Neap:

Trial Examination 2012

VCE Chemistry Unit 4

Written Examination

Suggested Solutions

SECTION A: MULTIPLE-CHOICE QUESTIONS

1	D
2	B
3	A
4	D
5	A
6	D
7	B
8	C
9	B
10	A
11	C
12	C
13	D
14	B
15	C
16	A
17	B
18	C
19	D
20	A

Question 1 **D**

Each of the conditions I, II and III plays a part in ensuring the chemical reactions used in destroying the organic wastes will go to completion.

Question 2 **B**

$[H_3O^+] = 10^{-pH} = 10^{-2.62}$

$$\%\text{ ionisation} = \frac{[H_3O^+]}{[HA]} \times 100 = \frac{10^{-2.62}}{0.10} \times 100 = 2.4$$

Question 3 **A**

Heating an exothermic reaction will result in the reverse reaction occurring, with a consequent decrease in temperature. The value of the equilibrium constant is decreased at the higher temperature. Less hydronium ion will be produced, leading to an increase in pH. When equilibrium is re-established, the pH will remain higher than the pre-change value because the new equilibrium constant applies.

Question 4 **D**

The rate of the forward reaction would be high initially and decrease until equilibrium is reached. Thus, variable I could not be used on the graph. The total gas pressure in the container would be expected to increase over time, as two molecules of gas products are produced from one reactant gas molecule. Initially, however, the total gas pressure would not be zero. Therefore variable III cannot be used on the graph. The number of mole of each product (and each concentration or gas partial pressure) would be zero initially but would increase until equilibrium was reached. Both variables II and IV could be used on the graph.

Question 5 **A**

Decreasing the volume of the container will increase the pressure. Increasing pressure will increase the rate of reaction. The yield will decrease as there are two product gas molecules for every reactant gas molecule, and thus the position of equilibrium will favour the reactants. Therefore the rate and yield of PCl_3 have been affected by decreasing the volume, and **A** is the required answer. **B** is incorrect, as adding an inert gas will affect neither the rate nor the position of equilibrium. **C** is not correct because the action will have no effect on the rate of reaction, even though it will increase the yield of PCl_3. A catalyst will increase the rate of reaction, but not the yield of the reaction, and so **D** is incorrect.

Question 6 **D**

For this reaction, it is not possible to determine the equilibrium constant without knowing the vessel volume, and thus the concentration of the components of the equilibrium mixture. **D** is the required answer.

Question 7 **B**

$$n(\text{methyl palmitate}) = \frac{m}{M} = \frac{0.350}{270}\text{ mol}$$

$$\text{energy released on combustion} = \frac{(2.14 \times 10^4)}{2} \times \frac{0.350}{270} = 13.87\text{ kJ}$$

$$\text{calibration factor} = \frac{E}{\Delta T} = \frac{13.87}{4.22} = 3.29\text{ kJ °C}^{-1}$$

Question 8 **C**

The biochemical fuel is not used for the large scale generation of electricity, so **D** is incorrect. Nuclear reactions produce vastly more energy per mole of fuel than either of the other fuels listed, which are used widely for electricity production. **C** is the required answer.

Question 9 **B**

From the equation for the biodiesel:

34 mol of CO_2 are produced for 2.14×10^4 kJ of energy released,
i.e. 0.00159 mol of CO_2 per kJ of energy.

From the heat of combustion for methane:

1.0 mol of CO_2 is produced for 889 kJ of energy released
i.e. 0.00112 mol of CO_2 per kJ of energy.

Therefore the 'best' fuel for minimal CO_2 per kJ of energy is natural gas.

Natural gas is a non-renewable, limited resource. Combustion of the gas adds carbon dioxide to the atmosphere. Biochemical fuels are derived from animal or plant products and are thus renewable and sustainable. Biochemical fuels recycle carbon dioxide from the air (but do generate some extra gas in their life cycle in processing, extraction, transport, etc.). Biodiesel is therefore the closest to 'carbon neutral' of the fuels listed.

Question 10 **A**

The concentration of the hydroxide is the square root of the K_w at 5°C, i.e. 4.30×10^{-8} M . Therefore **A** is the correct answer. The pH of water at 5°C is 7.37, however, in pure water $[H_3O^+] = [OH^-]$, thus water is neutral at any temperature. **B** and **C** are incorrect. As the K_w is 10^{-14} at 25°C, and cooling the water decreases the value of K_w, the self-ionisation reaction must be endothermic. **D** is incorrect.

Question 11 **C**

Oxidation occurs at the anode. When being recharged, the cell's anode is positive. To achieve recharging, the power supply withdraws electrons from the positive electrode, forcing an oxidation reaction to occur there (the reverse of the spontaneous electrode II reaction).

Question 12 **C**

$Q = I \times t = 0.81 \times 387 = 313.47$ C

$n(\text{Cu}) = \dfrac{m}{M} = \dfrac{0.102}{63.5}$ mol

$n(\text{e}^-) = 2 \times n(\text{Cu}) = 0.003213$ mol

The charge carried by 1 mol of electrons $= \dfrac{Q}{n(\text{e}^-)} = \dfrac{313.47}{0.003213} = 97\ 600$ C

Question 13 **D**

These deductions can be made from the experiments: I – Cd is a stronger reductant than Cu; II – Zn is a stronger reductant than Cd; III – Cr is a stronger reductant than Cd. It is not clear which of Zn or Cr is the stronger reductant. So the order in alternative **D** is correct with Zn being omitted.

Question 14 **B**

To determine which of Zn or Cr is the stronger reductant, a further experiment using chromium ions with zinc, or zinc ions with chromium, will need to be undertaken.

Question 15 C

From experiment III, Cr will be oxidised at the anode and Cd will be the cathode where reduction of Cd^{2+} will occur. Both **A** and **B** are correct. The salt bridge allows ions to travel between the half-cells so that no build-up of charge occurs. Alternative **D** is also correct. Anions travel towards the anode half-cell through the internal circuit or salt bridge, not the external circuit (the wire carrying electrons). Thus **C** is incorrect.

Question 16 A

For experiment 1, $K = \frac{[Z]^2}{[X]^2[Y]} = \frac{(0.260)^2}{(0.590)^2(0.0450)} = 4.32\ M^{-1}$

For experiment 2, $K = \frac{[Z]^2}{[X]^2[Y]} = \frac{(0.650)^2}{(1.48)^2(0.0446)} = 4.32\ M^{-1}$

For both experiments the *K* value is the same, and so both must be at the same temperature.

Question 17 B

The rate of reaction does not affect the potential between the half-cells and so statement I is not relevant, even though it is factually correct. The EC series is formulated using standard conditions of 25°C and 1 M concentrations of solutions. As the voltage differs from the predicted value, the concentration of the solutions must not be 1 M. Statement II is valid and could explain the variation from the prediction. Statement III is also correct as the concentration of species in an equilibrium reaction at a set temperature will determine the direction of reaction that will occur, and thus the potential difference between the half-cells.

Question 18 C

Alternative **C** is the correct answer, as more reactants can be regenerated using electrical energy to force the spontaneous reaction in the reverse direction. The other alternatives do not give a distinguishing feature of a secondary cell: **A** describes a fuel cell, **B** describes a primary cell and **D** outlines the chemical principle allowing all galvanic cells to produce electrical energy.

Question 19 D

H_2 is oxidised at electrode I. Oxidation generates electrons, making the electrode negatively charged. **A** and **B** are incorrect. H^+ is generated, thus pH will decrease as the reaction occurs.

Question 20 A

Statement I is correct, as the gases need to be in contact with the electrode and the electrolyte and participate in a reaction of reasonable rate. Statement II is also correct, as there are fewer energy transformations in a fuel cell and thus less energy is lost. Water produced by the cell reaction will be converted to a vapour as the cell runs at 190°C. It will not interfere with the operation of the cell and thus statement III is not correct.

SECTION B: SHORT-ANSWER QUESTIONS

Question 1

a.

Reaction conditions	Advantage	Disadvantage
reaction temperature of 1400°C	*Any one of:* • fast rate of reaction producing products rapidly • higher yield of products as it is an endothermic reaction	• high energy costs required to produce and maintain this temperature
atmospheric pressure	*Any one of:* • higher yield of products • energy saved by not using expensive high pressure equipment	• slow reaction rate

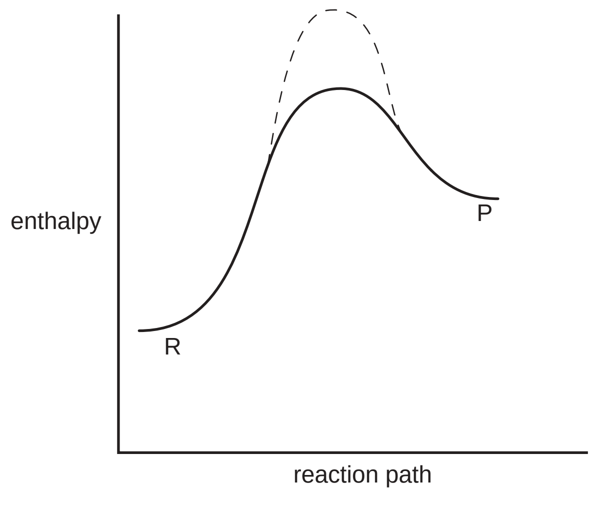
4 marks

Two marks for one advantage and one disadvantage of reaction temperature of 1400°C
Two marks for one advantage and one disadvantage of atmospheric pressure

b. i. By having the piping lined with platinum, a greater surface area of the catalyst is available for interaction with the reactant molecules and thus the rate of reaction will be increased.

1 mark

ii.



1 mark

c. i. Reaction I uses methane, a fossil fuel which is a non-renewable resource. 1 mark

ii. The reaction generates the greenhouse-enhancing gas, carbon dioxide. 1 mark

d. *Any one of:*

- Breathing apparatus must be worn in confined spaces where exposure to HCN is a possibility.
- Confined spaces must have monitoring devices for HCN leakage and appropriate warning and safety protocols when a leak is detected.
- Areas in proximity to HCN gas must be well ventilated using fan-assisted air movement.

1 mark

e. *For example, any one of the following:*

Ammonia

i. Ammonia acts as a base in the reaction. 1 mark

ii. $NH_3(aq) + HNO_3(aq) \rightarrow NH_4NO_3(aq)$ 2 marks

1 mark for correct reactants/products
1 mark for correct states/balancing

Nitric acid

i. Nitric acid acts as an acid in the reaction. 1 mark

ii. $NH_3(aq) + HNO_3(aq) \rightarrow NH_4NO_3(aq)$ 2 marks

1 mark for correct reactants/products
1 mark for correct states/balancing

Sulfuric acid

i. Sulfuric acid acts as an acid in the reaction. 1 mark

ii. $2NH_3(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq)$ 2 marks

1 mark for correct reactants/products
1 mark for correct states/balancing

Ethene

i. Ethene acts as an oxidant in the reaction. 1 mark

ii. $C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$ 2 marks

1 mark for correct reactants/products
1 mark for correct states/balancing
Total 12 marks

Question 2

a. Determining the rate by measuring the gas produced over time depends on whether you are able to collect all the gas. SO_2 is soluble in water and so an accurate measurement of gas volume is not possible. 1 mark

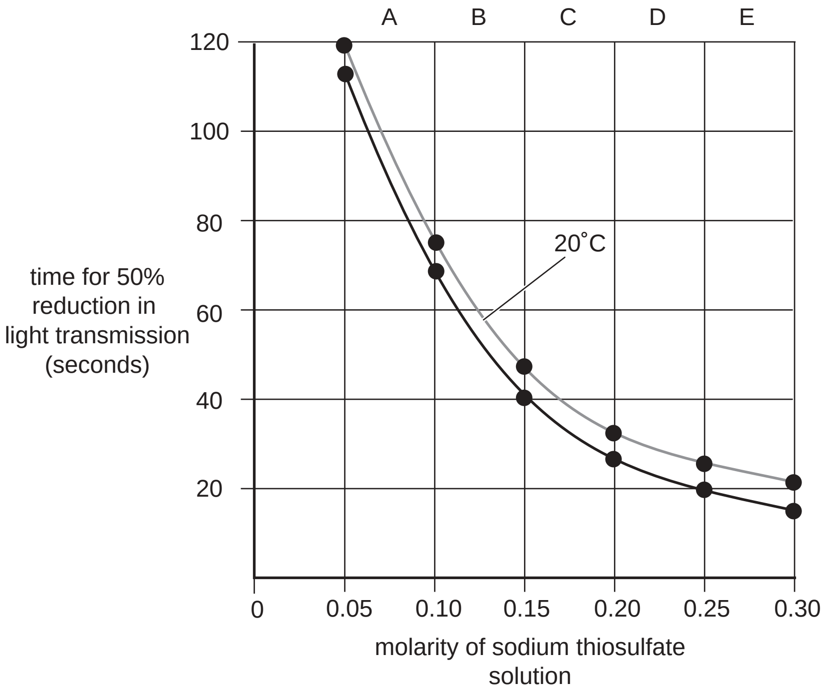
b. **i.** section E 1 mark

ii. The rate of reaction is being measured by the rate of appearance of sulfur, which decreases the transmission of light. In section E of the graph, it takes the smallest amount of time for the transmission of light to reduce by 50%, and thus the rate of reaction is highest. 1 mark

iii. Measurement of the rate of reaction depends on the concentration of sulfur particles in the glass vessel. 1 mark

The total volume of reactants must be constant to ensure that the decrease in transmission of light depends only on the amount of sulfur formed in a set volume of solution. 1 mark

c.



1 mark

d. Reactant particles must collide with sufficient energy to break bonds, so that new bonds can be made when the products form. The most significant effect of increasing the temperature is that more reactant particles have energies greater than the activation energy, and the number of successful collisions increases as a result. 1 mark

Increasing the temperature also gives more energy to the particles and so collisions occur more often, producing more successful collisions. 1 mark

Question 3

a. Using molten electrolytes is costly because of the energy required to melt the solid and keep it molten. 1 mark

The melting point of magnesium chloride is likely to be much lower than the melting point of magnesium oxide. Less energy is required to produce a molten electrolyte, and so costs are reduced. 1 mark

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

ii.

	Positive	Negative
Anode	✓	
Cathode		

1 mark

iii. The ceramic hood is to ensure that the electrolytic products magnesium metal and chlorine gas do not come into contact; otherwise, a spontaneous reaction will occur. 1 mark

c. **i.** An oxidant (A) will only react spontaneously with a reductant (B) if the conjugate of A is a weaker reductant than B.The conjugate of Mg^{2+} is the reductant Mg. Mg is a stronger reductant than Fe. 1 mark

ii. The electrochemical series is formulated using standard conditions of 1 M concentration of solutions, gas pressure of 1 atm and temperature of 25°C. 1 mark

The conditions in this cell vary significantly from these conditions and thus any predictions may be unreliable. 1 mark

d. $Mg^{2+}(l) + 2e^{-} \rightarrow Mg(l)$

For 1 mol of Mg, 2 mol of electrons are required. 1 mark

$Q = n(e) \times F = 2 \times 96500$ C 1 mark

$E = V \times Q = 24 \times 2 \times 96500 = 4632$ kJ 1 mark

But if the cell is only 50% efficient,

$E = 4632 \times \frac{100}{50} = 9264$ kJ = 9.3 MJ 1 mark

e. **i.** *Any one of*:

- Suitable mountainous regions where dams can be built are of limited availability.
- Regions of adequate rainfall with catchment areas to fill dams are required.
- There are serious environmental concerns about the destruction of plant and animal habitats that is necessary in dam construction and flooding of land to fill dams.

1 mark

ii. *Any one of*:

- Coal-fired power stations produce gases (e.g. CO_2 and SO_2) which harm the environment, whereas generation of hydroelectricity does not.
- Hydroelectricity is a sustainable resource, whereas coal is non- renewable.

1 mark

iii. Gravitational potential energy (of water) → kinetic energy (of water) 1 mark

Question 4

a. **i.** $n(HCl) = c \times V = 2.0 \times 0.0500 = 0.10$ mol 1 mark

Energy required to heat 100 mL of solution = $m \times c \times \Delta T = 100 \times 4.18 \times 10.1 = 4221.8$ J

1 mark

$\Delta H = \frac{E}{n} = \frac{-4221.8}{0.10} = -4\ 2218 = -42$ kJ mol^{-1} 1 mark

ii. A significant amount of the heat generated by the reaction was lost due to inadequate insulation of the ‘calorimeter’, and thus the measured temperature rise was less than the true value, leading to a smaller value for ΔH. 1 mark

b. The temperature change should be approximately the same. 1 mark

The hydroxide ion is the limiting reagent. The same number of mol of hydroxide ions will be consumed in the reaction even though the hydrogen ions will be in excess. 1 mark

 TEVCHEMU4_SS_2012.FM

c. **i.** $K_a = \frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]} = 1.7 \times 10^{-5}$ 1 mark

$[CH_3COO^-] = [H_3O^+]$

$[CH_3COOH]$ at equilibrium is approximately equal to $[CH_3COOH]$ initially, i.e. 2.0 M.

Therefore $[H_3O^+] = \sqrt{(3.4 \times 10^{-5})} = 5.8 \times 10^{-3}$ 1 mark

$pH = -\log[H_3O^+] = -\log(5.8 \times 10^{-3}) = 2.2$ 1 mark

ii. less than 1 mark

(*Hydrochloric acid solution consists of hydrated ions and so when neutralisation occurs, the* ΔH *is the difference between the energy of these ions and the energy of products of the reaction. Ethanoic acid consists mostly of molecules and before a neutralisation reaction can happen, ionisation and hydration must occur, which leaves an energy deficit, resulting in a smaller value of* ΔH *for neutralisation.*)

d. A chemical reaction of known ΔH is used in the 'calorimeter' and the temperature change is measured. 1 mark

Using stoichiometric calculations, the amount of energy produced in the reaction is determined and this value is divided by the temperature change to produce a calibration factor (kJ °C^{-1}). 1 mark

Question 5

a. $K = \frac{[Z]^2}{[X]^2[O_2]} = \frac{(0.30)^2}{(0.164)^2(0.057)} = 59\ M^{-1}$ 1 mark

Since this value does not equal the equilibrium constant $(K = 4.3\ M^{-1})$, the system is not at equilibrium. 1 mark

b. **i.** $p(X) = \frac{nRT}{V} = cRT = 0.274 \times 8.31 \times 873$ 1 mark

$= 1988 = 1.99 \times 10^3$ kPa 1 mark

ii. $c_1V_1 = c_2V_2$

$c(X) = \frac{0.274 \times 5.0}{7.0} = 0.196$ M 1 mark

iii.

Characteristic at equilibrium in the 5.0 L vessel	Value is greater than, less than or equal to	Characteristic at equilibrium in the 7.0 L vessel
total pressure	greater than	total pressure
total mass	equal to	total mass
molar concentration of X	greater than	molar concentration of X

3 marks