Chemistry - 2006

HAHS Trial HSC Examination

Exemplar Answers

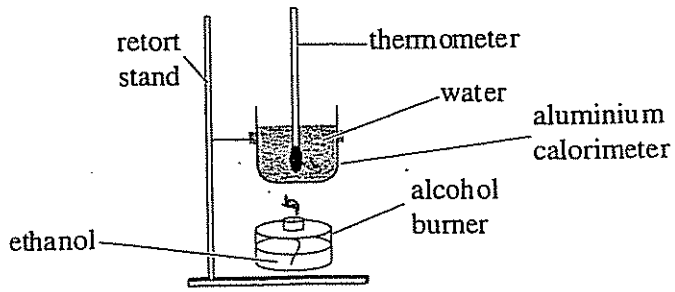
	A	B	C	D	
1	●	○	○	○	✓
2	●	○	○	○	✓
3	○	●	○	○	✓
4	○	○	○	●	✓
5	○	○	○	●	✓
6	●	○	○	○	✓
7	○	○	●	○	✓
8	○	○	●	○	✓
9	○	○	○	●	✓
10	○	●	○	○	✓
11	○	○	●	○	✓
12	○	○	○	●	✓
13	○	○	●	○	✓
14	○	●	○	○	✓
15	○	●	○	○	✓

15/15

Marks

Question 16 (6 marks)

A student assembled the following equipment in order to determine the molar heat of combustion of ethanol.



Experimental results found that the temperature of 100 mL of water increased from 18°C to 58°C on burning 0.76 g of ethanol.

(a) Define the term *molar heat of combustion.* 1

The amount of heat liberated when one mole of a substance undergoes complete combustion at 1 atm to produce Carbon dioxide and liquid water. (1)

(b) Write a balanced chemical equation to show the complete combustion of ethanol. 1

$C_2H_5OH_{(aq)} + 3O_{2(g)} \longrightarrow 2CO_{2(g)} + 3H_2O_{(l)}$ (1)

(c) Calculate the molar heat of combustion of ethanol based on the experimental results. 2

$m = 100$, $\Delta t = 58 - 18 = 40$, $m(\text{ethanol}) = 0.76\,g$ (2)

$\Delta H = -mc\Delta t$

$= -100 \times 4.18 \times 10^{-3} \times 40\ kJ / 0.76\,g$

$= -16.72\ kJ / 0.76\,g$

$= -1013.496\ kJ/mol$ $\Delta H_c = 1013.496\ kJ/mol$

$n(\text{ethanol}) = \frac{0.76}{2\times12.01 + 6\times1.008 + 16} = 0.0164\ mol$

(d) Explain how this calculated value would compare to the theoretical value. 2

This calculated value would be lower than the theoretical value, due to heat lost to the surroundings (such as the air) and/or other factors such as incomplete combustion. (2)

(a) Define the term *molar heat of combustion.* 1

The molar heat of combustion is the heat liberated by the combustion of a fuel in its standard state at standard conditions. (1/2)

(b) Write a balanced chemical equation to show the complete combustion of ethanol. 1

$C_2H_5OH + 3O_2 \xrightarrow{heat} 2CO_2 + 3H_2O$ (1)

(c) Calculate the molar heat of combustion of ethanol based on the experimental results. 2

$\Delta H = -mc\Delta t$

$= -(100)(4.18)(58-18)$

$= 16\,720\ J$

$= 16.72\ kJ$

$M_{C_2H_5OH} = 2\times12.01 + 1.008\times6 + 16 = 46.068$

$n = \frac{m}{M} = \frac{0.76}{46.068}$

$= 0.0164\ldots\ mol$

$\frac{\Delta H}{n} = \frac{-16.72\ kJ}{0.0164\ldots\ mol}$ (2)

$= -1013.50\ kJ/mol$

∴ The molar heat of combustion is $1013.50\ kJ/mol$

(d) Explain how this calculated value would compare to the theoretical value. 2

The calculated value would be less than the theoretical value. This is due to the loss of heat from the flame to the environment, from the water's surface to the environment and from the water to the calorimeter. Therefore, the value of ΔH is less than it should be and so the magnitude of ΔH (molar heat of combustion) will be less than the theoretical value. (2)

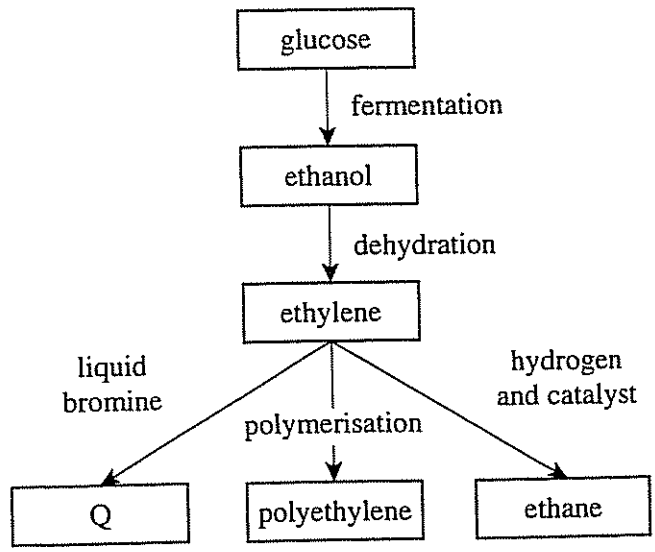
(d) Explain how this calculated value would compare to the theoretical value.

Thus calculated value would be less than the theoretic value. The difference could be due to incomplete combustion as seen in the soot formed at the bottom of the beaker (2) hindering heat transfer from wick to water. The theoretic value considers complete combustion of ethanol

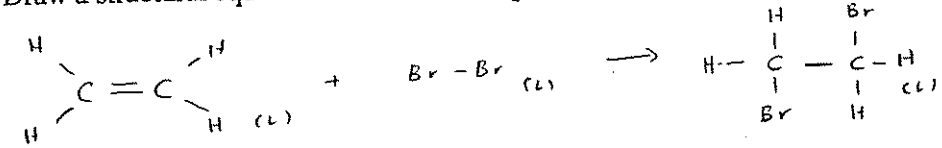
Marks

Question 17 (4 marks)

The following flow diagram shows a series of reactions.



(a) Draw a structural equation to illustrate the production of Q. 1



(1)

(b) Ethylene can be readily converted into ethane. Give a reason for the presence of a catalyst in this reaction. 1

The catalyst lowers the activation energy requirement for the reaction to occur and thus, speeds up the rate of reaction. (1)

(c) Polyethylene can be used as a cling film. Describe this use in terms of its properties. 2

Polyethylene used in cling film is known as low density polyethylene and this type is flexible and has low density. Thus its flexibility allows it to stretch to cover food. It is also quite resistant which is important in the use of cling-wraps as it protects food from being contaminated. (2)

Marks

Question 18 (3 marks)

On February 1, 2004, the synthesis of the transuranic elements ununpentium (Z = 115) and ununtrium (Z = 113) was reported by Russian and American scientists.

Describe how transuranic elements such as ununpentium and ununtrium may be synthesised and identify ONE safe practice which must be adopted when working with radioactive elements such as these. 3

Transuranic elements are elements with an atomic number greater than 93. Transuranic elements can be produced in nuclear reactors whereby an appropriate target nuclei is placed in the nuclear reactor (such as uranium) and is bombarded with neutrons to form a transuranic element. Alternatively, heavy nuclei can be collided with each other in cyclotrons or particle accelerators to produce a transuranic element. Transuranic elements such as ununpentium have very short half-lives and so very readily emit harmful radiation which can cause cancer etc. Therefore, those working near or with these radioactive elements need to wear appropriate, protective clothing and glasses to protect them from the radiation. (3)

Describe how transuranic elements such as ununpentium and ununtrium may be synthesised and identify ONE safe practice which must be adopted when working with radioactive elements such as these. 3

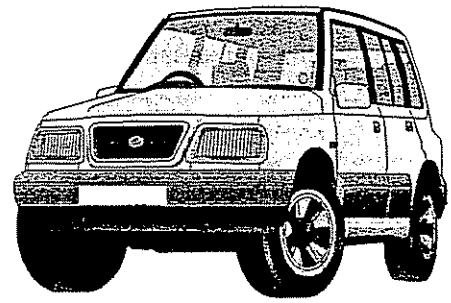
Transuranic elements such as ununpentium and ununtrium are produced in particle accelerators. Here, smaller nuclei are accelerated to extremely high speeds (usually using electromagnetic fields) and then collided into the nucleus of another, usually larger, atom. For example Hassium-266: (Iron-58 nucleus collided with Lead-208 nucleus) $^{208}_{82}Pb + ^{58}_{26}Fe \longrightarrow ^{266}_{108}Hs$ (3)

One safe practice used when handling radioactive elements such as these is to minimise exposure to the harmful radiation produced. This can be done by wearing lead protective clothing (eg lead apron), storing in suitable lead containers and working with them behind lead shields.

Marks

Question 19 (5 marks)

A new vehicle is said to combine hybrid-electric power with the capability of operating on a mixture of 15 per cent petrol and 85 per cent ethanol.



Evaluate the likelihood of the success of ethanol as an alternative fuel.

At the moment ethanol isn't a successful fuel in Australia because the cost of building infrastructure to produce ethanol far exceeds the cost of producing petroleum from crude oil supplies. However crude oil is a finite resource & is expected to 'run out' in the next couple of decades. And as a result, as crude oil commodities diminish prices for its products will inevitably increase. Thus in the future an alternative fuel, such as ethanol will be more ~~economically~~ economical to produce! and thus will increase in its use in ~~to~~ car fuels. / 5

ethanol has numerous properties which make it a good fuel alternative. It is ~~biodegra~~ produced from plant material & thus is readily renewable (plants take 3 mths to develope before harvesting. Also ethanol has a high flash point (+13°) compared to petroleum (-43°) and thus is less likely to form an explosive mixture with air. currently cars have the potential to run of ethanol fuel blends comprising 10-15% ethanol, however in excess of this amount will require engine modifications as rusting will occur.

In contrast to the benefits of ethanol over petroleum its downside is that large quantities of land need to be cultivated & managed to provide the feedstock needed to produce sufficient quantities of ethanol. The production is also very expensive and does not liberate the same amount of energy as petroleum.

However as crude oil reserves diminish so the push for alternative fuels will increase. As mentioned above currently much of the petrol used in cars contains small traces of ethanol. If ethanol was to be increased car modifications will need to occur to prevent damage. this is relatively expensive but as crude oil prices increase will become more economical. Thus in the future ethanol will be used as an alternative fuel particularly in cars where fuel blends might exceed 85% ethanol 15% petrol.

5

Evaluate the likelihood of the success of ethanol as an alternative fuel.

The combustion of ethanol is an exothermic reaction, so it could be a potential fuel source. Also, it is a biomass fuel, and would be strongly desired over non-renewable forms of fuel. For these reasons, ethanol is being considered as a possible alternative to the depleting crude oil supplies. 5

Advantages:

- Renewable as it can be produced from sugar cane and other biomass. $C_6H_{12}O_6 \xrightarrow{\text{fermentation}} 2C_2H_6O + 2CO_2$.
- It would reduce the dependance on finite crude oil.
- It could lower [CO] and [CO_2] in atmosphere (always)
  - → Undergoes more complete combustion due to presence of Oxygen atom
  - → CO_2 is returned to make biomass (photosynthesis).

Disadvantages:

- It would compete with food crops for suitable growing land.
- Costly conversion of current cars (only mod. (15% now).
- Increase water use, which is a problem especially in drought
- Increased soil salinity.
- It is a less 'powerful' fuel than octane, and hence more frequent 'fill ups' would be needed.

Evaluation: It has great potential as an alternative fuel in future, although not currently economically viable, it is the most suitable alternative in the future.

Evaluate the likelihood of the success of ethanol as an alternative fuel.

There are many advantages of using ethanol as a fuel source: 5

- it is made from renewable resources
- combusts more completely than petrol, thus causing less pollution
- it can be made in Australia, therefore providing more jobs
- cheaper to produce than petrol, so it is cheaper to run cars on ethanol

However, there are also problems involved with the use of ethanol as a fuel:
- engines would need expensive readjustments
- land to grow biomass to produce ethanol would compromise land for food.

Although, if new cars all had engines made to run from higher percentages of ethanol, one of the disadvantages would be cancelled out. Therefore, if cars were structured to run off ethanol, its use as a fuel would be advantageous and as such be successful as an alternative fuel.

Evaluate the likelihood of the success of ethanol as an alternative fuel.

Ethanol is unlikely to be a successful alternative fuel because of all the drawbacks of its use.

Firstly, while ethanol is a renewable resource, it is more expensive to produce than conventional petrol. This will increase the cost of fuel and deter users from it. (+)

Secondly, to produce ethanol on a large scale a lot of agricultural land is required to meet the demand to grow crops as a source of glucose for fermentation. This can lead to unsustainable farming, causing problems such as erosion and deforestation. These problems, along with the monetary cost, will result in a halt of ethanol production.

Thirdly, ethanol is 100% miscible with water so, if water enters the fuel tank, it can dissolve in the engine and precede to cause corrosion of the engine. This will further deter people from using it, as repairing it would be expensive.

Fourthly, ethanol produces less energy per gram than petrol. This means more fuel will be required to travel the same distance. This further increases the cost

of fuel for the consumer and may lead to cars being ineffuent if say, larger tanks are employed as it adds mass to the car.

Ethanol has several advantages to its use - it is a renewable resource, it combusts more completely due to the presence of an oxygen atom and has the potential to decrease the emission of greenhouse gases if solar energy is used to distil it.

Despite these advantages however, it has downfalls which will inevitably inhibit its success as an alternative car fuel. So, unless these problems can be solved, petrol will continue to be the dominant fuel.

Marks

Question 20 (6 marks)

Although the atmosphere naturally contains acidic oxides of carbon, nitrogen and sulfur, the levels of these oxides have been increasing since the industrial revolution.

It has been observed that the pH of rainwater is lower near significant sources of these gases.

(a) Account for the increasing concentration of oxides of nitrogen (NO_x) in the atmosphere. 2

Increasing concentration of NO_x in the atmosphere is largely due to the increase in car use and its by-products it produces $N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$ Also from the increased demand & thus combustion of fossil fuels, that have increased significantly throughout time. (2)

(b) Explain the formation of acidic solutions from oxides of nitrogen and evaluate reasons for concern about the effects of acid rain. 4

Acid rain forms when NO_x combine with moisture in the atmosphere. $NO_2 + H_2O \rightarrow H_2NO_3$. This results in the pH of rain decreasing to an acidic level. Acid rain has numerous detrimental effects in our environment. When entering river systems it decreases the pH of the water & thus dramatically impacts on fish populations in the following ways
- fish eggs only hatch if the pH is above an optimum level eg pH is for salmon.
- decreased pH reduces calcium uptake in fish & thus limits their growth & development thus leading to more smaller sick fish which are easily preyed upon by larger fish.

Acid rain also effects forrests causing defoliation. As a result photosynthesis & thus food production is decreased because the tree can ~~also suffer~~ convert sufficient amounts of sunlight into food. acid rain also decreases the plants ability to survive in frosts & extreme weather conditions. acid rain also erodes building made out of $CaCO_3$ & Fe. This can be potentially deadly to humans & thus needs monitoring. (4)

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(a) Account for the increasing concentration of oxides of nitrogen (NO_x) in the atmosphere. 2

The invention of the car, and the increased use of the car over time, ~~due to~~ the advent of electricity generated by power stations. Both are sources of sparks that combine nitrogen & oxygen to form oxides of nitrogen: $N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$ $2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)}$ (2)

(b) Explain the formation of acidic solutions from oxides of nitrogen and evaluate reasons for concern about the effects of acid rain. 4

Nitrogen monoxide is formed from the reaction of nitrogen & oxygen: $N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$
The NO, then reacts with O_2, forming NO_2: $2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)}$.
The nitrogen dioxide reacts with water, forming acidic solutions: $2NO_{2(g)} + H_2O_{(l)} \rightarrow HNO_{3(aq)} + HNO_{2(aq)}$. The nitrous acid then reacts with oxygen to form nitric acid: $2HNO_{2(aq)} + O_{2(g)} \rightarrow 2HNO_{3(aq)}$. (4)
Acid rain can lower the pH of lakes, or even the ocean, having detrimental effects on ecosystems. Aquatic organisms could die from the raised acidity, altering food chains. Acid rain can also damage marble statues: $2HNO_{3(aq)} + CaCO_{3(s)} \rightarrow Ca(NO_3)_{2(aq)} + CO_{2(g)} + H_2O$
This causes it is expensive to fix the damage, and some may not be able to be recreated, meaning loss of possible historical architecture. As a result, the effect of acid rain is negative, and are of significant concern

Marks

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It has been observed that the pH of rainwater is lower near significant sources of these gases.

(a) Account for the increasing concentration of oxides of nitrogen (NO_x) in the atmosphere. 2

The increase use of motor vehicles and power stations has lead to the increase of NO emissions due to the high temperatures in combustion engines which combine nitrogen and oxygen. The increased use of nitrogen fertilisers has also lead to increased emissions of N_2O as microbes in soils have more nitrogen to decompose with. Therefore, there are increasing concentrations of NO_x in the atmosphere. (2)

(b) Explain the formation of acidic solutions from oxides of nitrogen and evaluate reasons for concern about the effects of acid rain. 4

Oxides of nitrogen can dissolve in and react with water to form acid rain: $NO_{2(aq)} + H_2O_{(l)} \rightarrow HNO_{3(aq)} + NO$. (4)
NO can also react with oxygen to produce NO_2, which subsequently reacts with water to form nitric acid. The concerns about acid rain are justifiable due to the negative impact it can have on the man-made and natural environment. It can fall into bodies of water and increase it's acidity, killing aquatic organisms. It can damage the waxy cuticle on leaves of plants and increase the acidity of soils, inhibiting ion uptake from plants. Acid rain can also displace metals on man-made structures:
$Fe_{(s)} + HNO_{3(aq)} \rightarrow H_{2(g)} + Fe(NO_3)_{2(aq)}$.
It can also damage limestone structures: $2HNO_3 + CaCO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2$.
These impacts of acid rain are definitely reason for concern as they will clearly damage natural and man-made environments.

The acid can dissociate in water: $HNO_{3(aq)} \rightleftharpoons H^+_{(aq)} + NO_3^-{}_{(aq)}$, thus increasing the acidity of rain by lowering the pH.

Question 21 (3 marks)

During the HSC Chemistry course you performed a first-hand investigation in which you identified the pH of a variety of salt solutions. If solutions of NH_4Cl and Na_2CO_3 were used in this task, predict the acidic, basic or neutral nature that you would identify. Justify your prediction, including relevant equations in your answer. 3

NH_4Cl would be acidic because it was produced from a weak base and strong acid: $HCl_{(aq)} + NH_{3(aq)} \rightarrow NH_4Cl_{(aq)}$. Therefore, NH_4^+ is a strong conjugate base that reacts with water to produce hydronium ions: $NH_4^+{}_{(aq)} + H_2O_{(l)} \rightarrow NH_{3(aq)} + H_3O^+_{(aq)}$, thus increasing the acidity of the solution. (3)

Na_2CO_3 would be basic because it was produced from a strong base and weak acid: $2NaOH_{(aq)} + H_2CO_{3(aq)} \rightarrow Na_2CO_{3(aq)} + 2H_2O_{(l)}$. Therefore a strong conjugate base, CO_3^{2-} is formed, which reacts with water to produce hydroxide ions, decreasing the acidity of the solution, making it basic.

$CO_3^{2-}{}_{(aq)} + H_2O_{(l)} \rightarrow HCO_3^-{}_{(aq)} + OH^-{}_{(aq)}$

Question 21 (3 marks)

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For NH_4Cl: $NH_4Cl_{(aq)} \rightarrow NH_4^+{}_{(aq)} + Cl^-{}_{(aq)}$. Cl^- is the weak conjugate base of a strong acid (HCl), while NH_4^+ is the strong conjugate acid of a weak base (NH_3). As a result, the NH_4^+ will react with water: $NH_4^+{}_{(aq)} + H_2O_{(l)} \rightarrow NH_{3(aq)} + H_3O^+_{(aq)}$ (3)

$H_3O^+_{(aq)}$ — acidic

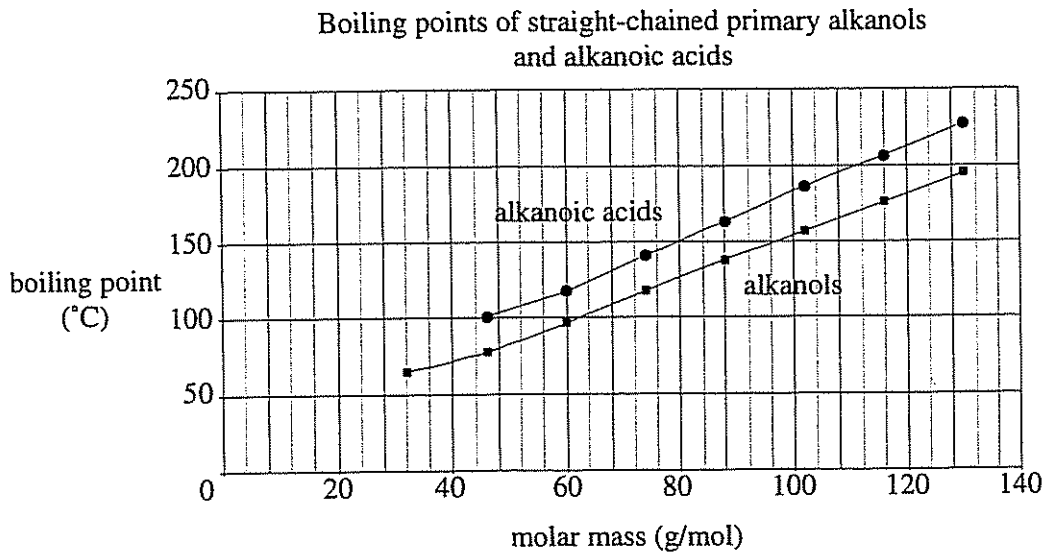
$\therefore NH_4Cl$ is an acidic salt.

For Na_2CO_3: $Na_2CO_{3(aq)} \rightarrow 2Na^+{}_{(aq)} + CO_3^{2-}{}_{(aq)}$. Na^+ is the weak conjugate acid of a strong base ($NaOH$), while CO_3^{2-} is the strong conjugate base of a weak acid (H_2CO_3). As a result, the CO_3^{2-} will react with water: $CO_3^{2-}{}_{(aq)} + H_2O_{(l)} \rightarrow HCO_3^-{}_{(aq)} + OH^-{}_{(aq)}$

$OH^-{}_{(aq)}$ — basic

$\therefore Na_2CO_3$ is a basic salt.

Question 22 (5 marks)



(a) Using the graph above, explain the trend observed in the boiling points for molecules of the same molar mass. **3**

In the graph, alkanoic acids of equal (approx.) ~~boiling pt~~ molar mass to (corresponding) alkanols have greater boiling points. This is due to their carboxyl ($C^{=O}_{-O-H}$) functional group, which allows two strong hydrogen bonds to be formed between its molecules. The hydroxy (O-H) functional group of the alkanols is also polar, but can only form one hydrogen bond. Thus, the ~~hyd~~ forces between molecules is greater for alkanoic acids than alkanols ∴ bp is higher, as more energy is required to dissociate the molecules. Also, as molar mass ↑, bp↑ ('heavier' molecule = stronger intermolecular forces). (3)

(a) Using the graph above, explain the trend observed in the boiling points for molecules of the same molar mass. **3**

From the graph, the boiling points of alkanoic acids is higher than the alkanols of the same molar mass. As shown, the molar mass of 60 for both alkanoic acids & alkanols has a boiling point of 120 & 98 respectively. This ~~suggests~~ demonstrates the strength of intramolecular bonds being more evident due to a slightly more polar alkanoic acid relative to the alkanol (1)

(a) Using the graph above, explain the trend observed in the boiling points for molecules of the same molar mass. 3

Molecules of alkanols and alkanoic acids with the same molar mass have different boiling points. Despite having the same mass, the boiling points of alkanols are lower than their corresponding alkanoic acids (as shown in the graph). This is due to the extra hydrogen bond between alkanoic acid molecules compared to the alkanol. Alkanols have dispersion forces, as well as a H-bond from the OH. Alkanoic acids (of the same mass), however, have dispersion forces and two H-bonds from the COOH. As a result, more energy is required to break the extra H-bonds in the alkanoic acid, meaning a higher boiling point than the corresponding alkanol. (3)

(b) Many products found in the supermarket contain acids or esters. Some of these are extracted from natural resources but an increasing number are being synthetically prepared. 2

Providing specific examples, outline the use of acids and esters in food products.

Acids such as ethanoic acid (CH_3COOH) - vinegar are available in food products. Acids such as SO_4^{2-} can be added to foods such as meat products to make them appear more fresh and this acid ion becomes H_2SO_4. (2)

Esters are commercially used as flavourings eg Ethyl Methanoate (a rum flavouring that may be used in things like Rum and Raisin icecream where alcohol is not a good additive) or in the cosmetics industry (for things i.e. flavourings or scents) for lipgloss eg Ethyl Butanoate is a pineapple scent.

(b) Many products found in the supermarket contain acids or esters. Some of these are extracted from natural resources but an increasing number are being synthetically prepared. 2

Providing specific examples, outline the use of acids and esters in food products.

Acids & esters are often added to food products as flavourings, or more specifically to add flavours. Acids such as citric is often added to jams to add a sharp fruity flavour & is done so as a flavour enhancer. Esters, such as pentyl propanoate is banana flavouring which is often used in flavoured milks as the basis of the flavour. (2)

(b) Many products found in the supermarket contain acids or esters. Some of these are extracted from natural resources but an increasing number are being synthetically prepared. **2**

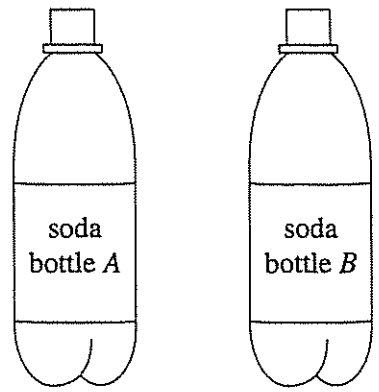
Providing specific examples, outline the use of acids and esters in food products.

Esters are used to flavour food products. eg. pentyl ethanoate is the banana-flavoured esters, used in banana-flavoured lollies or ice-cream paddle-pops. The taste and smell is added, without the 'browning' effect of natural banana. Citric acid is added to food products to give it a sharp, sour taste eg. in sour lollies. It also acts as a preservative for the food products. (2)

Marks

Question 23 (4 marks)

The following results were obtained during an investigation involving the decarbonation of two bottles of soda water. Each bottle was opened for a 24-hour period before re-sealing.



	bottle *A*	**bottle *B***
Initial mass of sealed bottle (g)	125.5	125.5
Final mass of sealed bottle (g)	125.1	124.8
Change in mass (g)	0.4	0.7
Room conditions	cold	warm
Volume of CO_2 released at 25°C and 100 kPa (mL)	225.3	

(a) Calculate the volume of carbon dioxide (CO_2) gas lost from bottle *B* at 25°C and 100 kPa. **1**

$m(CO_2) = 125.5 - 124.8$

$= 0.7g$

$n(CO_2) = \frac{m}{M}$

$= \frac{0.7}{44.01}$

$= 0.0159... mol$

$V(CO_2) = 0.0159... \times 24.79$

$= 0.394291... L$

$= 394.3 mL$ (4 sig figs)

How many digits should I use in calculations and include in my answers?

As a general rule, the answer should have the same number of significant figures as the number of significant figures in the data with the least number.

What is a significant figure? Significant figures tell us about the implied accuracy to which a quantity has been measured or calculated.

e.g.

- 1.49 m tells us that the distance has been measured to the nearest cm whereas 1.492 m tells us that it's been measured to the nearest mm. The measurement 1.49 has 3 significant figures and 1.492 has 4 significant figures.

How do you count the number of significant figures?

- All non-zero digits are significant e.g. 1.298 m s^{-1} has 4 significant figures and is a speed measured/calculated to the nearest mm s^{-1}
- Leading zeroes are not counted e.g. 0.0023 has two significant figures.
- Trailing zeroes before a decimal point are not counted unless there are significant digits after the decimal point e.g. 1200 has 2 significant figures but 1200.1 has 5
- Zeros after a decimal point are always significant e.g. 21.00 has 4 significant figures.

While doing the calculation, do not round at intermediate steps. Only round your final answer. When rounding, 5 or above goes up and less than 5 goes down.

e.g. 2.34 rounds to 2.3 whereas 14.85 would round to 14.9 and if you rounded this further it would be 15 (no decimal point)

So finally a couple of examples to clarify:

If distance and time were accurately measured a 12.1 m and 2.987 s then the calculator value of the speed would be 4.050887 but should be stated as 4.05 m/s

(b) In each bottle the following equilibrium process exists:

$$CO_{2(g)} + H_2O_{(l)} \rightleftharpoons H_2CO_{3(aq)} + \text{heat}$$

Explain the difference in the volume of carbon dioxide lost from the two bottles in terms of Le Chatelier's Principle. 3

When the system was warmed, a greater amount of CO_2 was lost.
From the eqn, the forward RXN is exothermic.
Le Chatelier's principle states, when a system at equilibrium is disturbed, the position of equilibrium will shift to minimize the disturbance.
Hence this system would try to ~~other~~ minimise the increase in heat in bottle B, by favouring the endothermic reverse reaction. Hence, this will favour formation of gaseous CO_2, and a greater volume of CO_2 will be released from cans.

3

(b) In each bottle the following equilibrium process exists:

$$CO_{2(g)} + H_2O_{(l)} \rightleftharpoons H_2CO_{3(aq)} + \text{heat}$$

Explain the difference in the volume of carbon dioxide lost from the two bottles in terms of Le Chatelier's Principle. **3**

Le Chatelier's Principle states that "if a system at equilibrium is disturbed, the position of equilibrium will shift to minimise the disturbance" As the above reaction is exothermic, adding heat to the system will favour the reverse reaction, to partially counteract the imposed change (as by le Chatelier's Principle). Thus, adding heat would favour the production of reactants i.e. $CO_{2(g)}$. This is what occurred in soda bottle B, which was warm. Cold soda bottle A, thus favoured the forward exothermic reaction, to minimise the imposed change (of reduced heat, by replacing it). Thus, $CO_{2(g)}$ was used up. Bottle B had released more $CO_{2(g)}$ than bottle A, which dissolved ↑ $CO_{2(g)}$, ∴ less CO_2 lost.

3

Question 24 (3 marks)

Evaluate the significance of the Haber process at that time in world history. **3**

The Haber Process - converting atmospheric $N_{2(g)}$ and $H_{2(g)}$ into $NH_{3(g)}$ - was a major factor furthering the first World War. It allowed the Germans to continue to produce explosives and gunpowder (of which the nitrogen from ammonia is a primary constituent) when their ~~Americ~~ supply of saltpetre had been cut off from Chile. Thus, the WWI was allowed to continue for many more years, resulting in thousands/millions of deaths. The Russian Revolution, which also caused hardship for many peoples, was a further result of the prolonged war. The Haber process also allowed nitrogenous fertiliser production, and thus food production to be increased. (a benefit for growing populations) However, the detriment of the Haber process far outweighed this advantage, making it a significantly negative innovation at that time in world history.

3

Question 24 (3 marks)

Evaluate the significance of the Haber process at that time in world history.

3

The Haber process was first developed in 1908, but not used until 1914, during the war (WWI). The Germans major supply of fertiliser for producing lead, and nitric acid for producing explosives came from saltpetre imported from Chile ($NaNO_3$ or KNO_3). However, the British navy intercepted that supply, which forced the Germans to look for alternatives. This is when the Haber process was adopted; which was suitable, as it could produce ammonia from atmospheric nitrogen and oxygen. (which was found in Germany amazingly). This allowed Germany to continue fighting in the war. Hence, in that time in world history, the Haber process had a large negative impact, but significant.

3

Question 24 (3 marks)

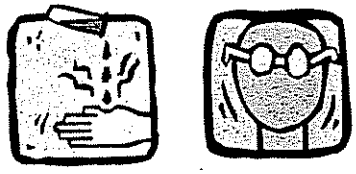
Evaluate the significance of the Haber process at that time in world history.

3

At the time in world History, the Haber process was developed to cater for the increasing demand of nitrates. This was because the war meant military required nitrates to make ammunition and TNT. Also, the growing European population meant an increased demand for food and thus, demand for nitrates to make fertilisers to grow the crops. For the starving society, the Haber process was extremely beneficial as nitrates could be made into fertilisers without having to rely on saltpetre from Chile (then blocked off by British Navy). The Haber process relieved a starving population by providing a reliable source of nitrogen. However, it also had a detrimental effect. No longer relying on Chile, Germany created its own ammunition which prolonged the war effort. This drastically increased the number of war fatalities.

3

Question 25 (5 marks)



It is well known that safety glasses should always be worn during practicals involving acids since spills and splashes can occur. The corrosive nature of acids can damage workbenches or pose a risk to people working in the lab.

A handbook for risk assessment states:

'To minimise risk, large acid spills should be neutralised with lime ($CaCO_3$) before mopping up.'

Assess this recommended method. 5

The risk assessment method for acid spills ~~isn't very~~ is relatively efficient/advantageous. The large acid spill should (ideally) be mopped up before it is neutralised, ~~so~~ NO - too dangerous, as to minimise/prevent further damage from the acid spreading, i.e. it allows the spill to be better contained. $CaCO_3$ is a solid, thus it is easy to transport, store, and supply/apply, making it ideal for use. Also, $CaCO_3$ will bubble when reacting with the acid (due to $CO_{2(g)}$ release), which may pose a breathing hazard in small/enclosed spaces, but is advantageous in that it is easy to detect when the substance is neutralised i.e. when the bubbling stops. The recommended method does not include that the site should be washed/rinsed after words (as it should) nor how to dispose of the products, which are both concerns. Also, as neutralisation is an exothermic reaction, it should be stated that care must be taken from excess heat. Overall, this method provides a reasonable hazard/acid neutralisation procedure.

5

Assess this recommended method. 5

This recommended method would be useful in cleaning large acid spills.

Lime can act as a base and neutralise the acid - the intended purpose of its use. If the acid was sulfuric acid, say: $H_2SO_{4(aq)} + CaCO_{3(s)} \rightarrow H_2O_{(l)} + CO_{2(g)} + CaSO_{4(s)}$. It would therefore be appropriate for neutralisation.

Lime is a stable solid and so will be easy to transport without risk. Furthermore, when applied to the

4

acid, it will not spread the acid spill like an aqueous base solution such as sodium hydroxide would. This helps to 'minimise risk' in the neutralisation by protecting infrastructure and people from further damage.

Lime is also a weak base and so the neutralisation reaction will be slow. This can 'minimise risk' as neutralisation is an exothermic reaction. The slow reaction means that not much heat will accumulate and destroy infrastructure further.

Neutralisation in general is a good way to deal with acid spill as it reduces the danger in cleaning and disposing of the acid.

Therefore, the handbook's recommendation to neutralise the acid, and to do this with $CaCO_3$ is correct.

Assess this recommended method. 5

There are some properties which make a substance suitable for neutralising acids:

→ Powder/solids are better than liquids; as they will not spread the spill further, and are more easily cleaned.

→ Weak bases are the most suitable for acid spills as they do neutralise the spill, which reduces the harmful potential problems; but also, this means that excessive production of heat (which could be produced using a strong base) can be avoided. Also, when using a weak base, if too much of the substance is added, it will not significantly damage the environment, or harm the people as it is only mild. This is especially useful when exact quantities of spill is not known.

→ Handlability: It is preferable if the substance can be handled, and hence is more convenient, and does not pose an extra risk to the cleaner.

Hence, lime is a solid, weak base which can be handled; which makes it suitable for cleaning up acid spills.

This statement is hence very informed and correct.

Question 26 (4 marks)

Marks

A student was given a sample of an unknown soluble salt. She suspected the sample contained barium ions. Describe the procedures she may have used to confirm her suspicion. Include at least one precaution taken to minimise risk. **4**

She would have to place a sample of the soluble salt in a test tube and add HCl to the test tube. If her suspicions are correct, then no precipitate should form. She should get a fresh sample and add H_2SO_4 to the test tube. If Ba^{2+} ions are present, a white precipitate will form, but Ca^{2+} ions would also produce a ppt. precipitate. She should start with another fresh sample and add NaF AF^- ions. If no precipitate forms then the soluble salt has Ba^{2+} ions when adding the acid to the test tube, it is essential to pour slowly and carefully to prevent spilling down the sides and contact with hands. Additionally, safety glasses should be worn.

4

A student was given a sample of an unknown soluble salt. She suspected the sample contained barium ions. Describe the procedures she may have used to confirm her suspicion. Include at least one precaution taken to minimise risk. **4**

Before the student begins, she should put on safety goggles to prevent damage if salt solutions were spilt or splashed.

The easiest way to confirm the presence of barium ions is to do a flame test. She should take a small portion of her sample, pour it into a spray bottle and spray a thin mist into the blue flame of a bunsen burner. The flame should turn an apple-green colour indicating the presence of barium ions.

If she wanted to confirm it was barium ions further, she could add a few drops of $FeSO_4$ to a fresh sample. If a white precipitate formed, barium ions are present. (It would not be calcium ions as the flame test did not produce a brick-red flame).

4

not a good chance!

H_2SO_4 is much better

To confirm there aren't any other common cations in her sample, to a fresh sample each time, she should:

- add a few drops of NaCl solution - no precipitate should form
- add a few drops of solution with OH^- ions - no precipitate should form

If she obtained the above result, she can be quite sure it is barium ions in her sample.

Question 27 (6 marks)

Assess the impact of the use of Atomic Absorption Spectroscopy on society and on the environment.

Atomic Absorption Spectroscopy (substances (NOT just compounds)) is a technique used to identify metal ions in ~~salts~~. As such technology has enabled scientists & as a result society to learn about the importance of trace elements in our body & the detrimental effects of some of the metal ions that have been frequently used in society over the years.

Lead is one such heavy metal that has been linked to mental ~~retarding~~ retardation in children & neurological disorders in adults. Lead was identified to be a major problem to humans, however it wasn't until the use of AAS technology that standards & exposure levels were developed. As enabled ~~each~~ yearly comparisons to be made with concentrations of Pb in the environment. Since the discovery of the detrimental effects of lead it has been strictly regulated by government organisations using AAS technology ensuring the safety & well being of society. Lead petrol has been phased out & alternatives implemented.

AAS has also had significant impact in Bangladesh. As technology identified large amounts of arsenic in drinking water. ~~to be identified~~. As a result scientists devised methods to combat this issue & ensuring drinking water is safe & arsenic free. As method of removing arsenic involved using lemon, water sunlight & a PET bottle to cause a chemical rxn & precipitate out the lead. As has had significant impact on the people of Bangladesh who are now using lead free wells.

In the environment traces of molybdenum has been linked with the functioning of nitrogen fixing bacteria. Without this microbiology molybdenum deficient pastures would not be able to sustain pasture and its impact on the functioning in the entire ecosystem.

6

Question 27 (6 marks)

Assess the impact of the use of Atomic Absorption Spectroscopy on society and on the environment.

Atomic absorption spectroscopy allows for the identification of trace elements within a sample by passing a beam of light (wavelength known) through a sample containing an element known to absorb that wavelength of light. The degree of absorption indicates the amount of that element present in the sample. within society, the use of AAS in areas such as underground tunnels has revealed that the air is polluted with heavy metals such as lead, which has impacted largely on the way many people travel. Additionally, AAS has been used by scientists to discover trace elements eg. within the human body, and has thus led to their understanding of how trace elements help in the functioning of the human body, and has led to a greater awareness of society of the required dietary intakes, such as iron and sodium. In environment, the use of AAS has revealed the amount of elements present in the soil, as well as which elements are essential to plant growth. Additionally, with the use of AAS, it was discovered that high acidity in soils leads to an increase in aluminum ions within the soil, leading to aluminum poisoning of plants. Therefore, the use of AAS has impact tremendously on society and on the environment.

5

by using AAS to monitor Al levels?

Question 27 (6 marks)

Assess the impact of the use of Atomic Absorption Spectroscopy on society and on the environment.

Atomic Absorption Spectroscopy (AAS) is a method used to detect trace concentrations of elements in the 'ppm' range. The use of AAS has had a very positive impact on the environment & society.

AAS has allowed for the detection of trace elements (eg zinc, molybdenum, cobalt) in the human body. This has led to the increased understanding of how the human body functions and what it requires to do so. This has in turn led to understanding of diseases due to the deficiency of trace elements, allowing for better health care, development of health care products and as a result a higher standard of living for a healthier society. This is clearly a positive impact for society.

AAS has also allowed for the monitoring of pollution in the environment, which is clearly positive impact for society and the environment.

Samples from waterways are easily attainable and analysed using AAS to determine if there is any pollution (particularly by toxic heavy metals such as lead). This information can result in authorities detecting and preventing pollution. This will lead to better aquatic environments for aquatic organisms, conserving biodiversity and ecosystems. It can also lead to clean water supplies for human consumption/usage which prevents disease due to heavy metal poisoning say...

AAS can also analyse soil samples to detect pollutants and thus allow authorities to solve it. This provides better environments for terrestrial organisms and land to grow crops for human consumption.

AAS has therefore had a beneficial impact on society and the environment, providing greater understanding of the human body and controlling pollution in the environment.

This has been the case in Bangladesh where the population were warned of high arsenic levels and taught how to overcome this; protecting their health as a result.

5

Question 27 (6 marks)

Assess the impact of the use of Atomic Absorption Spectroscopy on society and on the environment.

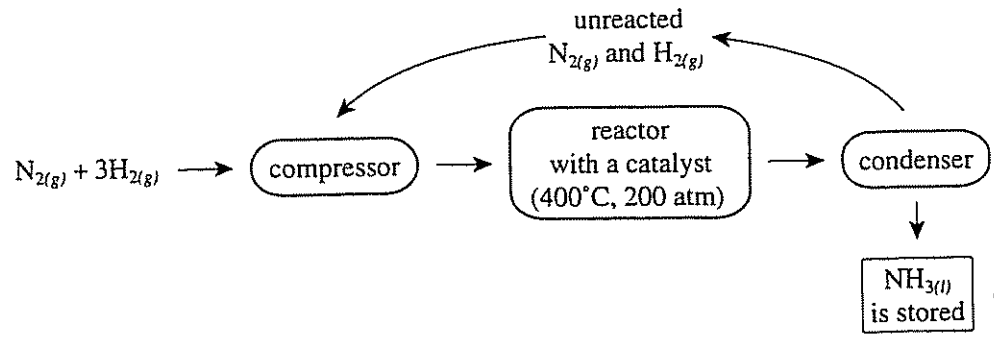
6 Atomic Absorption Spectroscopy (AAS) has had a hugely beneficial impact on both society and the environt. Firstly, in terms of society, AAS is able to be used to detect the low concentration of poisonous metals such as mercury/lead heavy metals in food and water. For example, it can be used to detect low lead (mercury?) concentrations in seafood (lead even at very low concentrations can cause nervous system damage → before AAS it was not possible to detect these low concentrations). This is beneficial to society, as disease due to heavy metal poisoning can be avoided, thus resulting in a higher quality of life, and money spent to treat these diseases can be spent elsewhere. AAS can also be used to monitor pollution levels of elements such as lead ~~in~~ in the air. By doing this, dangerous areas where pollution levels are high can be identified, and people be told to avoid these areas. This is beneficial to society as less people will be sick, thus easing the pressure on the health system, and saving money on expensive treatment.

In terms of the environt, AAS has also had beneficial effects. This is because, before AAS, trace elements, which are elements needed in very small concentrations by living things to function properly, such as Fe & Cu were not known about (since their small concentrations could not be detected). The reasons as to why plants in certain areas were not growing properly were not known. With the use of AAS, trace elements could be identified, and soils could be monitored and corrected when we trace elements were not in high enough concentrations. Thus, the use of AAS, indirectly allowed for plants to grow in certain areas, a benefit to the environt. Also, AAS could be used to monitor and subsequently correct any high levels of metal pollutants that would likely damage the environt. This is beneficial to the environt as damage to the environt by metals can be prevented.

Thus, the use of AAS has had a large beneficial impact on both society & the environment.

Question 28 (6 marks)

In a modern ammonia-producing plant many factors need to be monitored carefully. The following diagram describes the main features of such a plant:



In this production plant, the pressure and temperature are closely monitored for the combination of the reactant gases (in the reactor) and for the removal of the product (in the condenser).

Explain why the temperature and pressure must be carefully monitored in these chambers. Use appropriate equations to illustrate your answer.

Marks

6

The equation for the synthesis of ammonia is: $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$, which is an exothermic reaction. For the reaction to occur at a reasonable rate, heat must be applied to provide the molecules with more kinetic energy to increase the likelihood of collisions and thus synthesis of ammonia. However, the reaction is exothermic. Le Chatelier's principle states that if a system at equilibrium is disturbed it will counteract the disturbance. So, if heat is added, by Le Chatelier's principle, the equilibrium will shift to the left, favouring the decomposition of ammonia to consume the excess heat. A compromise (of 400°C) thus has to be made in the reaction chamber between the rate of reaction and yield of ammonia. Because this is an industrial process, time is precious and profits need to be maximised, so the temperature must be carefully monitored.

If the pressure is increased, by Le Chatelier's principle, the equilibrium will shift to the left to decrease the number of molecules and thus decrease the pressure. This favours the production of ammonia. Therefore, high pressure is favourable. But, this needs to be compromised too due to the safety issues of having high pressure

Pressure considerations in the condenser?

→ chambers and the possible damage to equipment that can be made. Therefore, monitoring of pressure is important in the reaction chamber.

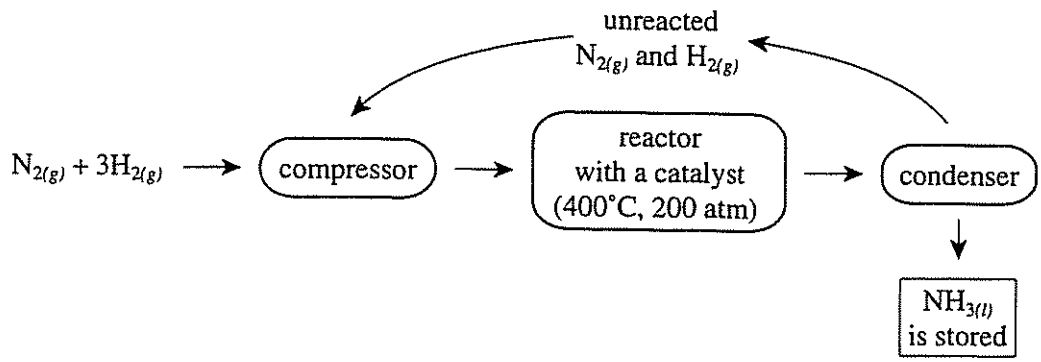
In the condenser, the following occurs: $NH_{3(g)} \rightleftharpoons NH_{3(l)}$. To increase the ammonia, the temperature must be decreased to a low enough level so that ammonia converts to its liquid form and hydrogen remains in the gaseous state to be fed back into the reaction chamber. Therefore, the temperature in the condenser needs to be carefully monitored as well.

5

Question 28 (6 marks)

Marks

In a modern ammonia-producing plant many factors need to be monitored carefully. The following diagram describes the main features of such a plant:



In this production plant, the pressure and temperature are closely monitored for the combination of the reactant gases (in the reactor) and for the removal of the product (in the condenser).

Explain why the temperature and pressure must be carefully monitored in these chambers. Use appropriate equations to illustrate your answer. **6**

the above production plant reaction can be summarised as:

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons NH_{3(g)} + heat$

As $NH_{3(g)}$ is the desired product, the temperature and pressure of the system is altered to manipulate the most efficient, economic production of $NH_{3(g)}$ (least temp & pressure, but most NH_3)

In the reactor, temperature and pressure must be carefully monitored for this above reaction (maximum products, economically). Also, at such high temperatures and pressure, this poses a hazard, so the reactor must be monitored to prevent explosions / dangerous situations.

Temperature must remain high enough to facilitate the reaction, and pressure high enough to force the forward reaction (Le Chatelier's Principle) but not too high as to cause danger.

In the condenser, temperature must be monitored to ensure the NH_3 is collected as liquid and doesn't escape as gas, which would make the system inefficient. $NH_{3(g)} \rightleftharpoons NH_{3(l)}$

(pressure isn't as major an issue here).

Though the pressure should still be monitored to be kept at safe level.

4

OPTION 29 - INDUSTRIAL CHEMISTRY

a) i- $K_{eq} = \frac{[H_2O_{(g)}][CO_{(g)}]}{[H_{2(g)}][CO_{2(g)}]}$

(ii)

	H_2	CO_2	H_2O	CO
initial amount	2.0 mol	2.0	0	0
[initial]	2.0 mol L^{-1}	2.0 mol L^{-1}	0	0
amount reacting	0.87	0.87	0	0
[final]	1.13	1.13	0.87	0.87

Volume 1.0 L

eqn: $H_{2(g)} + CO_{2(g)} \rightleftharpoons H_2O_{(g)} + CO_{(g)}$

∴ from eqn; $n(CO) = n(H_2O) = 0.87$

∴ from eqn; $n(CO) = n(H_2 \text{ reacting}) = n(CO_2 \text{ reacting}) = 0.87$

∴ final amount $H_2 = 2.0 - 0.87 = 1.13$ mol

" " " $CO_2 = 1.13$ mol

∴ $K = \frac{(0.87)(0.87)}{(1.13)(1.13)} = 0.5927637\ldots$

$\doteq 0.59$

ii) $n(H_2) = 2$ moles $\quad n(CO) : n(H_2)$

$n(CO_2) = 2$ moles $\quad 1 : 1$

~~$H_{2(g)} + CO_{2(g)}$~~ $\quad n(H_2) = 0.87$ moles used up

$n(CO) : n(CO_2)$

∴ $c(H_2) = \frac{n}{V} = \frac{1.13}{1} = 1.13$ mol.L^{-1} $\quad 1 : 1$

∴ $n(CO_2) = 0.87$ moles used up

$c(CO_2) = \frac{n}{V} = \frac{1.13}{1} = 1.13$ mol.L^{-1}

$c(CO) = \frac{n}{V} = \frac{0.87}{1} = 0.87$ mol.L^{-1}

$c(H_2O) = \frac{n}{V} = \frac{0.87}{1} = 0.87$ mol.L^{-1}

$\therefore K = \frac{[CO].[H_2O]}{[H_2].[CO_2]}$

$= \frac{[0.87][0.87]}{[1.13][1.13]}$

$= 0.59$

iii) The reaction is endothermic because if ~~the~~ K increases when the temperature increases there is a greater number of products, than reactants meaning the forward reaction is favoured. By Le Chatlier's principle as the temperature favours the reaction ~~side~~ that absorbs the heat would be favoured, thus the forward reaction is endothermic.

iii) $K_{(927°C)} = 2.1$

$K_{(627°C)} = 0.59$

∴ as heat is increased, K increases.

as K increases, products are favoured

∴ equilibrium shifts to right

If a system at equilibrium is disturbed, the position of equilibrium will shift to minimise the disturbance, according to Le Chatelier's principle

∴ when heat is added, the system moves away from production of heat

∴ heat is a reactant

∴ reaction is endothermic

Well explained.

iii) when temperature ↑, K ↑

when K ↑, ~~concent~~ products are favoured ie. forward reaction favoured.

∴ when temperature ↑, forward reaction favoured

when temp. ↑, endothermic reaction favoured

∴ reaction is ENDOTHERMIC

iv) Carrying out the experiment (ii) in a 2.0 L container would have no effect (i.e. not alter from the results in (ii)) on the no. of moles of $CO_{(g)}$ at equilibrium.

There is an equal number of gaseous molecules on either side of the equilibrium equation, thus a decrease in pressure would not favour either reaction (forward or reverse).

∴ the no mol $CO_{(g)}$ would still be 0.87 (but the concentration would decrease to 0.935 mol/L)

iv) Increasing the volume of the reaction vessel from 1L to 2L, and thus decreasing the pressure, would cause a decrease in the concentration of carbon monoxide (CO) but would not change the number of moles of CO at equilibrium. This is because there are equal numbers of gaseous molecules on each side of the reaction, meaning that equilibrium will not be shifted by a change in pressure. Thus, there would be no change to the number of moles of CO at equilibrium at 900°C.

b) i) Sodium carbonate is used in the manufacture of glass.

$Na_2CO_{3(s)} \xrightarrow{heat} Na_2O_{(s)} + CO_{2(g)}$ (thermally decomposed at 1500°C)

The Na_2O is then used to make glass → 75% SiO_2, 15% Na_2O, 10% CaO.

b) i) One use of sodium carbonate: (1) in glass making. The carbonate is decomposed to sodium oxide by heat, eg

$Na_2CO_{3(s)} \xrightarrow{heat} Na_2O_{(s)} + CO_{2(g)}$

with calcium carbonate. Then, it is combined with silica, to form a silicate, and then incorporated into glass. SiO_2

ii) The raw materials consumed in the above process are sodium chloride ($NaCl$ → in the form of a brine solution) and calcium carbonate ($CaCO_3$ → limestone).

b) i) Na_2CO_3 is used to make glass where it is heated with sandstone and limestone so that it decomposes to produce Na_2O and limestone decomposes to produce CaO. The oxides then react with silica in sandstone to make silicates used for glass.

ii) → sodium chloride ($NaCl$)
→ limestone ($CaCO_3$)

iii) ~~$NaCl + CaCO_3 \rightarrow$~~

$$2NaCl_{(s)/(aq)} + CaCO_{3(s)} \rightarrow Na_2CO_{3(aq)} + CaCl_{2(aq)}$$

iii) Overall reaction:

$$2NaCl_{(aq)} + CaCO_{3(s)} \longrightarrow CaCl_{2(aq)} + Na_2CO_{3(s)}$$

iv) Hydrogen carbonate formation.
→ First brine is ammoniated:

$$NH_{3(g)} + H_2O_{(l)} \longrightarrow NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$$

→ CO_2 obtained from the decomposition of $CaCO_3$ reacts with water:

$$CO_{2(g)} + H_2O_{(l)} \rightleftharpoons H_2CO_{3(aq)}$$

As H_2CO_3 is a weak acid, it partially dissociates: $H_2CO_{3(aq)} \rightleftharpoons H^+{}_{(aq)} + HCO_3^-{}_{(aq)}$

→ Hence,

$$NaCl + NH_4^+ + H^+ + OH^- + HCO_3^- \longrightarrow NaHCO_{3(s)} + NH_4Cl_{(aq)} + H_2O_{(l)}$$

Ammonia is used because NH_4Cl is more soluble than $NaCl$, which would force the formation of $NaHCO_{3(s)}$. The NH_4Cl also makes the solution more alkaline. At high pH's, $NaHCO_3$ is much less soluble & so precipitates out of solution more readily.

IV) Purifying of brine

An solution of 30% NaCl is required for the Solvay process. Purifying brine is required because it contains impurities (calcium, magnesium, and iron) that precipitate out with $NaHCO_3$. The calcium is removed by adding Na_2CO_3 (sodium carbonate):

$$Na_2CO_{3(s)} + Ca^{2+}_{(aq)} \longrightarrow CaCO_{3(s)} + 2Na^{+}_{(aq)}$$

OH^- is used to precipitate magnesium and iron:

$$2OH^-_{(aq)} + Mg^{2+}_{(aq)} \longrightarrow Mg(OH)_{2(s)}$$

$$2OH^-_{(aq)} + Fe^{2+}_{(aq)} \longrightarrow Fe(OH)_{2(aq)}$$

The mixture is then precipitated (the large crystals crumble) and filtered, leaving concentrated sodium chloride.

filtered

v) $2NaCl_{(aq)} + CaCO_{3(s)} \rightarrow Na_2CO_{3(s)} + CaCl_{2(s)}$

ratio of $n(Na_2CO_3) : n(CaCl_2)$ is 1:1

$m_{(Na_2CO_3)} = 1 \text{ tonne} = 1000 \text{ kg} = 1000\,000 \text{ g}$

$\therefore n_{(Na_2CO_3)} = \frac{m}{M} = \frac{1000\,000}{2(22.99) + (12.01) + 3(16.00)}$

$= \frac{1000\,000}{105.99} = 9434.8523 \text{ mol}$ (to 4 d.p.)

$= n(CaCl_2)$

$\therefore m_{(CaCl_2)} = n.M = \frac{1000\,000}{105.99} \times (40.08 + 2(35.45))$ 2

$= \frac{1000\,000 \times 110.98}{105.99}$

$= 1\,047\,079.913 \text{ g}$

$= 1.047$ tonnes (to 3 d.p.)

c) The solvay process has several environmental issues, the main 3 being thermal pollution, $CaCl_2$ waste and ammonia.

$CaCl_{2(s)}$ is the main waste-product of the solvay process. While it does have uses eg. as a drying agent, melting ice in the Northern hemisphere, production far outweighs demand. Disposal is thus a problem. It can be dehydrated and buried in lined pits, but due to its high solubility, it eventually leaches out. Disposal in waterways is also a problem, as salt levels in the water is significantly increased, and is detrimental to aquatic life of the ecosystem. The best way to address this problem (though not practical for all plants) is to dump the $CaCl_2$ in the ocean, where dilution is significant enough to make the salt ions levels insignificant

Thermal pollution of waterways occurs when water used from river is used ~~as to~~ as a coolant in the Solvay plant, but returned

hot to the waterway. This reduces O_2 in the water, promotes algal blooms (which also ↓ O_2 dissolved in the water) and is thus detrimental to aquatic life / ecosystems. Thermal pollution is addressed successfully by cooling the water in ponds or using expensive heat diffusers, before returning it to the waterway. Also, dumping the water in oceans, where dilution is significant enough to minimise the problem.

Ammonia can escape from the plant as a gas, and subsequently enter the atmosphere as a pollutant. However, this may be addressed through careful monitoring and maintenance of the plant, to reduce ammonia emission to a minimum. (locating the Solvay plant away from residential / populated areas also allows emission levels to be less stringent, thus posing less of a problem).

(c) There are four main environmental issues associated with the solvay process: Calcium Chloride disposal; ammonia pollution, thermal pollution, and mining for calcium carbonate:

5. CALCIUM CARBONATE DISPOSAL:

There are not many uses of $CaCl_2$. It does lower the melting point of ice, and can be spread on snow to clear roads. But this is a minor use, and hence the production far exceeds demand. As a result, $CaCl_2$ could be deposited into waterways, but in rivers and lakes, this would significantly increase the ion concentration, and cause possible death to marine life. To minimise this problem, $CaCl_2$ is deposited into the oceans, where the mass amounts of water are such that ion

concentration is not greatly altered.

AMMONIA POLLUTION.

While ammonia is not intentally let out into the environment, some gas does leak out into atmosphere. This is particularly a problem around cities. However, with good design of plants and careful monitoring this pollution can be kept to a minimum.

THERMAL POLLUTION.

Large amounts of heat are produced in the nuclear process, which therefore requires cooling. Water is used to cool much of the reactor process, but as a result, there is huge amounts of hot water to dispose of. This can not be deposited straight into waterways as this could ~~cause~~ eutrophication, and killing aquatic life. As a result, cooling ponds are used, which allow the water to cool slowly, dissipating heat into atmosphere. & then.....

MINING FOR MATERIALS

This poses a slight problem in some countries (not so much Australia), as raw materials such as limestone cause extensive mining. This increases soil erosion, and is damaging to the natural environment. To minimise this, careful analysis of ground structure is used to locate, and excavate only the most suitable sites for raw material extraction.

6 a) The main environmental issues associated with the Solvay process are the disposal of waste calcium chloride ($CaCl_2$), the safe discharge of hot water, the loss of ammonia to the atmosphere, and the safe disposal of calcium hydroxide ($Ca(OH)_2$).

$CaCl_2$ is produced as a waste product from the ammonia recovery step of the Solvay Process ($Ca(OH)_{2(aq)} + 2NH_4Cl_{(aq)} \longrightarrow 2NH_{3(g)} + CaCl_{2(aq)} + H_2O_{(l)}$). Whilst some of it is given to council for use as a salt for de-icing roads, its supply far outstrips its demand. Thus, appropriate disposal of it is an environmental concern. If the Solvay plant is located near the ocean, this issue is addressed by discharging the $CaCl_2$ solution into the ocean, as the ocean has so much water that the calcium and chloride ions will not upset the balance of ions in the ocean. However, for an inland Solvay plant, discharging it into smaller waterways is unacceptable, since there is insufficient dilution of the calcium and chloride ions, meaning that the balance of ions is upset. Thus, these plants address this issue by evaporating the solution to dryness, the burying them in pits (pits should be specially designed to prevent leaching).

The safe discharge of hot water is another environmental concern in the Solvay process. Because the net reaction is exothermic, reaction chambers must be cooled. This is done using water. However, disposal of this heated water is then a problem. If the Solvay plant is near the ocean, then the water can be discharged straight into the ocean, as the ocean is so large that the amount of heat that is introduced is negligible. However, if the plant is inland, disposing hot water into smaller waterways such as lakes and rivers is unacceptable, since the temperature of the water is raised, contributing to thermal pollution. Higher temperature waters mean that less oxygen is dissolved in the water, thus eventually leading to aquatic life death. Thus, these plants

address the issue of disposing hot water by first cooling the water in cooling ponds, then discharging the water.

Since ammonia is used in the process, it is unavoidable that there are some losses. However, because ammonia is toxic, losses of ammonia must be kept minimal. This is done through a good design of the plant.

Excess calcium hydroxide is produced in the ammonia recovery process. Because it is a strong base, it must be disposed of carefully. This is addressed through first neutralising with hydrochloric acid (HCl), then disposal of as $CaCl_2$ would be disposed of.

c) The Solvay process produces Na_2CO_3 but it also produces a large amount of $CaCl_2$ which is waste material. In colder areas of the world, this could be used to de-ice roads, but the supply is much greater than demand. Therefore, $CaCl_2$ must be disposed of somewhere safely. If $CaCl_2$ were disposed in local waterways, such as creeks, lakes, the concentration of Cl^- in the water would kill off aquatic life. $CaCl_2$ could also be disposed of in pits and then buried, but these could leach out affecting the concentration of Ca^{2+} and Cl^- ions in the soil, which could affect plant growth. This environmental issue has been addressed by the disposal of the waste $CaCl_2$ in the ocean as the Cl^- ions do not greatly change the concentration of Cl^- ions in the seawater due to the extremely large volume of water in which it can be diluted.

The emissions of ammonia, although technically they are meant to remain in the process continually recycled, some ammonia can escape into the atmosphere and cause respiratory distress if in large quantities. However, with careful monitoring and plant design, the issue is addressed quite easily.

The Solvay Process generates a large amount of heat due to the many exothermic reactions. This results in large amounts of hot water being produced. If this hot water were discharged straight into local waterways, this would cause the temperature of the water to rise, resulting in thermal pollution. This increase would result in the death of all aquatic life, destroying the ecosystem. This problem can be addressed by circulating the hot discharged water into a cooling pond first, and then into the waterway, after the water has been cooled sufficiently. Solvay Process Plants next to the ocean can discharge the hot water directly into the ocean as the water will be circulated and significantly cooled before any damage takes place.

5

Well set out!

c) Environmental issues associated with the Solvay process can be categorised in 3 main things 1. Excess production of $CaCl_2$, 2. thermal pollution 3. escape of NH_3

EXCESS PRODUCTION OF ~~CaCl~~ $CaCl_2$

5 Although this product has some uses, like melting snow on roads, the supply far exceeds demand and thus this product must be disposed of. The problem is $CaCl_2$ has the potential to alter ion concentrations if pumped into waterways such as rivers and lakes.

How it is addressed

$CaCl_2$ is commonly distributed into the ocean at points where ocean currents will rapidly distribute the ~~the~~ solution so as to cause minimal impact on the environment.

Excess $CaCl_2$ can also be buried in the ground but such pits must be sealed to prevent the soluble substance from leaching out when it rains

THERMAL POLLUTION

The Solvay process generates a lot of heat so to maintain efficient conditions in the plant and to improve safety water from local waterways is used as a heat absorber. This water cannot be pumped directly back into the water supply however because heated water has a lower oxygen saturation & content and thus has the potential to alter the natural ecosystem and have damaging effects.

How it is addressed

Cooling ponds may be used to lower water temperatures before water is returned to its source. Heat diffusers may also be used, but this is an expensive process.

ESCAPE OF NH_3

It is inevitable that some of the ammonia will escape ~~whilst~~ into the atmosphere ~~on~~ whilst it is being bubbled through the brine. Ammonia reacts with water in the atmosphere to form ammonium hydroxide, a weak base that when it rains may damage the environment. or being recovered

How it is addressed

This problem cannot be completely eliminated or solved but it can be minimised through specialised design of chimneys etc and through constant careful monitoring and management.

d.) Two measuring cylinders were set: one with 100mL of water and the other with none. A thin pipette and a wide pipette were used to transfer water from one measuring cylinder to the other. The thicker pipette was used to transfer water from the cylinder with 100mL by placing it upside down in the cylinder, and then covering the other opening. The water inside was transferred to the cylinder with no water. The thin pipette then transferred some water back to the first cylinder. This continued on until both cylinders remained at constant volumes after several transfers of water. This therefore 3 modelled equilibrium. At the end, the amount being transferred was the same as the amount be transferred back, thus modelling the fact that at equilibrium, the rate of the forward reaction equals the rate of the reverse reaction. Additionally, the volumes of both cylinders remained constant at the end, thus modelling the fact that at equilibrium, the concentrations of all products and reactants remains constant. Therefore, this model effectively demonstrated an equilibrium reaction.

d) An equilibrium reaction was modelled by having 2 identical measuring cylinders (A&B) each with 50ml of water in each. 2 pipettes, one large and one small were used to transfer water from one to the other. This was done as follows: the larger pipette was inverted and placed so that it touched the bottom of A. The top was then sealed/covered, and the water was transfered to B. The small pipette, though not inverted, transfered water from B to A. The volume in each was then noted. Then, the process above was repeated until between cycles, the volumes in A & B remained unchanged. The whole system represented the equilibrium reaction. The transfer of water with the large pipette represented the forward reaction in the equilibrium would start faster, then gradually get slower (as the rate in A

decreased, the volume transferred by the large pipette increases). The transfer of water using the small pipette represented that one reaction in the equilibrium started slow, then sped up (since as the volume of B increased the amount of water transferred increased). The point where an equilibrium system is reached is modelled by the fact that at a certain point, the volumes in A & B remained unchanged (symbolic of concentrations of product & reactants being unchanged → i.e. volumes represented concentrations). This was also representative of the constant macroscopic properties of a system at equilibrium. This also meant that at this point, the amount of water transferred by each pipette was the same, representing the fact that at equilibrium, the rates of forward & reverse reactions were the same.

One shortcoming of this model was that it did not show that equilibrium was a dynamic, whereby both reactions occured simultaneously (in this model, water transfer was done one after the other).

3 Yes it did - since water was being moved from A ⇒ B AND from B ⇒ A
∴ Dynamic - things are happening even though macroscopic properties remain unchanged.