy value than products b/c exothermic reaction)

$\frac{1}{2}$ * correct labelling of E_A (forward and backward reaction)

$\frac{1}{2}$ * correct labelling of ΔH

Consequential marks possible if ΔH in f) was determined as positive.

Question 7 (6 marks)

a) The volume of hydrogen gas is doubled so the mass of magnesium must have been doubled. *
(An increase in acid concentration, or a temperature rise are not correct responses.)

b) Possible changes include:

- decreasing the magnesium surface area by adding it as a ball *
- reducing the volume of the acid *
- reducing the concentration of acid *
- adding less magnesium*

c) - change in mass of the reactor over time *

- the change in pH of the solution over time*

Question 8 (11 marks)

a) biodiesel structural formula: (not drawn here due to space...)

$C_{17}H_{35}COOCH_3$ * (all bonds need to be shown to obtain full marks, lone pairs not necessary)

b) ester linkage *

c) $2C_{17}H_{35}COOCH_3(s) + 55O_2(g) \rightarrow 38CO_2(g) + 38H_2O(g)$ * (all needs to be correct to obtain the 1 mark)

d) $E = c_f \times \Delta T = 1175 \times 15.83 = 18.60 \text{ kJ}$ *

$M_{\text{biodiesel}} = 298.5 \text{ g/mol}$

$n_{\text{biodiesel}} = 0.50 / 298 = 0.00168 \text{ mol}$ *

18.6 kJ per 0.00168 mol therefore

$\Delta H_c = -1.1 \times 10^4 \text{ kJ/mol}$ ** (-1 mark if not a negative value)

e) ΔH_c (butane) from the data booklet = -2874 kJ/mol

$n(\text{butane}) = 10 \text{ g} / 58 \text{ g mol}^{-1} = 0.17 \text{ mol}$ *

Energy released: $E = 4.9 \times 10^2 \text{ kJ}$ * (energy value has to be positive!)

e) Energy released by 10g butane = $4.9 \times 10^2 \text{ kJ}$

Energy released by 10g biodiesel = $3.7 \times 10^2 \text{ kJ}$

Therefore the energy released by the biodiesel is slightly **less** than butane*

f) biodiesel is a solid so easier to transport *

Question 9 (9 marks)

Note: The electrodes in the diagram were NOT labelled with A and B. I went through all the rooms and told students to label them so answer **a)** and **b)** could be the other way around but have to be correct and written as below:

a) $Al(s) \rightarrow Al^{3+}(aq) + 3e^-$ *

b) $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ *

c) $1s^2 2s^2 2p^6 3s^2 3p^1$ *

d) Anode. Oxidation (loss of electrons) occurs at the anode*

e) Electrical energy *

f) No harmful emissions *

g) Does not have a continuous supply of reactants $\frac{1}{2}$ * and Al is not considered a fuel $\frac{1}{2}$ *

h) Advantage: one of the following: *

- higher efficiency, continual supply of energy, long lasting, not polluting (rechargeable is incorrect)

Disadvantage: one of the following *

- very expensive, needs continual fuel addition, high temperature etc