Neap:

Trial Examination 2008

VCE Chemistry Unit 4

Written Examination

Suggested Solutions

SECTION A: MULTIPLE-CHOICE QUESTIONS

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

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Question 1 **B**

$n(\text{benzoic acid}) = \frac{m}{M} = \frac{1.131}{122.0} = 9.270 \times 10^{-3}$ mol

2 mol of benzoic acid yields 6454 kJ

9.270×10^{-3} mol yields x

$x = \frac{6454 \times 9.270 \times 10^{-3}}{2} = 29.92$ kJ

$\text{CF} = \frac{29.92}{30.94} = 0.9669 \text{ kJ °C}^{-1} = 966.9 \text{ J °C}^{-1}$

Question 2 **A**

The relative rates of formation and disappearance are given by the coefficients in the equation. Thus for every 1.0 mole (per minute) of Q which reacts, 0.25 mole (per minute) of R will be formed.

Question 3 **A**

Catalysts increase the rate of reaction (hence **D** is incorrect). Catalysts have no effect on the equilibrium yield of a product (other than to produce the yield more quickly).

Question 4 **C**.

To obtain the reaction required, add the first equation to twice the second.

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -393.5 \text{ kJ mol}^{-1}$

$2S(s) + 2O_2(g) \rightarrow 2SO_2(g)$ $\Delta H = 2 \times -296.1 \text{ kJ mol}^{-1}$

$C(s) + 2S(s) + 3O_2(g) \rightarrow CO_2(g) + 2SO_2(g)$ $\Delta H = -985.7 \text{ kJ mol}^{-1}$

To this equation, add the reverse of the third equation.

$CO_2(g) + 2SO_2(g) \rightarrow CS_2(l) + 3O_2(g)$ $\Delta H = +1072 \text{ kJ mol}^{-1}$

$C(s) + 2S(s) \rightarrow CS_2(l)$ $\Delta H = +86.3 \text{ kJ mol}^{-1}$

Question 5 **A**

H_2S is a weak acid and only partially ionises in water. With a K_a value of 10^{-7}, the equilibrium lies well to the left, i.e. very little H_2S is ionised. Even less HS^- is ionised, hence the species in highest concentration will be H_2S.

Question 6 **D**

To increase the yield of this exothermic reaction we need to push the position of equilibrium of the reaction further to the right and/or increase the equilibrium constant. A volume increase leads to a pressure decrease. This results in a shift to the left (more moles of gas) in order to increase the pressure. This decreases the yield (so **A** is incorrect). The use of an inert gas has no effect on the partial pressures of each reactant or product gas in the equilibrium system and so has no effect on the equilibrium position (so **B** is incorrect). An increase in temperature will favour the endothermic process and so the reaction will proceed backwards (so **C** is incorrect). An excess of the reactant gas SO_2 will force the reaction to the right to partly compensate (so **D** is correct).

Question 7 **D**

Bond breaking requires energy (so **A** and **C** are incorrect). Bond formation releases energy (so **B** and **C** are incorrect).

Question 8 **B**

$n(NH_4ClO_4) = \frac{m}{M} = \frac{500\ 000}{117.5} = 4.26 \times 10^3$ mol

3 mol of ammonium perchlorate yields 2667 kJ

4.26×10^3 mol yields x

$x = \frac{2667 \times 4.26 \times 10^3}{3} = 3.78 \times 10^6$ kJ = 3780 MJ

Question 9 **C**

The strongest acid is the one with the largest K_a value. This is lactic acid, with a K_a of 1.4×10^{-4}. The weakest acid is the one with the smallest K_a. This is hypochlorous acid, with a K_a of 2.9×10^{-8}.

Question 10 **A**

From the energy profile diagram, ΔH for the reaction = $H_P - H_R = -800 - 200 = -1000$ kJ mol^{-1}. We require the change in enthalpy for double the reaction represented on the diagram, so $\Delta H = -2000$ kJ mol^{-1}.

Question 11 **C**

The reaction for which we need to determine the activation energy is the reverse of the one represented in the energy profile diagram. As the activation energy is defined as the 'amount of energy required to initiate the reaction', $E_A = 700 - (-800) = +1500$ kJ mol^{-1}. As a catalyst is to be employed for the reaction, the activation energy must be less than 1500 kJ mol^{-1} (so **D** is incorrect) but still greater than 1000 kJ mol^{-1}, as this is the magnitude of ΔH for the reaction (so **A** and **B** are incorrect).

Question 12 **D**

$E = m \times c \times \Delta T$ (where E is in J)

$\Delta T = \frac{1000E}{m \times c}$ (as E was given in kJ)

Note that the ΔT *will be in K, since the units for the given* c *are* J g^{-1} K^{-1}. *However the change in temperature in K will be the same as the change in temperature in °C. The two scales have the same increments, but different zero points.*

Question 13 **B**

$n(Sn) = \frac{m}{M} = \frac{5.94}{118.7} = 0.050$ mol

1 faraday is the charge on one mole of electrons, hence 0.10 faradays represents the charge on 0.10 mole of electrons.

$n(Sn) : n(e) = 0.050 : 0.10 = 1:2$

The charge on the Sn must therefore be +2.

Question 14 **C**

$n(Ba(OH)_2) = c \times V = 0.150 \times 0.0800 = 0.0120$ mol

$n(OH^-) = 2 \times 0.0120 = 0.0240$ mol

$n(HNO_3) = c \times V = 0.250 \times 0.120 = 0.0300$ mol

$n(H^+) = 0.0300$ mol

$n(H^+)$ in excess = $0.0300 - 0.0240 = 0.00600$ mol

$[H^+] = \frac{n}{V} = \frac{0.00600}{0.200} = 0.0300$ M

$pH = -\log_{10}[H^+] = -\log(0.0300) = 1.52$

Question 15

$K = \frac{[C]}{[A][B]^2} = 0.318$ M^{-2}

$[B] = \sqrt{\frac{[C]}{[A] \times 0.318}} = \sqrt{\frac{0.0914}{0.532 \times 0.318}} = 0.735$ M

Question 16 **B**

$K_a = \frac{[CH_3NH_2][H_3O^+]}{[CH_3NH_3^+]} = 2.7 \times 10^{-11}$ M

$[CH_3NH_2] = [H_3O^+]$ at equilibrium and $[CH_3NH_3^+]_i \approx [CH_3NH_3^+]_{eq} = 0.050$ M (for a weak acid)

$\frac{[CH_3NH_2][H_3O^+]}{[CH_3NH_3^+]} = \frac{[H_3O^+]^2}{0.050} = 2.7 \times 10^{-11}$

$[H_3O^+] = 1.16 \times 10^{-6}$ M, $\therefore$ pH = 5.9

Question 17 **D**

The addition of acid increases the concentration of H_3O^+ ions which, in turn, drives the reaction to the left. As the reaction only partly compensates for this change, the concentration of the H_3O^+ ions at the new position of equilibrium will still be higher than initially, and so the pH will be lower (so **B** is incorrect). As the reaction proceeds to the left, the concentration of $CH_3NH_3^+$ will increase (so **A** is incorrect). The ratio is equivalent to the K_a ratio and so will not change, as the reaction is in equilibrium.

Question 18 **B**

An increase in temperature will cause an increase in the rate of reaction, as the particles have more energy and so are more likely to overcome the activation energy barrier. An increase in temperature for an exothermic reaction will however lower the yield as the equilibrium moves to the left to try to decrease the temperature. The conflict thus arises only for exothermic reactions. For endothermic reactions, increasing temperature increases both the rate and yield of the reaction, thus no conflict arises.

Question 19 **A**

Biogas is produced by the anaerobic decomposition of organic matter by the action of a variety of microorganisms. It largely consists of a mixture of methane and carbon dioxide.

Question 20 **D**

The oxidation number of carbon in CH_4 is –4. The oxidation number of carbon in CO_2 is +4. Therefore oxidation has occurred and so the CH_4 is the reductant (so **A** and **C** are incorrect). Reduction occurs at the cathode (so **A** or **B** are incorrect).

SECTION B: SHORT-ANSWER QUESTIONS

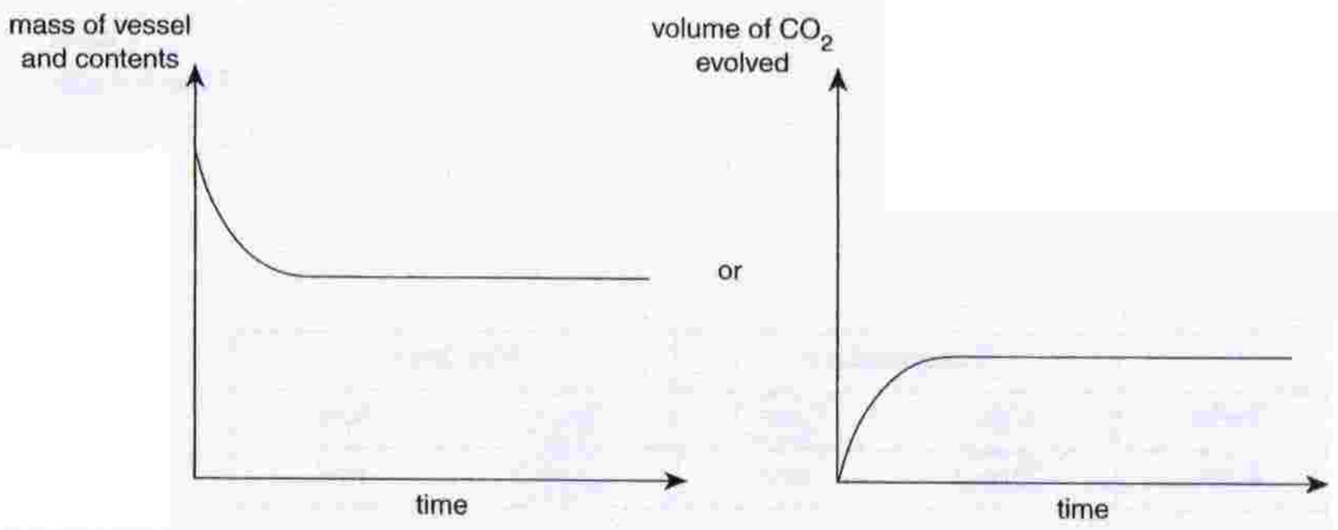
Question 1

a. *Any one of:*

- by recording the decreasing mass of the open vessel as the carbon dioxide escapes.
- by collecting and recording the volume of the carbon dioxide evolved over time.
- any other suitable method.

1 mark

b.



*Any graph consistent with the response given to part **a** is acceptable.*

2 marks
1 mark for correctly labelled axes
1 mark for correct shape of the graph

c. remains the same 1 mark

The calcium carbonate was in excess. Adding more of the excess reactant will not change the yield. 1 mark

Total 5 marks

Question 2

a. **i.**

	Reactants	Products	
Mole ratio in equation	$2NOBr_2$	2NO	Br_2
n_i	2.00	0	0
change	–0.472	+0.472	+0.236
n_{eq}	1.528	0.472	0.236
$[\ ]_{eq}$, $V = 5.00$ L	0.306	0.0944	0.0472

$[NOBr_2] = 0.306$ M, $[NO] = 0.0944$ M, $[Br_2] = 0.0472$ M 2 marks

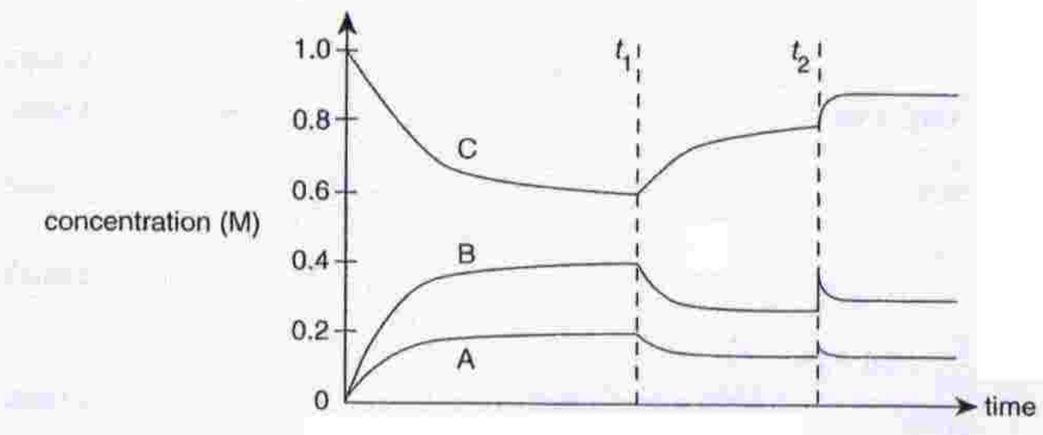
ii. $K = \dfrac{[NO]^2[Br_2]}{[NOBr_2]^2} = \dfrac{(0.0944)^2 \times 0.0472}{(0.306)^2} = 4.49 \times 10^{-3}$ M 1 mark

b. **i.** NO 1 mark

ii. increased 1 mark

At t_1 the concentration of $NOBr_2$ increased and the concentration of NO and Br_2 decreased. The reaction must have proceeded to the left to effect these concentration changes. As the forward reaction is exothermic, the temperature must have increased at t_1, as a temperature increase favours the endothermic (backwards) reaction. 1 mark

iii.



2 marks

A small quantity of NO was added at time t_2. Addition of a product will cause the reaction to proceed to the left to partly compensate.

To gain full marks the extension of the graph must show the proportional increase in concentration of the $NOBr_2$ (C) with the decrease of NO (B) and Br_2 (A) in the ratio 1 : 1 : 0.5.

Total 8 marks

Question 3

a. **i.** $n(Na_2SO_4.10H_2O) = \dfrac{m}{M} = \dfrac{25.0 \times 10^3}{322.1} = 77.6$ mol 1 mark

energy absorbed $= 77.6 \times 78.2 = 6.07 \times 10^3$ kJ 1 mark

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

$6.07 \times 10^6 = 4.18 \times 25\,000 \times \Delta T$

$\Delta T = 58.1°C$ 1 mark

b. **i.** $6CO_2(g) + 6H_2O(l) \xrightarrow[\text{light}]{\text{chlorophyll}} C_6H_{12}O_6(aq) + 6O_2(g)$ 1 mark

ii. For example:
The fuel is 'wet' and so does not produce large amounts of energy per gram of fuel. 1 mark

iii. For example:
It could be mixed with petrol as a fuel for combustion engines. 1 mark

c. For example:
The efficiency of transformation of light energy to electrical energy is low. 1 mark

d. **i.** It is difficult to obtain the high temperatures needed to initiate the reaction, and to contain the reaction at the very high temperatures generated. 1 mark

ii. There is a limited number of accessible sites to tap into the geothermal energy source. 1 mark

e. **i.** It is a renewable source of hydrocarbons for use as fuel. 1 mark

ii. The arable land needed to grow the trees could otherwise be used for food production. 1 mark

Note: the gopher tree grows well in arid soil, so may in fact ultimately be a viable biofuel source.

Total 11 marks

Question 4

a. **i.** Br_2 1 mark

ii. H_2O is a stronger oxidant than Mg^{2+}. 1 mark

In aqueous solution, water will be reduced to form hydrogen gas and hydroxide ions in preference to the reduction of magnesium ions to deposit magnesium. 1 mark

iii. For example,
$CuBr_2(aq)$ 1 mark

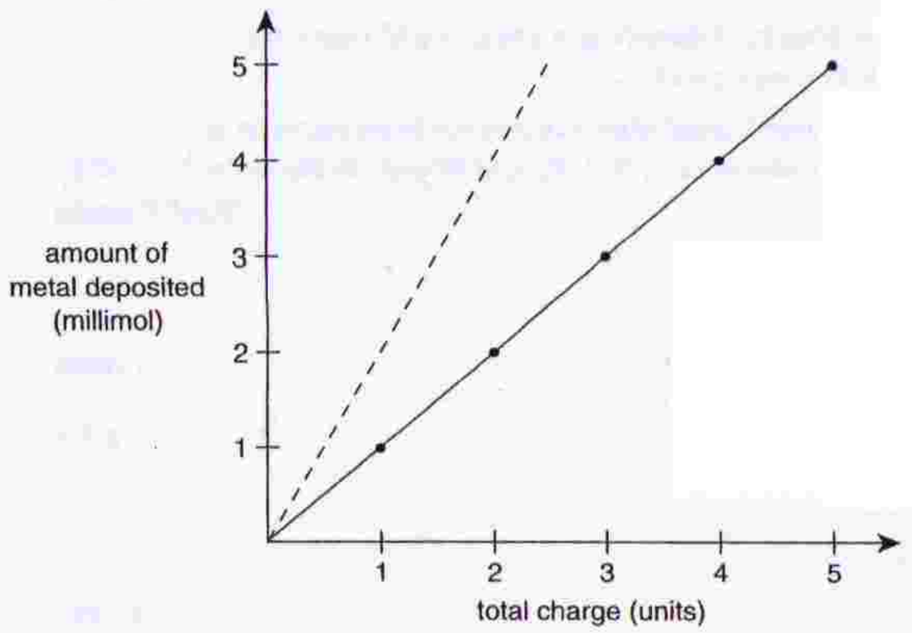
b. **i.** $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e$ 1 mark

ii. $n(O_2) = \dfrac{V}{V_M} = \dfrac{25.0}{24\ 500}$ mol 1 mark

$n(e) = 4 \times n(O_2)$ 1 mark

$$t = \frac{n(e) \times F}{I} = \frac{4 \times \dfrac{25.0}{24\ 500} \times 96\ 500}{0.060} = 6565 \text{ s} = 109 \text{ min}$$ 1 mark

c.



2 marks

Relevant half equations are $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ and $Ag^+(aq) + e^- \rightarrow Ag(s)$. For a given amount of charge (i.e. a given number of electrons) the amount, in mole, of Ag deposited will be twice that of Cu.

Total 10 marks

Question 5

a. **i.** → 1 mark

ii. → 1 mark

b. **i.** $A(s) \rightarrow A^{2+}(aq) + 2e$ 1 mark

ii. $B^+(aq) + e \rightarrow B(s)$ 1 mark

c. **i.** $n(A) = \dfrac{m}{M} = \dfrac{0.34}{M(A)}$

$n(B) = \dfrac{m}{M} = \dfrac{1.3}{M(B)}$ 1 mark

$n(B) = 2 \times n(A)$

$\dfrac{1.3}{M(B)} = 2 \times \dfrac{0.34}{M(A)}$

$\dfrac{M(A)}{M(B)} = \dfrac{0.68}{1.3} = 0.5$

$M(A) : M(B) = 1 : 2$ 1 mark

ii. A may be Mn ($M = 54.9$ g mol^{-1}) or Fe ($M = 55.8$ g mol^{-1}) 1 mark

B may be Ag ($M = 107.9$ g mol^{-1}) 1 mark

Total 8 marks

Question 6

Ammonia

a. **i.**

	Temperature		Pressure	
Yield	high	(low)	(high)	low
Rate	(high)	low	(high)	low

1 mark

1 mark

ii. temperature: 400°C to 500°C 1 mark

pressure: 100 to 250 atm 1 mark

iii. A compromise in temperature is reached as high temperatures will result in a fast rate of reaction but a poor yield for this exothermic reaction. 1 mark

Moderately high pressures are used. Achieving very high pressure is too expensive. 1 mark

b. **i.** Carbon dioxide is a significant waste product in the steam reforming process to generate hydrogen gas. The carbon dioxide gas is collected and used in the production of carbonated drinks and the fertiliser urea. 1 mark

ii. Ammonia is a severe respiratory irritant and is extremely toxic in the environment, both in gaseous and aqueous forms. Exposure to this substance must be strictly limited. 1 mark

Nitric acid

a. **i.**

	Temperature		Pressure	
Yield	high	(low)	high	(low)
Rate	(high)	low	(high)	low

1 mark

1 mark

ii. temperature: 820°C to 930°C 1 mark

pressure: 4 to 10 atm 1 mark

iii. A compromise in temperature is reached, as high temperatures will result in a fast rate of reaction but a poor yield for this exothermic reaction. 1 mark

Moderately high pressures are used to assist in passing the reactant gas mixture swiftly over the catalyst and so improving the rate of the reaction and the control over the reaction process. 1 mark

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

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

Sulfuric acid

a. **i.**

	Temperature		Pressure	
Yield	high	(low)	(high)	low
Rate	(high)	low	(high)	low

1 mark

1 mark

ii. temperature: 400°C to 500°C 1 mark
pressure: atmospheric pressure 1 mark

iii. A compromise in temperature is reached as high temperatures will result in a fast rate of reaction but a poor yield for this exothermic reaction. 1 mark
Atmospheric pressure is used as adequate yields are achieved without the need to use expensive high-pressure equipment. 1 mark

b. **i.** The loss of SO_2 and SO_3 to the atmosphere must be minimised as these gases are significant contributors to acid rain. 1 mark

ii. Sulfuric acid is severely corrosive to all body tissue and must be managed accordingly. Exposure to this substance must be strictly limited. 1 mark

Ethene

c. **i.**

	Temperature		Pressure	
Yield	(high)	low	high	(low)
Rate	(high)	low	(high)	low

1 mark

1 mark

ii. temperature: 1000°C 1 mark
pressure: atmospheric pressure 1 mark

iii. A compromise in pressure is reached as high pressures will result in a fast rate of reaction but the elevated temperatures used already achieve this aim. In terms of extent of reaction, pressures less than atmospheric pressure would increase yield. 1 mark

This is potentially hazardous as a break in a pipe could cause air to be sucked into the reaction mixture with explosive consequences and so it is not done. Atmospheric pressure is used instead. 1 mark

d. **i.** Losses of hydrocarbons to the environment are limited by recycling or by burning off any excess gases. 1 mark

ii. Ethene is a highly flammable gas as well as being toxic at moderate concentrations in the atmosphere. Exposure to sources of ignition must be prevented to limit possible explosions. 1 mark

Total 8 marks