Strathfield
Girls High
School

2005

Trial Higher School Certificate Examination

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Board-approved calculators may be used
- Write using blue or black pen
- Draw diagrams using pencil
- A Data Sheet and Periodic Table are provided at the back of this paper.

Section I

Pages 2 – 16

Total marks (**75**)

This section has two parts, Part A and Part B

Part A
Total marks (**15**)
- Attempt questions 1 – 15
- Allow about 30 minutes for this part

Part B
Total marks (**60**)
- Attempt questions 16 – XX
- Allow about 1 hour and 55 minutes for this part.

NOTE: Section 2 (Options) is not included.

Section I - 75 marks

Part A : Multiple Choice questions - 15 marks

Attempt all Questions **1.** to **15.** (1 mark each)
Allow about 30 minutes to complete this Part.

Use the Multiple Choice Answer sheet provided.

Select the alternative A, B, C or D, that best answers the question and indicate your choice by clearly marking your answer in the appropriate place on the Answer sheet.

---

1. Which of the following is the correct systematic name for the monomer of polyvinylchloride?

(A) vinyl chloride
(B) chloroethene
(C) 1 - chloroethene
(D) vinyl ethene

2. A sample of 15.5g of pure zinc reacts with excess dilute hydrochloric acid. Which of the following gives the volume of dry hydrogen gas given off at 298K and 100kPa?

(A) 0.62L
(B) 2.94L
(C) 5.87L
(D) 11.76L

3. Which of the following best describes what is involved in the formation of a coordinate covalent bond?

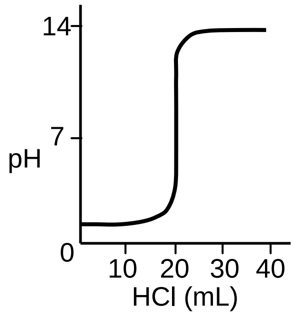
(A) attraction between oppositely charged ions.
(B) sharing of electrons forming a covalent bond.
(C) a group of atoms with one or more unpaired electrons.
(D) one of the atoms donates both the electrons in forming the covalent bond.

4. Which of the following statements best explains the term “addition polymer” ?

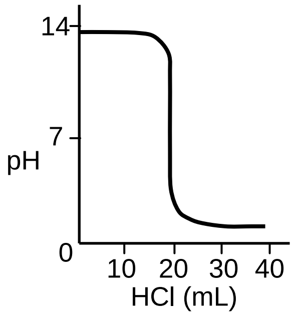
(A) A polymer which forms by monomers combining without the loss of electrons.
(B) A polymer which forms by monomers combining with the by-product of a water molecule.
(C) A polymer which forms by the use of a catalyst.
(D) Polymer which forms without the loss of atoms.

5. A 0.1mol/L hydrochloric acid solution was added drop-wise to 20.0mL of 0.1mol/L sodium hydroxide solution. The pH change during addition is best shown by which of the following graphs?

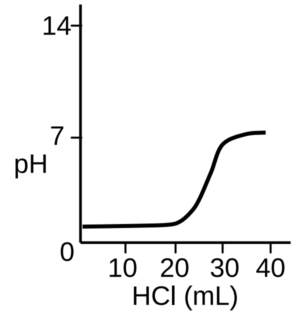
(A)



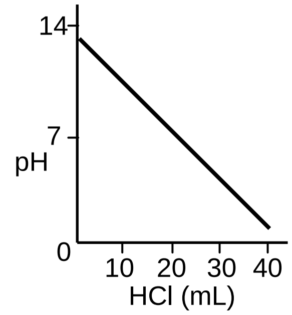
(B)



(C)



(D)



6. Which of the following best describes the cause of eutrophication of water ways?

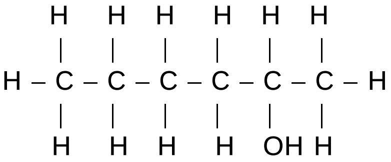
(A) Increased concentration of dissolved gases such as oxygen, hydrogen and carbon dioxide

(B) Contaminants such as cadmium and mercury making the water unsuitable for fishing by humans

(C) The total absence of any dissolved substances so that the water is crystal clear

(D) Increased availability of nutrients such as nitrates and phosphates promoting excessive algal growth

7. Which of the choices is the correct systematic name for the alkanol shown below?



$$\begin{array}{ccccccccccccc} & & H & & H & & H & & H & & H & & H \\ & & | & & | & & | & & | & & | & & | \\ H & - & C & - & C & - & C & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & | & & | & & | \\ & & H & & H & & H & & H & & OH & & H \end{array}$$

(A) 2-heptanol

(B) 5-heptanol

(C) 2-hexanol

(D) 5-hexanol

8. Consider the equilibrium reaction represented by the equation shown below;

$$2NO_{2(g)} \Leftrightarrow N_2O_{4(g)} \qquad \Delta H = -60kJ$$

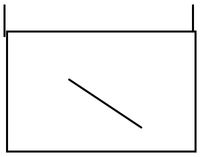
If the temperature is decreased and the volume kept constant, which of the following correctly describes the effect on the concentration of $N_2O_{4(g)}$?

(A) It will remain the same because of the mole ratios.
(B) It will decrease because the reaction is exothermic.
(C) It will increase because the reaction is exothermic.
(D) It will decrease because pressure increases.

9. In an investigation to compare the pH of a strong acid and a weak acid, which pair of solutions would be most appropriate?

(A) $1.0molL^{-1}$ citric acid and $1.0molL^{-1}$ acetic acid.
(B) $0.10molL^{-1}$ acetic acid and $10molL^{-1}$ hydrochloric acid.
(C) $0.30molL^{-1}$ citric acid and $0.1molL^{-1}$ hydrochloric acid.
(D) $0.10molL^{-1}$ acetic acid and $0.1molL^{-1}$ hydrochloric acid.

10. The following displacement reaction was set up :



An iron nail in 0.1mol/L $CuSO_4$ solution

Which of the following represents the species that undergoes reduction in the above reaction?

(A) Fe (B) Fe^{2+}
(C) Cu (D) Cu^{2+}

11. The Table below shows information about a variety of indicators.

Indicator	Colour in low pH	Colour in high pH	pH range
Methyl Orange	Red	Yellow	3.1 – 4.4
Bromophenol blue	Yellow	Blue	3.0 – 4.6
Methyl Red	Pink	Yellow	4.4 – 6.0
Phenol Red	Yellow	Red	6.8 – 8.4

Which two indicators could be best used together to identify rain with a pH of approximately 6.2?

(A) Methyl orange and bromophenol blue.
(B) Methyl red and phenol red.
(C) Methyl orange and methyl red.
(D) Methyl red and bromophenol blue.

12. Water hardness is used to describe water that contains significant amounts of specific ions. Hard water will not lather easily with soaps. These ions which cause this are:

(A) Na^+ and Cl^-
(B) NH_4^+ and OH^-
(C) Hg^{2+} and Pb^{2+}
(D) Mg^{2+} and Ca^{2+}

13. Which of the statements below describes a transuranic element?

(A) Elements transformed during nuclear reactions.

(B) Elements after Uranium in the Periodic Table.

(C) Elements before Uranium in the Periodic Table.

(D) Elements that undergo radioactive decay.

14. A 10.0mL volume of 10mol/L HCl is diluted to 1.0L with distilled water.
A volume of 100mL of this solution is then further diluted to 1.0L using distilled water. Which of the following would be closest to the pH of the final solution?

(A) 0 (B) 2

(C) 3 (D) 7

15. The Atomic Absorption Spectroscope would be a good analytical tool to detect the presence of which of the following?

(A) metals ions in solutions

(B) NO_x in the exhaust of cars

(C) various hydrocarbons in alcohols

(D) particulates in air

Section I. continued :

Part B : Written Response questions - 60 marks

Attempt all Questions (**16**. to **27**. – Marks for each question are shown)
Allow about 1 hour and 45 minutes to complete this Part.

Answer the questions in the space provided.

Where questions involve calculations show the required working.

Marks

Question 16.

The table below shows information on the uses for polyethylene. **3**

Type of Polyethylene	Uses
Low-Density Polyethylene	Cling-wrap, plastic bags, milk and fruit juice containers, insulation wires
High-Density Polyethylene	Children's toys, plastic buckets, playground equipment, lunch boxes

Account for the uses of low-density polyethylene and high-density polyethylene, in terms of their properties, using information in the Table.

Question 17. **5**

The accuracy of a titration depends upon care in preparing a Primary Standard and the correct preparation and use of equipment.

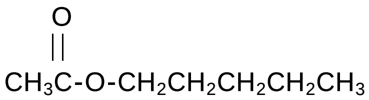
(a) Identify one substance that is not suitable to prepare a primary standard and justify your choice. **2**

(b) A student used the titration process to determine the concentration of a potassium hydroxide solution. She found that 25.00mL of a 0.10$molL^{-1}$ sulfuric acid solution reacted with exactly 10.0mL of the potassium hydroxide solution. Calculate the concentration of the potassium hydroxide solution. **3**

Marks

Question 18. **4**

Below is the formula of a common ester found in lollies.



$$CH_3\overset{\overset{\large O}{||}}{C}\text{-}O\text{-}CH_2CH_2CH_2CH_2CH_3$$

(a) Identify the ester, using IUPAC nomenclature. **1**

(b) Describe how this ester could be produced in the school laboratory. **3**

Question 19. **2**

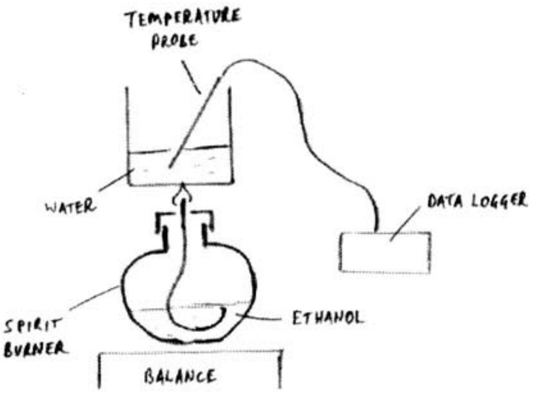
The Table below shows the pH of some common salt solutions.

Salt Solution	**pH**
Ammonium Nitrate	4.8
Sodium Ethanoate	9.1

Choose <u>one</u> salt solution, and using an appropriate equation as support, explain the resulting pH of this salt solution.

Question 20. **9**

A quantity of ethanol was placed in a spirit burner, the wick lit and the energy produced used to heat 100.00 g of water in a beaker. The change in mass of the spirit burner was measured using an electronic balance. The initial and final temperature was measured using a probe attached to a data logger. A diagram of the apparatus is shown.



The results are shown below.

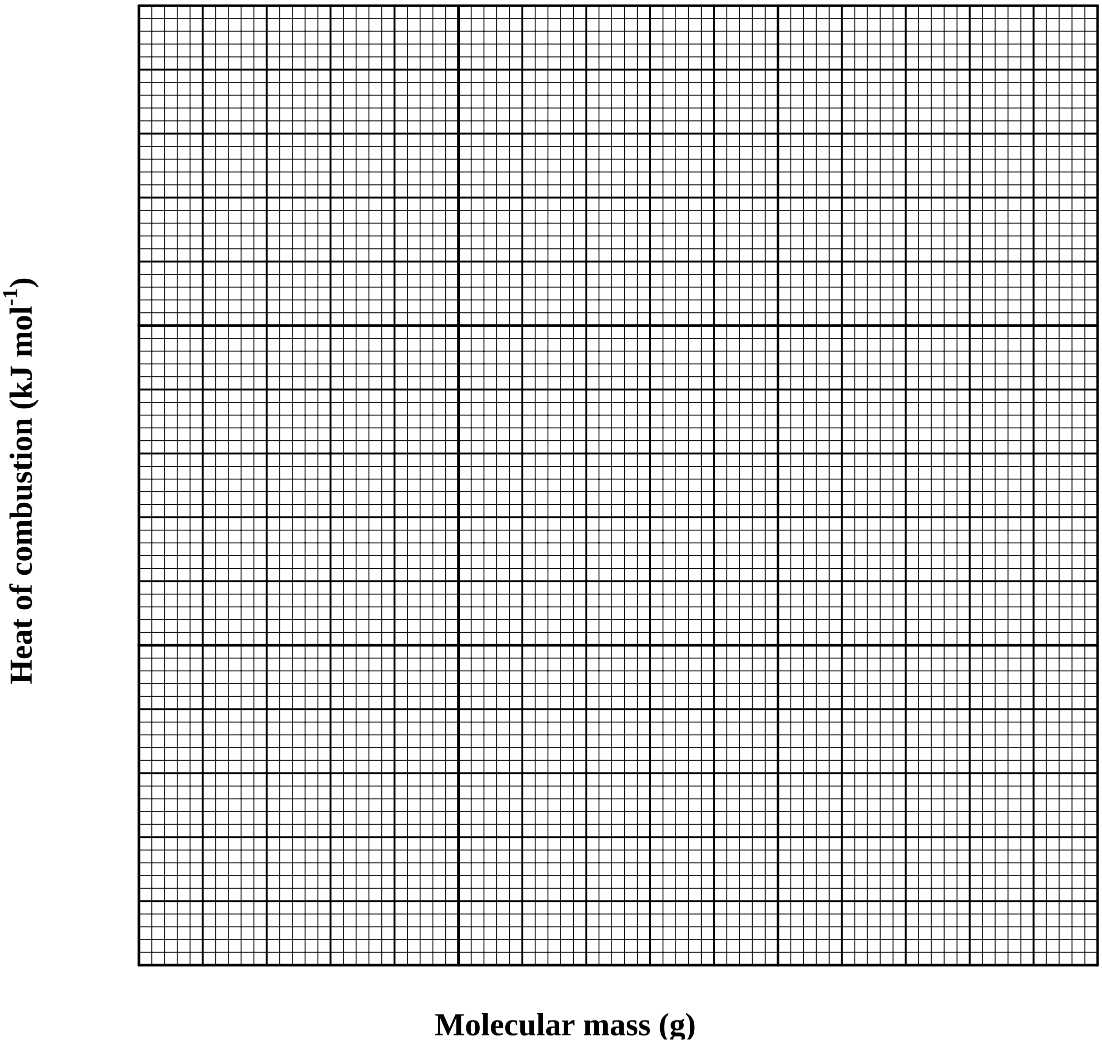
Initial mass of burner = 228.30 g
Final mass of burner = 226.27 g
Initial temperature of water = 24.0°C
Final temperature of water = 58.0°C

(a) Calculate the Molar Heat of Combustion of ethanol using this data. **3**

(c) The theoretical molar heat of combustion for a variety of alkanols is shown in the table below.

Alcohol	Molecular mass	Heat of combustion (kJ mol^{-1})
Methanol	32	726
ethanol	46	1367
1-propanol	60	2021
1-butanol	74	2676
1-heptanol	116	4638

Plot a graph of this data on the grid provided below. **2**



(d) Account for the difference between the calculated value for the heat of combustion of ethanol from part (a) and the theoretical value for the heat of combustion of ethanol from part (c) **1**

____

____

____

(e) Explain the trend shown by the graph. **2**

____

____

____

(f) Predict the theoretical value for the heat of combustion of 1-pentanol. **1**

____

____

Question 21. **3**

Chemists are employed in a variety of chemical occupations. During your study you would have gathered detailed information on the specific role played by a chemist in a named industry. Outline the role played by a chemist in a named industry explaining the chemical principle(s) that the chemist uses as they do their work.

Question 22. **4**

Two identical bottles of soda water (carbonated water), one at room temperature (25°C) and one just out of the refrigerator, had their pH determined using a probe and data logger. The results are tabulated below.

Soda Water	pH	Temperature (°C)
Bottle A	5.21	25
Bottle B	4.63	4

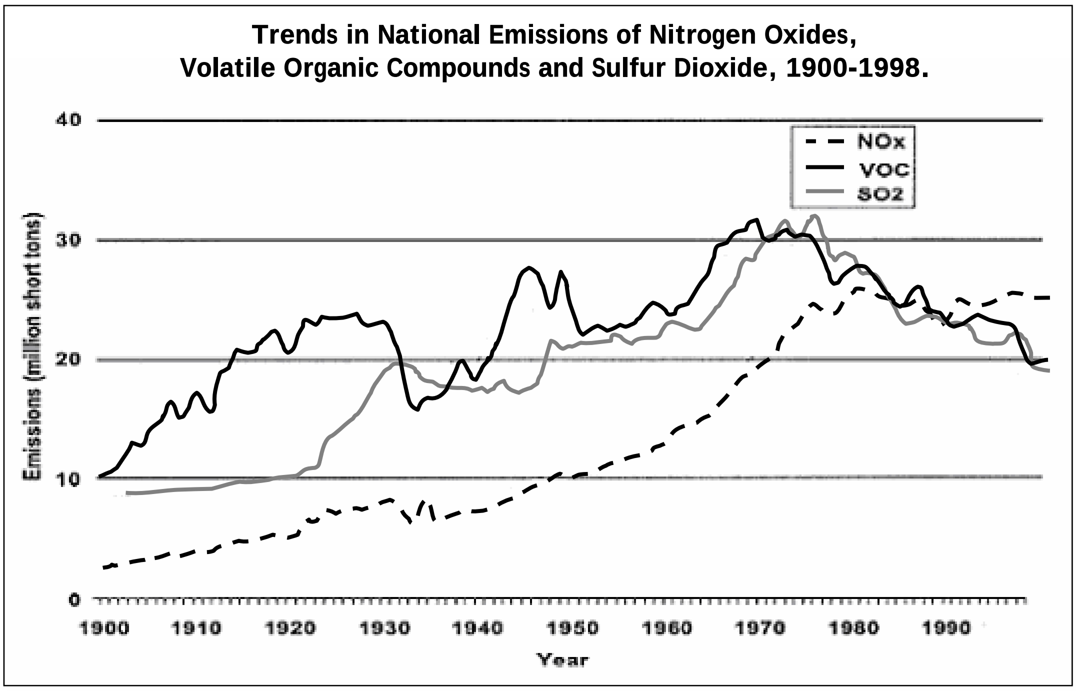
Account for the difference in pH in terms of Le Chatelier's principle.

Marks

Question 23. **5**

The graph below shows the emission of certain gases for nearly 100 years in the United States of America.

(Source:www.epa.gov/airmarkets/articles/nitrogren.pdf)



Trends in National Emissions of Nitrogen Oxides, Volatile Organic Compounds and Sulfur Dioxide, 1900-1998.

Explain the trends shown in the graph above and assess the reasons for concern about the release of sulfur and nitrogen oxides into the environment.

Marks

Question 24 **6**

Evaluate the potential of ethanol as an alternative fuel source.

Question 25. **6**

a.) Describe the conditions under which Haber developed the industrial synthesis of ammonia in the early twentieth century. **3**

b.) Explain why the Haber process is based on a delicate balancing act involving reaction energy, reaction rate, and equilibrium. **3**

Marks

Question 26. **4**

a.) Describe the effect of increased levels of ozone concentrations in the Troposphere, on life on earth. **2**

b.) Identify the molecule whose formula is given below, using IUPAC nomenclature and account for its presence in the atmosphere. **2**

CCl_3CF_3

Question 27.

Explain how the design and composition of microscopic filters plays a part in purifying contaminated water. **3**

Marks

Question 28 4

Assess the effectiveness of AAS in monitoring water pollution.

Question 29 2

The transuranic element Meitnerium was first detected in Germany in 1982. It existed for five-thousandths of a second. Describe how transuranic elements such as Meitnerium are produced.

END of Section I

Sample answers (*scoring full marks)
2005 Chemistry Trial HSC

Question 16

Student X

Because low density polyethylene has branches in its polymer chain, so there are less dispersion forces between chain, causing it to be soft. Therefore it's used for plastic bags and cling wrap. High density polyethylene doesn't have branches in its polymer chains so there are more dispersion forces, causing it to be harder and stronger and so is used for toys and buckets.

Question 17

Student X

(a) Sodium hydroxide is not a suitable substance because it reacts with water when it's exposed to air, so its mass is not accurately known.

(b) $2KOH(aq)^+ H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O_{(1)}$

$nH_2SO_4 = 0.1 \times 0.025$ $\therefore nKOH = 0.0025 \times 2 = 0.005mol$

$= 0.0025mol$ $\therefore$ $C = \frac{0.005}{0.01} = 0.5mol/L$

$\therefore 0.5M$ of KOH

Student Y

(a) Sodium hydroxide is not suitable. It absorbs atmospheric moisture and CO_2 hence the mass of the primary standard will increase due to its chemical reactions with H_2O and CO_2 while preparing primary standard $\therefore$ the titration will be inaccurate.

(b) $2KOH(aq) + H_2SO_4(aq) \rightarrow 2H_2O(l) + K_2SO_4(aq)$

C O.1M

V 100ml 25ml

$N(H_2SO_4) = CV = 0.1 \times 25 \times 10^{-3} = 25 \times 10^{-4}mol = 2.4 \times 10^{-3}mol$

$\therefore n(KOH) = 2 \times n(H_2SO_4) = 5.0 \times 10^{-3}mol$

$$\therefore C = \frac{n}{V} = \frac{5.0x10^{-3}}{10x10^{-3}} = 0.5M$$

Question 18

Student X

(a) 1-pentylethanoate

(b)

1. Add 10mL 1-pentanol and 20mL ethanoic acid into a pear shaped flask in which boiling chips are placed at the bottom for even heat distribution.
2. Add 5 drops of concentrated H_2SO_4 into the flask as catalyst and connect the flask with all mixtures to the refluxing condenser.
3. Place the set of apparatus into a beaker with water (as a hot water bath) while heating by bunsen burner.
4. Leave the top of the tube open to prevent dangerous build up of pressure and reflux the mixture for about 1 hour.
5. Allow to cool
6. Take out the pear shaped flask and transfer the mixture into a separation funnel.
7. Excess anhydrous Na_2CO_3 is added to the mixture to remove water and excess acids.
8. When two layers form remove the aqueous lower layer leaving the ester behind.

9. Further distilling will be carried out for purifying ester.

Student Y

(a) 1-pentyl – ethanoate

(b) The ester could be produced by reaction between acetic acid and pentanol under the catalyst of concentrated sulfuric acid in a pear shaped flask. Refluxing is needed to condense the volatile component such as pentanol and ester vapour, the vapour would be cooled down and return to the flask.

Question 19

Student X

For example of sodium ethanoate, as it dissolves in water, ionisation occurs.
CH_3COONa (aq) + Na^+(aq)+$OH^=$(aq). As we know, the acetic acid CH_3COOH is a weak acid, that means only a little part of hydrogen ions can be ionised from CHCOOH molecules, and the amount is less then the amount of hydroxide ions. Therefore the amount of ionised hydrogen ions is insufficient to neutralize the hydroxide ions and the solution would be basic.

Student Y

NH_4NO_3(aq)$\leftrightarrows$ NH_4^+(aq) + NO_3^-(aq). In the solution of NH_4NO_3 the NH_4^+ present can act as a proton donor, while H_2O accepts the proton from NH_4^+. NH_4^+(aq)+H_2O(l) $\leftrightarrows$ NH_3(aq) + H_3O^+(aq) and the H_3O^+ formed in the proton transfer reaction accounts for the acidic nature of the solution hence the pH of NH_4NO_3(aq) is below 7(4.8).

Question 20

Student X

(a) Mass of ethanol used = 222.30g – 226.27g = 2.03g
M.M of ethanol C_2H_5OH = 46.068g/mol
$\therefore$ n ethanol = $\frac{m}{MM} = \frac{2.03}{46.068}$ = 0.044mol
$\Delta H = -CM\Delta T$
= -4.18 x 100 x (58-24)
= -14212J
$\therefore$ $\Delta HC = \frac{-14212}{0.044}$ = 323,000j/mol = 323kj/mol

(d) Heat is lost to the surrounding air and the equipment such as the beaker, so the water doesn't absorb all the heat and so the value is lower than the theoretical one.

(e) The trend is the higher the molecular mass, the higher the heat of combustion. This is due to the fact that there are more carbon oxygen atoms which can undergo combustion.

(f) $C_5H_{11}OH$: 88.146 g/mol
Approximately 3300 kJ/mol

Student Y

(a) $\Delta H = -MC\Delta T$
= -100 x 4118 x 34
= -14212J
C_2H_sOH = 46.068 mole = 0.044065294

Δ H per mole = $-\dfrac{14212}{\text{moles}}$
= -322521.3872 Jlmol
= -322.5 kJ/mol Δ H_c = 322.5kJ/mol

(d) When burning ethanol, some heat is lost to the surrounding environment and absorbed by the beaker $\therefore$ the experimental result of the heat absorbed by water is smaller than the theoretical prediction $\therefore$ small experimental ΔHC than theoretical ΔHC.

(e) As the molecular mass of alkanols increases, their molar heat of combustion also increases. This is due to more carbons in the molecules are available for combustion $\therefore$ more heat will produce in burning alcohol with higher MM.

(f) MM of 1-pentanol = 88 g/mol
$\therefore$ theoretical Δ HC = 3320 kj/mol

Question 21

Student X
Surface and colloid chemists heavily rely their work upon the fundamental principles of surface tension and intermolecular forces of attraction. They major in specific industries such as that of the cosmetics. For example lipsticks are made to last longer, remain its appeal and stay on only the lips (intermolecular forces of attraction). Also skin products to enhance the skin's visual well being (surface tension etc. Detergents are a prime example. They are made to have a hydrophilic and hydrophobic end to dissolve dirt, oil, grease, etc (the non polar end) and at the same time be soluble in water.

Question 22

Student X
$CO_2(g) + H_2O_{(1)} \leftrightarrows H_2CO_3(aq) \leftrightarrows HCO_3^-(aq) + H^+(aq)$
Because CO_2 gas dissolving in water is an exothermic reaction, the lower the temperature, the more $CO_2(g)$ dissolves and consequently more H+ ions are formed, giving the solution a lower pH. This is because it's an exothermic reaction, so when there's a decrease in temperature, the system tries to counteract the change by increasing the temperature and thus drives the reaction to the right forming more H+ ions. However, when the temperature increases, it counteracts the change by absorbing the heat, leading to an endothermic reaction which drives it to the left and lowering the number of H+ causing a higher pH.

Student Y

eqn 1 - $CO_2(g) + H_2O(aq) \leftrightarrows H_2CO\Delta(aq) +$ H. This reaction is exothermic and as Le Chatelier's principle states an increase in temperature will reverse an exothermic reaction.
Eqn 2 - $H_2CO_3(aq) \leftrightarrows H^+(aq) + HCO_3^-(aq)$. In this equation the H_2CO_3 produces hydrogen ions making the solution much acidic. In bottle B the concentration of H^+ ions are greater due to the lower temperature in comparison to bottle A (23°C). The less hydrogen ions there are the greater the pH, this is the reason why the pH of bottle A is greater.

Student Z
$CO_2(g) \leftrightarrows CO_2(aq)$ …. 1
$CO_2(g) + H_2O(l) \leftrightarrow H^+(aq) + HCO_3^-(aq) \leftrightarrows 2H^+(aq) + CO_3^{2-}(aq)$….2

CO_2(g) has higher solubility in cold water (B) than in cold water (A). When temperature increases according to Le Chatelier's principle that the equilibrium will shift to the side to favour the endothermic reaction to reduce the extra heat. In eqn 1 the forward reaction is exothermic $\therefore$ increase ion temperature will favour the reverse eqn ie the equilibrium shifts to the left, which is endothermic to reduce the heat. Hence more CO_2 gas is produced from CO_2(aq). The disturbance in reducing [CO_2](aq) causes eqn (2) equilibrium shifts to the left to produce more CO_2(aq) [Le Chatelier's Principle]. This results in a decrease in [H^+] hence the pH in bottle A (warm water) is higher than the one in cold water.

Student W
The left direction of equilibrium H_2CO_3(aq) $\leftrightarrows$ H^+(aq) + $HCO3^-$(aq) is endothermic reaction, that is why when the temperature is higher by Le Chatelier's principle that the equilibrium will shift to prevent the change of equilibrium system, the equilibrium will shift to endothermic side i.e. shift to left, then the concentration of hydrogen ions will decrease, which results in the increasing of pH of bottle A.

Question 24

As our source of fossil fuel is declining the search for alternative fuel source is a priority now.

Ethanol can be used as an alternative fuel as it has high combustion efficiency and the products are clean (only H_2O and CO_2). It can also be used a portable fuel for campers and hikers. Most importantly, ethanol can be considered as a renewable source as it can be made by fermentation of glucose, which is the component monomer of cellidose contributing to 50% of biomass.

$C_6H_{12}0_6 \rightarrow 2C_2H_5OH$(aq) + $2C0_2$(g) and the products containing carbons can form carbon cycle with reactants and the establishment of C-cycle makes ethanol a renewable alternative fuel. However, only 15% ethanol can be produced in the fermentation and even higher cost will required than using fossil fuel as it's expensive to perform distillation of ethanol and water (same problem if ethanol is made by hydration of ethane and the concentration of >95% ethanol is virtually impossible to achieve due to high miscibility b/w water and ethanol. Also, if ethanol is used as car fuel, high cost is needed for modification of car engines to suit ethanol and replacement of all service stations. To obtain raw material of ethanol, the large amount of arable land for growing ethanol crops are required hence less amount of food – crop and lands are available and there is also environment impact e.g. soil, erosion and salinity etc. The disposal of waste from fermentation is very hard too. Although ethanol is superior than current fossil fuel as it's renewable and producing cleaner products, the high cost involved in distillation, waste disposal and cleaning of land make it still unviable for fuel use environmentally and economically, unless another cheaper and cleaner way to convert calulose into ethanol can be found.

Question 25 (a)

Student X

AT the time when Germany was preparing for WWI and rapid growth of world population requires ammonia for both military and agricultural uses. When British navy cut the sea path to Chile. A good nitrogen source, the Europe, especially Germany facing problems for their preparation for WWI and the political tension grew. Haber developed the Haber process to produce ammonia via the reaction b/w N_2 and H_2 i.e. $N_2(g)+3H_2(g)\rightarrow 2NH_3(g)$. it initially resolved the urgency for deficiency in agricultural ammonium fertilizers but later directly fulfilled Germany's hostile desire in using NH_3 for explosives.

Student Y

Haber developed his process before World War I for the industrial synthesis of ammonia. At that time, under the control of the sea routes by Britain and its allies, Germany were cut off from the Chile Salt Perer and Peruvian Guano, which is the source of fixed nitrogen for agriculture or explosives such as TNT to fuel the war. Due to the shortage of munitions, the German army took a large amount of nitrogen compound so that was not enough left to farmers. The bad harvest caused the people to go hungry. Lack of the fertiliisers also caused the bad harvest in 1913. Haber developed his synthesis of ammonia.

Student Z

Haber developed his process of reacting nitrogen and hydrogen to produce ammonia before WWI. At first this process seemed to be able to produce ammonia needed for fertilizers, which was used to grow crops to meet the growing world population in the early 20th Century. The allies had stopped Chile's salt petre and guano exports to Germany thus Haber's process filled this demand for ammonia. Germany then used this to produce explosives due to it being made industrially due to Carl Bosch; this prolonged the war by 1 or 2 years in which approximately 1 million people died.

Question 25 (b)

Student X

$N_2(g)+3H_2(g)\leftrightarrows 2NH_3(g)$. The ideal conditions to achieve maximized yield is low temperature (200^{0}C) and high pressure (-1000atm). However, low temperature will have a later rate of reaction which made the industrial production economically unviable but high temperature will have less yield as the forward reaction is exothermic. By Le Chatelier Principle (LCP) equilibrium will shift to the left which is endothermic to reduce extra heat, although higher rate of reaction is good, better the result of less yield is undesired. High pressure (1000 atm) will shift the equilibrium to the right which has less # of gas molecules to reduce the pressure however 100atm is very hard to achieve, also high pressure will damage the catalyst ← powdered Fe_3O_4 and the maintenance of equipment at constant pressure is costly, therefore, the delicate balancing b/w energy rate of reaction and equilibrium is required. Thus, the optimised condition is at 450^{0}C 200atm with addition of powdered Fe_3O_4.

Sample answers (*scoring full marks)
2005 Chemistry Trial HSC

Question 30 – Elective Shipwrecks, Corrosion and Conservation

Student X

a) **(i)** Cathodic protection refers to the protection used on ships hulls when the iron is made to become the cathode. This can be done by either sacrificial anodes or impressed currents.

(**ii)** The process of cathodic protection is to make the iron the cathode and a more reluctant metal such as Al the anode. This means the anode will oxidise and the Fe will remain corrosion free as the water and oxygen will undergo reduction. In wet terrestrial environments, such as underground pipes, cathodic protection is used in the form of impressed current. This method is more reliable and convenient as it does not require regular maintenance and replacement of the anodes.

Student Y

a) **(i)** Cathodic Protection is protection when the metal being protected is forced to be the site of reduction.

(ii) There are 3 types of cathodic protection, galvanized iron, sacrificial anode and impressed current. For sacrificial anode, a metal more reactive than iron such as zinc B attached to the iron forcing iron to be reduced, thus zinc is oxidized.

Anode: $Zn(s) \rightarrow Zn^{2+} + 2e^-$
Cathode: (i) $Fe^{2+} + 2e^- \rightarrow Fe(s)$
(ii) $H_2O + O_2{}^+4e^- \rightarrow 4CH^-$

In a wet terrestrial environment, for example underground tanks where moisture, salt in soil can expose the metal to corrosion, by attaching sacrificial anodes the tank is protected.

Student X

b) **(i)** Knowing that static electricity causes frog legs to twitch, when he connected the frogs spinal chord with copper hooks attached to an iron railing, Galvani forced that the frog's legs to twitch even without a source of electricity. When repeating the experiment and noticing this twitching only occurred when two dissimilar metals were in contact. Galvani concluded that he had observed animal electricity where the frog produced an electrical potential between the two metals.

Volta disagreed with Galvani attributing the twitching to metallic electricity caused by the contact of two dissimilar metals with a salty solution. He supported his theory in 1800 when he produced the first battery, (voltaic pile) that had disks of silver and zinc stacked alternatively and separate in pairs with cloth soaked in brine.

Hence, whilst Galvani attributed the frog twitching to the 'vital force' of life, Volta more correctly interpreted it as metallic electricity which led to his invention of the first battery.

(ii) Michael Faraday.

Student Y

b) **(i)** Galvani believed that there is a electric conducting material within the human tissue and muscle but Volta said that it was the electric current produced that made the muscle twitch, because a galvanic cell was set up.

Galvani wrongly concluded that within the frog there is an electric conducting solution and thus when wires are attached to the frog, a transfer of current/electricity occurred and thus animal leg twitched. He called it animal electricity. Volta however discovered that it was a chemical reaction that caused this phenomenon and that it was the electric current produced by the setting up of a galvanic cell, which he proved by creating the first battery 'voltaic pile' with 2 metals alternating with a piece of cardboard soaked in an electrolyte in between. He created a battery.

Thus, Volta used the discovery of Galvani to come up with a better explanation of redox reactions.

(ii) Michael Faraday

Student X

c) In the 19th Century steel ships were used as they were strong, allowing for their use as war cargo and steam turbine ships. However, these ships regularly needed to be dry docked and cleaned due to steel's high corrosion rate in marine environments.

In the 20th Century, as new materials and development of corrosion protection systems were developed, their impact on marine going vessels were profound allowing them to have created corrosion resistance and this not need to be dry docked so they can travel longer distances. For example, the extraction of alluminium, a passivating metal on a large and cost effective scale, has prompted its uses as hulls of light weight marine going boats, due to its light weight, increased speed and corrosion resistant properties, although its lightness restricts its use in larger vessels.

Also, alloys of steel containing passivating metals, such as chromium and nickel (like in stainless steel) has corrosion resistant properties, allowing it to be used as fittings for marine going vessels. Its cost, however, prevents its use on larger scales, e.g. hulls.

The invention of laser beam technology in the 20th Century also allowed the production of surface alloys. By bombarding and thus embedding chromium and nickel atoms on the steel's surface, a passivating oxide layer is formed protecting the steel from corrosion, without too much expensive Cr and Ni atoms needed to be added. These alloys can also be used in some parts e.g. keels of ships due to its increased corrosion resistant properties.

Furthermore, paints have been developed that provide a physical barrier between the iron atoms and oxygen and water that cause corrosion. For example, Rustmaster when applied, forms an insoluble, tightly bound mineral layer (pyroaurite) with the iron surface, protecting it from corrosion. However, this corrosion protected system requires regular maintenance to prevent cracks. As a result some ships/ferries are pointed both above and below water surface with these paints to reduce corrosion, even the Harbour Bridge is painted as such.

The most significant impact on the construction of marine going vessels is our increased knowledge of metal transfer reactions allowing us to use cathodic protection of steel. By attaching more active metals (e.g. zinc) to steel hulls, zinc (or etc) preferentially oxidises, i.e. $Zn \rightarrow Zn^{2+} + 2e^-$ making the steel structure the cathode and protecting it from corrosion. This is very effective in reducing corrosion and needs only little maintenance, ie replacing zinc blocks. Hence the impact of new materials etc on marine going vessels is profound, allowing them to require less maintenance and travel further distances. This has reduced the cost of maintaining such vessels, leading to the more extensive use of vessels, e.g. speed boats by the community.

Student Y

c) In Ancient times, boats were made of raw materials e.g. bamboo covered in fur. As time went on boats were made of wood which with the advent of the Bronze Age were easier to make and metal nails were used. Metal sheeting began to be used to prevent the biofouling of wood by marine organisms (especially that of copper which is toxic to the marine worms) The metal sheeting was nailed to the wood with metal bolts which were repeatedly changed over time as an attempt was made to prevent the corrosion that occurred between certain types of metals used. Around the 20th Century hulls begun to be constructed completely of metal, due to its greater strength (compared to wood) and as it was not decayed by marine organisms. This use of metal began a process of the development of corrosion protection systems on the production of marine going vessels. Paint e.g. zinc-rich paint and rustmaster paint are used on hulls of ships to create a physical barrier between the metal and its corrosion conditions (water and oxygen), however, paints can be scratched creating a vulnerable section in the metal. Rust is porous so it can occur deeper and deeper into the hull of an iron ship without being noticed. Paints are difficult to maintain as the ship must be dry docked before it can be re-painted. Cathodic protection (explained in question a) is used but can be quite expensive as significantly sized clumps are needed to protect the hull. They also must be replaced quite often. Impressed current is another way that corrosion is prevented in ships today. A circuit is set up from the hull to the propeller making the hull the anode (if connected to external circuit, anode is site of reduction). The elections are pushed from the propeller to the hull, protecting it from corrosion.

Student Z

c) Ships have a long history of development, from wooden boats, to metal sheeting and then iron boats. In the 20th Century, iron and steel are the main components of ship building. However, a constant problem with these materials is corrosion, i.e. rusting.

Methods of protection have been developed over time to protect ships & they include epoxy resins, paint, rustmaster, paint high in zinc content, cathodic protection, surface alloying etc.

Paints such as epoxy resin provided a good protection for the outside of the ships as it provided a physical barrier but they are not abrasion resistant, a scratch or crack will increase the speed at which corrosion attacks. New paints have been developed and they include rustmaster which forms a strong physical coating which bonds with the iron and thus stops corrosion. Paint high in zinc content acts as a sacrificial anode in which the iron hull of the ship is forced to be reduced. Paints require high maintenance and need to be repainted if scratched and thus not economical.

Surface alloying such as stainless steel or the addition of other metals (e.g. Cr) increase corrosion resistance but they are expensive.

Cathodic protection such as impressed current is used in the protection of ship hulls in particular in the 20th Century as it is convenient, low maintenance and protects areas hard to access by humans.

Student X

d) **(i)**

1. Place 4 clean, dry, identical iron nails in separate, clean, dry, labeled small tubes.
2. In the first tube, half fill with distilled water.
3. In the next, half fill with salty water (i.e. where 2 teaspoons of table salt have been dissolved in 200mL).
4. In the third, half fill with vinegar.
5. Leave the last test tube as is.
6. Repeat steps 1-5 with stainless steel nails the same shape/size as the iron nails.
7. For 2 weeks, record the level of rusting (i.e. orange flakey deposits on nails and bottom of test tube) daily at the same time of day, rating the level of rusting from 1-10 (i.e. 1 being least and 10 being highly rusted).

In this experiment, the results obtained would comprise of the stainless steel nails not rusting at all whilst the iron nails would have rusted in varying degrees i.e. least to most rusting in water-less nail, half water filled nail, in vinegar nail and then salty nail hence this would have indicated that iron corrodes more extensively than stainless steel.

(ii) The additive of impurities impacts on the mechanical and chemical properties of iron. For example, carbon increases the mechanical strength and hardiness of steel. By filling spaces in the iron lattice to prevent its layers from sliding from sliding over one another As a result, mild steel (0.20%C) is consequently soft, malleable and easily welded causing it to be used in roofing & car panels. Meanwhile structural steel (0.3 – 0.6%C) is stronger and more rigid allowing it to be used in beams, girders and railway lines.

Similarly, passivating metals, can be added to steel to improve its corrosion resistant properties as the metals form an impermeable, strongly bound surface oxide layer. As a result, stainless steel (10 – 20% Cr, 5-20% Ni), despite having the same C content as structural steel, has its uses extended to cutlery, surgical instruments and razors due to its lack of corrosion.

Thus the different uses of steel can be accounted by their composition.

Student Y

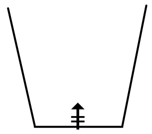
d) **(i)** The procedure of the experiments are as follows:

Method:

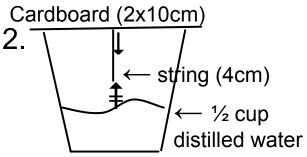
1. Set up 6 different conditions tested. Use 6 iron screws.

Key
_/ = Cup ǂ = Screw

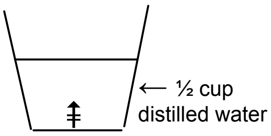
1.



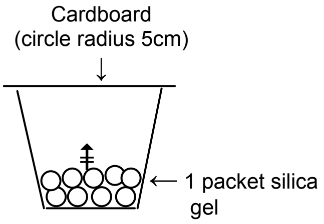
2.



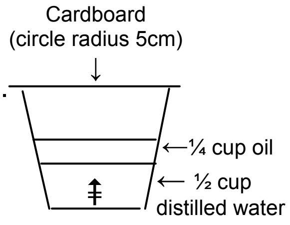
3.



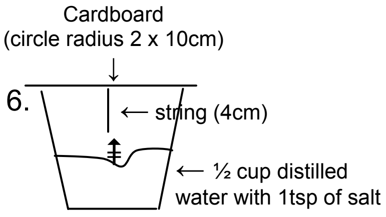
4.



5.



6.



2. Repeat step 1 for 6 stainless steel screws.
3. Make sure all cups are put in the same area so they endure the same conditions.
4. Leave for 12 days and record observations each second day.
5. Repeat steps 1-4.

It was found that the iron screws rusted while no stainless steel rusted. This is due to the composition within the iron, as impurities (e.g. C) provided cathodic areas for corrosion to occur, while alloying of steel in stainless steel such as chromium (passivating metal) prevents the metal from rusting.

For the iron screws tested, screws in air (condition 1), screw in silica gel (condition 4) did not rust because moisture (water) essential for rusting is not present. Condition (2), (3), (6) rusted as they are exposed to oxygen and water, which are both essential for rusting. However, condition (6) rusted faster as salt solution is a stronger electrolyte than water.

Condition (5) rusted in the first couple of days but did not rust further. This is because the rust occurred due to dissolved oxygen in water and after all the dissolved oxygen has reacted, there is not more oxygen present (blocked by layer of oil) and thus corrosion can’t continue to occur.

d) **(ii)** Mild steel contains ,0.2%C, so it is soft, malleable and ductile. Due to these properties it is used for roofing and car bodies.

Structural steel contains 0.3-0.6%C, so it has increased hardness and thus used for beams and girders. However, it corrodes more quickly than mild steel.

Stainless steel contains the alloying of other metals such as Chromium and Nickel which make it very resistant to corrosion & of high tensile strength. Chromium is a passivating metal and thus protects the steel from corrosion. Thus, it is used in cutlery and surgical instruments where corrosion must be minimal. However, it is expensive to produce stainless steel and thus not used in all products.