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   **B**

The molecular formulas of benzene and cyclohexane are C_6H_6 and C_6H_{12} and their empirical formulas are thus CH and CH_2 respectively. So **A** is a correct statement. **B** is incorrect because, even though the compounds do have a ring structure, benzene does not have single bonds between the carbon atoms. The bonds are often referred to as being intermediate between single and double bonds but all C to C bond lengths are equivalent. Thus **C** is a correct statement. The percentage of carbon must be higher in benzene than cyclohexane as the molecules have six carbon atoms each but cyclohexane has a higher molar mass. **D** is correct. **B** is the required answer as the incorrect statement was sought by the question.

Question 2   **B**

As the temperature increases, the distribution graph flattens and the mean kinetic energy of the particles increases. Thus $T_2 > T_1$ and so statement I is incorrect and statement II is correct. At higher temperatures, there is a greater proportion of particles with energies above the activation energy. Statement III is correct. For a particular reaction, the activation energy is constant except when a catalyst is present. Statement IV is incorrect, as the activation energy for the reaction does not depend on the temperature.

Question 3   **C**

$\Delta H = H_p - H_r$ which is positive in this instance. Thus this is an endothermic reaction.

Question 4   **B**

The activation energy is the energy required to break the bonds in the reactants in the reverse reaction (the products of the forward reaction). This value is represented by 'y', but is also equivalent to w – z.

Question 5   **B**

The amine functional group will gain a proton in acidic conditions as it acts as a base. Neither of the two hydrogen atoms is not lost as a proton in any pH conditions. The ionisable hydrogen atoms in the two carboxyl functional groups will be lost as protons in alkaline conditions and so **B** is the correct answer.

Question 6   **C**

The glycaemic index indicates the ability of different foods to release glucose into body.

Question 7   **D**

Statement I is not correct as the peptide bond involves the CONH group of atoms. The amino acid residues from the left are: alanine, serine, leucine, valine, cysteine, and glycine. There is no isoleucine in the chain and so Statement II is incorrect. Cysteine could form a disulfide bridge with another cysteine further along the chain. But this covalent bond between sulfur atoms would be part of the tertiary structure of the protein not the secondary structure. Statement III is also not correct.

Question 8   **D**

The functions detailed in **A**, **B** and **C** are all parts of the role of a coenzyme. The coenzyme can also facilitate the transport of electrons or groups of atoms. Intermediate carriage of neutrons is not a function of a coenzyme. **D** is not correct and thus is the required answer.

Question 9   **A**

According to the induced-fit model of enzyme action, the size and shape of the active site cavity changes when the substrate enters, much like a hand entering a glove. Only the active site changes – there are no changes in the whole enzyme molecule or in the substrate before catalysis occurs.

Question 10   B

The reactants butanoic acid and propan-1-ol form the ester 1-propyl butanoate.

Question 11   D

$\% \text{ atom economy} = \dfrac{130}{148} \times 100 = 88\%$

Question 12   C

$n(CH_3CH_2CH_2COOH) = \dfrac{m}{M} = \dfrac{4.50}{88} = 0.0511 \text{ mol}$

$n(\text{ester}) = n(CH_3CH_2CH_2COOH)$

$m(\text{ester}) = n \times M = 0.0511 \times 130 = 6.65 \text{ g}$

$\% \text{ yield} = \dfrac{5.32}{6.65} \times 100 = 80\%$

Question 13   A

A chiral carbon atom has four different atoms or groups of atoms arranged tetrahedrally around it. Only the carbon atom with the chlorine atom attached is chiral.

Question 14   C

Both cells convert chemical energy to electrical energy in spontaneous redox reactions and so **A** and **D** are incorrect. Neither cell has efficiency close to 100% and so **B** is incorrect. The reason that a secondary cell can be recharged is that the products of the energy-producing reaction remain in contact with the electrodes and are used as the reactants for the reverse reaction driven by the input of electrical energy. In a primary cell, the products move away from the electrodes and are not available to produce the reverse reaction. **C** is the required answer as the feature applies only to secondary cells.

Question 15   D

Silver ions are stronger oxidising agents than tin ions and so the anode is the tin electrode where oxidation occurs. EMF = +0.80 – (–0.14) = 0.94 V

Question 16   C

The number of mole of metal lost from one electrode will be related to the number of mole of metal formed at the other electrode according to the stoichiometric ratio of the overall cell equation. This principle does not apply to mass loss or gain and so **A** is incorrect. Electrons travel from the negative anode to the positive cathode, that is, from Sn to Ag. **B** is incorrect. This is a galvanic cell in which the stronger oxidising agent (Ag^+) will react with the stronger reducing agent (Sn) and so no gas bubbles should appear. **D** is also incorrect. In all electrochemical cells, positive ions (cations) travel towards the cathode. **C** is correct and is the required answer.

Question 17   A

Ions travel through the salt bridge so that there is no charge disparity between the two half-cells. **A** is the correct answer. Electrons move through the wire and so **B** is incorrect. As oxidation of tin and reduction of silver ions proceed, the concentrations of the electrolytes will change and the salt bridge has no role preventing this. **C** is incorrect. There is no requirement for the level of electrolytes to be equal for the cell to operate. **D** is also incorrect.

Question 18   B

$n(\text{NaOH}) = c \times V = 0.150 \times 0.0134 = 0.00201 \text{ mol}$

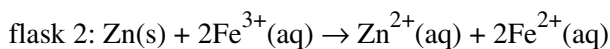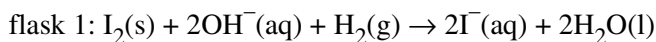$n(\text{HCOOH}) = n(\text{NaOH})$

$c(\text{HCOOH}) = \dfrac{n}{V} = \dfrac{0.00201}{0.010} = 0.201 \text{ M}$

Question 19   B

Water in the pipette or burette will change the concentration of the solutions dispensed from them and so affect the number of mole dispensed. This will affect the calculated concentration of methanoic acid. Water in the flask is of no consequence as it is the reactant particles which are reacting together which is crucial, and not the volume in which they react; that is, placing a solution into a wet flask will decrease its concentration but will not change the number of mole of solute.

Question 20   C

An incorrectly calibrated pipette is an example of a systematic error. Repetition of the experiment will not correct this error. The variation in the values given in **A** represents random error. **B** is an example of a mistake. The change suggested in **D** has no effect on the results of the experiment. The flask is the reaction vessel only, so its size is not relevant.

Question 21   A

flask 1: $I_2(s) + 2OH^-(aq) + H_2(g) \rightarrow 2I^-(aq) + 2H_2O(l)$

flask 2: $Zn(s) + 2Fe^{3+}(aq) \rightarrow Zn^{2+}(aq) + 2Fe^{2+}(aq)$

flask 3: no reaction as H_2O_2 is a weaker reducing agent than Ni and Ni^{2+} is a weak oxidising agent

Question 22   A

Each of the methods in **B**, **C** and **D** are used in measuring rate of reaction as they do not interfere with the course of the reaction. It would not be practical to determine how much magnesium carbonate has been used in the reaction whilst the reaction is proceeding. It could be achieved by weighing the solid before the reaction and after the experiment is completed but this would only indicate an average rate of reaction. So **A** is the least practical method.

Question 23   A

The independent variable is the one altered by the experimenter, in this case the surface area of the magnesium carbonate. Time taken for complete reaction is the dependent variable. The amount of hydrochloric acid in the flask is a controlled variable. The volume of carbon dioxide collected in each test would be expected to be the same.

Question 24   C

As conditions are not standard, the volume is calculated using $pV = nRT$.

$n(\text{MgCO}_3) = \dfrac{m}{M} = \dfrac{0.35}{84.3} \text{ mol}$

$n(\text{CO}_2) = n(\text{MgCO}_3)$

$V(\text{CO}_2) = \dfrac{nRT}{p} = \dfrac{0.35 \times 8.31 \times 298 \times 0.987}{84.3 \times 1.0 \times 100} = 0.101 \text{ L} = 101 \text{ mL}$

Question 25   B

Collecting the gas at a lower pressure will lead to a larger volume, so this is not likely to explain the lower than expected volume. **B** is the required response. The events in **A**, **C** and **D** would lead to a lower than expected collected volume of gas.

Question 26   D

In recharging a cell, the external power source forces electrons onto the negative electrode to produce a non-spontaneous reduction reaction.

Question 27   D

Oxygen is a reactant in cellular respiration and so **A** is correct. The presence of CO will move reaction 2 forward and so remove some haemoglobin from the available supply. Thus reaction 1 will move in the reverse direction according to Le Chatelier's principle. **B** is also correct. The reason why the treatment for CO poisoning is to give pure oxygen is because the position of equilibrium for reaction 2 lies strongly with the products. Giving excess oxygen moves reaction 1 forward which causes reaction 2 to move in the reverse direction. **C** is also correct. CO is not a catalyst for reaction 1 and even if it was a catalyst, it would increase the rate of both the forward and reverse reactions. It cannot promote the dissociation of Hb_4O_8 alone. **D** is incorrect and thus is the required answer.

Question 28   A

Both compounds are formed in condensation reactions. Sucrose has hydroxyl and ether functional groups whereas aspartame has ester, amide, amine, carboxyl and arene (benzene) functional groups.

Question 29   D

In a fuel cell the oxidising agent is oxygen. It reacts at the positively charged cathode in the acidic fuel cell to produce water.

Question 30   D

In all energy transformations, heat energy is lost and so the PAFC must produce less electrical energy than combustion of hydrogen gas would produce as heat energy. Statement I is incorrect. The electrodes in the PAFC are porous to allow passage of gases and catalytic to enable the reactions to occur at lower temperatures. However, these properties are not necessary for all galvanic cells which use non-porous electrodes with a gaseous reactant being fed onto the surface of the electrode in contact with the electrolyte. Statement II is also incorrect. The only waste product produced in the operation of the PAFC is water which is not a major greenhouse gas. Statement III is incorrect.

SECTION B

Question 1 (6 marks)

a. Vitamin C has numerous hydroxyl functional groups in the molecule. These –OH groups are able to form hydrogen bonding with water molecules which hold the compound in solution.   1 mark

Vitamin D has only one hydroxyl group in the structure but many non-polar methyl groups and other hydrocarbon structures. Water molecules will not form extensive intermolecular bonding with non-polar groups but the non-polar oil will be attracted to the vitamin D molecule and will form intermolecular bonds.   1 mark

b.   **i.** The double bonds in unsaturated fatty acids make the molecules susceptible to oxidation by atmospheric oxygen which produces unstable new compounds.   1 mark

Often these new compounds degrade to produce short-chain aldehydes and carboxylic acids which have unpleasant rancid odours.   1 mark

   ii. The oxygen in the air reacts readily with the vitamin C molecule which prevents the oxidation of the fatty acids.   1 mark

The new compound formed by this oxidation does not have an unpleasant odour and so no rancidity occurs.   1 mark

Question 2 (10 marks)

a. Two rennin tablets should have been dissolved in 10.0 mL of water to produce a single enzyme solution.   1 mark

The beakers of milk should remain in their water baths throughout the experiment so that the temperature could not vary, as it would by placing them on the bench.   1 mark

b. 38°C   1 mark

c.   **i.** The milk at 10°C took so long to solidify as the molecules were moving slowly and interaction with the active site was not occurring readily – the active sites were not disrupted.   1 mark

   ii. The milk solidifies due to the action of rennin on a particular protein in the milk, not due to denaturation of all milk protein.   1 mark

Denaturation does not involve the disruption of the primary structure of a protein (as the amino acids are covalently bonded) it is the disruption of the weaker intermolecular bonding involved in the secondary and tertiary structures of the protein.   1 mark

   iii. The milk in beaker 8 was at 80°C which would have caused denaturation of the enzyme.   1 mark

Returning the milk to 40°C would not produce solidification as the structure of the enzyme has been permanently disrupted so that no interaction with the active site is possible.   1 mark

d. The suggested experiment would have produced less useful information as more than one variable is altered in the investigation, that is, both the type of milk and temperature in the one experiment and so no result can be attributed to a single variable. — 1 mark

Investigating the effect of the different types of milk should be undertaken in a separate experiment so that the results can be compared with the outcome using normal milk. — 1 mark

Question 3 (13 marks)

a. i. Excess oxygen ensures that all of the benzoic acid is used in the calibration. — 1 mark

ii. $n(C_7H_6O_2) = \dfrac{m}{M} = \dfrac{1.25}{122.0} = 0.01025$ mol — 1 mark

2 mol $C_7H_6O_2$ produces 6526 kJ and so 0.01025 mol will produce

$0.01025 \times \dfrac{6526}{2} = 33.4$ kJ — 1 mark

iii. calibration factor $= \dfrac{\text{energy}}{\text{change in temperature}} = \dfrac{33.43}{(24.19 - 19.74)} = 7.51$ kJ °C^{-1} — 1 mark

b. i. energy produced $= 3.36 \times 7.51 = 25.23$ kJ — 1 mark

energy of the sample $= \dfrac{25.23}{1.47} = 17.2$ kJ g^{-1} — 1 mark

ii. *For example:*

The human body does not have enzymes which can metabolise cellulose and so none of the chemical energy in this carbohydrate is available to the body. — 1 mark

Cellulose will be oxidised in a calorimeter, releasing energy and so this is one cause of the disparity. — 1 mark

c. 15.57 kJ for 1 g, hence $15.57 \times 180.0 = 2803$ kJ for 1.0 mole. — 1 mark

$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$ — 1 mark

$\Delta H = -2803$ kJ mol^{-1} — 1 mark

d. i. The amino acid group is attached to the same carbon atom as the carboxyl group – in this case to the carbon numbered 2. — 1 mark

ii. 2-amino-3-methylbutanoic acid — 1 mark

Question 4 (11 marks)

a. i. *Any one of:*

$C_{11}H_{23}COOH$ or $C_{13}H_{27}COOH$ or $C_{15}H_{31}COOH$ or $C_{17}H_{35}COOH$ — 1 mark

ii.

— 2 marks
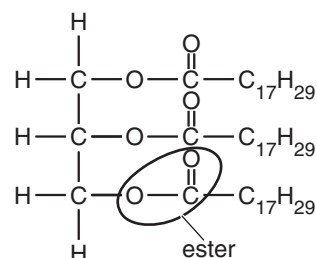
1 mark for correct structure and correct linolenic acid residues.
1 mark for correct ester linkage.

b. **i.** The section is from elaidic acid because the there is a *trans* arrangement around the double bond. 1 mark

ii.

1 mark

c. **i.** $C_{17}H_{31}COOH$ or $C_{17}H_{29}COOH$ 1 mark

ii. The melting point will be higher for the hydrogenated product. 1 mark

As there are less double bonds in the molecule, the fatty acid chains are able to pack together more closely and so the dispersion forces are more intense. 1 mark

As the dispersion forces are stronger and require more energy to disrupt, the hydrogenated compound has a higher melting point compared to the unhydrogenated oil. 1 mark

d. From the calibration graph, an area of 10 000 units is for 0.40% and so an area of 8150 units is a concentration of $8150 \times \dfrac{0.40}{10\,000}$, that is, 0.33% m/v. 1 mark
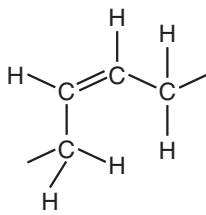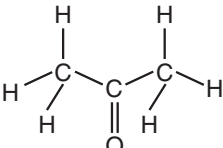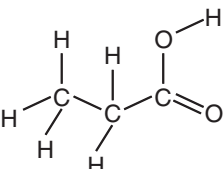
0.33% = 0.33 g per 100 mL = 0.033 g per 10 mL and, as the 10 mL contained 0.50 g of margarine, the mass of elaidic acid is 0.033 g. 1 mark

Question 5 (11 marks)

a. $C_2H_5OH(l) + 2O_2(g) \rightarrow 2CO(g) + 3H_2O(l)$ 1 mark

b. **i.** The rate of reaction increases. 1 mark

Higher temperatures result in more reactant particles having energies greater than the activation energy and so a higher proportion of collisions are successful (*and a greater frequency of collisions occur as the molecules are moving faster*). 1 mark

ii. The rate of reaction increases. 1 mark

As the reactants are in a smaller volume, the frequency of collisions increases and so the number of successful collisions also increases. 1 mark

c. The yield of HCN will increase. 1 mark

Removing a product from the equilibrium will result in the reaction moving in the forward direction to partially oppose the decrease in the concentration of hydrogen gas. 1 mark

d. The rate of reaction is higher at higher pressures but no benefit is gained for the yield as there are 3 mol of gas on each side of the reaction. 1 mark

However, building and using high pressure equipment is costly and the rate and yield of reaction could be acceptable at atmospheric pressure. 1 mark

e. **i.** The source of methane is fossil fuels either from natural gas or from destructive reactions of longer-chain hydrocarbons. Fossil fuels are non-renewable as they cannot be replenished for many millions of years. 1 mark

ii. It can be classified as a renewable resource if it is generated from resources which can be regenerated in a relatively short time. For example, researchers are now using methanogenic microbes which use plant material to generate methane gas. 1 mark

Question 6 (10 marks)

a. **i.** The relative molecular mass of the compound is 58. 1 mark

ii. An element in the compound has a heavier isotope with low abundance, for example, ^{13}C. 1 mark

iii. C_3H_6O 1 mark

iv. CH_3CO^+ or $C_2H_3O^+$ 1 mark

b. **i.** If it was an acid, there should be a large signal at 2500–3500 cm^{-1}, due to absorption by the OH bond of the COOH group 1 mark

ii.

1 mark

c. **i.**

1 mark

ii. $MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$ 1 mark

d. **i.** peak A : peak B : peak C is 1 : 2 : 3 1 mark

ii. 4 fine peaks (*3 neighbouring H atoms*) 1 mark

Question 7 (8 marks)

a. **i.** hydrolysis 1 mark

ii. *Any one of:*
- potassium hydroxide
- methanol
- glycerol

1 mark

b. **i.** The crude oil is heated so that most components become gases and these gases are fed into a column which decreases in temperature from the base upwards. 1 mark

When petrodiesel reaches a region where the temperature is just below its boiling point, it will condense into a liquid and be removed. 1 mark

ii. dispersion forces   1 mark

c. **i.** Petrodiesel is composed of a number of alkanes of similar boiling points
and so the molar mass of petrodiesel cannot be determined.   1 mark

ii. energy use to heat the water = $m \times c \times \Delta T = 140.0 \times 4.18 \times (49.2 - 25.0) = 14.16$ kJ   1 mark

heat of reaction = $\dfrac{E}{m} = \dfrac{14.16}{0.371} = 38.2$ kJ g^{-1} 1 mark

Question 8 (11 marks)

a. **i.** $K = \dfrac{[COCl_2]}{[CO][Cl_2]}$ 1 mark

ii. $K = \dfrac{0.020}{0.040 \times 0.060} = 8.3$ M^{-1} 1 mark

b. **i.**

	K value increased	*K* value decreased
Temperature increased		
Temperature decreased	✓	

1 mark

ii. By LCP, removing heat will cause the reaction to move so as to partially
oppose the change, that is, forward as this is heat producing.   1 mark

As the reaction moves forward, the concentration of the products will
increase and the concentration of the reactants will decrease.   1 mark

c. *The sketch should have these features:*

- the initial slope should be steeper   1 mark
- plateau should be earlier but at the same level   1 mark

d. **i.** The collisions between the reactant molecules are producing product
molecules at the same rate as the collisions between the product molecules
are generating reactant molecules.   1 mark

ii. As the volume is doubled, the reactant molecules will collide much less
frequently and so the rate of formation of the products falls sharply.   1 mark

iii. As the pressure was decreased, the reverse reaction is favoured (to partially
oppose the change).   1 mark

The frequency of collisions between the reactant particles decreases and
the frequency of collisions between the product particles increases.   1 mark

Question 9 (10 marks)

a. **i.** The oxidation number (S) changes from –2 in ZnS to +4 in SO_2 while the
oxidation number (O) changes from 0 in O_2 to –2 in SO_2.   1 mark

As there has been an increase in oxidation number for one species and a
decrease in oxidation number for another species, it is a redox reaction.   1 mark

ii. $Zn^{2+}(s) + 2e^- \rightarrow Zn(s)$ 1 mark

iii. $n(ZnO) = \dfrac{m}{M} = \dfrac{1.0 \times 10^6}{81.4} \text{ mol}$

$n(CO_2) = \dfrac{1}{2} \times n(ZnO) = \dfrac{1}{2} \times \dfrac{1.0 \times 10^6}{81.4} \text{ mol}$ 1 mark

volume at SLC $= n \times V_m = \dfrac{1}{2} \times \left(\dfrac{1.0 \times 10^6}{81.4} \right) \times 24.8 = 1.5 \times 10^5 \text{ L}$ 1 mark

b. **i.** $Q = I \times t = 150\,000 \times 24 \times 60 \times 60 = 1.296 \times 10^{10} \text{ C}$

$n(e^-) = \dfrac{Q}{F} = \dfrac{1.296 \times 10^{10}}{96\,500} = 1.343 \times 10^5 \text{ mol}$ 1 mark

$n(Al) = \dfrac{1}{3} \times n(e^-)$ 1 mark

$m(Al) = n \times M = \dfrac{1}{3} \times 1.343 \times 10^5 \times 27.0 = 1.2 \times 10^6 \text{ g} = 1.2 \text{ tonne}$ 1 mark

ii. It is assumed that the electrolysis is 100% efficient; that is, one mole of aluminium is generated for each three mole of electrons passed through the electrolyte.   1 mark

iii. Al^{3+} is a stronger oxidising agent than Na^+ and so will be preferentially reduced at the cathode.   1 mark

(Although this prediction assumes standard conditions.)