Neap:

Trial Examination 2015

VCE Chemistry Units 3&4

Written Examination

Suggested Solutions

SECTION A: MULTIPLE-CHOICE QUESTIONS

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

Question 1 C

Sodium hydroxide pellets absorb moisture from the air and also react with carbon dioxide gas to produce sodium carbonate. Thus weighing a mass to determine the number of mole of sodium hydroxide is not possible, as the mass will contain sodium hydroxide as well as water and sodium carbonate. Statements I and III are correct. Solutions of sodium hydroxide are clear but this does not prevent its use in titrations. Statement II is not a valid reason. Sodium carbonate does have a higher molar mass than sodium hydroxide and ensures that percentage weighing errors are much smaller. However, sodium carbonate cannot be used in all reactions in place of sodium hydroxide. Statement IV is thus not valid.

Question 2 D

The oxygens at I and II are involved in the formation of bonds with phosphate units. The oxygen at III is involved in the formation of the sugar-to-nitrogenous base bond. The oxygen at IV is not involved in bonding.

Question 3 C

The activation energy is *W*, which is equivalent to $Z - X$. **A** is not correct. The energy of the products is lower than the energy of the reactants and so energy must have been released in the reaction. The profile is for an exothermic reaction and so **B** is incorrect and **C** is correct. The intermediate chemical species, after the reactants have been disrupted and before the products form, have higher energy than either the reactants or the products. According to the profile, this energy is equivalent to *Y*, not *Z*. Thus **D** is incorrect.

Question 4 B

If a catalyst was used in the reaction, the energy peak of the profile would become lower. Thus *W*, *Y* and *Z* are smaller values, but *X* does not change.

Question 5 D

$\Delta H = H_P - H_R$, and so for the reverse reaction (which is endothermic) this is numerically equivalent to $Z - W$.

Question 6 D

At elevated temperatures hydrogen bonding, dispersion forces and dipole-dipole interactions in protein molecules are disrupted and can cause the secondary and tertiary structures of the protein to be altered. The protein shape can change and, more importantly for an enzyme, its active site will no longer bond to substrate molecules. **A**, **B** and **C** are all valid explanations for the stated observation. Far more severe conditions than 85°C are needed to break the peptide bonds in a protein molecule. **D** is not a valid explanation, and so is the required response.

Question 7 A

For gases at high temperatures and low pressures, the gas volume is independent of the size of the gas molecules or molar masses. Molar volume at SLC is 24.5 L and at STP is 22.4 L. Therefore **A** is the correct answer.

Question 8 D

As the bases are of equal volume, they cannot be of the same concentration, as the volume of acid required for neutralisation differs. **A** and **B** are incorrect. The shape of the curve for base E indicates that is a weak base. The titration for base E has an equivalence point at pH less than 7, indicating the presence of a weak acid; hence E is a weak base. The titration for base F has an equivalence point at pH 7, characteristic of a strong acid–strong base titration. Base F is stronger than base E.

Question 9 C

Diluting base F with water will alter the hydrogen ion concentration and thus the pH. So **A** and **B** are incorrect. As the number of mole of base F has not changed with dilution (even though its concentration has decreased), the same amount of acid is required for neutralisation. **C** is the required answer.

Question 10 D

Standard 3 is the least polar as it moved the greatest distance on a polar stationary phase using a non-polar solvent. Therefore it was not attracted to the stationary phase and moved quickly in the non-polar solvent. Standard 2 is the most polar as it moved the least distance. Hence the order of increasing polarity is $3 < 1 < 2$.

Question 11 B

Only standards 2 and 3 line up exactly with two spots in the mixture and so these two standards were components of the mixture. Standard 1 does not line up with any spot.

Question 12 A

Running the TLC on a longer plate for greater duration means that the solvent front runs further, as do the spots. The ratio which gives the R_f value will remain the same. So **A** is the correct answer and **D** is incorrect. The distance between the spots will increase as the TLC plate runs longer. **B** and **C** are both incorrect.

Question 13 A

As the pH is less than 7, $[H_3O^+]$ is greater than $[OH^-]$. Thus reaction I proceeds to the right to a greater extent than reaction II. This means that reaction I must have the larger equilibrium constant.

Question 14 B

Action I will decrease the pressure of the vessel and the system would respond by moving forward to partially oppose the change (9 mol of reactant gas particles become 10 mol of product gas particles). However, this would not reach the pressure before the change was made and so action I is not part of the required answer. Injecting an inert gas will not affect the position of equilibrium but will increase the total pressure in the vessel. Action II is correct. Adding water vapour will increase the total pressure and the equilibrium will move to the left to partially oppose the change. Again, this will not restore the original pressure and so action III is also correct. Thus **B** is the required answer.

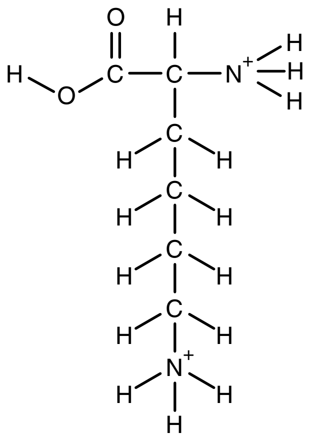
Question 15 A

Changes in oxidation numbers are: (N) –3 to +2; and (O) 0 to –2.

As the oxidation number of H does not change, **A** is therefore incorrect and is the required answer. By considering the changes in oxidation numbers, it is seen that **B**, **C** and **D** are all correct statements.

Question 16 A

In a solution of pH 2 (highly acidic), amino acids will act as bases, accepting protons. To form a doubly charged ion requires that two protons are accepted; that is, two basic groups are present, as is the case for lysine. Serine and valine have neutral side groups, while glutamic acid has an acidic side group.



Question 17 B

It is not likely that guanine constitutes 29% of both strands of the DNA. It is much more likely that the percentages are different for each strand but that the total is 29%. It certainly does not follow that 29% of the bases in one strand **must** be guanine. Thus statement **A** is incorrect. If guanine and cytosine are both 29%, both thymine and adenine are each 21%. Statement **D** is incorrect. As 21% of 500 = 105, statement **B** is correct. Adenine and cytosine would be 50% of the bases (21% and 29% respectively). Statement **C** is incorrect.

Question 18 B

Catalysts do not change the energy of the reactants or products and thus will not affect the enthalpy change in a reaction. Variable I is not correct. Catalysts will affect how quickly products form and this is accomplished by using an alternative pathway which has lower activation energy. Variables II and III are both correct. Catalysts will affect how quickly equilibrium is achieved but not the extent of a reaction and thus not the value of K. Variable IV is not correct.

Question 19 C

Aspirin synthesis is a condensation reaction between carboxyl and hydroxyl groups. Ethanoic acid provides the carboxyl group. The salicylic acid molecule provides the hydroxyl group. In the salicylic acid molecule, neither the carboxyl group nor the benzene ring react with ethanoic acid.

Question 20 B

A and **D** are both features of cells which generate electrical energy. The polarity of electrodes in fuel cells and secondary cells is the same. **C** is incorrect. In secondary cells, the reaction products remain in contact with the electrodes so that the cell reaction can be reversed by the input of electrical energy. In fuel cells, the reactants are constantly being fed to the electrodes.

Question 21 A

There are fewer energy transformations using a fuel cell (chemical to electrical) and so less energy is lost in conversions. At each step in the generator process energy is lost (chemical to thermal to mechanical to electrical). Therefore there would be a greater amount of electrical energy produced for a set mass of methanol in the fuel cell.

Question 22 A

Natural gas is a fossil fuel and thus the supply is finite. Extracting methane and then converting it to methanol is not sustainable. **A** is the required answer. **B**, **C** and **D** involve using microbes on raw materials which are of plant origin and which can be regrown. These are all sustainable methods.

Question 23 D

There are three peptide bonds shown in the section of protein molecule, which means that four amino residues are present: glycine-alanine-aspartic acid-cysteine.

Question 24 B

The primary structure of a protein involves the type, sequence and number of amino acids in the protein molecule. **I** and **II** are not involved in the primary structure. The O and H atoms in the peptide bonds interact at different parts of the protein chain to form hydrogen bonds which result in the secondary structure of the protein. **I** is involved in the secondary structure. The tertiary structure involves the interactions between the side groups of the amino acid residues. **II** is involved in the tertiary structure.

Question 25 C

Electrolysis allows non-spontaneous reactions to occur by the input of electrical energy. Thus the products must be kept apart, as they would be the reactants of the spontaneous reaction. **C** is the main reason for this design feature. The other reasons, **A**, **B** and **D**, may be applicable, but none of these is the main reason for the design feature.

Question 26 C

The hydrocarbon is an isomer of nonane, but this is not its systematic name. **B** is incorrect. The longest unbranched chain of carbon atoms is six-long and so the name is based on hexane. **A** is incorrect. The correct name in **C** gives smaller numbers (of the carbon atoms of attached groups) than those in **D**, and so **C** is correct. **D** is also incorrectly written as it does not use the tri- prefix when three identical side groups are included.

Question 27 D

If the volume of the container was decreased, the concentration of the components should all increase instantaneously, as is shown at $t = 10$ minutes. **A** is not correct. As it is an exothermic reaction, adding heat will move the equilibrium reaction to the left and cause an increase in the concentration of the reactants, as shown at $t = 15$ minutes. The system is not at equilibrium at $t = 5$ minutes and the reactants decrease in concentration after the change. **B** is incorrect. Removing sulfur trioxide gas would produce a dip in the SO_3 graph. **C** is also incorrect. At $t = 5$ minutes the change causes a rapid attainment of equilibrium at around 7 minutes. Only a catalyst could do this. **D** is the required answer.

Question 28 B

The changes made are adding a catalyst (at 5 minutes) and decreasing the volume of the container (at 10 minutes). Neither of these changes alters the value of K because the temperature is unchanged. The temperature change at 15 minutes will alter the K value. Thus there are two values for the equilibrium constant.

Question 29 **C**

The absorbance of 0.35 corresponds to a MnO_4^- concentration of approximately 2.9 mg L^{-1} in the 100.0 mL of diluted solution. Thus the MnO_4^- concentration of the 1.0 L original solution is 10 × 2.9 = 29 mg L^{-1}. Thus $m(MnO_4^-)$ = 29 mg.

$$m(\text{Mn}) = m(\text{MnO}_4^-) \times \frac{M(\text{Mn})}{M(\text{MnO}_4^-)} = 29 \times \frac{54.9}{118.9} = 13.3 \text{ mg}$$

Question 30 **D**

The absorbance spectrum of $MnO_4^-(aq)$ would be examined to identify a wavelength at which there is maximum absorbance of $MnO_4^-(aq)$, and any other substances present in the solution do not absorb at this wavelength. **A** is incorrect as maximum absorbance is required. **B** is incorrect as there will be a range of wavelengths at which absorbance occurs. **C** is incorrect as any wavelength in the UV-visible spectrum can be selected by the operator to conduct absorbance readings. **D** is correct as the absorbance of other substances will interfere with an accurate determination if the wavelength is not chosen so as to exclude them.

SECTION B: SHORT-ANSWER QUESTIONS

Question 1 (9 marks)

a. **i.** Use a laboratory coat, eye protection and gloves when handling the chemical to avoid eye and skin contact. 1 mark

ii. The hydroxyl group is highly polar and thus will interact with the polar water molecules. However, much of the dimethylglyoxime molecule is non-polar. 1 mark

Ethanol (CH_3CH_2OH) has a non-polar section (CH_3CH_2–) and a polar functional group (–OH). This allows the ethanol molecule to interact with both the polar and non-polar parts of the larger molecule, resulting in a much higher solubility. 1 mark

b. **i.** When dimethylglyoxime reacts with ammonia (a weak base), its conjugate base is formed. Thus a supply of the anion which reacts with the nickel ions is provided. 1 mark

ii. $n(\text{precipitate}) = \frac{m}{M} = \frac{5.68}{288.7}$ mol 1 mark

$n(\text{Ni}) = n(\text{Ni}^{2+}) = n(\text{precipitate}) = \frac{5.68}{288.7}$ mol 1 mark

$m(\text{Ni}) = n \times M = \frac{5.68}{288.7} \times 58.7 = 1.155$ g 1 mark

$\%\ \text{Ni} = \frac{1.155 \times 100}{5.17} = 22.3\%$ 1 mark

c. atomic absorption spectroscopy 1 mark

Question 2 (7 marks)

a. *Any one of:*

- volume of the dilute acid
- concentration of the dilute acid
- pH of the dilute acid

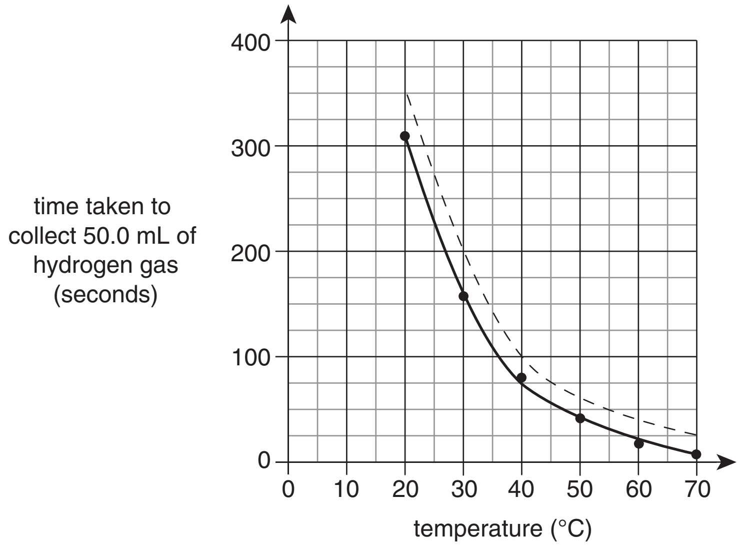
1 mark

b. **i.** $n(H_2) = \frac{V}{V_M} = \frac{50.0 \times 10^{-3}}{24.5} = 2.04 \times 10^{-3}$ mol 1 mark

$n(\text{Zn}) = n(H_2) = 2.04 \times 10^{-3}$ mol 1 mark

$m(\text{Zn}) = n \times M = 2.04 \times 10^{-3} \times 65.4 = 0.133$ g 1 mark

c.



1 mark

d. Increasing temperature increases the average kinetic energy of the molecules. 1 mark

More molecules will now have sufficient energy in collisions to reach the activation energy for the reaction, thus increasing the number of successful collisions; that is, rate increases. 1 mark

Question 3 (5 marks)

a. $n(\text{HCl})$ initially = $c \times V = 0.250 \times 100.0 \times 10^{-3} = 0.0250$ mol 1 mark

$n(\text{HCl})$ unreacted = $n(\text{NaOH}) = c \times V = 0.375 \times 17.80 \times 10^{-3} = 0.006675$ mol 1 mark

$n(\text{HCl})$ used in reaction = $n(\text{HCl})$ initially – $n(\text{HCl})$ unreacted

$= 0.0250 - 0.006675 = 0.0183$ mol 1 mark

b. *For example:*

The grain may contain another basic substance which reacts with the HCl. 1 mark

c. Ammonia is a volatile gas which may escape from the solution during titration. Reacting with excess HCl prevents this loss. 1 mark

Question 4 (12 marks)

a. mass ratio in 100 g of compound C : H : O = 41.4 g : 3.4 g : 55.2 g

mol ratio = $\left(\frac{41.4}{12}\right) : \left(\frac{3.4}{1.0}\right) : \left(\frac{55.2}{16}\right)$ 1 mark

= 3.45 : 3.4 : 3.45

= 1 : 1 : 1

So the empirical formula is CHO. 1 mark

b. The molecular ion has m/z of 116 and so M(compound) = 116 g mol^{-1}. 1 mark

M(CHO) = 29 and so there are $\frac{116}{29}$ units of CHO in the molecule.

So the molecular formula is $C_4H_4O_4$. 1 mark

c. X: O–H in acids (2500 to 3300 cm^{-1}) 1 mark

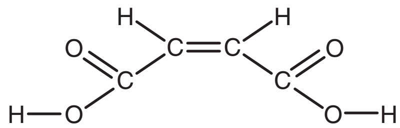
Z: C=C (1610 to 1680 cm^{-1}) 1 mark

d. $n(\text{KOH}) = \frac{5.05}{56.1} = 0.090$ mol 1 mark

$n(\text{compound}) = 0.045 = \frac{1}{2} \times n(\text{KOH})$

The compound can donate two protons per molecule and so each molecule has two acidic (carboxyl) groups. 1 mark

e.



2 marks

1 mark for showing all bonds

1 mark for showing C=C and –COOH groupings

f. There are two carbon environments shown on the ^{13}C NMR spectrum:

- the peak at 165 ppm corresponds to –COOH in the compound 1 mark
- the peak at 130 ppm corresponds to –C=C– in the compound 1 mark

Question 5 (11 marks)

a. $n(\text{linoleic acid}) = \frac{m}{M} = \frac{15.89}{280.0}$ mol 1 mark

The formula C_nH_{2n-3} indicates that linoleic acid contains two C=C bonds (or use the equation $C_{17}H_{31}COOH + 2H_2 \rightarrow C_{17}H_{35}COOH$).

So $n(H_2) = 2 \times n(\text{linoleic acid}) = 2 \times \frac{15.89}{280.0}$ mol 1 mark

$V(H_2) = \frac{nRT}{P} = \frac{2 \times 15.89 \times 8.31 \times 323}{280.0 \times 1.2 \times 101.3} = 2.51$ L 2 marks

1 mark for formula and unit conversions

1 mark for correct volume

b. i. linoleic acid 1 mark

It has the higher concentration as it has the larger area under the peak. 1 mark

ii. stearic 1 mark

Both fatty acids are largely non-polar and will interact with the non-polar stationary phase by dispersion forces. The stearic acid was more strongly attracted than the linoleic acid (as it had the longer R_t). 1 mark

As stearic acid has the stronger dispersion forces, it would have the higher melting point, as a greater amount of energy is needed to disrupt the intermolecular bonding. 1 mark

c. i. $C_{17}H_{35}COOH + CH_3OH \rightleftharpoons C_{17}H_{35}COOCH_3 + H_2O$ 1 mark

ii. The esters would vaporise at a lower temperature *(because the ester functional group is not as polar as the carboxyl functional group in the carboxylic acids).* 1 mark

Question 6 (7 marks)

a.

Proton NMR spectral feature	Ethanol only	Ethyl ethanoate only	Both ethanol and ethyl ethanoate
Apart from the TMS peak, there are three peaks on the low resolution NMR.			✓
The peak at 3.7 ppm is split into four fine peaks (a quartet).	✓		
One of the peaks is split into three fine peaks (a triplet).			✓
The area under the low-resolution NMR peaks is in the ratio of 2 : 3 : 3.		✓	

4 marks
1 mark for each correct box

b. Use some of the ethanol and oxidise it to ethanoic acid by heating using acidified potassium dichromate (or other strong oxidant). 1 mark

React the remaining ethanol with the ethanoic acid by heating in the presence of drops of a concentrated sulfuric acid catalyst. 1 mark

The ester has low solubility in aqueous solutions and can be collected as the upper layer of the reaction mixture. 1 mark

Question 7 (7 marks)

a. **i.** ether (or glycosidic) linkage 1 mark

ii. hydrolysis 1 mark

b. The microbes do not use oxygen (anaerobic) to produce the alkanols and are unable to function in an atmosphere of oxygen. 1 mark

c. **i.** $E = \text{C.F.} \times \Delta T = 3.49 \times 5.16 = 18.01$ kJ 1 mark

$n(\text{biobutanol}) = \frac{m}{M} = \frac{0.498}{74.0} = 0.006729$ mol

energy released per mol $= \frac{18.01}{0.006729} = 2676 \text{ kJ} = 2.68 \times 10^3$ kJ 1 mark

ii. $C_4H_9OH(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(g) \quad \Delta H = -2.68 \text{ MJ mol}^{-1}$ 2 marks

1 mark for correctly balanced equation
1 mark for correct ΔH and sign

Question 8 (8 marks)

a. **i.** $2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$ 2 marks

1 mark for correct reactants and products
1 mark for correct balancing

ii. It must allow lithium ions to move through. 1 mark

b. **i.** catalyst 1 mark

ii. porous to gases 1 mark

c. **i.** $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$ 1 mark

ii. voltage = E^o(cathode) – E^o(anode) = +1.23 – (–3.02) = 4.25 V 1 mark

iii.

	Positive	**Negative**
Anode		
Cathode	✓	

1 mark

Question 9 (8 marks)

a. **i.** $K_a = \dfrac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]}$ 1 mark

ii. $[H_3O^+] = 10^{-pH} = 10^{-3.38} = 4.17 \times 10^{-4}$ M 1 mark

$K_a = 1.7 \times 10^{-5} = \dfrac{(4.17 \times 10^{-4} \times [CH_3COO^-])}{[CH_3COOH]}$

% ionisation = $\dfrac{[CH_3COO^-]}{[CH_3COOH]} \times 100$ 1 mark

$= \dfrac{1.7 \times 10^{-5}}{4.17 \times 10^{-4}} \times 100 = 4.1\%$ 1 mark

b. $[H_3O^+][OH^-] = 10^{-14} = 10^{-2.56} \times [OH^-]$ 1 mark

$[OH^-] = 3.63 \times 10^{-12}$ M 1 mark

c. $c_1V_1 = c_2V_2 = 10^{-2.00} \times 0.0100 = 10^{-2.37} \times V_2$

$V_2 = \dfrac{10^{-4}}{10^{-2.37}} = 2.34 \times 10^{-2}$ L = 23.4 mL 1 mark

Thus the volume of water added = 23.4 – 10.0 = 13.4 mL. 1 mark

Question 10 (4 marks)

$Q = I \times t = 0.541 \times 30 \times 60 = 973.8$ C 1 mark

$n(e^-) = \frac{I \times t}{F} = \frac{973.8}{96\ 500} = 0.01009$ mol 1 mark

If the metal is A, then the reduction reaction is $A^{3+}(aq) + 3e^- \rightarrow A(s)$

$n(A) = \frac{1}{3} \times n(e^-) = \frac{0.01009}{3} = 3.363 \times 10^{-3}$ mol 1 mark

$M(A) = \frac{m}{n} = \frac{0.151}{3.363 \times 10^{-3}} = 44.9$ g mol^{-1}

The metal is scandium. 1 mark

Question 11 (5 marks)

a. **i.** $Au^{3+}(aq)$ 1 mark

ii. Cr (s) 1 mark

b. $2NO_3^-(aq) + 8H^+(aq) + 3Cr(s) \rightarrow 2NO(g) + 4H_2O(l) + 3Cr^{2+}(aq)$ 1 mark

c. Connect each half-cell in turn to the standard hydrogen half-cell, noting the voltage and polarity of each. 1 mark

Those half-cells which are positive in the cell are given positive voltages and those which are negative are given negative voltages. Half-cell reactions can then be placed in order of decreasing voltage to generate an electrochemical series. 1 mark

Question 12 (7 marks)

a. **i.** It is an exothermic reaction and so the forward reaction produces heat. 1 mark

If the temperature is lowered, the forward reaction is favoured so that the change in temperature is partially opposed, according to Le Chatelier's Principle. 1 mark

ii. Using low temperatures produces a low rate but a high yield. By choosing a slightly higher temperature, a reasonable yield is achieved at an acceptable rate which is economically viable for the manufacturer. 1 mark

iii. *One of:*

- using an excess of gaseous water 1 mark

  Increasing the concentration of a reactant will move the reaction forward so that the change is partially opposed. 1 mark

OR

- increasing pressure 1 mark

  In the reaction, 2 mole of gas becomes 1 mole of gas, and so by increasing the pressure, the reaction will move forward to partially oppose the change. 1 mark

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b.

	C_2H_4	H_2O	C_2H_5OH
n_i	0.736	0.985	0
change	–0.650	–0.650	+0.650
n_e	0.086		0.130 × 5.00 = 0.650
$c_e = \frac{n_e}{5.00}$	<u>0.0172 M</u>		0.130 M

2 marks

1 mark for mole calculations

1 mark for correct concentration