Neap:

Trial Examination 2011

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

Extent of reaction is related to the difference in E^0 values of the oxidant and reductant reactions. We require the combination which has the oxidant and reductant separated by the largest difference in E^0 values, with the oxidant having a higher E^0 value than the reductant. In **A**, no reaction is expected as the oxidant Zn^{2+} is too weak to oxidise the reductant, Sn^{2+}. In **B**, Ag^+ will oxidise Fe^{2+} with an E^0 difference of 0.03 V. In **C**, Pb^{2+} will oxidise Ni with an E^0 difference of 0.10 V. In **D**, no reaction is expected as the oxidant Mn^{2+} is too weak to oxidise the reductant, Cu. Alternative **C** is therefore the required response.

Question 2 A

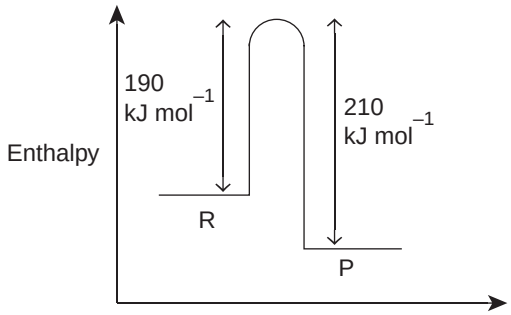
The gas molecules must collide with sufficient energy in the correct orientation to break bonds in the reactants so that products are formed. Both reactant and product gas molecules present in a system will collide and thus **C** is accurate. Only a small proportion of molecules at a set temperature will have the energy required for reaction, so **B** is a correct statement. Increasing the temperature by 10°C will increase the proportion of molecules that can produce successful collisions (so statement **D** is correct) but will not necessarily double the number of collisions. Thus statement **A** is incorrect.

Question 3 D

Moving from 15°C to 45°C involves three increases of 10°C. Thus the rate of reaction will double three times from the initial rate of 1.9 M s^{-1} (to a value of 15.2 M s^{-1}).

Question 4 B

The diagram below shows that the enthalpy difference between reactants and products is –20 kJ mol^{-1}.



Question 5 C

The required equation is; $Cu(s) + \frac{1}{2}O_2(g) \rightarrow CuO(s)$ $\Delta H = ?$ kJ mol^{-1}

To obtain this equation we need to halve equation I, and add the reverse of equation II. Thus the required enthalpy change value is $\frac{1}{2} \times (-288) - 11 = -155$ kJ mol^{-1}.

Question 6 A

In the reaction shown two smaller nuclei combine to form a larger nucleus. This is a fusion process, hence **C** and **D** are incorrect responses. Nuclear fusion requires a very high temperature to initiate reaction, and the nuclear process generates extremely high temperatures. Such temperatures are difficult to obtain and contain, and so this reaction is not currently used as an energy source on Earth. The raw material is hydrogen. This is readily available from, for example, the electrolysis of seawater (so **B** is an incorrect response).

Question 7 **C**

Any modification should aim to increase the amount of heat transferred to the vessel containing the water, and to prevent heat from leaving the heated water. Change I is likely to decrease the amount of heat transferred, as glass is a poor conductor of heat. Change II should prevent some of the heat from the flame being lost and thus improve the amount transferred. Change III will prevent heat being lost from the heated water, producing a more accurate recording of the temperature change in the water. Thus changes II and III would increase the accuracy, and so **C** is the required response.

Question 8 **D**

$$[OH^-] = 2 \times [Ca(OH)_2] = 2 \times 3.50 \times 10^{-3}\ M$$

$$[H_3O^+] = \frac{10^{-14}}{[OH^-]} = \frac{10^{-14}}{2 \times 3.50 \times 10^{-3}} = 0.143 \times 10^{-11}\ M$$

$$pH = -\log[H_3O^+] = -\log(0.143 \times 10^{-11}) = 11.8$$

Question 9 **A**

	2HI	**H_2**	**I_2**
n_i	**5.00**		
change	–0.500	+0.250	+0.250
n_e	4.50		**0.250**
c_e	$\frac{4.50}{2} = 2.25\ M$		

Question 10 **C**

For a strong acid, dilution by a factor of ten will increase the pH by one unit. However this is not true for a weak acid. Thus alternative **B** is incorrect. The equilibrium reaction involved is:

$$HOCl(aq) + H_2O(aq) \rightleftharpoons OCl^-(aq) + H_3O^+(aq)$$

When water (a reactant) is added, the equilibrium moves to the right. This increases the amount of hydronium ion, and so may be expected to decrease the pH. However, the effect of the dilution is to decrease the concentration of all species and so increase the pH. The effect of the change (the dilution) is greater than the effect of the response (the increase in hydronium ion), and so the pH will increase. The increase will be by less than one unit. Thus alternative **C** is correct.

Question 11 **D**

In an electrolytic cell, electrons are moved by the power supply from the positive anode to the cathode, and so **A** is incorrect. As the cadmium anode is oxidised, it will lose mass as the electrolysis proceeds. Thus **B** is incorrect. Cadmium ions are being produced at the anode and consumed at the cathode, resulting in a constant concentration of the ion in the electrolyte. Therefore **C** is not correct. In an electrolytic cell, cations travel towards the negatively charged cathode. Alternative **D** is therefore the required response.

Question 12 **B**

The equation has been reversed and halved:

$$K' = \frac{1}{\sqrt{K}} = \frac{1}{\sqrt{49}} = 0.14$$

Question 13 D

The negatively charged sulfate ion will be attracted to the positively charged anode in the electrolytic cell. However, SO_4^{2-} is a weaker reductant than H_2O, and so it will not be oxidised. Sulfate ion (in acidified solution) is an oxidant, but as it is negatively charged, it is not attracted to the negatively charged cathode to be reduced. Thus **D** is the correct response.

Question 14 A

When the volume of the reaction vessel is altered, the concentrations of all species will be altered. Since only the concentration of *Y* alters at time t_2, response **B** is not correct. A catalyst does not change the position of equilibrium and thus response **C** is not correct. At time t_2 some reactant *Y* was added and the equilibrium shifted to the right. The forward reaction was faster than the backward reaction until equilibrium was restored, thus **D** is not correct. The ratio of changes in the concentrations of *X*, *Y* and *Z* after t_2 (0.03 : 0.09 : 0.06) indicate that the ratio of coefficients 1 : *y* : *z* in the equation is 1 : 3 : 2. There are more gas particles on the reactant side of the equation than on the product side. According to Le Chatelier's principle, when the pressure is increased in a gaseous equilibrium, the side of the reaction with fewer particles will be favoured. i.e. more gas *Z* will be produced. Thus **A** is a valid deduction from the data, and is the required response.

Question 15 B

$$K = \frac{[Z]^2}{[X][Y]^3} = \frac{(0.10)^2}{(0.20)(0.30)^3} = 1.9$$

Question 16 C

Using half-cells 1 and 2 shows that *Q* is a weaker reductant than P^{2+}. Using half-cells 1 and 3 shows that P^{2+} is a weaker reductant than *R*. Thus *R* is the strongest reductant of the three.

Question 17 A

A	$m(\text{ethanol}) = 0.785 \times 5.9 = 4.6$ g $n(\text{ethanol}) = \frac{m}{M} = \frac{4.6}{46.0} = 0.10$ mol energy released = $1364 \times 0.10 = 136$ kJ
B	energy released = $3509 \times 0.10 = 350$ kJ
C	$n(H_2) = \frac{V}{V_M} = \frac{24.5}{24.5} = 1.0$ mol energy released = $286 \times 1.0 = 286$ kJ
D	$n(\text{butane}) = \frac{m}{M} = \frac{5.8}{58.0} = 0.10$ mol energy released = $2874 \times 0.10 = 287$ kJ

Question 18 D

The pH is 6.5, and so the $[H^+]$ is $10^{-6.5}$. As it is pure water, $[OH^-] = [H^+]$ and so statement I is incorrect. An acidic pH of less than 7 refers to solutions at 25°C. Because the liquid is pure water, it must be neutral. Statement II is incorrect. Statement III is also incorrect as the value of K_w is temperature-dependent. None of the statements is correct, and so **D** is the required response.

Question 19 B

From the graph; 0.124 g is produced from 400 C, hence 58.7 g (1.00 mol) will be produced from

$\frac{58.7}{0.124} \times 400 = 189\ 355\ \text{C}$.

1.00 mol of nickel requires 2.00 mol of electrons for reaction, hence the charge of 1.00 mol of electrons is

$\frac{189\ 355}{2} = 946\ 77.5 = 9.47 \times 10^4\ \text{C}$.

Question 20 B

The theoretical value for the charge on one mole of electrons is 96 500 C (Faraday's constant). The calculated value is less than this, hence alternatives **A** and **C** are incorrect. Contamination of the solution with zinc is unlikely to alter the results because the zinc ion, being a weaker oxidant than the nickel ion, will not deposit at the cathode. The copper ion is a stronger oxidant than the nickel ion. Copper will deposit on the nickel electrodes, leading to an increased mass of the cathode. This in turn will lead to a decreased value for the calculated amount of charge carried by one mole of electrons.

SECTION B: SHORT-ANSWER QUESTIONS

Question 1

a. For the heating of 1.00 kg of water by 1.0°C

$E = m \times c \times \Delta T = 1.00 \times 1000 \times 4.18 \times 1.0 = 4180 \text{ J} = 4.18 \text{ kJ}$

1 mark

Calibration factor for the calorimeter components = 9.56 – 4.18 = 5.38 kJ $°C^{-1}$.

1 mark

b. **i.** Combustion of 60.0 g (1.00 mol) of 2-propanol releases 2003 kJ of energy.

1 mark

$\therefore$ 3.05 g releases $\frac{3.05}{60.0} \times 2003 = 101.8 \text{ kJ} = 102 \text{ kJ}$

1 mark

ii. $E = CF \times \Delta T = (5.38 \times 1000 \times \Delta T) + (1058 \times 4.18 \times \Delta T)$ J

$E = 102 \times 1000$ J

$\therefore 102 \times 1000 = (5.38 \times 1000 \times \Delta T) + (1058 \times 4.18 \times \Delta T)$

1 mark

Solving for ΔT gives 10.4°C.

1 mark

$\Delta T = T_f - T_i$

$\therefore T_f = 22.8 + 10.4 = 33.2°C$

1 mark

Total 7 marks

Question 2

a. **i.** $K_a = \frac{[H_3O^+][C_3H_5O_3^-]}{[HC_3H_5O_3]}$

1 mark

ii. % ionisation = $\frac{[C_3H_5O_3^-]}{[HC_3H_5O_3]} \times 100 = 3.0$

1 mark

$[C_3H_5O_3^-] = \frac{0.15 \times 3.0}{100} = 0.0045$ M

1 mark

iii. $[H_3O^+] = [C_3H_5O_3^-] = 0.0045$ M

1 mark

$K_a = \frac{[H_3O^+][C_3H_5O_3^-]}{[HC_3H_5O_3]} = \frac{(0.0045)^2}{0.15} = 1.35 \times 10^{-4} = 1.4 \times 10^{-4}$ (2 significant figures)

1 mark

b. **i.** $K_{a2} = \dfrac{[H_3O^+][HPO_4^{2-}]}{[H_2PO_4^-]}$

1 mark

ii. less than

1 mark

With the removal of each proton (H^+) the acid molecule/ion becomes increasingly negatively charged. With increasing negative charge it becomes progressively more difficult to remove a positively charged H^+ due to the electrostatic attractions involved. Thus successive ionisation constants decrease in value.

Total 7 marks

Question 3

a. This method increases the time of exposure of the reactants to the surface of the catalyst and so increases the efficiency of the process

1 mark

b. High pressure for a gaseous equilibrium will produce a high rate of reaction as the reactant molecules are more likely to collide

1 mark

There are two reactant molecules and four product molecules in reaction I. If high pressures are used, Le Chatelier's principle predicts that the reverse reaction would be favoured, i.e. a low yield.

1 mark

A compromise is chosen using moderate pressure to produce a reasonable rate of reaction and an economically acceptable yield.

1 mark

c. Reaction II is an exothermic reaction and by using high temperatures the reverse reaction will be favoured, resulting in a low yield.

1 mark

If the temperature is too low (producing a high yield), the rate of reaction will be too slow.

1 mark

A compromise temperature is chosen which gives acceptable rate and yield.

1 mark

d. In Reaction I the products CO and H_2 are in the ratio of 1 : 3 but in Reaction II these are used in the ratio of 1 : 2. Thus H_2 will be in excess.

1 mark

To ensure the excess H_2 is used beneficially, injecting CO_2 into the reactor will improve the overall efficiency of the synthesis.

1 mark

e. *Any one of (for example)*:

- the use of gloves and protective clothing to prevent absorption of methanol through the skin
- the use of respiratory masks to prevent inhalation of methanol vapours

1 mark

f. *Ammonia*

i. Nitrogen is obtained from the air.

Hydrogen by the steam reforming of hydrocarbon feedstocks such as methane or LPG (propane and butane).

1 mark

ii. Carbon dioxide (a greenhouse gas) is a significant waste product in the steam reforming process to generate hydrogen gas. This gas is collected and used in the production of carbonated drinks and the fertiliser urea.

1 mark

Sulfuric acid

i. Sulfur dioxide is obtained from three possible sources: the burning of sulfur; as a by-product of the desulfurisation of petroleum and coal-fired power stations; as a waste product from the roasting of metal sulfide ores. Oxygen is obtained from the air.

1 mark

ii. The loss of SO_2 and SO_3 (significant contributors to acid rain) to the atmosphere are minimised by recycling unreacted gases from the tower back to the converter.

1 mark

Nitric acid

i. Ammonia is obtained via the Haber Process by the reaction of nitrogen and hydrogen gases. Oxygen is obtained from the air.

1 mark

ii. Loss of NO and NO_2 (contributors to photochemical smog and acid rain) to the atmosphere are minimised by catalytic reduction to produce N_2 gas.

1 mark

Ethene

i. Ethane is produced from natural gas.

Gas-oil is produced by fractional distillation of petroleum.

1 mark

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

1 mark

Total 12 marks

Question 4

a. Use colorimetry to monitor the change in brown colour of the flask contents.

1 mark

b. The gradient of the tangent to the curve at a particular time gives the rate of reaction at that time.

1 mark

c. $$\text{Rate} = \frac{\text{change in concentration}}{\text{time interval}} = \frac{(0.0080 - 0.0065)}{50} = 3.0 \times 10^{-5}\ \text{M s}^{-1}$$

1 mark

d. O_2 is produced from NO_2 in the mole ratio 1 : 2.

The rate is therefore $\frac{3.0 \times 10^{-5}}{2} = 1.5 \times 10^{-5}\ \text{M s}^{-1}$

1 mark

e. As reaction proceeds the concentration of NO_2 in the flask decreases.

1 mark

Reaction rate depends on the number of successful collisions between molecules. Reaction will therefore occur more slowly as there are less molecules in a given volume, and therefore less collisions occurring.

1 mark

Total 6 marks

Question 5

a. **i.** $CH_3COOH(aq) + 2H_2O(l) \rightarrow 2CO_2(g) + 8H^+(aq) + 8e^-$

1 mark

ii. 1 mol of CH_3COOH produces 8 mol of electrons, i.e. $8 \times 96\,500$ C

1 mark

$E = V \times Q = 0.30 \times 8 \times 96\,500 = 231\,600 \text{ J} = 2.3 \times 10^5 \text{ J}$

1 mark

b. **i.** Platinum could be a catalyst for the reaction which thus requires less energy to be supplied to ensure the reaction occurs.

1 mark

ii. $2H^+(aq) + 2e^- \rightarrow H_2(g)$

1 mark

c. **i.** The fuel cell (method I).

1 mark

Only one energy transformation occurs in the fuel cell. There are several energy transformations in method II, and as each transformation loses some energy, the amount of energy at the end of the process is reduced.

1 mark

ii. *Any one of (for example):*

- To carry a reasonable amount of hydrogen in a car, the hydrogen must be liquefied and kept under pressure, resulting in increased costs.
- Refilling stations are not readily available for cars using hydrogen as the fuel source.

1 mark

Total 8 marks

Question 6

a. **i.** $n(e^-) = \dfrac{I \times t}{F} = \dfrac{2.00 \times 6.75 \times 60}{96\,500} = 8.39 \times 10^{-3} \text{ mol}$

1 mark

ii. $n(\text{Au}) = \dfrac{m}{M} = \dfrac{0.551}{197.0} = 2.80 \times 10^{-3} \text{ mol}$

1 mark

iii. $\frac{n(e^-)}{n(Au)} = \frac{8.39 \times 10^{-3}}{2.80 \times 10^{-3}} = 2.996$

1 mark

The charge on gold ions is therefore +3.

1 mark

b. **i.** Anode reaction: $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

1 mark

$n(O_2) = \frac{1}{4} \times n(e^-) = \frac{1}{4} \times 8.39 \times 10^{-3}$ mol $= 2.10 \times 10^{-3}$ mol

1 mark

$V(O_2) = \frac{nRT}{p} = \frac{2.10 \times 10^{-3} \times 8.31 \times 293}{100} = 5.11 \times 10^{-2}$ L = 51.1 mL

1 mark

ii.

Changing the electrode surface area	
Increasing the concentration of the electrolyte	✓
Decreasing the duration of the electrolysis	
Using platinum electrodes instead of graphite	

1 mark

Total 8 marks

Question 7

a. $Br_2(l) + 2e^- \rightarrow 2Br^-(aq)$

1 mark

b. The anode decreases in mass (because the *zinc* metal is oxidised at the anode during discharge).

1 mark

c. **i.** The membrane allows for the flow of ions between the electrolyte in the two half-cell chambers.

1 mark

ii. During recharge, bromine and zinc are produced and must be kept isolated from each other to prevent a spontaneous redox reaction.

1 mark

d. The conditions used in the cell differ from the standard conditions under which the electrochemical series is constructed.

1 mark

e. Using a photovoltaic (or solar) cell, the Sun's energy can be converted directly to electrical energy.

1 mark

The solar cell could be put in place of the power source in the diagram, allowing the zinc-bromine battery to be recharged.

1 mark

Total 7 marks

