VCE CHEMISTRY 2008

YEAR 12 TRIAL EXAM UNIT 4

Time allowed: 90 Minutes
Total marks: 83

Section A
Contains 20 Multiple Choice Questions
22 minutes, 20 marks

Section B
Contains 7 Short Answer Questions
68 minutes, 63 marks

To download the Chemistry Data Book please visit the VCAA website:
http://www.vcaa.vic.edu.au/vce/studies/chemistry/chem1_sample_2008.pdf *Page 20*

• **Biology** • **Physics** • **Chemistry** • **Psychology** • **Mathematics** •

Student Name.....………………..…………………...

VCE Chemistry 2008 Year 12 Trial Exam Unit 4

Student Answer Sheet

Instructions for completing test. Use only an HB pencil. If you make a mistake erase and enter the correct answer. Marks will not be deducted for incorrect answers.

Write your answers to the Short Answer questions in the space provided directly below the question. There are 20 Multiple Choice questions to be answered by circling the correct letter in the table below.

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

VCE Chemistry 2008 Year 12 Trial Exam Unit 4

## Multiple Choice Questions – Section A

Section A consists of 20 multiple-choice questions.
Section A is worth approximately 24 per cent of the marks available.
*Choose the response that is **correct** or **best answers** the question.*
Indicate your choice on the answer sheet provided.

Question 1
The reaction between excess calcium carbonate and hydrochloric acid can be followed by plotting a graph of the total volume of carbon dioxide produced against time. The reaction occurs according to the equation
$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$
A plot of $V(CO_2)$ versus time for the reaction is shown below
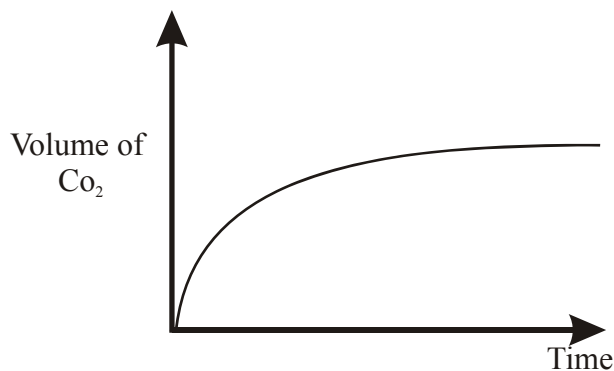
This graph is consistent with the observation that
A.   the rate of reaction increases with time because the surface area of the $CaCO_3$ increases.
B.   the rate of reaction increases with time because the acid becomes more dilute.
C.   the rate of reaction decreases with time because the surface area of the $CaCO_3$ increases.
D.   the rate of reaction decreases with time because the acid becomes more dilute.

Question 2
Two substances X and Y exist in equilibrium in a container of fixed volume.
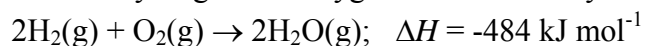The amount of X in the equilibrium mixture is increased by either
        i.   an increase in pressure at constant temperature, or
        ii.   an increase in temperature at constant pressure.

Which of the following equations accurately describes the equilibrium reaction?
A. $2X \rightleftharpoons 3Y, \quad \Delta H < 0$
B. $2X \rightleftharpoons 3Y, \quad \Delta H > 0$
C. $3X \rightleftharpoons 2Y, \quad \Delta H < 0$
D. $3X \rightleftharpoons 2Y, \quad \Delta H > 0$

Question 3
Consider the reaction between hydrogen and oxygen as described by the equation
$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g); \quad \Delta H = -484 \text{ kJ mol}^{-1}$$
The ΔH value indicates that
A.   the chemical bonds within two hydrogen molecules and one oxygen molecule are stronger than the chemical bonds within two water molecules.
B.   the chemical bonds within two hydrogen molecules and one oxygen molecule are weaker than the chemical bonds within two water molecules.
C.   there are fewer chemical bonds in two water molecules than there are in two hydrogen molecules and one oxygen molecule.
D.   water has a higher boiling temperature that either hydrogen or oxygen.

Question 4
The graphs below shows the concentrations, as a function of time, for a mixture of gases, X, Y and Z which react and come to equilibrium according to the equation
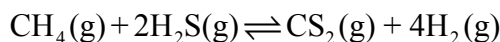$$Y + 3Z \rightleftharpoons 2X$$
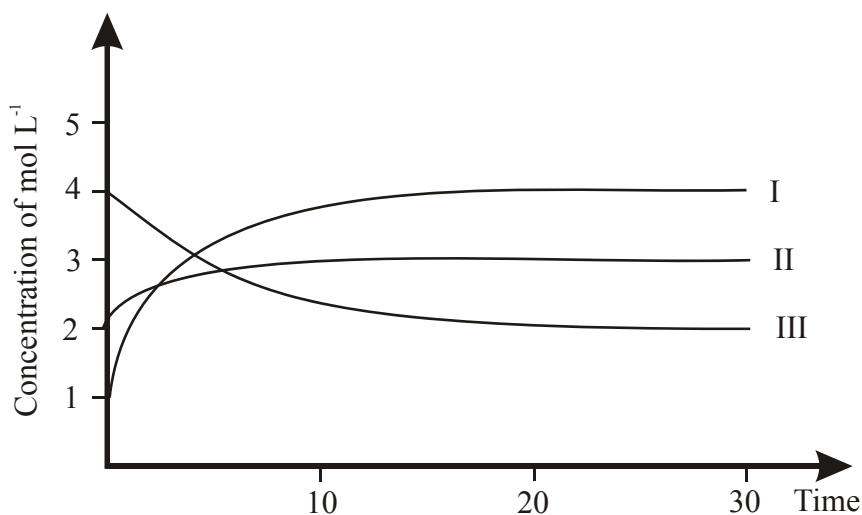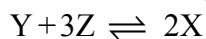
Which graph – I, II or III – best represents the change in concentration of Y?
A.   I
B.   II
C.   III
D.   It is not possible to identify the graph on the basis of the information given.

Question 5

The equilibrium constant for the reaction

$$CH_4(g) + 2H_2S(g) \rightleftharpoons CS_2(g) + 4H_2(g)$$

at 900°C is 3.59.

In an analysis of this reaction at 900°C, the concentration data collected was

$[CH_4] = 0.575$ M, $[H_2S] = 0.600$ M, $[CS_2] = 0.755$ M, $[H_2] = 1.08$ M

According to this data

A.   the reaction must continue to the left for equilibrium to be established.
B.   the reaction must continue to the right for equilibrium to be established.
C.   the reaction is endothermic.
D.   the reaction is at equilibrium .

Question 6

At 0°C, the self-ionisation constant of water, K_w, is 1.20×10^{-15}.

The pH of pure water at this temperature is

A.   6.88
B.   7.00
C.   7.46
D.   7.56

Question 7

Methanoic acid and propanoic acids are both weak monoprotic acids.

Which of the following statements relating to one molar aqueous solutions of these acids at 25°C is most likely to correct?

A.   Methanoic acid has a higher concentration of H_3O^+ and a lower pH.
B.   Methanoic acid has a higher concentration of H_3O^+ and a higher pH.
C.   Methanoic acid has a lower concentration of H_3O^+ and a lower pH.
D.   Methanoic acid has a lower concentration of H_3O^+ and a higher pH.

Question 8

When NO(g) reacts with O_2(g) to produce NO_2(g) equilibrium is established, according to

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g); \ \Delta H = -114\,kJ\,mol^{-1}$$
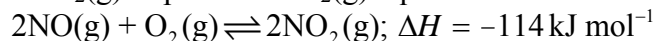
At 200ºC, the equilibrium constant has the value 7.10×10^5 M^{-1}

For the equilibrium $NO_2(g) \rightleftharpoons NO(g) + \frac{1}{2}O_2(g)$ at 200ºC, the numerical value of the equilibrium constant will be

A. 3.65×10^5
B. 1.41×10^{-6}
C. 1.19×10^{-3}
D.   604

Question 9
In designing a method for manufacturing a particular substance a chemical company incorporates the following strategies into its manufacturing processes.
    Maximising energy efficiency
    Using catalysts
    Maximising atom economy
    Minimising waste and
    Using renewable raw materials
These strategies are most commonly associated with
A.   waste management.
B.   green chemistry.
C.   occupational health and safety.
D.   sustainability.

Question 10
Hydrogen may be produced by the reaction between methane and steam.
The equation for the equilibrium reaction is:
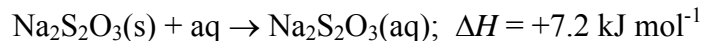$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g); \qquad \Delta H = +206.1 \, kJ \, mol^{-1}$$

Which of the following changes would **not** increase the yield of hydrogen?
A.   Increasing the pressure.
B.   Increasing the temperature.
C.   Removing hydrogen as it is produced.
D.   Increasing the concentration of methane in the mixture.

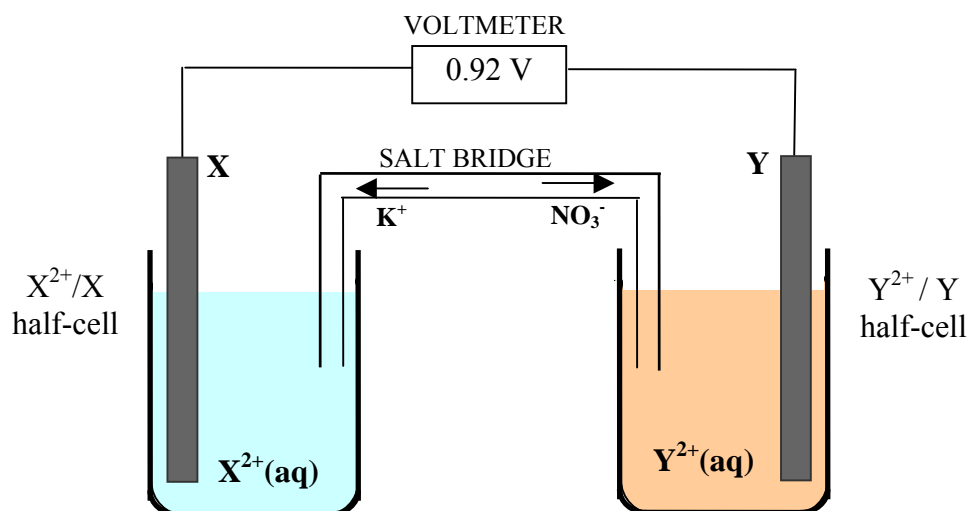**Question 11**
Consider the reaction
$$Na_2S_2O_3(s) + aq \rightarrow Na_2S_2O_3(aq); \ \Delta H = +7.2 \, kJ \, mol^{-1}$$
When 15.8 g of solid $Na_2S_2O_3$ (sodium thiosulfate) is dissolved in 500 mL of water
A.   3.6 kJ of energy is absorbed from the solution.
B.   0.72 kJ of energy is absorbed from the solution.
C.   3.6 kJ of energy is released into the solution.
D.   0.72 kJ of energy is released into the solution.

Question 12
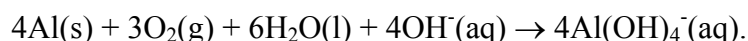Consider the galvanic cell represented below

In this cell
A. K^+ ions are moving towards the negative electrode.
B. NO_3^- ions are moving towards the cathode.
C.   oxidation is occurring at electrode X.
D.   oxidation is occurring at electrode Y.

Question 13
Aluminium-air cells have been investigated in the quest for enhanced performance in the conversion of chemical energy into electrical energy.
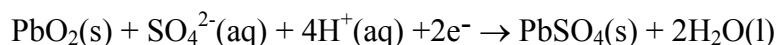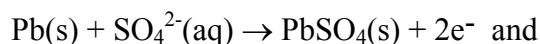In one type of aluminium-air cell, the overall redox reaction is described by the equation
$$4Al(s) + 3O_2(g) + 6H_2O(l) + 4OH^-(aq) \rightarrow 4Al(OH)_4^-(aq).$$
In this cell, aluminium, Al
A.   forms the negative electrode, and is reduced.
B.   forms the negative electrode, and is oxidised.
C.   forms the positive electrode, and is reduced.
D.   forms the positive electrode, and is oxidised.

Question 14
The lead acid-accumulator, used as a common car battery, converts chemical energy into electrical energy via the electrode reactions.

$Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$ and

$PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

When the lead acid accumulator is recharged
A.   Pb is produced at the negative electrode.
B.   the pH increases.
C. $PbSO_4$ is produced at the positive electrode.
D.   The changes in the oxidation numbers of lead are from 0 to +2 and +4 to +2.
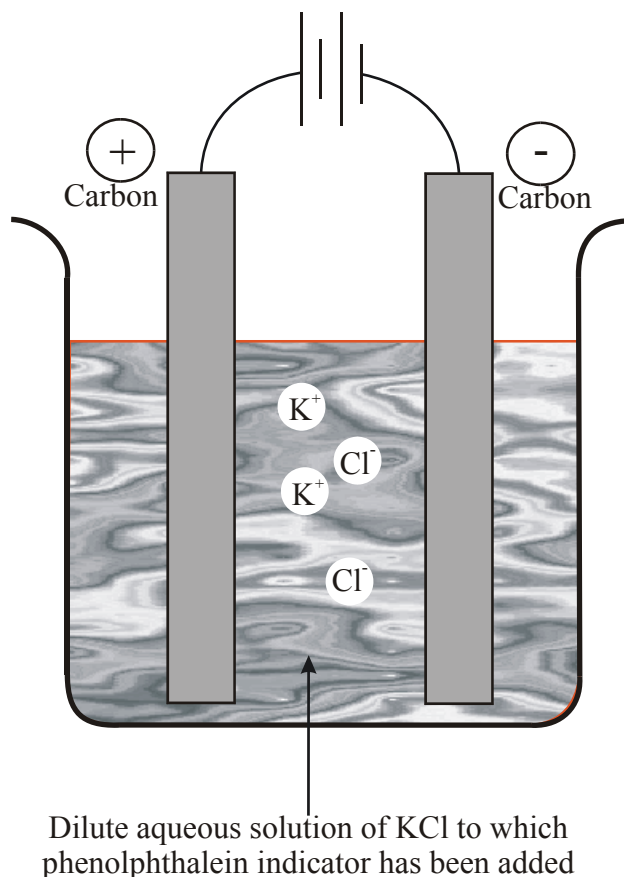
Question 15
When comparing the two types of electrochemical cells, i.e. galvanic cells with electrolytic cells, which of the following statements is correct?
A.   The anode is positive and the cathode negative in all electrochemical cells.
B.   Reduction occurs at the negative electrode in a galvanic cell.
C.   Reduction occurs at the cathode in all electrochemical cells.
D.   Oxidation occurs at the cathode in an electrolysis cell.

The following information applies to Questions 16 and 17
Consider the electrolytic cell represented below

Dilute aqueous solution of KCl to which
phenolphthalein indicator has been added

Question 16
When an electric current is passed through the cell
A.   bubbles of oxygen gas are produced at the negative electrode.
B.   a pink colour appears around the negative electrode.
C.   bubbles of chlorine gas are produced at the positive electrode.
D.   sodium metal is produced at the positive electrode.

Question 17
The chemical equation describing the overall redox reaction occurring in this cell is
A. $2K^+(aq) + 2Cl^-(aq) \rightarrow 2K(l) + Cl_2(g)$
B. $4K^+(aq) + 2H_2O(l) \rightarrow 4K(l) + O_2(g) + 4H^+(aq)$
C. $2Cl^-(aq) + 2H_2O(l) \rightarrow Cl_2(g) + H_2(g) + 2OH^-(aq)$
D. $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

Question 18

0.300 g of silver is to be plated onto a sporting trophy electrolytically from an aqueous solution of Ag^+ ions. Assuming the process is 100 % efficient, how long should the trophy be left in the plating cell if a current of 6.00 A is being applied?

A.   22.4 seconds.
B.   1.80 minutes.
C.   44.7 seconds.
D.   4.47 minutes.

Question 19

When 0.0100 mol of an alkanol is completely reacted with oxygen, the heat evolved raises the temperature of 200 g of water by 24.0°C.
Assuming the transfer of energy to the water is 100 per cent efficient then, the alkanol was most likely to be

A.   1-butanol.
B.   ethanol.
C.   methanol.
D.   1-propanol.

Question 20

Which of the following sets of chemical species contains only species that can, depending on their chemical environment, act as either oxidants or reductants?

A. $Sn^{2+}(aq)$, $H_2O_2(l)$, $OH^-(aq)$, $Fe^{2+}(aq)$
B. $H_2O(l)$, $Fe^{3+}(aq)$, $O_2(g)$, $Sn^{4+}(aq)$
C. $Sn^{2+}(aq)$, $H_2O_2(l)$, $Fe^{2+}(aq)$, $H_2O(l)$
D. $Sn^{4+}(aq)$, $H_2O(l)$, $Fe^{3+}(aq)$, $H_2S(g)$

End of Section A

VCE Chemistry 2008 Year 12 Trial Exam Unit 4

Short Answer Questions – Section B

> *Section B consists of 7 short answer questions.*
> *You should answer all of these questions.*
> *This section is worth approximately 76 per cent of the total marks available.*
> *The marks allotted are shown at the end of each part of each question.*
> *Questions should be answered in the spaces provided.*

Question 1

In your study of the 'industrial production of a selected chemical' during Unit 4 you should have encountered one of the following equilibria.

1. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

2. $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$

3. $C_3H_8(g) \rightleftharpoons C_2H_4(g) + CH_4(g)$

4. $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

Choose **one** of the equilibria given, by circling the number preceding it, and

a.   Give the name of the 'selected chemical' that is associated with the equilibrium.

(1 mark)

b.   State whether the forward reaction in the equilibrium is exothermic or endothermic.

(1 mark)

c.   State whether the yield of product(s) in the equilibrium is favoured by low or high temperatures, and describe the impact that rate considerations have on the temperature used.

(2 marks)

d.   State whether high or low pressure favours the yield of product(s) in the equilibrium and relate this to Le Chatelier's principle.

(2 marks)

e.   State one 'waste management' procedure used in the production of the 'selected chemical'.

(1 mark)

f.   State one 'occupational health and safety' issue associated with the production of the 'selected chemical'
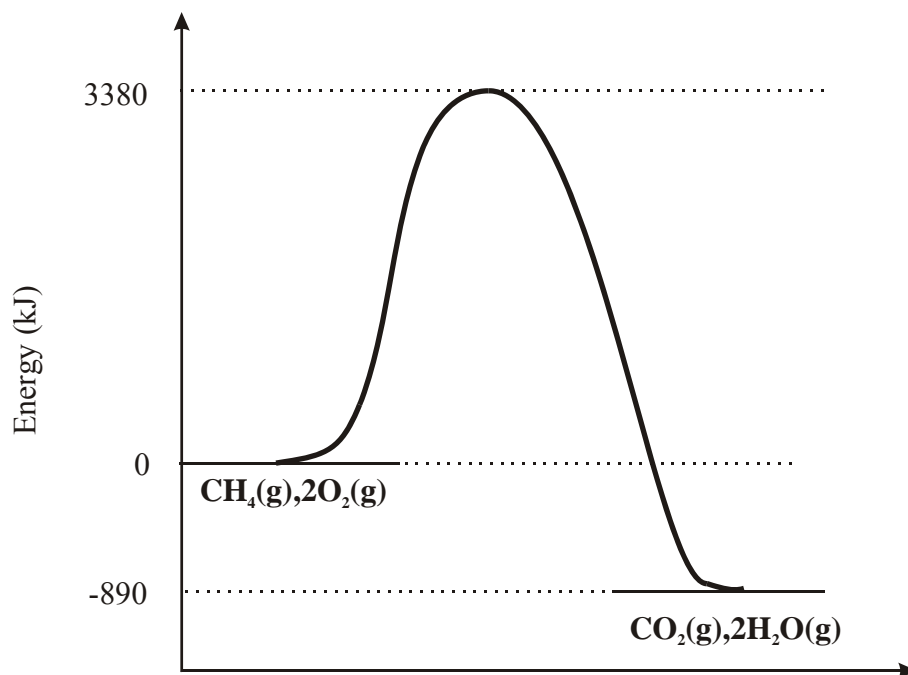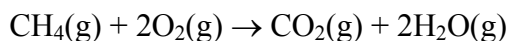
(1 mark)

g.   Give one use of the 'selected chemical'.

(1 mark)

Total 9 marks

Question 2

Shown below is an energy profile for combustion of methane according to:
$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

a.   Describe how the energy profile is related to 'bond breaking' and 'bond forming' and how the amounts of energy associated with these processes determine the thermochemistry of the reaction.

(3 marks)

b.   What is the value of the activation energy, in kJ, for the reaction
$$CO_2(g) + 2H_2O(l) \rightarrow CH_4(g) + 2O_2(g)$$

(1 mark)

c.   What determines whether or not a mixture of methane and oxygen reacts?

(1 mark)

d.   Explain why the use of a catalyst would be expected to increase the rate of reaction between methane and oxygen but not affect the relative positions of the reactants and products on the energy profile.

(2 marks)

Total 7 marks

Question 3
A well-insulated bomb calorimeter was used to determine experimentally the molar enthalpy of combustion (ΔH_c) of pentane, C_5H_{12}.

A 1.44 g sample of pentane was ignited in a bomb calorimeter in an atmosphere of pure oxygen. The temperature of the water surrounding the bomb in the calorimeter was observed to rise from 21.250°C to 24.164°C.

A current of 2.90 A was then passed through a heater immersed in the water surrounding the bomb at a potential difference of 6.50 V for three minutes and the temperature rose to 24.388°C.

a.   Calculate the calibration factor of the calorimeter.

(3 marks)

b.   Use the experimental data to calculate the ΔH_c of pentane.

(3 marks)

c. Suggest a reason for the difference between the calculated ΔH_c for pentane and the value given in the Data Booklet.
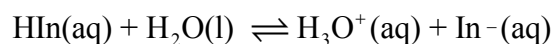
(1 mark)

Total 7 marks

Question 4

a. An aqueous solution of benzoic acid, a weak acid, has a pH of 2.45 at 25°C. What is the concentration of the solution with respect to benzoic acid?
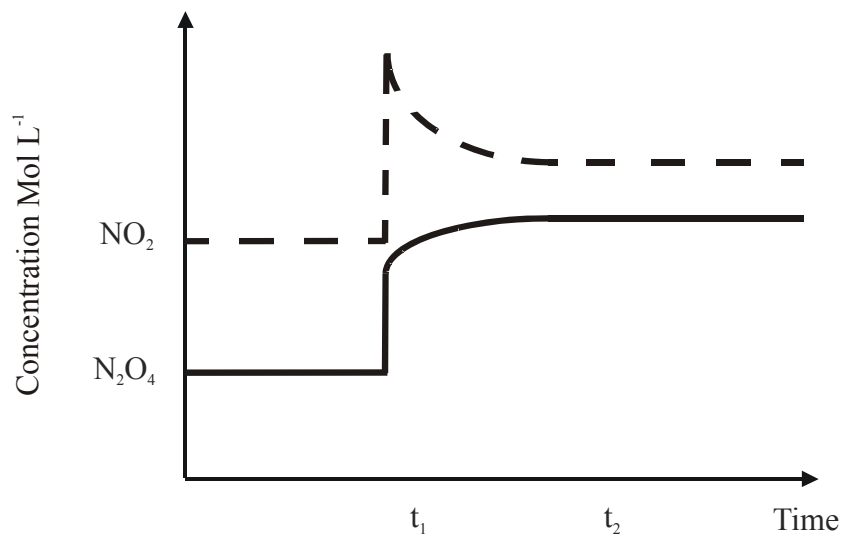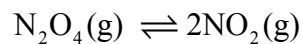
(4 marks)

b. The acid-base indicator bromphenol blue is an equilibrium mixture of a weak acid and its conjugate base. The equilibrium may be represented by the equation

$$HIn(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + In^-(aq)$$

At what pH will the ratio [HIn] / [In⁻] in bromphenol blue be 100 / 1?

(3 marks)

c. Shown below is a set of concentration-time graphs for the equilibrium system

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

i. What change was imposed on the equilibrium system at time **t₁**?

ii. How did the system respond to the imposed change?

iii. When equilibrium is regained at time **t₂** is the mass of NO_2 present less than, equal to, or greater than the mass present at the original equilibrium?

(1+1+1 = 3 marks)

Total 10 marks

Question 5

Continued increases in the price of oil has sharpened focus on alternative fuels for motor vehicles, particular biochemical fuels and hydrogen. Hydrogen can be produce from water and used in hydrogen internal combustion engines or fuel cells.

A hydrogen energy cycle for the use of hydrogen as a fuel is represented below.

```
┌──────────┐      ┌──────────────┐      ┌──────────────┐
│  Energy  │ ───→ │ Electrolysis │ ───→ │  Storage of  │
│  Source  │      │   of water   │      │   hydrogen   │
└──────────┘      └──────────────┘      └──────────────┘
                        ↑                       │
                        │                       ↓
                  ┌──────────────┐      ┌──────────────────┐
                  │              │      │ Use of hydrogen in│
                  │ Reaction product│ ← │ combustion engines│
                  │              │      │   or fuel cells   │
                  └──────────────┘      └──────────────────┘
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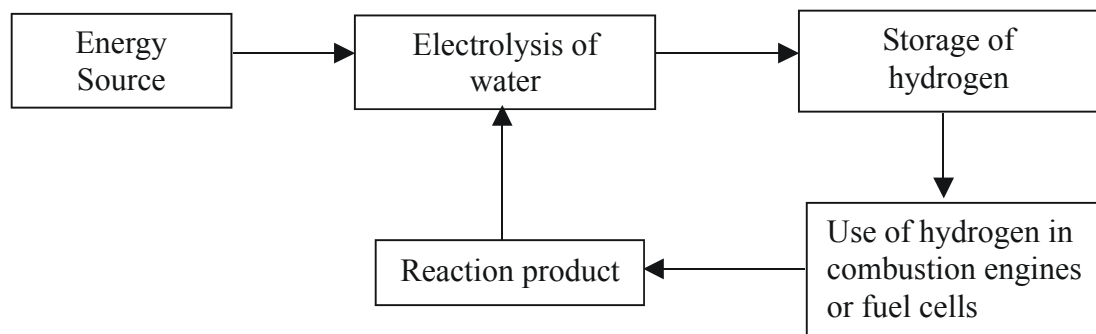
a.   Identify one concern currently associated with the production of biochemical fuels.

(1 mark)

b.   What is the main environmental impact of the use of brown coal to generate electricity?

(1 mark)

c.   Identify two sources of electricity which may be used for the electrolysis of water but do not have the environmental impact of brown coal.

(1 mark)

d.   Give the sign of the electrode at which hydrogen is produced during the electrolysis of water and write the associated half-equation.

(2 marks)

e.   Why is electrolyzing a dilute aqueous solution of sodium chloride a more efficient way to produce hydrogen than electrolyzing water.

(1 mark)

f.   Write the half-equation for the reaction occurring at the positive electrode in an operating hydrogen-oxygen fuel cell, using an alkaline electrolyte.

(1 mark)

g.   State three distinct properties which are desirable in the electrodes used in a fuel cell.

(2 marks)

h.   i.   Write a balanced equation describing the overall reaction occurring in both a hydrogen-oxygen fuel cell and the consumption of hydrogen in a combustion engine.

(1 mark)

ii.   Explain why hydrogen is described as a non-polluting energy source.

(1 mark)

Total 11 marks

Question 6

The isolation of fluorine from its compounds proved to be one of the most difficult and dangerous challenges of the late nineteenth century. In 1906 Henri Moissan was awarded the Nobel Prize in Chemistry '*in recognition of the great services rendered by him in his investigation and isolation of the element fluorine ………………*'

Earlier Moissan wrote about his work in isolating fluorine.

"I obtained the fluorine from a fluorine compound that had been added to a mineral having a low melting point and in which the fluorine compound dissolved readily. The use of electricity produced the fluorine at the positive terminal. Difficulty was experienced in getting any material for that terminal that would resist the chemical action of the gas."

a.   How does the position of fluorine on the electrochemical series explain why Moissan found it difficult to find any material that would resist the chemical action of the gas?

(1 mark)

b.   Write half-equations for the electrode reactions which occur during the electrolysis of molten potassium fluoride.

   (+) electrode

   (-) electrode

(2 marks)

c.   How long should it take to produce 5.00 g of fluorine gas in an electrolytic cell operating at 5.00 A and 12.0 V if the cell was operating at 100 per cent efficiency?

(3 marks)

d. Explain why fluorine, F_2, is not produced during the electrolysis of a dilute aqueous solution of potassium fluoride, and give the half-equation for the reaction occurring at the anode.
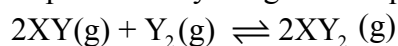
(2 marks)

e. Why is it that copper can be produced by the electrolysis of an aqueous solution of Cu^{2+} ions, but lithium cannot be produced by the electrolysis of an aqueous solution of Li^+ ions?

(2 marks)

Total 10 marks

Question 7
Consider the equilibrium system represented by the general equation
$$2XY(g) + Y_2(g) \rightleftharpoons 2XY_2 (g)$$
a. In a laboratory test of this equilibrium 6.00 mol of XY and 2.50 mol of Y_2 are added to 2.00 L reaction vessel and allowed to come to equilibrium.
If 4.00 mol XY_2 is present at equilibrium what is the value of the equilibrium constant?

(3 marks)

b.   In a second test 6.00 mol of XY and 2.50 mol of Y_2 are added to 2.00 L reaction vessel and allowed to come to equilibrium at a higher temperature. This time only 3.20 mol of XY_2 was present at equilibrium. What does this indicate about the reaction, $2XY(g) + Y_2(g) \rightarrow 2XY_2(g)$?

(1 mark)

c.   When neon gas is added to an equilibrium mixture of XY, Y_2 and XY_2, the pressure in the reaction vessel noticeably increases. However the position of equilibrium does not shift! Explain.

(2 marks)

d.   i.   What would you expect to happen to the position of equilibrium if some XY_2 was removed from the equilibrium system.

       ii.   In terms of reaction rates, how does the change in equilibrium position come about.

(1+2 = 3 marks)

Total 9 marks

End of Section B

End of Trial Exam

Suggested Answers VCE Chemistry Year 12 Trial Exam Unit 4

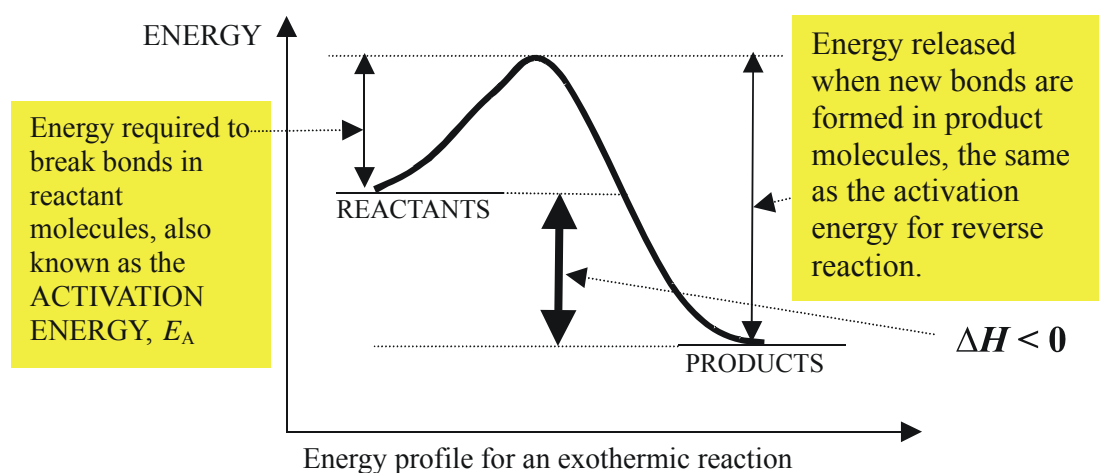## Multiple Choice Answers – Section A

Question 1

D. With the volume of CO_2 levelling off with time, the rate of reaction is clearly decreasing. Since the surface area of the $CaCO_3$ particles must decrease (not increase) as it is consumed alternatives A and C are not viable. The rate of reaction decreases as the acid concentration decreases, i.e. becomes more dilute.

Question 2

A. If X is favoured by an increase in pressure, then X must be on the side of the equilibrium with fewer particles. Hence, alternatives A or B must be correct. Equilibrium systems counteract an increase in pressure by moving the position of equilibrium to the side with fewer particles.

If the amount of X increases with an increase in temperature, then the production of X from Y is an endothermic reaction and has $\Delta H > 0$, i.e $3Y \rightleftharpoons 2X \qquad \Delta H > 0$.

This means that the production of Y from X is exothermic as is represented in the equation $2X \rightleftharpoons 3Y, \quad \Delta H < 0$. For this equilibrium an increase in pressure produces more X and an increase in temperature (favours endothermic reverse reaction) produces more X.

Question 3

B. Exothermic reactions release energy and so the energy content of the product molecules is lower than the energy content of the reactant molecules. This is consistent with the **bonds** (in total) **within the product molecules** (2 H_2O molecules) being **stronger than** the **bonds** (in total) **within the reactant molecules** (2 H_2 molecules and 1 O_2 molecule)

There is also evidence for this in that the activation energy for the reverse reaction is greater as indicated on the energy profile for an exothermic reaction.

ENERGY

Energy required to break bonds in reactant molecules, also known as the ACTIVATION ENERGY, E_A

REACTANTS

Energy released when new bonds are formed in product molecules, the same as the activation energy for reverse reaction.

$\Delta H < 0$

PRODUCTS

Energy profile for an exothermic reaction

Question 4

B. The concentration time graph shows that in getting to equilibrium

The substance represented by I has increased from 1 M to 4 M, i.e. by 3 M or 3 mol in 1 L.

The substance represented by II has increased from 2 M to 3 M, i.e. by 1 M or 1 mol in 1 L.

The substance represented by III has decreased from 4 M to 2M, i.e. by 2 M or 2 mol in 1 L.

This is consistent with 3 mol reacting with 1 mol to produce 2 mol,

i.e. $3Z + Y \rightarrow 2Z$

Y is best represented by **graph II**

Question 5

A $CH_4(g) + 2H_2S(g) \rightleftharpoons CS_2(g) + 4H_2(g)$; $K = 3.59$

Comparison of the concentration fraction (CF), [or reaction quotient (Q)] based on the supplied data with the value of the equilibrium constant provides insight into the 'position' of the reaction.

$CF = [CS_2][H_2]^4 / [CH_4][H_2S]^2$
$= (0.755 \times 1.08^4) / (0.575 \times 0.600^2)$
$= 1.027 / 0.207$
$= 4.96$

Since the CF (4.96) is not equal to K (3.59), the reaction is not at equilibrium. For equilibrium to be established the value of the concentration fraction must decrease. This requires a decrease in the product concentrations relative to the reactant concentrations, so the **reaction must continue to the left** for equilibrium to be established.

Question 6

C. The self-ionisation of water proceeds according to

$$2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$
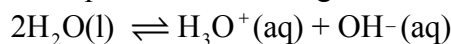
So in pure water $[H_3O^+] = [OH^-]$

Since $[H_3O^+][OH^-] = K_w$
$[H_3O^+]^2 = 1.20 \times 10^{-15}$
$[H_3O^+] = \sqrt{1.20 \times 10^{-15}}$
$= 3.46 \times 10^{-8}$ M

pH $= -\log_{10}[H_3O^+]$
$= -\log_{10}(3.46 \times 10^{-8})$
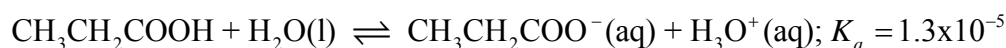$= -(-7.46)$
$= \mathbf{7.46}$

Question 7

A. According to the data book, the acidity constants for the two acids are

Methanoic acid – 1.8×10^{-4}

Propanoic acid – 1.3×10^{-5}

The acids ionise in aqueous solution according to

$HCOOH(aq) + H_2O(l) \rightleftharpoons HCOO^-(aq) + H_3O^+(aq)$; $K_a = 1.8 \times 10^{-4}$

$CH_3CH_2COOH + H_2O(l) \rightleftharpoons CH_3CH_2COO^-(aq) + H_3O^+(aq)$; $K_a = 1.3 \times 10^{-5}$

Since **HCOOH**(aq) has the higher acidity constant, it will ionise slightly more than CH_3CH_2OH(aq), thus producing a **higher $c(H_3O^+)$** and a **lower pH**.

Question 8

C. Consider the variations that occur in the equilibrium law expression as the equation stoichiometry is changed.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g);$$

$$K_1 = [NO_2]^2 / \{[NO]^2[O_2]\}$$
$$= 7.10 \times 10^5$$

$$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g) \text{ - } original\ equation\ is\ reversed$$

$$K_2 = \{[NO]^2[O_2]\} / [NO_2]^2$$
$$= 1 / ([NO_2]^2 / \{[NO]^2[O_2]\})$$
$$= 1 / K_1$$
$$= 1 / 7.10 \times 10^5$$
$$= 1.41 \times 10^{-6}$$

$$NO_2(g) \rightleftharpoons NO(g) + \tfrac{1}{2}O_2(g) \text{ -} original\ equation\ reversed\ and\ stoichiometry\ is\ halved.$$

$$K_3 = \{[NO][O_2]^{1/2}\} / [NO_2]$$
$$= (\{[NO]^2[O_2]\} / [NO_2]^2)^{1/2}$$
$$= K_2^{1/2}$$
$$= \sqrt{K_2}$$
$$= \sqrt{(1.41 \times 10^{-6})}$$
$$= \mathbf{1.19 \times 10^{-3}}$$

Question 9

B. Maximising energy efficiency is linked to 'sustainability' of energy resources and minimising waste is clearly a vital aspect of 'waste management'. However all five strategies listed are amongst the principles of 'green chemistry'.

Question 10

A. For the equilibrium

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g); \ \Delta H = +206.1 \text{ kJ mol}^{-1}, \text{the concentration of}$$

hydrogen in the equilibrium mixture (yield of H_2) will be increased by factors that move the position of equilibrium to the right.

A. An increase in pressure will cause the position of equilibrium to move to the side with fewer particles, in this case to the left. Hence this **decreases the yield of H_2**.

B. An increase in temperature will cause the position of equilibrium to move in the direction of the endothermic reaction, in this case to the right.

C. Removing hydrogen will cause the position of equilibrium to move to the right to compensate for the loss of hydrogen.

D. Increasing the amount of CH_4 in the reaction mixture will cause the position of equilibrium to move the right to compensate for the increase in [CH_4].

Question 11

B. According to the equation, the reaction is endothermic ($\Delta H > 0$) and 7.2 kJ of energy is absorbed from the solution when one mol $Na_2S_2O_3$ dissolves.

$$n(Na_2S_2O_3) \text{ dissolving} = m / M$$
$$= 15.8 \text{ g} / 158.2 \text{ g mol}^{-1}$$
$$= 0.0999 \text{ mol}$$

Energy absorbed $= n(Na_2S_2O_3) \times$ energy absorbed by one mole
$$= 0.0999 \text{ mol} \times 7.2 \text{ kJ mol}^{-1}$$
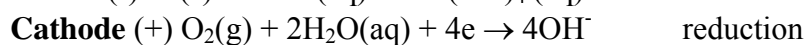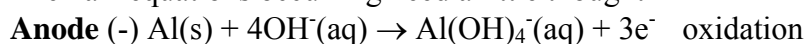$$= \mathbf{0.72 \text{ kJ}}$$

Question 12

D.	The key to this question was the direction of movement of the ions in the salt-bridge.
	Anions – NO_3^- – always move towards the anode, which is the site of oxidation, i.e. Y
	Cations – K^+ – always move towards the cathode, which is the site of reduction, i.e. X
	Hence, reduction is occurring at electrode X, and **oxidation is occurring at electrode Y.**
	In galvanic cells the electrons move spontaneously from the (-) electrode to the (+) electrode.

Question 13

B.	According to the oxidation number **Al is oxidised** (from 0 in Al to +3 in $Al(OH)_4^-$)
	and **O is reduced** (from 0 in O_2 to -2 in $Al(OH)_4^-$)
	Since oxidation occurs at the negative electrode (spontaneous reaction) then **Al** must be the **negative electrode.**
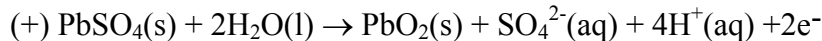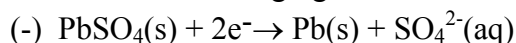	The half-equations occurring need a little thought
	Anode (-) $Al(s) + 4OH^-(aq) \rightarrow Al(OH)_4^-(aq) + 3e^-$ oxidation
	Cathode (+) $O_2(g) + 2H_2O(aq) + 4e \rightarrow 4OH^-$ reduction
	Multiply the oxidation half-equation by 4 and the reduction half-equation by 3 to get the overall redox equation $4Al(s) + 3O_2(g) + 6H_2O(l) + 4OH^-(aq) \rightarrow 4Al(OH)_4^-(aq)$.

Question 14

A.	The discharging reactions with electrode signs are

	(-) $Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$

	(+) $PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$
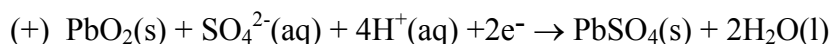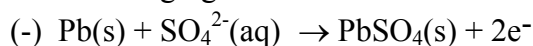
	Therefore the recharging reactions are

	(-) $PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$

	(+) $PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^-$

	Checking the various alternatives
	A.	Pb is produced at the (-) electrode
	B.	pH will decrease as H^+ ions are produced at (+) electrode
	C.	$PbSO_4$ is consumed
	D.	Oxidation number changes of Pb are from +2 to 0 and +2 to +4

Question 15
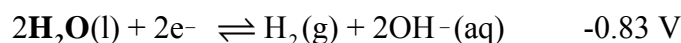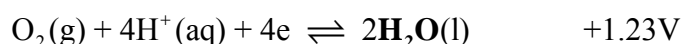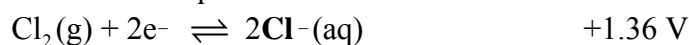
C.	Useful facts about electrochemical cells.
	In all electrochemical cells electrons move from the site of oxidation (anode) to the site of reduction (cathode).
	In galvanic cells electrons move spontaneously from the negative electrode to the positive electrode, whilst in electrolytic cells, electrons are forced to move from the negative electrode to the positive electrode.
	Reduction always occurs at the cathode, which is (+) in galvanic cells but (-) in electrolysis cells. Oxidation always occurs at the anode, which is (-) in galvanic cells but (+) in electrolysis cells.
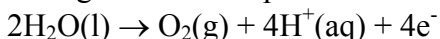
Question 16

B. During electrolysis of dilute KCl(aq), the strongest oxidant present will be reduced at the cathode (-) and the strongest reductant present will be oxidised at the anode (+). The main species present prior to electrolysis are K^+(aq), Cl^-(aq) and H_2O(l). Consider their positions on the relevant sections of the electrochemical series

$$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq) \qquad\qquad +1.36 \text{ V}$$

$$O_2(g) + 4H^+(aq) + 4e \rightleftharpoons 2H_2O(l) \qquad +1.23V$$

$$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq) \qquad -0.83 \text{ V}$$

$$K^+(aq) + e^- \rightleftharpoons K(s) \qquad\qquad -2.93V$$

Strongest oxidant present is H_2O(l), so the reaction at the cathode (-) will be

$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$
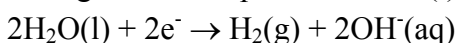
Strongest reductant present is H_2O(l), so the reaction at the anode (+) will be

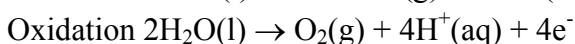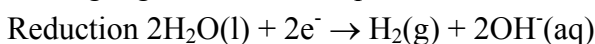$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

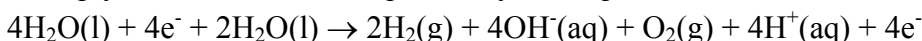Therefore, alternatives B, C and D are not correct.

The **production of OH^-(aq) ions** at the negative electrode will turn the **phenolphthalein indicator pink.**

Question 17

D. Adding together the half-equations identified in *Question 16*

Reduction $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

Oxidation $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

Multiply the reduction half-equation by 2 to equalise the electrons

$4H_2O(l) + 4e^- + 2H_2O(l) \rightarrow 2H_2(g) + 4OH^-(aq) + O_2(g) + 4H^+(aq) + 4e^-$

This simplifies to

$6H_2O(l) \rightarrow 2H_2(g) + 4OH^-(aq) + O_2(g) + 4H^+(aq)$

Which with $4H^+(aq) + 4OH^-(aq) \rightarrow 4H_2O$, further simplifies to

$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

Question 18

C. Silver would be plated according to the reduction

$$Ag^+(aq) + e^- \rightarrow Ag(s)$$
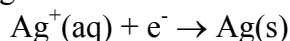
n(Ag) plated $= m / M$

$\qquad\qquad = 0.300 \text{ mol} / 107.9 \text{ g mol}^{-1}$

$\qquad\qquad = 2.78 \times 10^{-3} \text{ mol}$

n(e$^-$) required $= n$(Ag) $= 2.78 \times 10^{-3}$ mol

Since $Q = It$ and $Q = n$(e$^-$) x F

Then $It = n$(e$^-$) x F

and $t = \boldsymbol{n}$(e$^-$) x $\boldsymbol{F} / \boldsymbol{I}$

$\qquad = 2.78 \times 10^{-3}$ x 96500 / 6.00

$\qquad = \textbf{44.7 seconds}$

Question 19

D.   Using the specific heat of water, i.e. 4.18 J g^{-1} °C^{-1} from data booklet

Energy released from 0.0100 mol of the alkanol = 4.18 J g^{-1} °C^{-1} x 200 g x 24.0°C

= 2.01x10^4 J

Energy released per mol of the alkanol = 2.01x10^4 J / 0.0100 mol

= 2.01x10^6 J mol^{-1}

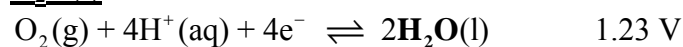= **2.01x10^3 kJ mol^{-1}**

Hence the molar enthalpy of combustion (Table 13 – Data Book) must be close to 2010 kJ mol^{-1}.

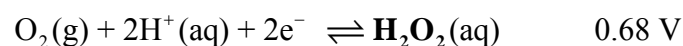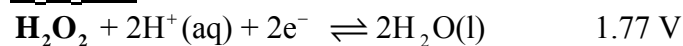The alkanol is **1-propanol** (2016 kJ mol^{-1})

Question 20

C.   For a species to be able to act as either an oxidant or an oxidant it should appear on both sides of the electrochemical series.
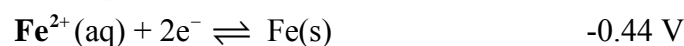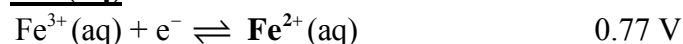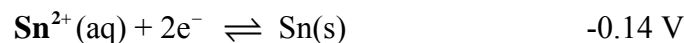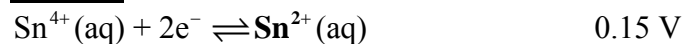
H$_2$O(l)

$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons \mathbf{2H_2O}(l)$		1.23 V
$\mathbf{2H_2O}(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$		-0.83 V

H$_2$O$_2$(aq)

$\mathbf{H_2O_2} + 2H^+(aq) + 2e^- \rightleftharpoons 2H_2O(l)$		1.77 V
$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons \mathbf{H_2O_2}(aq)$		0.68 V

Fe^{2+}(aq)

$Fe^{3+}(aq) + e^- \rightleftharpoons \mathbf{Fe^{2+}}(aq)$		0.77 V
$\mathbf{Fe^{2+}}(aq) + 2e^- \rightleftharpoons Fe(s)$		-0.44 V

Sn^{2+}(aq)

$Sn^{4+}(aq) + 2e^- \rightleftharpoons \mathbf{Sn^{2+}}(aq)$		0.15 V
$\mathbf{Sn^{2+}}(aq) + 2e^- \rightleftharpoons Sn(s)$		-0.14 V
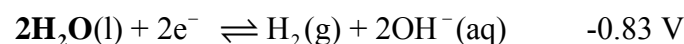
Short Answer (Answers) - Section B

Question 1
*NB In many parts of this question – particularly (e), (f) and (g) a variety of answers is possible.
Check your textbook and notes material for **your** 'selected chemical' for further options*

	1. $N_2 + 3H_2 \rightleftharpoons 2NH_3$	2. $2NO + O_2 \rightleftharpoons 2NO_2$	3. $C_3H_8 \rightleftharpoons C_2H_4 + CH_4$	4. $2SO_2 + O_2 \rightleftharpoons 2SO_3$
a. ❶	ammonia	nitric acid	ethane	sulfuric acid
b. ❶	exothermic	exothermic	endothermic	exothermic
c. ❶❶	low temperatures rate decreases at low temperatures 350-500°C and a porous iron catalyst are used.	low temperatures rate increases at low temperatures, so yield and rate both favoured. 30°C used.	high temperatures rate increases at high temperatures, so yield and rate both favoured. 750-900 °C used.	high temperatures rate decreases at low temperatures 400-500°C and a V_2O_5 catalyst are used.
d. ❶❶	high pressures – system moves to side with fewer particles increasing yield of NH_3	high pressures – system moves to side with fewer particles increasing yield of NO_2.	low pressures – system moves to side with more particles increasing yield of C_2H_4	high pressures – system moves to side with fewer particles increasing yield of SO_3
e. ❶	waste heat used to preheat reaction mixture	maximising conversion of NO_2 to nitric acid and minimising loss of NO / NO_2 to the atmosphere	methane extracted and used as fuel for heating	SO_3 emissions are minimised by using the double absorption process.
f. ❶	NH_3 is a severe, toxic irritant – workers must be protected against exposure	Concentrated HNO_3 is corrosive and causes severe burns – workers must be protected against spills	ethene can form an explosive mixture with air – clear fire prevention and fighting strategies are used.	SO_2 and SO_3 are severe respiratory irritants. Work areas are well ventilated and protective clothing is used
g. ❶	production of fertilisers	production of fertilisers	production of polymers	production of superphosphate.

Question 2
a.   The **energy released in the formation of the bonds in the products** [3380 - (-890) = 4270 kJ] is **greater than** the energy **used to break the bonds in the reactants** [3380 kJ]. ❶❶ Hence the reaction is **exothermic**. ❶
     The profile also shows that the energy content of the products, i.e. 1 mol CO_2 and 2 mol H_2O, is lower than the energy content of the reactants, i.e. 1 mol CH_4 and 2 mol O_2, hence the reaction is exothermic.
b.   Activation energy for the reaction $CO_2(g) + 2H_2O(l) \rightarrow CH_4(g) + 2O_2(g)$ will the difference between the 'top of the hill' and relative energy content of CO_2 and H_2O as given on the supplied profile.
 E_a $= 3380 – (-890)$
          $= $ **4270 kJ** ❶

c. Reaction between CH_4 and O_2 will only occur if the **collisions** between the molecules are fruitful / successful / effective **,** i.e. they collide with **energy greater than the activation energy**. ❶

d. A catalyst increases the reaction rate by providing an **alternative reaction pathway** which **lowers the activation energy**. Thus **increases the proportion of fruitful collisions. ❶**

However, the relative energy contents of the reactants and products does not change because **'difference' between the energy released in bond formation and the energy used in bond breaking does not change. ❶**

Question 3

a. Energy added during calibration, $E = VIt$
$$= 6.50 \text{ x } 2.90 \text{ x } 180$$
$$= 3393 \text{ J } ❶$$

Temperature change during calibration, $\Delta T_c = 24.378 - 24.164$
$$= 0.224°C ❶$$

Calibration factor $= E / \Delta T_c$
$$= 3393 \text{ J } / 0.224°C$$
$$= \mathbf{1.51x10^4 \text{ J }°C^{-1}} ❶$$

b. Energy from combustion of C_5H_{12} = Calibration factor x Temperature change during reaction
$$= 1.51x10^4 \text{ J }°C^{-1} \text{ x } (24.164 - 21.250) °C$$
$$= 1.51x10^4 \text{ x } 2.914 ❶$$
$$= 4.41x10^4 \text{ J}$$

$n(C_5H_{12}) = 1.44 / 72.0$
$$= \mathbf{0.0200 \text{ mol }} ❶$$

Energy per mol $C_5H_{12} = 4.41x10^4 \text{ J } / 0.0200 \text{ mol}$
$$= 2.21x10^6 \text{ J mol}^{-1}$$
$$= 2.21x10^3 \text{ kJ mol}^{-1}$$

Hence $\Delta H_c(C_5H_{12}) = -2.21x10^3 \text{ kJ mol}^{-1} ❶$

c. According to Data Booklet $\Delta H_c(C_5H_{12}) = -3509 \text{ kJ mol}^{-1}$

The most likely reason for the lower calculated value would be **incomplete reaction of pentane ❶** in the bomb calorimeter. This would lead to a lower temperature change during the reaction a lower calculated energy release from the combustion of pentane. The calculated value also depends on the accuracy of recorded readings of temperature, voltage, current and time, e.g. a higher than true recorded temperature during calibration would lead to a lower calibration factor and lower calculated energy release from the combustion of pentane.

Other factors could include evaporation of some pentane during transfer to the reaction bomb.

Question 4

a. $C_6H_5COOH(aq) + H_2O(l) \rightleftharpoons C_6H_5COO^-(aq) + H_3O^+(aq)$
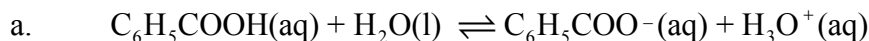
$K_a = 6.4 \times 10^{-5}$ – from data booklet

$pH = 2.45 \rightarrow [H_3O^+] = 10^{-2.45}$
$= 3.58 \times 10^{-3}$ ❶

Since $C_6H_5COOH(aq)$ is a weak acid we may assume that

$[C_6H_5COO^-] = [H_3O^+]$ ❶

$[C_6H_5COOH]_e = [C_6H_5COOH]_{initially}$

$K_a = [C_6H_5COO^-]_e \times [H_3O^+]_e / [C_6H_5COOH]_e$

$6.4 \times 10^{-5} = (3.58 \times 10^{-3})^2 / [C_6H_5COOH]$ ❶

$\mathbf{[C_6H_5COOH]} = (3.58 \times 10^{-3})^2 / (6.4 \times 10^{-5})$
$= 1.28 \times 10^{-5} / (6.4 \times 10^{-5})$
$= \mathbf{0.20\ M}$ ❶

b. $HIn(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + In^-(aq)$
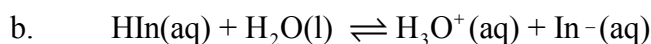
$K_a = 6 \times 10^{-5}$ – from data booklet

$K_a = [H_3O^+]_e \times [In^-]_e / [HIn]_e$

$6 \times 10^{-5} = [H_3O^+] \times 1 / 100$ ❶

$[H_3O^+] = 6 \times 10^{-3}\ M$ ❶

$pH = -\log_{10}(6 \times 10^{-3})$
$= \mathbf{2.2}$ ❶

c. i.   The increase in concentrations of both reactants and products at time t_1 suggests that the **volume** of the system was **decreased**. ❶

ii. The decrease in volume caused an overall pressure increase. According to Le Chatelier, the system **moves to the side with fewer particles** to counteract the pressure increase. The **position of equilibrium moves to the left.** ❶

iii. **less** ❶ the position of equilibrium has shifted left thus decreasing the amount of NO_2 present. The concentration time graph shows that the $[NO_2]$ at the new equilibrium is still greater than at the original equilibrium.

Question 5

a. The **use of crops that would normally be used in food production**. This may be driving up food prices. ❶

b. **Production of CO_2** – contribution to **global warming** ❶
    SO_2 can also be released into the environment but in much smaller quantities that CO_2.

c. photovoltaic cells which convert **solar energy** into electrical energy, or generators driven by **hydroelectricity**, **wind power**, **geothermal energy, nuclear energy** or **tidal power.** ❶ *for any two.*
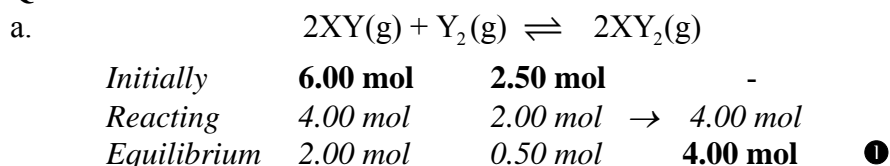
d. (-)❶ $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ ❶
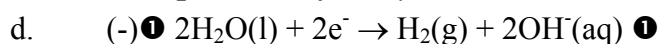
e. In **pure water** the concentration of ions, $H_3O^+(aq)$ and $OH^-(aq)$ is very low and so the electrolytic conduction in the electrolysis cell is very low and so the **rate of reaction** will be **low**. ❶
    In dilute NaCl(aq) the **Na^+(aq) and Cl^-(aq) enhance the electrolytic conduction between the electrodes** and so the rate of production of hydrogen increases.

f. $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ ❶ *from electrochemical series.*

g. The electrodes (1) must conduct, (2) be porous to allow contact between the gases and the electrolyte, (3) must be unreactive, (4) are usually impregnated with catalyst to speed up the rate of reaction. ❶❶ *for three properties,* ❶ *for two properties*

h. $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ ❶

i. Water is the only product of its use. ❶

Question 6

a. The position of fluorine on the electrochemical series shows that it is the **strongest oxidant.** Since electrodes must conduct electricity, and **metals are reductants**, the choice of electrode material is restricted to carbon (graphite) because fluorine will react explosively with most metals. ❶

b. (+) $2F^-(l) \rightarrow F_2(g) + 2e^-$ ❶
    (-) $K^+(l) + e^- \rightarrow K(l)$ ❶
    In electrolysis electrons move from the (+) electrode to the (-) electrode.

c. $2F^-(l) \rightarrow F_2(g) + 2e^-$
    $n(F_2) = 5.00$ g $/ 38.0$ g mol^{-1}
    $\quad\quad = 0.1316$ mol
    $n(e^-) = 2 \times 0.1316$
    $\quad\quad = 0.263$ mol ❶
    Since $Q = It$ and $Q = n(e^-)F$ then
    $It = n(e^-) \times F$
    $t = n(e^-) \times F / I$
    $\quad = 0.263 \times 96500 / 5.00$ ❶
    $\quad = 5076$ seconds
    $\quad = 84.6$ minutes ❶

d. In KF(aq) there are two reductants – F^-(aq) and $H_2O(l)$
    According to the elecrochemical series

    $F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$ 2.87 V

    $O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l)$ 1.23 V

    $H_2O(l)$ is a stronger reductant than F^-(aq) and so $H_2O(l)$ will be oxidised ❶, according to $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$ ❶ ….. at the anode (+)

e. Cu^{2+}(aq), Li^+(aq) and $H_2O(l)$ are all oxidants.
    According to the electrochemical series

    $Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$ 0.34 V

    $2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2H_2O(l)$ -0.83 V

    $Li^+(aq) + e^- \rightleftharpoons Li(s)$ -3.02 V

    Cu^{2+}(aq) is a stronger oxidant that $H_2O(l)$, so Cu^{2+}(aq) will be reduced to Cu ❶, but $H_2O(l)$ is a stronger oxidant than Li^{2+}, so H_2O will reduced and no Li will be produced ❶

Question 7

a. $2XY(g) + Y_2(g) \rightleftharpoons 2XY_2(g)$

Initially	**6.00 mol**	**2.50 mol**	-
Reacting	*4.00 mol*	*2.00 mol* $\rightarrow$	*4.00 mol*
Equilibrium	*2.00 mol*	*0.50 mol*	**4.00 mol** ❶

At equilibrium, $[XY] = 2.00 / 2 = 1.00$ M
$[Y_2] = 0.50 / 2 = 0.25$ M
$[XY_2] = 4.00 / 2 = 2.00$ M ❶

$K = [XY_2]^2 / ([XY]^2 \times [Y^2])$
$= (2.00)^2 / ((1.00)^2 \times 0.25)$
$= 16$ ❶ (M^{-1})

b. $2XY(g) + Y_2(g) \rightarrow 2XY_2(g)$ is **exothermic.** ❶ Since less XY_2 is present at the higher temperature, the **forward reaction is not favoured by high temperatures**.

c.   If the pressure exerted by the components of the equilibrium system increases, then according to Le Chatelier's principle the position of equilibrium should shift to the right to produce fewer particles. ❶ However since Neon is an inert gas and not part of the equilibrium system, it does not effect the pressure exerted by the equilibrium system, and so the position of equilibrium does not shift. ❶
Alternatively the concentration fraction (reaction quotient) $(XY_2)^2$ $([XY]^2 \times [Y_2])$ is not affected by the addition of the non-reacting Neon and so the system is not pushed out of equilibrium.

d.   i.   Position of equilibrium would shift to the right ❶ to counteract the loss of XY_2.
      ii.   The decrease in $[XY_2]$ due to its removal reduces the rate of the reverse reaction relative to the forward reaction. ❶ Hence the forward reaction dominates, and position of equilibrium shifts to the right, until the rates of forward and reverse reactions are again equal at the new equilibrium position. ❶

End of Trial Exam