Neap:

Trial Examination 2010

VCE Chemistry Unit 4

Written Examination

Suggested Solutions

SECTION A: MULTIPLE-CHOICE QUESTIONS

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

Question 1 **C**

$n(Fe^{3+}) = c \times V = 0.350 \times 0.0500 = 0.0175$ mol

$n(Sn^{2+}) = 0.150 \times 0.0500 = 0.00750$ mol

Thus Fe^{3+}(aq) is in excess by $0.0175 - (2 \times 0.00750) = 0.00250$ mol.

$E = CF \times \Delta T = 476 \times 0.730 = 347.48$ J

For 1 mol of Sn^{2+} reacting, $E = \frac{347.78}{0.0075} = 46\ 330$ J = 46.3 kJ mol^{-1}

(*The temperature increase shows that the reaction is exothermic, so ΔH would have a negative sign.)*

Question 2 **C**

$HCR(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CR^-(aq)$

$$K_a = \frac{[H_3O^+][CR^-]}{[HCR]} = 5.0 \times 10^{-9}$$

At pH = 7, $[H_3O^+] = 10^{-7}$ M

$$\frac{[CR^-]}{[HCR]} = \frac{5.0 \times 10^{-9}}{10^{-7}} = 5.0 \times 10^{-2} = 0.050$$

As the [HCR] > $[CR^-]$ by a factor of 20 $\left(\text{i.e. } \frac{1}{0.050}\right)$, the colour of the solution will be that of the HCR, i.e. yellow.

Question 3 **B**

A photovoltaic cell converts solar energy directly to electrical energy *(with very low efficiency)*. In power stations and generators, a series of energy conversions occurs *(resulting in a low overall energy conversion to electrical energy)*.

Question 4 **A**

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

$$K_a = \frac{[H_3O^+][SO_4^{2-}]}{[HSO_4^-]} = 9.9 \times 10^{-3}$$

$[H_3O^+] = [SO_4^{2-}]$

$$[H_3O^+]^2 = K_a \times [HSO_4^-]$$

Assuming that the amount of HSO_4^- that reacts is low as the K_a is small, then

$$[HSO_4^-]e = [HSO_4^-]i = \frac{n}{V} = \frac{0.010}{0.100} = 0.10 \text{ M}$$

$$[H_3O^+]^2 = 9.9 \times 10^{-3} \times 0.10 = 9.9 \times 10^{-4}$$

$$[H_3O^+] = 3.15 \times 10^{-2} \text{ M}$$

$$\text{pH} = -\log[H_3O^+] = 1.5$$

Question 5 **C**

The energy released as the hot water cools is used to heat the cold water to the required temperature.

$E = m \times c \times \Delta T$

$80.0 \times 4.18 \times (37 - 19) = m \times 4.18 \times (75 - 37)$

$m = 37.9$ g

The closest mass listed is therefore 40 g.

Question 6 **D**

Nitrogen is an inert gas under these conditions and will not participate in the equilibrium reaction, so change I will have no effect. Change II will produce a more intense colour due to the concentrating effect. The equilibrium will move forward to partially oppose the increase in pressure (two mole of reactants exert more pressure than one mole of product), and so the colour will become lighter. However, the change caused by the external factor is only partially overcome by the system's response, and thus the concentration of the gases remains higher than it was before the change, giving a darker colour. Change III will cause the reaction to move forward as it is an exothermic reaction. The equilibrium mixture will become lighter. Only change III will result in a lighter colour, and so **D** is the required response.

Question 7 **A**

$[\mathrm{HCl}] = [\mathrm{H_3O^+}] = 10^{-\mathrm{pH}} = 10^{-1} = 0.1\ \mathrm{M}$

Adding 20 mL of this acid to 20 mL of 0.1 M NaOH will neutralise the NaOH.

Additional acid will then be needed to produce a solution with the required pH of 4, i.e. one in which the $[\mathrm{H_3O^+}] = 10^{-4}$ M

Let y = the volume of acid required to achieve a pH of 4

$n(\mathrm{H_3O^+}) = c \times V = 10^{-4} \times (40 + y)$

and $n(\mathrm{H_3O^+}) = c \times V = 10^{-1} \times y$

Solving for y gives a volume of 0.04 mL.

Total volume of HCl added to neutralise the NaOH and produce a solution of pH = 4 is

$20 + 0.04 = 20.04\ \mathrm{mL}$, and so **A** shows the closest volume.

Question 8 **B**

As the $H_p > H_R$, there is residual energy in the products after the bonds are broken in the reactants. So alternative **A** is correct. The heat of reaction is given by $H_p - H_R$ which is equal to $z - x$. Thus alternative **C** is a correct statement. After the bonds in the reactants are broken, the system reaches a maximum energy state equivalent to $x + y$. When the products form, energy is released leaving the energy of the system equivalent to z. Thus the energy released after the state of maximum energy is $x + y - z$. Therefore, **D** is correct. The activation energy of the reverse reaction is equivalent to the energy from the level at P to the state of maximum energy, i.e. $x + y - z$ and not $x + y$ as stated in alternative **B**. Thus **B** is the incorrect statement and is therefore the required response.

Question 9 **D**

As water is heated, the self-ionisation reaction will move forwards in order to lower the temperature (the forward reaction is endothermic). The $[\mathrm{H_3O^+}]$ will increase, and so the pH will decrease. The concentrations of the hydronium and hydroxide ions remain equal, and so the water remains neutral.

Question 10 D

The area under the curve represents the total number of particles. This will be unchanged by a temperature decrease (so alternatives **A** and **C** are incorrect). As the temperature is decreased, the particles lose kinetic energy (so alternatives **A** and **C** are incorrect). With this decrease in kinetic energy the number of particles with energy above E also decreases (alternative **D**).

Question 11 A

The forward and reverse reactions are occurring at the same rate at equilibrium and so there must be successful collisions occurring at T_3. Statement I is valid. Straight after the change at T_2 occurs, a net forward reaction will occur so that the concentration of Z is increased and concentrations of the reactants decrease. Thus statement II is valid. The reaction is exothermic, so heating it will favour the reverse reaction and not the forward reaction as shown. Statement is III invalid for this reason. In addition, the instantaneous changes in concentrations shown will not be achieved simply by altering the temperature. Statement IV is invalid as the value of K is unchanged at constant temperature.
Thus the valid statements are I and II, and so **A** is the required response.

Question 12 D

The E^0 of reaction I is –0.76V and so this reaction will occur in the reverse direction, i.e oxidation of Zn occurring at the negatively charged anode. So **A** and **B** are incorrect. Reaction II occurs at the positive electrode and water is a product of this reaction. Thus **C** is not correct. As zinc is oxidised at the anode and will thus lose mass, alternative **D** is correct.

Question 13 B

The overall reaction is exothermic, so alternatives **A** and **D** are incorrect. The activation energy of the first step is larger than that of the second step, hence alternative **B** is correct.

Question 14 C

Changing the conditions of the galvanic cell will alter the voltage and, in experiment 3, the polarity of the electrodes from that predicted by the electrochemical series. In any galvanic cell, cell voltage depends on the concentrations of the chemicals involved. As the cell discharges and current flows, concentrations change and as a result the cell voltage changes. The cell spontaneously discharges until it reaches equilibrium, at which point the cell potential is zero. When the cell reaction reaches equilibrium there is no longer a chemical driving force to push electrons through the wire. This is the case in a ‘dead’ battery. Under the particular set of conditions in experiment 4, the reaction is at equilibrium and no voltage would be measured. Alternative **C** is the required answer. There is no evidence from the table that all the reactants had been consumed (so not alternative **A**) or that the half reactions had stopped, so alternative **B** is incorrect. The products building up and preventing the operation of the cell are unlikely events in a cell of this simplicity. **D** is not correct.

Question 15 A

The reaction is exothermic, hence heating will favour the reverse, temperature decreasing reaction. The amount of NH_3 will decrease, while the amount of H_2 will increase. Alternatives **C** and **D** are incorrect. The changes must occur in the mole ratio given in the equation, i.e $n(H_2) : n(NH_3) = 3 : 2 = 0.243 : 0.162$.

Question 16 D

This information can be deduced from the spontaneous reactions: Hg^{2+} is a stronger oxidant than Co^{2+} (first reaction); Ce^{4+} is a stronger oxidant than Hg^{2+} (second reaction); Co^{2+} is a stronger oxidant than Cr^{3+} (third reaction). In order, the oxidising strength is $Ce^{4+} > Hg^{2+} > Co^{2+} > Cr^{3+}$. An oxidant will spontaneously react with the conjugate reductant of a weaker oxidant. Only alternative **D** satisfies this requirement.

Question 17 B

Energy density of methane = $\frac{E}{M} = \frac{889}{16} = 55.56 \text{ kJ g}^{-1}$

Energy density of ethanol = $\frac{E}{M} = \frac{1364}{46} = 29.65 \text{ kJ g}^{-1}$

Methane has the larger energy density, hence **C** and **D** are incorrect.

Each mole of methane produces one mole of CO_2 and $\Delta H_c(CH_4) = -889 \text{ kJ mol}^{-1}$

Each mole of ethanol produces two mole of CO_2 and $\Delta H_c(C_2H_5OH) = -1364 \text{ kJ mol}^{-1}$, i.e. for each mole of CO_2, 682 kJ is produced. Alternative **B** is the required answer.

Question 18 B

$n(\text{Cu}) = \frac{m}{M} = \frac{1.11}{63.5} = 0.0175 \text{ mol}$

$n(\text{X}^{2+})$ initially $= c \times V = 1.00 \times 0.100 = 0.100 \text{ mol}$

$n(\text{X}^{2+})$ finally $= c \times V = 0.65 \times 0.100 = 0.065 \text{ mol}$

$n(\text{X}^{2+})$ reacting $= c \times V = 0.100 - 0.065 = 0.035 \text{ mol}$

$n(\text{Cu}) : n(\text{X}^{2+}) = 0.0175 : 0.035 = 1 : 2$

Question 19 C

Electrons flow towards the positively charged copper electrode. The reaction is therefore

$Cu^{2+}(aq) + 2X^{2+}(aq) \rightarrow Cu(s) + 2X^{3+}(aq)$

Question 20 A

At equilibrium: $[Br_2] = \frac{n}{V} = \frac{2.0}{4.0}$ M; $[H_2] = \frac{1.25}{4.0}$ M; $[HBr] = \frac{0.5}{4.0}$ M

$K_1 = \frac{[H_2][Br_2]}{[HBr]^2} = 10$

If K_2 is the equilibrium constant for the reverse reaction, $K_2 = \frac{1}{K_1} = \frac{1}{10} = 0.10$, i.e. alternative **A**.

SECTION B: SHORT-ANSWER QUESTIONS

Question 1

a. *For example (one of the following):*

- coal is expensive to transport; gaseous fuels may be more economically transported
- cleaner burning fuels may be produced — 1 mark

b. $2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l) \qquad \Delta H = -1450 \text{ kJ mol}^{-1}$ — 2 marks

c. $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(l) + 2CO_2(g)$ — 1 mark

Alternatively, $C_{14}H_{29}COOH(l) + CH_3OH(l) \rightarrow C_{14}H_{29}COOCH_3(l) + H_2O(l)$

d. **i.** the conversion of mass to energy as the nucleus reacts — 1 mark

ii. *For example (one of the following):*

- nuclear fuel has a much higher energy content per gram
- no atmospheric pollutants are produced during reaction — 1 mark

Total 6 marks

Question 2

a. **i.** $CH_3OH(aq) + H_2O(l) \rightarrow CO_2(g) + 6H^+(aq) + 6e^-$ — 1 mark

ii. 1 mole of methanol releases 6 mole of electrons

The total charge involved is 6 Faraday. $6 \times 96\,500 = 5.79 \times 10^5$ C — 1 mark

$E = VQ = 1.1 \times 5.79 \times 10^5 = 6.37 \times 10^5$ J — 1 mark

b. **i.** The H^+ ion moves towards electrode Q → — 1 mark

ii. Electrons move from electrode P to electrode Q → — 1 mark

iii. electrode Q — 1 mark

c. It is costly and requires more complex equipment to maintain high temperatures and pressures. Satisfactory performance can be achieved without the extreme, uneconomical conditions. — 1 mark

d. Water is a reactant for the electrode P oxidation reaction. If pure methanol were used, the water would not be available. — 1 mark

e. As the reactants temporarily bond to the surface of the catalyst, any blocking of that interaction by CO would severely affect the cell's performance. — 1 mark

f. A primary cell has a limited amount of chemical energy, and when this is depleted the cell cannot be recharged. The DMFC has fuel continuously fed into it without stopping its operation. — 1 mark

Total 10 marks

Question 3

a. $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ 1 mark

b. In this interval, the reactant particles were at their highest concentration. 1 mark
The rate of reaction depends on the number of successful collisions between reactant particles in a set time and this will be the greatest when the reactant particle concentration is highest. 1 mark

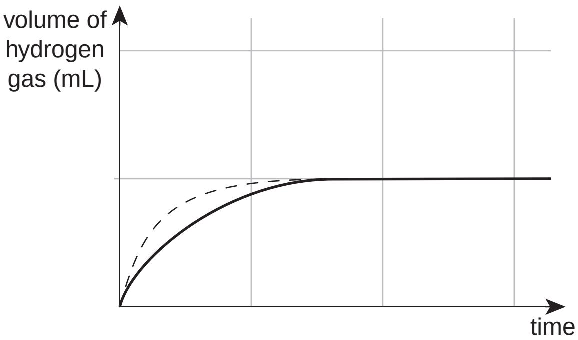
c. $\text{Rate} = \frac{\Delta \text{volume}(H_2)}{\Delta \text{time}} = \frac{(32 - 0)}{(6 - 0)} = 5.33 \text{ mL } H_2 \text{ per minute}$ 1 mark

d. $n(H_2) \text{ at SLC} = \frac{V}{V_M} = \frac{32.0 \times 10^{-3}}{24.5} \text{ mol}$

$n(H_2) = n(Mg)$ 1 mark

$m(Mg) = n \times M = \frac{32.0 \times 10^{-3}}{24.5} \times 24.3 = 0.0317 \text{ g}$ 1 mark

e.



1 mark
Total 7 marks

Question 4

a. $CH_3COOH(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH_3COO^-(aq)$ 1 mark

b. $K_a = \frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH]}$ 1 mark

c. **i.** $[H_3O^+] = [CH_3COO^-]$

$[H_3O^+]^2 = K_a \times [CH_3COOH]$

The amount of CH_3COOH that reacts is low as the K_a is small, so

$[CH_3COOH]e = [CH_3COOH]i = 0.50$ M 1 mark

$[H_3O^+]^2 = 1.7 \times 10^{-5} \times 0.50$

$[H_3O^+] = 2.915 \times 10^{-3}$ M 1 mark

$\% \text{ ionisation} = \frac{[CH_3\ COO^-]}{[CH_3COOH]} \times 100 = \frac{2.915 \times 10^{-3}}{0.50} \times 100 = 0.58\%$ 1 mark

ii. The concentration of the acid decreases as more water is added to the solution. 1 mark
Water is a reactant and so the equilibrium moves to the right, i.e. more ionisation occurs, increasing the percent ionisation. 1 mark

iii. As the concentration of the acid decreases the concentration of the hydronium ion decreases. This increases the pH. 1 mark
Any increase in percent ionisation (leading to higher hydronium ion concentration and so lower pH) is overcome by the dilution of ions that occurs as the concentration is lowered. 1 mark

Total 9 marks

Question 5

a. $K = \frac{[Z]}{[X][Y]}$

As temperature is increased, the value of K decreases, i.e. the reverse reaction is favoured. 1 mark

By Le Chatelier's principle, the equilibrium will move to partially oppose the increase in temperature and thus the reverse reaction is temperature decreasing, and so the forward reaction is exothermic. 1 mark

b. **i.** $[X] = \frac{n}{V} = \frac{0.020}{0.250}$ M ; $[Y] = \frac{0.015}{0.250}$ M ; $[Z] = \frac{0.10}{0.250}$ M

The equilibrium fraction is $\frac{[Z]}{[X][Y]} = 83$ M^{-1} 1 mark

At 500 K, the equilibrium constant is 75 M^{-1} and so the system is not at equilibrium. 1 mark

ii. To achieve the required K, the numerator of the fraction must decrease and the denominator must increase, i.e. the backward reaction is favoured. 1 mark

c. All species in the equilibrium are gases and it would be difficult to separate the gases (to remove a product) whilst the reaction continues. 1 mark

d. **i.**

	Decreased	**Unchanged**	**Increased**
Equilibrium yield of the chemical Z		✓	
Rate of the forward reaction			✓
Activation energy of the reverse reaction	✓		
Value of the equilibrium constant		✓	

2 marks

ii. the high cost of the catalyst 1 mark

e. A moderate temperature, e.g. 400 K: 1 mark

This produces a good yield at a reasonable rate. 1 mark

f. **Nitric acid**

i. Nitric acid is severely corrosive to all body tissues and must be managed accordingly. Exposure to this substance must be strictly limited. 1 mark

ii. The loss of nitrogen monoxide to the atmosphere must be minimised as this gas contributes to photochemical smog. 1 mark

Sulfuric acid

i. Sulfuric acid is severely corrosive to all body tissues and must be managed accordingly. Exposure to this substance must be strictly limited.

ii. The loss of SO_2 and SO_3 to the atmosphere must be minimised as these gases are significant contributors to acid rain.

Ethene

i. Ethene is a highly flammable gas as well as being toxic at moderate concentrations in the atmosphere. Exposure to sources of ignition must be avoided to prevent explosions.

ii. Losses of hydrocarbons to the environment are limited by recycling or by the burning of any excess gases.

Ammonia

i. Ammonia is a severe respiratory irritant in gaseous form. Exposure to this substance must be strictly limited.

ii. The loss of ammonia gas or liquid to the environment must be minimised as it is toxic to many plants and animals.

Total 13 marks

Question 6

a. pure copper sheet: negative
blister copper: positive — 1 mark

b. **i.** silver, gold — 1 mark

ii. Zinc and nickel are stronger reductants than copper and, as the cell voltage is set to cause copper metal to oxidise, zinc and nickel will be oxidised as well. — 1 mark

c. Aluminium is a stronger reductant than water and will be oxidised preferentially at the anode. — 1 mark
However, water is a stronger oxidant than aluminium ions and will be reduced at the cathode, preventing the production of the pure aluminium at the cathode. — 1 mark

d. **i.** $Q = I \times t = 0.100 \times (50 \times 60 + 35) = 303.5$ C — 1 mark

ii. $n(\text{Cu}) = \frac{0.100}{63.5} = 1.57 \times 10^{-3}$ mol — 1 mark

$Cu^{2+} + 2e^- \rightarrow Cu$

$n(e^-) = 2 \times 1.5748 \times 10^{-3}$ mol $= 3.15 \times 10^{-3}$ mol — 1 mark

iii. 3.15×10^{-3} mol of electrons carried 303.5 C

1 mol of electrons carries $\frac{303.5}{3.1496 \times 10^{-3}} = 9.64 \times 10^4$ C — 1 mark

iv. Charge carried by 1 electron $= 1.60 \times 10^{-19}$ C

The number of electrons in 1 mole $= \frac{9.636 \times 10^4}{(1.60 \times 10^{-19})} = 6.02 \times 10^{23}$ — 1 mark

Total 10 marks