Neap:

Trial Examination 2009

VCE Chemistry Unit 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

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Question 1 **C**

Oxidation occurs at the anode, the negative electrode, in a galvanic cell, so **A** and **D** are incorrect.
As H^+ ions are being consumed in the reaction, the pH will rise. Thus **B** is incorrect. Reduction occurs at the cathode, the positive electrode, and so **C** is the correct answer.

Question 2 **D**

The equilibrium system responds to oppose the change made. The response only partially overcomes the imposed change. Concentrations do not return to their former values (hence **B** is incorrect), and, if the imposed change is a change in temperature, the equilibrium constant will alter (hence **A** is incorrect). An equilibrium system in a closed, fixed volume vessel will not be able to alter the 'volume of the reaction vessel' (hence **C** is incorrect).

Question 3 **A**

$E = m \times c \times \Delta T = 50.0 \times 4.18 \times (20.3 - 19.0) = 271.7 \text{ J}$

$\Delta H = \frac{E}{n}$ where $n(\text{NaOH}) = \frac{m}{M} = \frac{0.250}{40.0} = 0.00625 \text{ mol}$

The reaction releases heat and so ΔH is negative.

$\therefore \Delta H = -43472 \text{ J mol}^{-1} = -43 \text{ kJ mol}^{-1}$

Question 4 **A**

NaCl will completely dissolve, Mg will completely react and HCl will completely ionise. Thus the systems in **B**, **C** and **D** do not reach a state of equilibrium. When a solid is added to an already saturated solution an equilibrium is reached where the rate of crystallisation equals the rate of dissolution of the solid.

Question 5 **B**

From the table, increasing the temperature causes lowering of pH, i.e. an increase in concentration of H_3O^+. The forward reaction must be favoured by increasing temperature, i.e. an endothermic reaction, as this is temperature reducing.

Question 6 **B**

At any temperature, in pure water, $[H_3O^+] = [OH^-]$.

Question 7 **D**

Rate will be increased by the use of a catalyst, high temperature and high pressure. Yield will be increased by high pressure (as the forward reaction is pressure reducing), and high temperature (as the forward endothermic reaction is temperature reducing). Yield is unaffected by the presence of a catalyst. Therefore, **D** gives the best set of conditions for increasing both rate and yield.

Question 8 **C**

The second equation is the reverse of the first equation and all coefficients are doubled. Reversing an equation produces the reciprocal of the equilibrium constant of the first reaction, i.e. $\frac{1}{K}$. Raising all concentrations in the equilibrium expression to the power of two causes the equilibrium constant to be squared, i.e. $\left(\frac{1}{K}\right)^2$ or $\frac{1}{K^2}$.

Question 9 **B**

The concentration of H^+ ions in 1.0 M sulfuric acid is 1.01 M, indicating that the acid is strong and able to donate both protons, so statement **A** is correct. The percentage hydrolysis given by $\left(\frac{[SO_4^{2-}]}{[HSO_4^-]}\right) \times 100$ is 0.98%, less than 1%. Therefore statement **C** is correct. The concentration of H^+ ions in 1.0 M sulfuric acid is 1.01 M, hence the pH (–0.004) is less than zero. Statement **D** is correct. The high concentration of HSO_4^- indicates a large K_a for H_2SO_4 and the low concentration of SO_4^{2-} indicates a low K_a for HSO_4^-.

Statement **B** is incorrect and, is therefore, the required response.

Question 10 **D**

A catalyst changes the rate of the forward and backward reactions equally so that equilibrium is reached faster, but the equilibrium yield and equilibrium constant are not affected. Therefore, statement I is incorrect and statement III is correct. The heat of reaction is the energy released or absorbed in a reaction and is not influenced by the presence of a catalyst, so statement II is incorrect. Catalysts offer an alternative pathway for a reaction, which requires less energy to initiate the reaction, so statement IV is correct. **D** is therefore the required response.

Question 11 **C**

If metal S reacts with Q^+ ions, then Q^+ is a stronger oxidant than S^{2+}. As metal R reacts with P^{2+} ions, P^{2+} is a stronger oxidant than R^{2+}. As metal P reacts with Q^+ ions, Q^+ is a stronger oxidant than P^{2+}.
As there was no reaction between metal S and R^{2+} ions, then S^{2+} is a stronger oxidant than R^{2+}.
Alternative **C** is the only response that is consistent with the data.

Question 12 **B**

Reverse the first equation, $\therefore \Delta H = -67.7$ kJ mol^{-1}.

Add the second equation, $\Delta H = -67.7 + 9.7 = -58.0$ kJ mol^{-1}.

Question 13 **B**

Br_2 and H_2O_2 will oxidise both Sn^{2+} and Fe^{2+}, so not **A** or **C**. Pb^{2+} will oxidise neither Sn^{2+} nor Fe^{2+}. Thus **D** is not the answer. I_2 will not oxidise Fe^{2+}, but I_2 will oxidise Sn^{2+}, and so alternative **B** is the required response.

Question 14 **A**

The added N_2O_4 leads to an increase in the concentration of N_2O_4 (so alternatives **C** and **D** are incorrect). This increase is partially overcome as reaction proceeds to the right to restore equilibrium. The shift to the right increases pressure as there are more moles of gaseous product than moles of gaseous reactant. Therefore **A**, and not **B**, is correct.

Question 15 **C**

At equilibrium, the rate of forward and reverse reactions will be equal.

Question 16 **A**

$$n(e^-) = \frac{It}{F} = \frac{(1.51 \times 90)}{96\ 500} = 1.4 \times 10^{-3} \text{ mol}$$

If the metal is singly charged, then $n(e^-) = n(M)$; so the molar mass of M is given by:

$$M(M) = \frac{m}{n} = \frac{0.150}{1.4 \times 10^{-3}} = 107 \text{ g mol}^{-1}.$$

In the second transition series, silver has a similar molar mass, so **A** is a possible response.

If the metal has a charge of 2+, 3+ or 4+, to deposit 0.150 g of metal, the molar masses of the metals would be close to 214, 321 or 428 g mol^{-1} respectively. No second transition series metal has one of these molar masses so **B**, **C** and **D** are incorrect.

Question 17 **D**

Methanoic acid has a larger K_a than ethanoic acid and so will have the higher percentage ionisation. Statement I is correct. There will be a higher concentration of H_3O^+ ions in 0.1 M methanoic acid than in 0.1 M ethanoic acid. Thus the pH of methanoic acid will be lower, so statement II is correct. As both acids are of the same concentration, the amount of NaOH required for neutralisation will be the same. Statement III is also correct. Therefore **D** is the required response.

Question 18 **A**

At electrode *Y*, the strongest oxidant will undergo a forced reduction. Thus the reaction is:
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$.

At electrode *Z*, the strongest reductant will undergo a forced oxidation. Thus the reaction is:
$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$.

The overall reaction is therefore the decomposition of water according to the equation:
$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$.

The H_2 : O_2 gas volume ratio is therefore 2 : 1, or x : $0.5x$.

Question 19 **D**

If the electrodes are copper, then at electrode Z the strongest reductant present is copper, and so the reaction is $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$.
No gas is produced at electrode Z.

Question 20 **C**

The energy densities are:

methanol $\left(725 \times \frac{1000}{32}\right) = 22\ 656\ kJ\ kg^{-1}$;

ethanol $\left(1364 \times \frac{1000}{46}\right) = 29\ 652\ kJ\ kg^{-1}$;

1–propanol $\left(2016 \times \frac{1000}{60}\right) = 33\ 600\ kJ\ kg^{-1}$; and

2–propanol $\left(2003 \times \frac{1000}{60}\right) = 33\ 383\ kJ\ kg^{-1}$.

Alternative **C** is the required response.

SECTION B: SHORT-ANSWER QUESTIONS

Question 1

a. i. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ 1 mark

ii. Energy for 100% efficiency = $m \times c \times \Delta T = 750 \times 4.18 \times (100 - 15)$ J 1 mark

Energy for 65% efficiency = $750 \times 4.18 \times (100 - 15) \times \frac{100}{65} = 409\,962$ J = 410 kJ 1 mark

1 mol of methane = 16.0 g releases 889 kJ when burnt

x g releases 410 kJ

$x = 7.4$ g 1 mark

b. i. chemical energy (in gas) → thermal energy (burning gas) → mechanical energy (turbine) → electrical energy (generator) 2 marks

ii. Gas-fired power stations use fewer energy transformations to generate electricity than coal-fired ones. 1 mark

Each energy transformation loses useful energy, so gas-fired stations, with fewer steps, are more efficient. 1 mark

c. i. $CH_4 + 4O^{2-} \rightarrow CO_2 + 2H_2O + 8e^-$ 1 mark

ii. Cathode: $O_2 + 4e^- \rightarrow 2O^{2-}$ 1 mark

iii. $E = V \times I \times t,\ \therefore V = \frac{E}{I \times t} = \frac{405}{0.450 \times 25.0 \times 60} = 0.600$ V 1 mark

iv. Fuel cells are more efficient at producing the same amount of electrical energy than power stations that use fossil fuels, such as natural gas. 1 mark

A fuel cell produces less carbon dioxide per unit of electrical energy than many other methods and so emissions that cause greenhouse problems are reduced. 1 mark

Total 13 marks

Question 2

a. $K_a = \frac{[OBr^-][H_3O^+]}{[HOBr]}$ 1 mark

b. Let $[H_3O^+] = x$

$\therefore [OBr^-] = x$

and $[HOBr] = 4.0 - x \approx 4.0$, since x is small for a weak acid. 1 mark

$\therefore K_a = 2.4 \times 10^{-9} = \frac{x^2}{4.0}$ 1 mark

$\therefore x = \sqrt{9.6 \times 10^{-9}}$

$pH = -\log[H_3O^+] = -\log(\sqrt{9.6 \times 10^{-9}}) = 4.0$ 1 mark

c. **i.** green (yellow/blue combination) 1 mark

ii. The solution would be expected to change to blue, as bromophenol blue will be blue in a solution of pH above 4.6. 1 mark

Dilution by a factor of 100 (10.0 mL to 1.0 L) will result in a pH change of 2 units. The new pH will be close to 6.0. Some adjustment may occur as the equilibrium moves to the right with the addition of water. However, the overall effect will be a decrease in the concentration of all species due to the volume increase. The pH would be expected to rise above 4.6, the colour at which the indicator changes to blue. 1 mark

d. Same rate expected in each beaker. 1 mark

Both solutions have the same concentration of $H^+(aq)$, the reacting species, and so would have the same reaction rate. 1 mark

Total 9 marks

Question 3

a. The oxidation number (O.N.) of one element increases and the oxidation number of another element decreases.

$C_2H_6 \rightarrow C_2H_4$ O.N. of C: –3 changes to –2

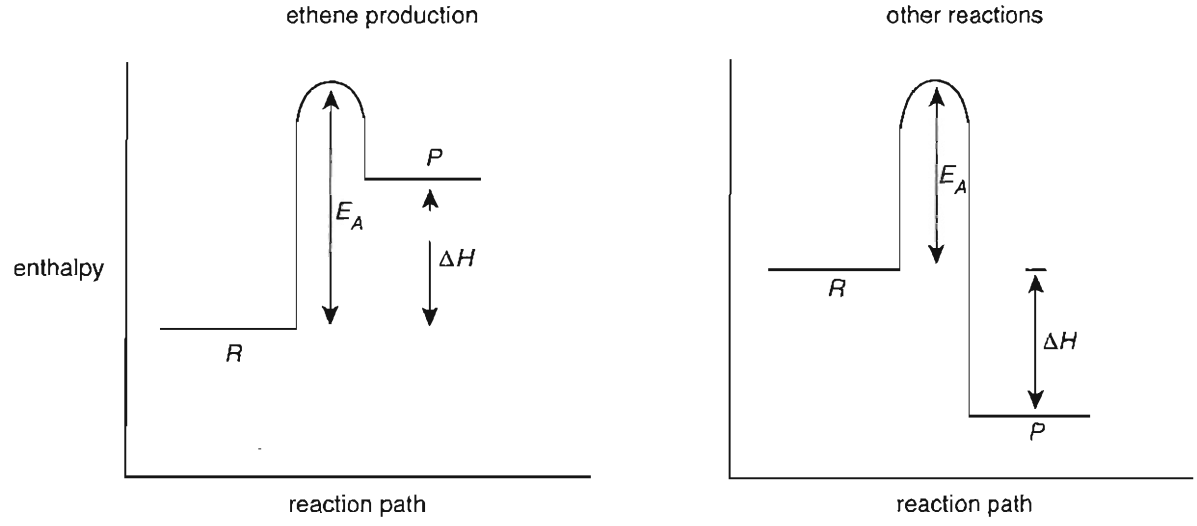
$SO_2 \rightarrow SO_3$ O.N. of S: +4 changes to +6

$N_2 \rightarrow NH_3$ O.N. of N: 0 changes to –3

$NO \rightarrow NO_2$ O.N. of N: +2 changes to +4

1 mark

b.



2 marks

1 mark for correct profile structure

1 mark for correct labelling

c. For $C_2H_6(g) \rightleftharpoons C_2H_4(g) + H_2(g)$ only:

Condition affecting yield	Choice of condition to produce maximum yield	Explanation
Pressure	low	By Le Chatelier's principle, the reaction will move to the side with the greater number of moles of gas (to the right) to oppose the lowering of pressure.
Temperature	high	For an endothermic reaction, increasing temperature will favour the products, because the forward reaction is temperature reducing.

OR

For the other three reactions:

Condition affecting yield	Choice of condition to produce maximum yield	Explanation
Pressure	high	By Le Chatelier's principle, the reaction will move to the side with the lower number of moles of gas (to the right) to oppose the increase in pressure.
Temperature	low	For an exothermic reaction, decreasing temperature will favour the products, because the forward reaction is temperature increasing.

3 marks
1 mark for correctly stating 'high' or 'low' pressure
1 mark for each correct explanation

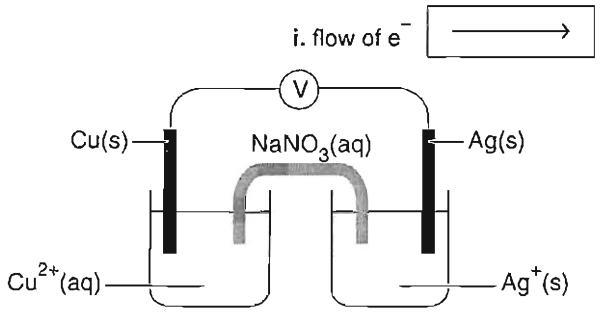
d. *Any one of:*

- **i.** $n C_2H_4(g) \rightarrow (CH_2CH_2)_n(s)$
  ii. polyethene
- **i.** $2NH_3(g) + H_2SO_4(l) \rightarrow (NH_4)_2SO_4(s)$
  ii. ammonium sulfate
- **i.** $NH_3(g) + HNO_3(l) \rightarrow NH_4NO_3(s)$
  ii. ammonium nitrate

2 marks
1 mark for chemical equation
1 mark for name of the reaction product
Total 8 marks

Question 4

a. **i.** →, i.e.



1 mark

ii. NO_3^- 1 mark

(Electrons flow away from the copper half-cell. As the positive charge in the half-cell increases, the negative ions migrate in to maintain electrical neutrality.)

iii. *Any two of:*

- the blue colour of the copper(II) ion increases
- the silver electrode increases in mass
- the copper electrode decreases in mass

2 marks

iv. The chloride ion would precipitate the silver ion in the half-cell, disrupting the correct cell function. 1 mark

b. The half-cell potential depends on the concentration of the species present. As the silver ion concentrations are very different in each cell, a potential difference may occur. 1 mark

A current would therefore be expected to flow between the two half-cells. 1 mark

c. **i.** metal cap (Zn) –

nickel/steel (Ag_2O) + 1 mark

ii. $Zn(s) + 2OH^-(aq) \rightarrow Zn(OH)_2(s) + 2e^-$ 1 mark

Total 9 marks

Question 5

a. A fine powder was used to achieve a rapid and complete reaction. Use of powder increases surface area and prevents clumps (which may not burn completely). 1 mark

b. $CF = \frac{E}{\Delta T} = \frac{31.4}{(19.626 - 18.170)} = 21.6 \text{ kJ } ^\circ\text{C}^{-1}$ 1 mark

c. $E = CF \times \Delta T = 21.6 \times (18.170 - 17.319) = 18.38 \text{ kJ}$ 1 mark

$\text{heat of combustion} = \frac{E}{m} = \frac{18.38}{5.19} = 3.54 \text{ kJ g}^{-1}$ 1 mark

d. To express the heat of combustion in kJ mol^{-1} requires that the molar mass can be determined. Coal is a mixture of many compounds and so a molar mass cannot be calculated. 1 mark

e. higher 1 mark

This is because some of the heat from the fresh sample would have been used to heat water in the sample. Heating the sample in the oven removed water from the coal and so the dried sample would produce more energy per gram as the water content was much lower. 1 mark

Total 7 marks

Question 6

a. At 3 minutes some SO_2 was added to the mixture. 1 mark

The system responded by moving forwards to partially overcome the change, hence the SO_2 concentration is falling. 1 mark

b. $K = \dfrac{[SO_2Cl_2]}{[SO_2][Cl_2]}$ 1 mark

$= \dfrac{(0.03)}{(0.09)(0.07)}$

$= 4.8\ M^{-1}$ 1 mark

c. Following the temperature decrease, the reaction moved in the forward direction. 1 mark

The forward reaction must therefore be temperature raising, and so the reaction is exothermic 1 mark

d. **i.** $c_1V_1 = c_2V_2$

$\therefore 0.08V_1 = c_2V_1 \times \dfrac{5}{4}$

$\therefore c_2 = 0.064\ M$ 1 mark

ii. Following the volume increase and the associated pressure decrease, the reaction will move in the reverse direction to overcome the change (since the greater number of mole of reactants exerts a greater pressure than the products). 1 mark

However, the SO_2 concentration will not be restored to its original value and will therefore remain below, i.e. less than the concentration at 9 minutes. 1 mark

Total 9 marks