![Neap logo]

Trial Examination 2016

VCE Chemistry Units 3&4

Written Examination

Suggested Solutions

SECTION A – MULTIPLE-CHOICE QUESTIONS

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

Question 1   **A**

In H_2O_2 the oxidation number of oxygen is –1. In O_2 the oxidation number of oxygen is 0, an increase of 1. Increase in oxidation number is an oxidation process, hence H_2O_2 is the reductant. The oxidation number of nitrogen decreases from +5 to +4, with acidified NO_3^- being the oxidant.

Question 2   **C**

If samples of the gases were added to the container, their concentrations would increase. The graphs show the concentrations decreasing instantaneously and so **A** is not correct. Heating the exothermic reaction would promote the reverse reaction, but there would not be a lowering of the concentration of both gases W and Y as there is at time t_1. **B** is also incorrect. Injecting an inert gas will increase the total gas pressure but will not change the concentration of any gas in the container. **D** is incorrect. Increasing the volume of the container would instantly lower the concentration of the gases as shown in the graph. Furthermore, the system will respond by favouring the side of the equation with the greater number of mole of gas so as to partially oppose the change by increasing the pressure in the container. This is shown in the graph and so **C** is the correct answer.

Question 3   **A**

Catalysts have no effect on the comparative heat energy of the reactants and products or on the yield of a chemical reaction. **A** is the correct answer. A catalyst operates by lowering the activation energy for a reaction by using an alternative pathway. Thus variable III is affected by the presence of a catalyst.

Question 4   **D**
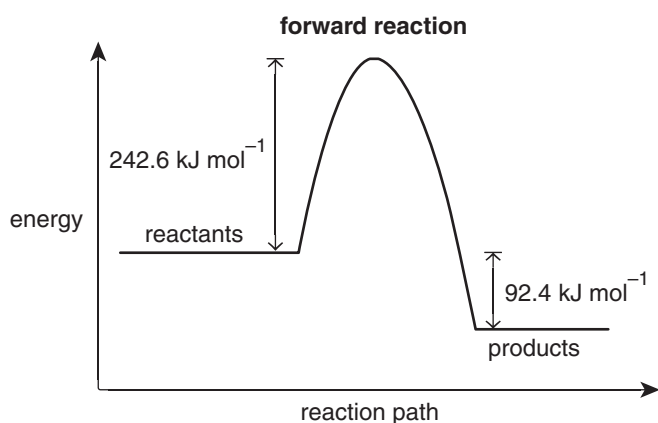
For the reverse reaction (the decomposition of ammonia), activation energy $= 242.6 + 92.4 = 335.0$ kJ mol^{-1}.

Question 5   **D**

For forward reaction: $K = \dfrac{[NH_3]^2}{[N_2][H_2]^3}$

For reverse reaction: $K_1 = \dfrac{1}{K} = \dfrac{[N_2][H_2]^3}{[NH_3]^2}$

For reverse reaction with double the coefficients: $K_2 = K_1^{\,2} = \left(\dfrac{1}{K}\right)^2 = \left(\dfrac{1}{0.0520}\right)^2 = 369.8$

Question 6   **B**

$K_w = [H_3O^+]^2 = 2.0 \times 10^{-13}$, hence $[H_3O^+] = [OH^-] = \sqrt{2.0 \times 10^{-13}} = 4.5 \times 10^{-7}$ M. As it is pure water, it is neutral at all temperatures. So **A** and **C** are incorrect. At 25°C, $K_w = 10^{-14}$, and at 75°C, $K_w = 2.0 \times 10^{-13}$. So it follows that at 90°C, the value will be higher. The reaction is endothermic. **D** is incorrect.

Question 7   **D**

Let the volume = V litres.

$n(\text{HCl}) = c \times V = 0.050V$ mol

$n(\text{OH}^-) = 2 \times n(\text{Ba(OH)}_2) = 2 \times c \times V = 0.10V$ mol

$n(\text{OH}^-)$ in excess after reaction with HCl $= 0.10V - 0.050V = 0.050V$ mol

$[\text{OH}^-] = \dfrac{n}{V} = \dfrac{0.050V}{2V} = 0.025$ M $= 10^{-1.6}$ M

$[H_3O^+] = 10^{-12.4}$ M and so pH = 12.4.

Question 8   **A**

In **A** the three components of the nucleotide are correctly joined. Each incorrect diagram has one fault. In **B** an oxygen atom is missing in the phosphate–sugar link. In **C** the sugar is connected to the wrong N atom on the base. In **D** the base and phosphate connections to the sugar are reversed to their correct locations.

Question 9   **C**

Unsaturated compounds typically participate in addition reactions and so HCl is 'added across' each double bond.

Question 10   **C**

The correct structure of the product is shown below. Note that both double bonds have reacted to produce the dichloro product. Option **D** is not a correctly named molecule.
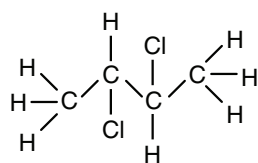
Question 11   **B**

Hydrogen bonding involved in the secondary structure is easily disrupted by elevated temperatures. The side groups along the protein chain are involved in the tertiary structure, and changing the pH may affect the interactions between the atoms in the side groups. The primary structure involves peptide covalent bonds and will only be affected by heating in low pH conditions for many hours.

Question 12   **C**

Reagent x is Cl_2, which acts in the presence of light in a substitution reaction to form the monochloroalkanes C_3H_7Cl and C_4H_9Cl. Reagent y is NaOH, which acts in a substitution reaction to convert the monochloroalkanes to alcohols. Reagent z is an oxidising agent, acidified MnO_4^-, which converts primary alcohols to carboxylic acids. The lack of reaction to produce $C_4H_8O_2$ suggests that the C_4H_9O alcohol is the secondary alcohol 2-butanol or the tertiary alcohol 2-methylpropan-2-ol.

Question 13   B

The compounds in **A**, **B** and **C** all have the molecular formula $C_7H_{14}O_2$. 1-butylbutanoate has the molecular formula $C_8H_{16}O_2$, and so is not an isomer of $C_7H_{14}O_2$.

Question 14   B

The identity and concentration of metals is analysed by AAS. Statement I is incorrect. To analyse a particular metal, calibration of the AAS device for that metal involves making up a set of standards of the metal ion, reading absorbances and constructing a calibration graph. Statement II is correct. **B** is the required answer.

Question 15   C

The gases are hotter after passing over each tray and so the reaction is exothermic. The forward reaction is favoured by low temperatures. The forward reaction is pressure-reducing (5 mol of reactants produce 2 mol of products), and so is favoured by high pressures.

Question 16   D

Catalysts work more effectively with a large surface area as the reactant molecules bond temporarily to the surface. Large blocks provide a low surface area for the volume of catalyst and so **A** is incorrect. A powder has a very large surface area as the particles are minute, but a powder spread out on a tray would not interact fully with gases being passed over. **B** is incorrect. A gauze arrangement does provide a large surface area but it is unlikely to be used sitting on a tray, as an appreciable amount of surface area is against the tray and not available to interact with the gases. **C** is not the answer. Small pellets have a very large surface area with only a small amount touching the tray. **D** is the required answer.

Question 17   C

The pH in the flask starts high and decreases as the HCOOH is added. All graphs have the correct form. The titre for complete reaction is given by $V(\text{HCOOH}) = \dfrac{n}{c} = \dfrac{0.087 \times 0.02000}{0.100} = 17.4$ mL. **B** and **D** are incorrect as they show a titre of 23 mL, not 17 mL. At the equivalence point the titration flask contains HCOONa, a weak base. The pH is therefore greater than 7. **A** and **B** are incorrect as they show a pH of 7 at equivalence.

Question 18   A

At the anode, oxidation occurs and the strongest reductant will be oxidised preferentially. Only water is capable of being oxidised: $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$.

At the cathode, reduction occurs and the strongest oxidant will be reduced preferentially. For the oxidants present in the cell, the order of increasing oxidising strength is $H_2O < Ni^{2+}$. Ni will therefore be deposited at the cathode.
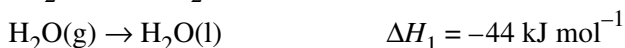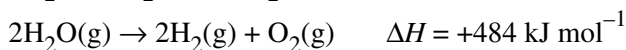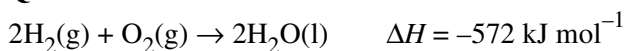
Question 19   B

Copper is a stronger reductant than water and so at the anode (+ electrode), copper will be preferentially oxidised. Copper ions will be produced instead of oxygen gas and hydrogen ions. At the cathode, no change in products will occur. *(Copper ions formed at the anode will eventually be reduced preferentially at the cathode, but this would occur at a later stage.)*

Question 20   B

A carrier gas must not react with the components being separated by GC. Hydrogen gas will react with ethene, ethyne and possibly other compounds, especially at the elevated temperatures used for GC. Only helium and nitrogen gases are unreactive under normal circumstances and so could be used as carrier gases.

Question 21   A

The rate of adsorption–desorption of compounds separated in the column is altered by temperature and so retention times will vary. **A** is the correct answer. The flow rate of the carrier gas is set by the operator and the area under the peaks is a function of concentration of the components, and so altering temperature does not alter these. The order in which the gases come out of the column depends on the properties of the column. These may not be significantly altered by the change in temperature.

Question 22   C

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) \qquad \Delta H = -572 \text{ kJ mol}^{-1}$$

$$2H_2O(g) \rightarrow 2H_2(g) + O_2(g) \qquad \Delta H = +484 \text{ kJ mol}^{-1}$$

$$2H_2O(g) \rightarrow 2H_2O(l) \qquad \Delta H = -572 + 484 = -88 \text{ kJ mol}^{-1}$$

$$H_2O(g) \rightarrow H_2O(l) \qquad \Delta H_1 = -44 \text{ kJ mol}^{-1}$$

Question 23   D

Cellulose forms by condensation polymerisation. The links between monomer units are called glycosidic or ether links.

Question 24   B

Enzymes are proteins. **A** is incorrect. One theory of enzyme action proposes that the substrate bonds temporarily to the enzyme molecule so that bonds are strained, and therefore are more easily broken. **B** is correct. The active site of an enzyme forms as part of the tertiary structure, resulting from the interactions between the various side groups of amino acid residues in the protein chain. **C** is not correct. Boiling will break many interactions in the secondary and tertiary structure of the enzyme and destroy the active site. When cooled, the denatured protein will not form the interactions it had before boiling, and so its catalytic activity and active site will no longer operate. **D** is incorrect.

Question 25   A

Zinc should react with oxidants which are stronger than zinc ions; that is, Pb^{2+} and acidified H_2O_2. Mn^{2+} is a weaker oxidant than zinc ions and so will not react with zinc.

Question 26   A

In the cell, Fe^{3+} ions will be reduced and Co will be oxidised. Pt is the positive electrode or cathode. **A** is the correct answer.

Question 27   C

The cell will stop producing energy when there is no difference in the potential between the two half-cells and the cell reaction has reached equilibrium. **C** is the correct answer.

Question 28   B

This is a back titration, as the acetylsalicylic acid is a weak acid and direct titration with a strong base would not produce a sharp endpoint. Excess strong base is used and the base which is unreacted is titrated with a strong acid.

Question 29   D

$n(\text{aspirin}) = n(\text{NaOH}) = 0.00864 \text{ mol}$

$m(\text{aspirin}) = n \times M = 0.00864 \times 180.2 = 1.557 \text{ g}$

$\% \text{ by mass} = \dfrac{1.557}{1.834} \times 100 = 84.9\%$

Question 30   D

The amount of base P added in step 2 is not altered by the error made in step 3. **D** is an incorrect statement and so is the required response. If the pipette had water droplets in it when used, there would be fewer mole of base P in the aliquot and the amount of acid Q would be lower than it should be. The calculated amount of unreacted base in step 2 is therefore too low. Subtracting the amount of unreacted base from the total amount of base initially added gives an amount of base reacting with the aspirin which is too high, and will give a percentage of aspirin which is too high. **A**, **B** and **C** are correct, and so are not the required answers.

SECTION B – SHORT-ANSWER QUESTIONS

Question 1 (9 marks)

a.   **i.**   peptide (or amide)   1 mark

    ii.   carboxyl (or carboxy) OR amino   1 mark

b.   **i.** R_f(lysine) = $\dfrac{1.3}{11}$ = 0.12 (allow 0.11 to 0.13)   1 mark

    ii.   *Any one of:*

- lysine
- valine
- tyrosine

                                                                       1 mark

c.   **i.**   Using solvent A, two amino acids (glycine and threonine) have the same R_f value and so formed one spot on the TLC plate.   1 mark

        Using solvent B, all of the amino acids in the peptide have different R_f values and so four spots are seen on the TLC plate.   1 mark

    ii.

                                                                    2 marks
1 mark for correct amino acid drawn.
1 mark for correct charges on relevant symbols.

    iii.   serine and threonine *(both have a hydroxyl group in the side chain)*   1 mark

Question 2 (9 marks)

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

    ii. $[CH_3COO^-] = [H^+]$, and $[H^+] = 10^{-pH}$.

        $K_a = \dfrac{(10^{-3.4})^2}{0.010}$ 1 mark

        $= 1.6 \times 10^{-5}$ M   1 mark

    iii.   *Any one of:*

- The concentration of ethanoic acid is approximately 0.010 M in the equilibrium mixture. This is a reasonable assumption as the % hydrolysis is very low.
- The contribution of $[H_3O^+]$ from self-ionisation of water is negligible.

                                                                   1 mark

b.   **i.** $H_2SO_4(l) + H_2O(l) \rightarrow HSO_4^-(aq) + H_3O^+(aq)$ 1 mark

        $HSO_4^-(aq) + H_2O(l) \rightleftharpoons SO_4^{2-}(aq) + H_3O^+(aq)$ 1 mark

ii. The student incorrectly assumed complete ionisation of both protons to give a H_3O^+ concentration of 0.020 M and so a pH of $-\log 0.020 = 1.69$. 1 mark

iii. Diluting the acid increased the percentage hydrolysis of the second proton. 1 mark

The assumption of complete ionisation of both protons is now much closer to being correct, giving a much better approximation of the actual pH. 1 mark

Question 3 (8 marks)

a. $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ 1 mark

b. $n(SO_4^{2-}) = n(BaSO_4) = \dfrac{m}{M} = \dfrac{3.2}{233.4} = 0.0137$ mol 1 mark

$m(SO_4^{2-}) = n \times M = 0.0137 \times 96.1 = 1.32$ g 1 mark

% by mass $= \dfrac{1.32}{2.0} \times 100 = 66\%$ 1 mark

c. *Any two of:*
- Step 1: The solution was not filtered and thus some solid particles could be trapped in the precipitate in later steps.
- Step 2: It is not certain that an excess of barium chloride was added and so some sulfate ions may not be precipitated.
- Step 3: It is not certain that the solid was completely dry as it would be if the solid had been weighed to constant mass.

2 marks

d. *Any one of:*
- For steps 1 or 3, the mass of the precipitate would be higher than the actual mass which is then used for the calculation of the mass of sulfate, resulting in a percentage by mass which is higher than the actual value.
- For step 2, some sulfate may not be precipitated and so the calculated mass of sulfate is too low, resulting in a percentage by mass which is lower than the actual value.

1 mark

e. Repeat the analysis for a number of different samples and take the average of the results to achieve a more reliable value for percentage by mass of sulfate. 1 mark

Question 4 (10 marks)

a. **i.** A catalyst provides an alternative pathway for the reaction. 1 mark

The alternative pathway has lower activation energy and so a greater proportion of collisions will be successful. 1 mark

ii. *For example:*

Increasing the temperature of a reaction requires energy input which incurs a cost, whereas using a catalyst does not require any extra energy input. 1 mark

b. reduction 1 mark
(oxygen is removed, hydrogen is added)

c.   **i.**   Radiation of particular wavelengths can be absorbed by electrons which are promoted from low energy levels to higher energy levels.   1 mark

As each substance is unique in its structure and its various energy levels, the energy and wavelength of radiation required to promote electrons will vary.   1 mark

       ii.   The absorbance of the compound is measured for a range of wavelengths and an absorbance spectrum is produced which reveals the wavelength of maximum absorbance.   1 mark

d.   **i.**   The solvent or other components of the mixture and/or the reactant and product molecules could absorb some radiation of the wavelengths shown in the diagram.   1 mark

       ii.   The very large peak at 400 nm shows the reactant 4-nitrophenol absorbing radiation before the reaction commences.   1 mark

After the reaction has been going for 20 seconds, there is no reactant present (no peak at 400 nm) but there is some absorbance at 295 nm, the wavelength that the product absorbs. Reaction has occurred within 20 seconds.   1 mark

Question 5 (11 marks)

a.   lauric (1%) + palmitic (28%) + stearic (17%) = 46%   1 mark

b.   **i.** $HOCH_2(CHOH)CH_2OH$ or $C_3H_8O_3$ *(glycerol)*   1 mark

       ii.   Glycerol has three polar hydroxyl functional groups and is a reasonably small molecule.   1 mark

Water molecules form hydrogen bonds with the hydroxyl groups and hold the glycerol molecules tightly in an aqueous solution.   1 mark

(Note that sodium hydroxide (NaOH) will also be found in the aqueous layer, as the ions (Na^+ and OH^-) form ion-dipole bonds with water molecules and so are soluble in the aqueous layer.)

c.   Unsaturated fatty acids which will react with the hydrogen gas are oleic acid: 23.5 g and linoleic acid: 3.5 g.   1 mark

$n(\text{double bonds}) = 1 \times n(\text{oleic}) + 2 \times n(\text{linoleic})$

$$= \frac{23.5}{282} + 2 \times \frac{3.5}{280}$$

$$= 0.108 \text{ mol}$$ 1 mark

Each mol of double bonds requires one mol of hydrogen gas.

$m(H_2) = n(H_2) \times M = 0.108 \times 2 = 0.22$ g   1 mark

d.   **i.** $CH_3OH(l) + C_{15}H_{31}COOH(l) \xrightarrow{KOH} C_{15}H_{31}COOCH_3(l) + H_2O(l)$ 2 marks

1 mark for correct reactants.
1 mark for correct products.

       ii.   The fuel is produced from reactants formed by plants which take in carbon dioxide gas from the air for photosynthesis.   1 mark

Burning the fuel simply releases the carbon dioxide gas which was used by the plant in reaction pathways; that is, carbon output is matched by carbon intake.   1 mark

Question 6 (7 marks)

a.   *Any one of:*

   •   to keep the electrodes from touching each other, as this would cause no electrical energy to be available

   •   to allow the flow of ions between the electrodes

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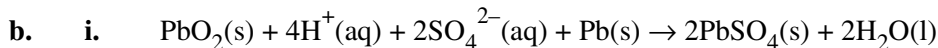
b.   i. $PbO_2(s) + 4H^+(aq) + 2SO_4^{2-}(aq) + Pb(s) \rightarrow 2PbSO_4(s) + 2H_2O(l)$ 1 mark

   ii. $1.69 - (-0.36) = 2.05$ V   1 mark

   iii.   The $E°$ values are measured under standard conditions and, as the lead–acid cell does not use these conditions, the calculated cell voltage will not be reliable.   1 mark
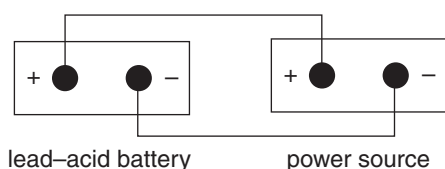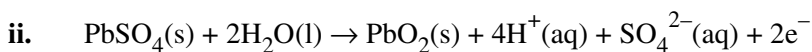
c.

	Positive	**Negative**
Oxidation		
Reduction	✓	

1 mark

d.   i.

lead–acid battery   power source

1 mark

   ii. $PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^-$ 1 mark
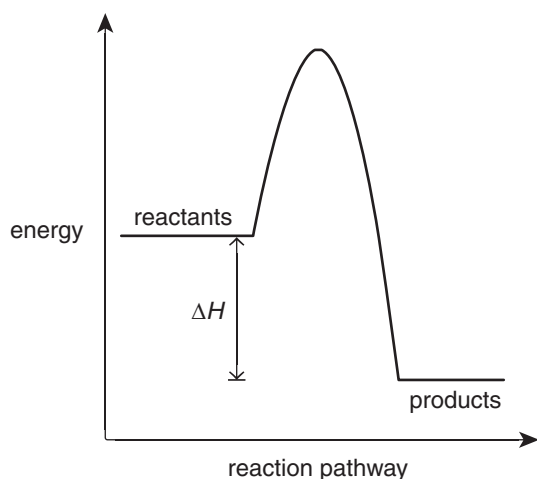
Question 7 (10 marks)

a.

2 marks
1 mark for correct shape of profile.
1 mark for correct labels.

b.   **i.**   energy = $m \times c \times \Delta T = 200 \times 4.18 \times 37.6 = 31.43$ kJ   1 mark

$n(\text{2-propanol}) = \dfrac{m}{M} = \dfrac{1.29}{60.0} = 0.0215$ mol   1 mark

energy per mole = $\dfrac{31.43}{0.0215} = 1462 = 1.46 \times 10^3$ kJ mol^{-1} 1 mark

ii.   The accepted value as given in the Data Booklet is 2003 kJ mol^{-1}.

% energy transferred = $\dfrac{1462}{2003} \times 100 = 73.0\%$ 1 mark

c. $n(\text{2-propanol}) = \dfrac{m}{M} = \dfrac{2.80}{60.0}$ mol

energy released during combustion = $\dfrac{2.80}{60.0} \times 2003 = 93.47$ kJ   1 mark

$\Delta T = \dfrac{E}{\text{CF}} = \dfrac{93.47}{1.473} = 63.5\,°\text{C}$ 1 mark

d.   In the presence of H_3PO_4 catalyst: $CH_3CHCH_2 + H_2O \rightarrow CH_3CHOHCH_3$ 2 marks

1 mark for correct reactants.
1 mark for correct catalyst.

Question 8 (7 marks)

a.   Natural gas is a fossil fuel which has limited and finite deposits remaining in the ground and thus is not sustainable.   1 mark

b.   High temperatures would give the reactant particles more kinetic energy and so a greater proportion would have energies greater than the activation energy, resulting in more successful collisions between the particles. Rate increases.   1 mark

It is an endothermic reaction and so adding heat will move the position of equilibrium to the products as the system responds by opposing the temperature increase.   1 mark

c.   **i.**   concentration fraction = $\dfrac{[CO][H_2]^3}{[CH_4][H_2O]}$

$= \dfrac{\left(\dfrac{0.90}{3}\right)\left(\dfrac{0.60}{3}\right)^3}{\left(\dfrac{1.5}{3}\right)\left(\dfrac{0.75}{3}\right)}$ 1 mark

$= 0.019 \text{ M}^2$ 1 mark

The value of K at this temperature is 0.26 and so the reaction cannot be at equilibrium because the concentration fraction $\neq$ K.   1 mark

ii.   The concentration fraction is lower than the value of K, and so the reaction shifts to the product side to raise the value of the concentration fraction to K.   1 mark

Question 9 (8 marks)

a.   Water is a stronger oxidant than sodium ions.   1 mark

At the cathode, water will react preferentially to produce hydrogen gas and hydroxide ions.   1 mark

b. **i.** $2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$ 1 mark

ii.   As iron is a stronger reductant than chloride ions, it would be oxidised in preference to the chloride ion, resulting in no chlorine production.   1 mark
(An inert material such as carbon must be used for the anode.)

c.   If the products of the non-spontaneous reaction (Na and Cl_2) are allowed to come into contact they would react spontaneously.   1 mark

d. $Q = I \times t = 30\,000 \times 12.0 \times 60 \times 60 = 1.296 \times 10^9$ C   1 mark

$n(Na) = n(e^-) = \dfrac{Q}{F} = \dfrac{1.296 \times 10^9}{96\,500} = 1.343 \times 10^4$ mol   1 mark

$m(Na) = 1.343 \times 10^4 \times 23 = 3.09 \times 10^5$ g   1 mark

Question 10 (11 marks)

a. **i.** $C_4H_8O_2^+$ 1 mark

ii. $V(\text{compound}) = \dfrac{nRT}{p}$

$= \dfrac{mRT}{Mp}$

$= \dfrac{5.81 \times 8.31 \times 373}{88 \times 101.3}$ 1 mark

$= 2.0$ L   1 mark

b. **i.**   A C=O grouping is present in the compound.   1 mark

ii.   There are three different hydrogen environments.   1 mark

iii.   The three ^{1}H/proton types in the compound have 2, 3 and 0 adjacent/neighbouring protons respectively.   1 mark

iv.   There are four different carbon environments.   1 mark

c. **i.**   Add sodium carbonate to the sample.   1 mark

If no evolution of carbon dioxide gas occurs, the sample is not acidic.   1 mark

ii.
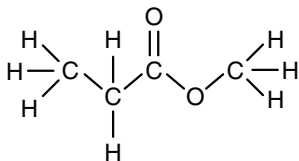
(CH$_3$COOCH$_2$CH$_3$ is not correct as this would show a ^{1}H NMR peak at 2.0 for the CH$_3$COOR proton.)

2 marks
1 mark for structure consistent with IR and ^{13}C NMR data.
1 mark for structure consistent with proton NMR data.