Lisachem Materials
Chemistry Physics Biology
Psychology

VCE CHEMISTRY 2007
EQUILIBRIA TEST
UNIT 3

Time allowed: 50 minutes
Total marks: 40

SECTION A
Contains 12 multiple choice questions

SECTION B
4 Extended response questions

A data sheet and multiple choice answer sheet are provided. Answer extended response questions in the space provided. Use the marks and time allowed as a guide to how much time you should spend answering each question.

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						relative atomic number symbol name relative atomic mass	1 H Hydrogen 1.0										2 He Helium 4.0
3 Li Lithium 6.9	4 Be Beryllium 9.0											5 B Boron 10.8	6 C Carbon 12.0	7 N Nitrogen 14.0	8 O Oxygen 16.0	9 F Fluorine 19.0	10 Ne Neon 20.2
11 Na Sodium 23.0	12 Mg Magnesium 24.3											13 Al Aluminium 27.0	14 Si Silicon 28.1	15 P Phosphorus 31.0	16 S Sulfur 32.1	17 Cl Chlorine 35.5	18 Ar Argon 39.9
19 K Potassium 39.1	20 Ca Calcium 40.1	21 Sc Scandium 44.9	22 Ti Titanium 47.9	23 V Vanadium 50.9	24 Cr Chromium 52.0	25 Mn Manganese 54.9	26 Fe Iron 55.9	27 Co Cobalt 58.9	28 Ni Nickel 58.7	29 Cu Copper 63.6	30 Zn Zinc 65.4	31 Ga Gallium 69.7	32 Ge Germanium 72.6	33 As Arsenic 74.9	34 Se Selenium 79.0	35 Br Bromine 79.9	36 Kr Krypton 83.8
37 Rb Rubidium 85.5	38 Sr Strontium 87.6	39 Y Yttrium 88.9	40 Zr Zirconium 91.2	41 Nb Niobium 92.9	42 Mo Molybdenum 95.9	43 Tc Technetium 98.1	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
55 Cs Caesium 132.9	56 Ba Barium 137.3	57 La Lanthanum 138.9	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.8	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Ha Hahnium (262)	106 Sg Seaborgium (266)	107 Ns Neilsbohrium (264)	108 Hs Hassium (269)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (272)	111 Rg Roentgenium (272)	112 Uub Ununbium (277)		114 Uuq Ununquadium (289)				

Lanthanide series	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.3	63 Eu Europium 152.0	64 Gd Gadolinium 157.2	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
Actinide series	90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	93 Np Neptunium 237.1	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (254)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (255)	103 Lr Lawrencium (256)

DATA SHEET

Physical Constants

F = 96 500 C mol^{-1}
R = 8.31 JK^{-1} mol^{-1}
V_m (STP) = 22.4 L mol^{-1}
V_m (SLC) = 24.5 L mol^{-1}
Specific heat of water = 4.184 J mL^{-1} ^{o}C^{-1}

Ideal gas equation

$pV = nRT$

$K_W = [H_3O^+]\,[OH^-] = 10^{-14}\ M^2$ at 25^{o}C

The Electrochemical Series

E° in volt

$F_2(g) + 2e^-$	$\rightarrow 2F^-(aq)$	+ 2.87
$H_2O_2(aq) + 2H^+(aq) + 2e^-$	$\rightarrow 2H_2O(l)$	+ 1.77
$Au^+(aq) + e^-$	$\rightarrow Au(s)$	+ 1.68
$MnO_4^-(aq) + 8H^+(aq) + 5e^-$	$\rightarrow Mn^{2+}(aq) + 4H_2O(l)$	+ 1.50
$Cl_2(g) + 2e^-$	$\rightarrow 2Cl^-(aq)$	+ 1.36
$O_2(g) + 4H^+(aq) + 4e^-$	$\rightarrow 2H_2O(l)$	+ 1.23
$Br_2(l) + 2e^-$	$\rightarrow 2Br^-(aq)$	+ 1.09
$Ag^+(aq) + e^-$	$\rightarrow Ag(s)$	+ 0.80
$Fe^{3+}(aq) + e^-$	$\rightarrow Fe^{2+}(aq)$	+ 0.77
$I_2(s) + 2e^-$	$\rightarrow 2I^-(aq)$	+ 0.54
$O_2(g) + 2H_2O(l) + 4e^-$	$\rightarrow 4OH^-(aq)$	+ 0.40
$Cu^{2+}(aq) + 2e^-$	$\rightarrow Cu(s)$	+ 0.34
$CO_2(g) + 8H^+(aq) + 8e^-$	$\rightarrow CH_4(g) + 2H_2O(l)$	+ 0.17
$S(s) + 2H^+(aq) + 2e^-$	$\rightarrow H_2S(g)$	+ 0.14
$2H^+(aq) + 2e^-$	$\rightarrow H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^-$	$\rightarrow Pb(s)$	- 0.13
$Sn^{2+}(aq) + 2e^-$	$\rightarrow Sn(s)$	- 0.14
$Ni^{2+}(aq) + 2e^-$	$\rightarrow Ni(s)$	- 0.23
$Co^{2+}(aq) + 2e^-$	$\rightarrow Co(s)$	- 0.28
$Fe^{2+}(aq) + 2e^-$	$\rightarrow Fe(s)$	- 0.44
$Zn^{2+}(aq) + 2e^-$	$\rightarrow Zn(s)$	- 0.76
$2H_2O(l) + 2e^-$	$\rightarrow H_2(g) + 2OH^-(aq)$	- 0.83
$Mn^{2+}(aq) + 2e^-$	$\rightarrow Mn(s)$	- 1.03
$Al^{3+}(aq) + 3e^-$	$\rightarrow Al(s)$	- 1.67
$Mg^{2+}(aq) + 2e^-$	$\rightarrow Mg(s)$	- 2.34
$Na^+(aq) + e^-$	$\rightarrow Na(s)$	- 2.71
$Ca^{2+}(aq) + 2e^-$	$\rightarrow Ca(s)$	- 2.87
$K^+(aq) + e^-$	$\rightarrow K(s)$	- 2.93
$Li^+(aq) + e$	$\rightarrow Li(s)$	- 3.02

Student Name……………………………..

VCE Chemistry 2007 Equilibria Test Unit 3

SECTION A

MULTIPLE CHOICE ANSWER SHEET

Instructions:

For each question choose the response that is correct or best answers the question.
Circle the chosen response on this answer sheet.
Only circle **one** response for each question.

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

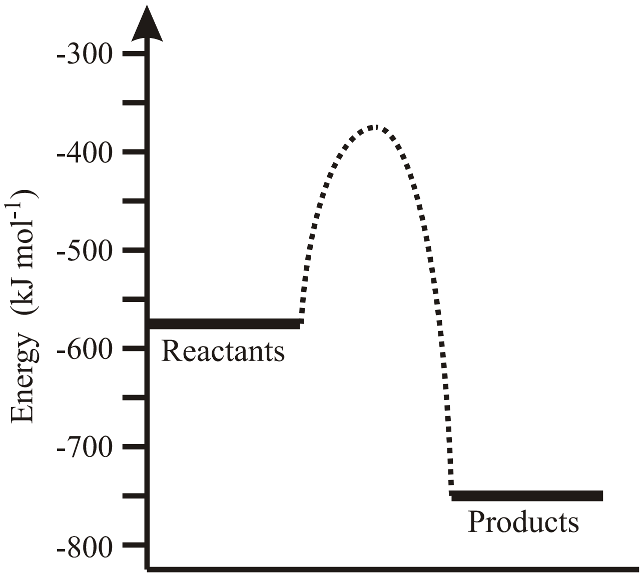
VCE Chemistry 2007 Equilibria Test Unit 3

SECTION A - [12 marks, 15 minutes]

This section contains 12 multiple choice questions.
For each question choose the response that is correct or best answers the question.
Indicate your answer on the answer sheet provided.
*(Choose only **one** answer for each question.)*

Questions 1 & 2 refer to the following information.
The diagram below shows the energy profile for the reaction between phosphorous(III) chloride and chlorine to form phosphorous(V) chloride and can be represented by the chemical equation;

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$$



Question 1
The activation energy for the forward reaction is

A. 100 kJ mol^{-1}.
B. 200 kJ mol^{-1}.
C. -200 kJ mol^{-1}.
D. -180 kJ mol^{-1}.

Question 2
When 2 mole of phosphorous(V) chloride completely decomposes

A. 350 kJ of energy will be absorbed.
B. 175 kJ of energy will be absorbed.
C. 175 kJ of energy will be released.
D. 350 kJ of energy will be released.

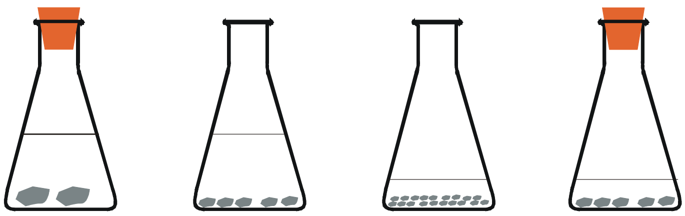
Question 3
The pH of a solution prepared by adding 900.0 mL of deionised water to 100.0 mL of 0.0400 M aqueous barium hydroxide solution would be closest to
A. 11.9
B. 11.6
C. 12.6
D. 12.9

Question 4
The reaction between nitrogen(II) oxide and oxygen can be described by the chemical equation;

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

At 600 °C the concentrations of NO, O_2 and NO_2 in an equilibrium mixture are 0.046 M, 0.042 M and 0.028 M respectively. The value for the equilibrium constant at this temperature is
A. 0.11 M^{-1}.
B. 7.2×10^{-4} M^{-1}.
C. 8.8 M^{-1}.
D. 14 M^{-1}.

Question 5
The diagram below shows four flasks each containing 2 M aqueous hydrochloric acid and the same mass of zinc metal. In which two flasks would the initial rate of hydrogen formation be the same?



I II III IV

A. II & IV.
B. I & II.
C. III & IV.
D. I & IV.

Question 6
Butanol can be prepared by the substitution reaction that occurs between chlorobutane and sodium hydroxide as described by the chemical equation;

$$C_4H_9Cl(l) + NaOH(aq) \rightleftharpoons C_4H_9OH(l) + NaCl(aq)$$

Under certain conditions 45.7 g of butanol was prepared from the reaction of 66.9 g of chlorobutane with excess sodium hydroxide. What is the percentage yield for this reaction?
A. 68.3 %.
B. 85.4 %.
C. 100 %.
D. 80.0 %.

Question 7 & 8 refer to the following information.
The reaction between aqueous solutions of iodine and potassium iodide can be represented by the chemical equation;

$$I_2(aq) + I^-(aq) \rightleftharpoons I_3^-(aq) \quad \Delta H = -19 \text{ kJ mol}^{-1} \qquad K(25\ ^\circ C) = 1000 \text{ M}^{-1}$$

Question 7
Which one of the following changes to an equilibrium mixture would result in a decrease in the number of mole of triiodide ions when equilibrium has been re-established?

A. Lowering the temperature to 15 ºC.
B. Evaporating some of the solution and returning the mixture to 25 ºC.
C. Adding 10 mL of 1M potassium iodide solution to the mixture.
D. Diluting the solution by adding the same volume of deionised water.

Question 8
Which one of the following statements would best describe the rates of the forward and reverse reactions when aqueous solutions of iodine and potassium iodide are mixed and before equilibrium is established?

A. The rates of the forward and reverse reactions are the same.
B. The rate of the reverse reaction remains the same while the rate of the forward reaction decreases.
C. The rate of the forward reaction remains the same while the rate of the reverse reaction decreases.
D. The rate of the forward reaction decreases while the rate of the reverse reaction increases.

Question 9
Methanol is one of the fuels that is being suggested to replace petrol. It can be manufactured by the reaction of hydrogen and carbon monoxide as described by the chemical equation;

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = -96 \text{ kJ mol}^{-1}$$

One industrial process operates at 300 ºC and 5000 kPa in the presence of a copper-zinc catalyst. These conditions are chosen because

A. this temperature will result in a higher equilibrium yield than at lower temperatures.
B. the catalyst will produce a higher equilibrium yield faster.
C. the high pressure will shift the position of equilibrium to favour the forward reaction.
D. at temperatures higher than 300 ºC the methanol will begin to decompose to carbon dioxide and water.

Question 10
Which one of the following statements best describes why the rate of an endothermic gas phase reaction will increase when the temperature is increased?

A. There is a higher chance of collision between the reactant particles at higher temperatures.
B. More of the reactant particles have sufficient energy to overcome the energy barrier for the reaction.
C. The position of equilibria will be shifted to favour the formation of the products.
D. There is a higher chance of fruitful collisions between the reactant particles.

Question 11

Fluoroethanoic acid is a weak acid the dissociation of which in aqueous solutions can be represented by the chemical equation;

$$FCH_2COOH(aq) + H_2O(l) \rightleftharpoons FCH_2COO^-(aq) + H_3O^+(aq) \quad K_a = 5.9\times10^{-3}\ M$$

The pH of a 0.010 M aqueous solution of fluoroethanoic acid would be closest to

A. 1.1.
B. 4.2.
C. 2.1.
D. 1.8.

Question 12

Haemoglobin in blood transports oxygen around the body that keeps the cells alive. Haemoglobin can undergo competing equilibria reactions with oxygen and carbon monoxide that can be represented by the chemical equations;

$$Hb(aq) + 4O_2(aq) \rightleftharpoons Hb(O_2)_4(aq) \qquad K_1$$

$$Hb(aq) + 4CO(aq) \rightleftharpoons Hb(CO)_4(aq) \qquad K_2$$

Carbon monoxide is extremely toxic causing death at concentrations as low as 200 ppm. The values for the two equilibrium constants would be such that

A. K_1 would be approximately equal to K_2.
B. K_1 would be very much smaller than K_2.
C. K_1 would be very much larger than K_2.
D. both K_1 and K_2 are both very large.

End of Section A

SECTION B - [28 marks, 35 minutes]

This section contains four questions, numbered 1 to 4.
All questions should be answered in the spaces provided.
The mark allocation and approximate time that should be spent on each question are given.

Question 1 - [7 marks, 8 minutes]
Magnesium hydroxide, $Mg(OH)_2$, is only slightly soluble in water. A saturated solution was prepared by adding excess solid magnesium hydroxide to 1.00 L of deionised water at 25 ºC, mixing thoroughly then filtering the solution to remove any excess solid. The pH of this solution was found to be 10.4.

a. Write an appropriate chemical equation for the dissociation of magnesium hydroxide in water.

[1 mark]

b. What is the concentration of the hydroxide ions in this solution?

[2 marks]

c. What mass of solid magnesium hydroxide would have dissolved in 1.00 L of water to prepare this solution?

[2 marks]

d. What would be the effect of adding 5 mL of 2 M aqueous sodium hydroxide solution to a 10 mL sample of the saturated magnesium hydroxide solution?

[2 marks]

Question 2 - [6 marks, 8 minutes]
The chemical reactions that occur in cells and the blood stream are many and complex, however part of the processes involved can be simplified to the following five competing chemical equations to represent the reactions that are occurring.
(Haemoglobin is represented by HHb.)

(1) $O_2(g) \rightleftharpoons O_2(aq)$

(2) $O_2(aq) + HHb(aq) \rightleftharpoons Hb(O_2)^-(aq) + H^+(aq)$

(3) $CO_2(aq) + HHb(aq) \rightleftharpoons Hb(CO_2)^-(aq) + H^+(aq)$

(4) $CO_2(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H^+(aq)$

(5) $CO_2(g) \rightleftharpoons CO_2(aq)$

a. In the lungs the concentration of oxygen gas is relatively high compared with the rest of the body.

i. Only using chemical equations (1) and (2), from above, explain the process that would occur in blood that is entering the blood vessels in the lungs and what effect this would have on the pH of the blood.

[2 marks]

ii. What would be the consequences of the pH change that occurred in i. above with reference to chemical equations (3), (4) and (5)?

[2 marks]

b. The treatment of different medical conditions often involves the direct injection of various solutions into the blood stream. Use chemical equations (2) and (4) only, what effect injecting a solution of sodium hydrogen carbonate would have on these reactions?

[2 marks]

Question 3 - [4 marks, 5 minutes]

A weak acid can be represented by the formula, HA and its ionisation in solution can be represented by the chemical equation;

$$HA(aq) + H_2O(l) \rightleftharpoons A^-(aq) + H_3O^+(aq)$$

2.50% of a weak acid was found to be ionised when a solution prepared by dissolving 0.00500 mol of the acid in 100.0 mL of deionised water had reached equilibrium.

a. What is the pH of this solution?

[2 marks]

b. What is the valve for the acidity constant for this weak acid?

[1 mark]

c. How would adding 0.001 mol of the sodium salt of the acid, NaA, to the solution change the pH?

[1 mark]

Question 4 - [11 marks, 14 minutes]

The gas phase reaction between hydrogen and iodine can be represented by the chemical equation;

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = -12 \text{ kJ mol}^{-1}$$

a. Write the expression for the equilibrium constant.

[1 mark]

b. 0.020 mol of both hydrogen and iodine gases are mixed in a 1.00 L piston and allowed to reach equilibrium. The resultant mixture had a hydrogen iodide concentration of 0.030 M.

i. Calculate the concentration of hydrogen gas in the equilibrium mixture.

[2 marks]

ii. Calculate the value for the equilibrium constant at this temperature.

[1 mark]

iii. The system is at equilibrium between t_1 and t_2. On the grid below plot the concentrations for both hydrogen and hydrogen iodide on this grid between 0 and t_2.

[1 mark]

c. At t_2 an additional 0.010 mol of hydrogen gas is added to the piston while keeping the temperature and volume constant. When the system returns to equilibrium at t_3 the concentration of hydrogen gas is 0.0125 M.

i. What is the change in the concentration of the hydrogen iodide gas between t_2 and t_3?

[2 marks]

ii. The system is at equilibrium between t_3 and t_4 on the grid above. Plot the concentrations for both hydrogen and hydrogen iodide on this grid between t_2 and t_4.

[1 mark]

d. At t_4 the volume of the piston is halved.

i. What effect will this have on the concentrations of hydrogen and hydrogen iodide when equilibrium is re-established following the volume change?

[1 mark]

ii. The system is at equilibrium between t_5 and t_6. On the grid above, plot the concentrations for both hydrogen and hydrogen iodide on this grid between t_4 and t_6.

[1 mark]

e. At t_6 the temperature of the system is increased. What effect will this have on the concentration of the hydrogen once equilibrium has been re-established?

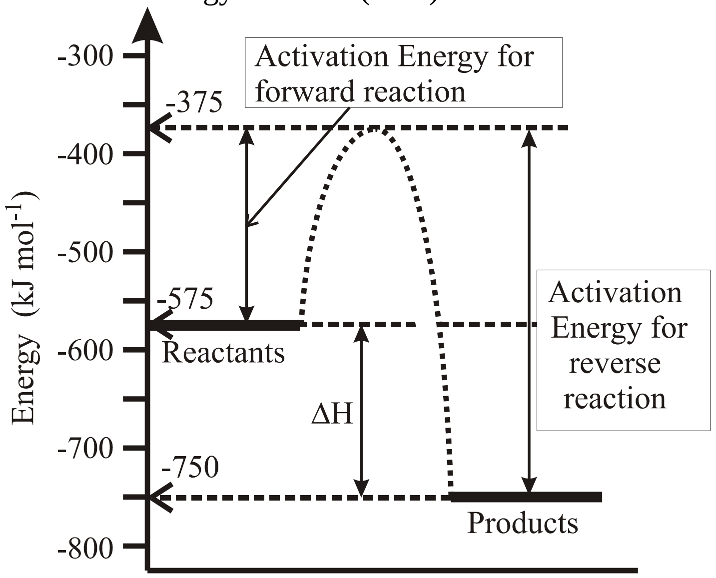
[1 mark]

END OF TASK

Suggested Answers VCE Chemistry 2007 Equilibria Test

SECTION A [1 mark per question.]

Q1 B The activation energy for the forward reaction is the energy difference between the energy at the top of the energy barrier and the energy of the reactants.
Activation Energy = -375 – (-575) = **200 kJ mol^{-1}**.



Activation energies are always positive as these are a measure of the energy required to break the bonds necessary for the reaction to proceed.

The activation energy for the reverse reaction in this example would be -375 – (-750) = 375 kJ mol^{-1}.

Q2 A The enthalpy change for the forward reaction, $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$, is
ΔH = energy(Products) – energy(Reactants) = -750 – (-575) = -175 kJ mol^{-1}
Therefore the enthalpy change for the reverse reaction will be
ΔH = +175 kJ mol^{-1}.
From the chemical equation and the ΔH:
The decomposition of 1 mol of PCl_5 will absorb 175 kJ of energy, therefore the **decomposition of 2 mol of PCl_5 will absorb 350 kJ of energy**.

Q3 A Barium hydroxide ionises in solution as described by the chemical equation;
$Ba(OH)_2(aq) \rightarrow Ba^{2+}(aq) + \mathbf{2OH^-}(aq)$
Therefore the initial c(OH^-) = **2 × c($Ba(OH)_2$) = 2 × 0.0400 M = 0.0800 M**
n(OH^-) = c × V = 0.0800 × (100/1000) = 8.00×10^{-3} mol
After dilution the total volume is 100 + 900 = 1000 mL = 1.00 L
c(OH^-) = [OH^-] = n / V = 8.00×10^{-3} / 1.00 = 8.00×10^{-3} M
[H_3O^+] = 10^{-14} / [OH^-] = 10^{-14} / (8.00×10^{-3}) = 1.25×10^{-12} M
pH = $-\log_{10}[H_3O^+] = -\log_{10}(1.3\times10^{-12})$ = **11.9**

Q4 C The expression for the equilibrium constant for this reaction is

$$K = \frac{[NO_2]^2}{[NO]^2\,[O_2]} = \frac{(0.028)^2}{(0.046)^2\;(0.043)} = \mathbf{8.8\ M^{-1}}$$

Q5 A The rate of a chemical reaction depends on;
i. the concentration of the reactants,
ii. the temperature of the system,
iii. the surface area of any solid reactants, and,
iv. the presence of a catalyst.

Since the acid is the same concentration and the masses of zinc are the same then in this question the **variable that will alter the rate will be the surface area of the zinc**. **Flasks II and IV contain the same size zinc pieces, therefore the**

rates of reaction for these two flasks will be the same. The amount of acid will not change the rate, but may alter the final volume of hydrogen produced.

Q6 B $C_4H_9Cl(l) + NaOH(aq) \rightleftharpoons C_4H_9OH(l) + NaCl(aq)$

First need to calculate the expected mass of butanol.
$M(C_4H_9Cl) = 4\times12.0 + 9\times1.0 + 34.5 = 92.5$ g mol^{-1}
$M(C_4H_9OH) = 4\times12.0 + 10\times1.0 + 16.0 = 74.0$ g mol^{-1}
$n(C_4H_9Cl) = m / M = 66.9 / 92.5 = 0.723$ mol
$n(C_4H_9OH) = n(C_4H_9Cl) = 0.723$ mol
$m(C_4H_9OH) = n \times M = 0.723 \times 74.0 = 53.5$ g

$$\% \text{ Yield} = \frac{\text{actual mass}}{\text{expected mass}} \times \frac{100}{1} = \frac{45.7}{53.5} \times \frac{100}{1} = \mathbf{85.4\ \%}$$

Q7 D Diluting the solution would result initially **lower the concentrations of all of the reacting particles.** Using **LeChatelier's principle** that the system will move to oppose the change,therefore the **position of equilibrium would shift and favour the reverse reaction to form more particles**, in this case the reverse reaction. **This would result in triiodide ions reacting to form iodine and iodide ions**, therefore **the number of mole of triodide ions would decrease**.

Response A: Lowering the temperature, as the forward reaction is exothermic, would result in the position of equilibrium shifting to the right and an increase in the value of the equilibrium constant. Therefore the number of mole of triiodide ions would increase.

Response B: Initially this would increase the concentration of particles, therefore the system would move to oppose this change and shift to the right, forming more triiodide ions.

Response C: Adding iodide ions would cause the reaction to move in the forward direction and form more triiodide ions.

Q8 D The rate of a reaction depends on the concentration of the reacting species. When the iodine and iodide solutions are initially mixed the concentrations of these species will be high while the concentration of the triiodide ion will be zero. Therefore the rate of the forward reaction will be high. As the reaction proceeds towards equilibrium the concentrations of the iodine and iodide ions decreases and as a result the rate of the forward reaction would decrease. At the same time the concentration of the triiodide ions is increasing, therefore the rate of the reverse reaction will increase. This will continue until equilibrium, where the rate of the forward and reverse reactions are equal.

Q9 C The higher pressure will as a result of LeChatelier's principle favour the side with the lesser number of particles, in this case the forward reaction and thereby improve the equilibrium yield of the methanol.

Q10 D The best response mentions fruitful reactions, this is one where the particles have sufficient energy to overcome the energy barrier (activation energy) and a high chance of collision.

Q11 C The dissociation chemical equation is;

$FCH_2COOH(aq) + H_2O(l) \rightleftharpoons FCH_2COO^-(aq) + H_3O^+(aq)$ $K_a = 5.9\times10^{-3}$ M

The expression for the acidity constant is

$$K_a = \frac{[FCH_2COO^-][H_3O^+]}{[FCH_2COOH]}$$

At equilibrium $[FCH_2COO^-] = [H_3O^+]$
If we let $[H_3O^+] = x$ therefore $[FCH_2COO^-] = x$

Since this is a weak acid it can be assumed that the value for x is small, therefore $[FCH_2COOH] = 0.010$ M

Substituting into the expression for the acidity constant;

$$Ka = \frac{[FCH_2COO^-][H_3O^+]}{[FCH_2COOH]} = \frac{(x)(x)}{(0.010)} = \frac{x^2}{(0.010)} = 5.9\times10^{-3} \text{ M}$$

$x^2 = 5.9\times10^{-3} \times (0.010) = 5.9\times10^{-5}$

$x = \sqrt{(5.9\times10^{-5})} = 7.7\times10^{-3}$

$[H_3O^+] = 7.7\times10^{-3}$ M

pH = $-\log_{10}[H_3O^+] = -\log_{10}(7.7\times10^{-3})$ = **2.1**

Q12 B For cells to function the following reaction must occur, so that oxygen is transported to the cells from the lungs;

$Hb(aq) + 4O_2(aq) \rightleftharpoons Hb(O_2)_4(aq)$ K_1

Since carbon monoxide can cause death at such low concentrations, 200 ppm, compared with the normal concentration of oxygen in the atmosphere of 20.9% (209000 ppm), then the following reaction strongly competes with the previous reaction;

$Hb(aq) + 4CO(aq) \rightleftharpoons Hb(CO)_4(aq)$ K_2

For this to happen then **the value of the equilibrium constant, K_1, must be significantly smaller than the value for the equilibrium constant K_2.**

SECTION B

Question 1 - [7 marks, 8 minutes]

a. **$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$ [1 mark]**

b. pH = 10.4

pH = $-\log_{10}[H_3O^+]$

$[H_3O^+] = 10^{-pH} = 10^{-10.4} = 3.98\times10^{-11}$ M **[1 mark]**

At 25 ºC $K_w = 10^{-14} = [H_3O^+][OH^-]$

$[OH^-] = 10^{-14} / [H_3O^+] = 10^{-14} / (3.98\times10^{-11})$ = **2.51×10^{-4} M [1 mark]**

c. $M(Mg(OH)_2) = 24.3 + 2\times16.0 + 2\times 1.0 = 58.3$ g mol^{-1}

$c(OH^-) = [OH^-] = 2.51\times10^{-4}$ M

$n(OH^-) = c \times V = 2.51\times10^{-4} \times 1.00 = 2.51\times10^{-4}$ mol

Since each mole of $Mg(OH)_2$ produces 2 mol of $OH^-(aq)$ ions, then

$n(Mg(OH)_2) = ½\, n(OH^-) = ½ \times 2.51\times10^{-4} = 1.26\times10^{-4}$ mol **[1 mark]**

$m(Mg(OH)_2) = n \times M = 1.26\times10^{-4} \times 58.3$ = **7.35×10^{-3} g [1 mark]**

d. Sodium hydroxide is a base and this is a relatively concentrated solution therefore, adding this solution to the sample **would significantly increase the concentration of the hydroxide ions and at the same increase the pH of the solution. [1 mark]**

The increased in the hydroxide ion concentration would **shift the position of equilibrium for the dissociation of solid magnesium hydroxide to the left, thereby resulting in the precipitation of solid $Mg(OH)_2$ from the solution. [1 mark]**

Question 2 - [6 marks, 8 minutes]

LeChatelier's principle which states that if a system at equilibrium is subjected to a change it will shift its position to oppose the change. This principle is used to explain the consequences in each of the following.

a. i. In the lungs $[O_2(g)]$ is relatively high. Blood entering the blood vessels in the lungs will be low in oxygen content.

(1) $O_2(g) \rightleftharpoons O_2(aq)$

An **increased [O_2(g)] will shift the position of equilibrium for reaction (1) towards the right resulting in an increased [O_2(aq)]**. **[1 mark]**

(2) $O_2(aq) + HHb(aq) \rightleftharpoons Hb(O_2)^-(aq) + H^+(aq)$

An **increased [O_2(aq)] will have a similar effect on reaction (2) resulting in an increased [H^+(aq)]. When the [H^+(aq)] increases the pH will decrease. [1 mark]**

ii. Reactions (1) and (2) give an overall result of a lower pH.

(3) $CO_2(aq) + HHb(aq) \rightleftharpoons Hb(CO_2)^-(aq) + H^+(aq)$

This reduction in pH will shift the position of equilibrium for reaction (3) towards the left increasing the [CO_2(aq)] and increasing the pH as the [H^+(aq)] decreases as a consequence. [1 mark]

(4) $CO_2(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H^+(aq)$

It will also have a similar effect on reaction (4). Together both these reactions will increase the [CO_2(aq]. In reaction (5) this increase, will also shift the position of equilibrium towards the left increasing the [CO_2(g)]. [1 mark]

(5) $CO_2(g) \rightleftharpoons CO_2(aq)$

As can be seen the net effect would be to increase the [$Hb(O_2)^-(aq)$] while releasing $CO_2(g)$ which will be exhaled. The pH of the blood would not vary much as a consequence of all five reactions.

b. Injecting sodium hydrogen carbonate solution, HCO_3^-(aq), would increase the concentration of this ion in the blood. **This would result in the position of equilibrium for reaction (4) shifting towards the left consequently lowering the [H^+(aq)] and increasing the pH**. **[1 mark]** This would then allow the **position of equilibrium for reaction (2) to shift towards the right to counter the effect thereby increasing the [$Hb(O_2)^-$(aq)]**. **[1 mark]**

Question 3 - [4 marks, 5 minutes]

a. $HA(aq) + H_2O(l) \rightleftharpoons A^-(aq) + H_3O^+(aq)$

n(HA) = 0.0050 mol

2.5% of the acid is ionised at equilibrium, therefore

$n(H_3O^+) = (2.5/100) \times 0.0050 = 1.25\times10^{-4}$ mol.

$c(H_3O^+) = n / V = 1.25\times10^{-4} / (100.0/1000) = 1.25\times10^{-3}$ M **[1 mark]**

$[H_3O^+] = 1.25\times10^{-3}$ M

$pH = -\log_{10}[H_3O^+] = -\log_{10}(1.25\times10^{-3}) =$ **2.9 [1 mark]**

b. [HA] = n / V = 0.0050 / (100.0/1000) = 0.050 M

At equilibrium $[A^-] = [H_3O^+] = 1.25\times10^{-3}$ M

$$K_a = \frac{[H_3O^+][A^-]}{[HA]} = \frac{(1.25\times10^{-3})(1.25\times10^{-3})}{(0.050)} = \mathbf{3.1\times10^{-5}\ M}$$ **[1 mark]**

The concentration of the water is **not** included in the acidity constant as it is large compared with the concentrations of other species.

c. The addition of the salt, NaA, would increase the [A^-] and to restore equilibrium, using LeChatelier's principle, the position of equilibrium would shift to the left. In doing so the concentration of the hydrogen ion, H_3O^+(aq), would decrease. **A decrease in [H_3O^+] will increase the pH of the solution. [1 mark]**

Question 4 - [11 marks, 10 minutes]

$H_2(g) + I_2(g) \leftrightharpoons 2HI(g)$ $\Delta H = -12$ kJ mol^{-1}

a. $K = \dfrac{[HI]^2}{[H_2][I_2]}$ **[1 mark]**

b. i.

	$H_2(g)$ +	$I_2(g)$	$\leftrightharpoons$	$2HI(g)$
Initial:	0.020 mol	0.020 mol		0 mol

To reach equilibrium H_2 and I_2 reacted, if x mol of these reacted then

Reacted:	x mol	x mol	$\rightarrow$	2x mol
At equilibrium:	(0.020 – x) mol	(0.020 – x) mol		0.030 mol

$2x = 0.030 \Rightarrow x = 0.030/2 = 0.015$ mol **[1 mark]**

Since the volume of the piston is 1.00 L

At equilibrium: $n(H_2) = 0.020 - 0.015 = 0.005$ mol

$[H_2]$ = n / V = 0.005 / 1.00 = 0.005 M [1 mark]

$[I_2] = [H_2] = 0.005$ M

ii. $K = \dfrac{[HI]^2}{[H_2][I_2]} = \dfrac{(0.030)^2}{(0.005)(0.005)}$ = **36 [1 mark]**

iii. The diagram below shows how the concentrations of the hydrogen and hydrogen iodide change between 0 and t_2.

At equilibrium (t_1) $[H_2] = 0.005$ M : $[HI] = 0.030$ M **[1 mark]**

The $[H_2]$ decreases from 0.020 M at t=0 to 0.005M at t_1 and [HI] increases from 0 M at t=0 to 0.030 M at t_1. Both remains constant through to t_2.

c. i. The $[H_2]$ would increase immediately to 0.015 M following the addition of hydrogen at t_2, then decrease to 0.0125 M when equilibrium is re-established at t_3.

Change in $[H_2] = 0.0125 - 0.0150 = -0.0025$ M **[1 mark]**

Therefore since the stoichiometry of the reaction is 1:2.

The increase in [HI] = 0.005 M

[HI] at $t_3 = 0.030 + 0.005 = 0.035$ M **[1 mark]**

ii. The changes to be shown:

At t_2 $[H_2]$ increases from 0.005 M to 0.015 M

Between t_2 and t_3 $[H_2]$ decreases from 0.015 M to 0.0125 M and [HI] increases from 0.030 M to 0.035 M.

Between t_3 and t_4 both concentrations remain constant. **[1 mark]**

d. i. Since the volume of the system is halved at t_4, the concentrations of both species will double initially.

In this reaction both sides of the reaction have the same number of particles therefore the concentrations will remain at the value there were following the volume chance. **[1 mark]**

ii. At t_4 the $[H_2]$ will increase to 0.025 M and [HI] will increase to 0.070 M.

The concentrations will remain constant through to t_6. **[1 mark]**

e. The **forward reaction is exothermic**. The system will **move its position of equilibrium to oppose any increase in the temperature (LeChatelier's principle)**. Therefore the **reverse reaction will be fravoured**, and the **concentration of hydrogen will have increased when equilibrium is re-established**. **[1 mark] This is shown on the concentration versus time graph.**