VCE CHEMISTRY
CAT 1 1993

"CHEMISTRY IN A PRACTICAL CONTEXT"

DETAILED SUGGESTED SOLUTIONS

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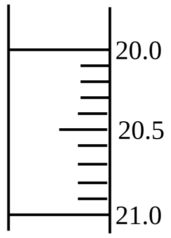
Section A

Question 1

Item 1 **ANS B**

A 50 ml (cm^3) burette has 50 x 1 ml divisions and 10 x 0.1 ml divisions as illustrated below.



A liquid meniscus can be read easily to an accuracy of half of one scale division. This is 0.05 ml. With care, it could be read to 0.02 ml. 0.2 ml is not nearly accurate enough. 0.002 ml and 0.0002 ml are impossible accuracies with this burette.

Item 2 **ANS D**

Molar mass of dimethyl dichlorovinyl phoshate (DDVP) = M = 221.
The molecular formula is $C_4H_7Cl_2PO_4$

Hence, mass of DDVP in one strip = m = $\frac{18.6}{100}$ x 29.0 g.

Hence, number of mole of DDVP in one strip = n = $\frac{0.186 \times 29.0}{221}$ = 0.0244 mole

Item 3 **ANS B**

Lethal mass of DDVP for a little doggie (10 kg) = 30 x 10^{-3} x 10 = 0.30 g.
Let W = mass of strip that contains the lethal amount of DDVP.
Hence, $\frac{18.6}{100}$ x W = 0.3 g. Therefore, W = $\frac{0.30 \times 100}{18.6}$ = 1.6 g.
Note that this is only a small amount (5.6%) of a whole pest strip .
Keep these strips away from your dog!

Item 4 **ANS D**

The pH of a solution is defined by the relationship pH = $-\log_{10}[H_3O^+]$.
Hence, 3 = $-\log_{10}[H_3O^+]$. Therefore, $[H_3O^+] = 10^{-3}$ M = 0.001 M

Item 5 **ANS C**

The number of mole of HCl remains constant. n(HCl) = 1 x 10^{-3}.
Hence, $c_1 \times v_1 = c_2 \times v_2$. Therefore, $10^{-3} \times 1 = c_2 \times 100$.
Hence, $c_2 = 10^{-5}$M. This is the concentration of the HCl.
In an aqueous solution of HCl, the HCl is completely ionised according to the equation
$HCl(aq) + H_2O(l) = H_3O^+(aq) + Cl^-(aq)$. Hence, $[H_3O^+] = [HCl] = 10^{-5}$M.
Hence, pH = 5.

Section A

Question 1

Item 6 **ANS B**

$K_w = [OH^-] \times [H_3O^+] = 10^{-14}$. pH = 9 $[H_3O^+] = 10^{-9}$ M

$$[OH^-] = \frac{10^{-14}}{10^{-9}} = 10^{-5} \text{ M}$$

Item 7 **ANS C**

According to the graph, the original solution has a pH of approximately 1. It is an acid. As the other solution is added, the pH increases, passes through the neutral value 7 and rises to 13 approximately. The solution is now basic. Hence, a base has been added to an acidic solution.

Item 8 **ANS B**

'Waterproofer' is a non-polar molecule that does **not** attract the polar water molecules. It is hydrophobic ('water hating'). Hence, it prevents the water from coming into contact with the surface of the ski boots. That is, it prevents wetting.

Item 9 **ANS D**

Ethylene polymerises by addition polymerisation. No mass is lost in this process. $n(C_2H_4) = \frac{PV}{RT} = \frac{1000 \times 10^3 \times 250 \times 10^{-3}}{8.31 \times 293}$ where P is measured in Pa (Nm^{-2}), V is measured in m^3 and T is measured in K.

$$m(C_2H_4) = n \times M = \frac{1000 \times 10^3 \times 250 \times 10^{-3}}{8.31 \times 293} \times 28 = 2874.9 \text{ g} = 2.87 \times 10^3 \text{ g}$$

Item 10 **ANS A**

The equilibrium expression for this equation is $K_c = \frac{[C_9H_7O_4{}^-{}_{(aq)}]\,[H_3O^+{}_{(l)}]}{[C_9H_8O_{4(aq)}]\,[H_2O_{(l)}]}$

The value of K_c is constant at constant temperature. If sodium hydroxide is added to an aqueous solution of aspirin, OH^- is added to the equilibrium mixture. OH^- will react with H_3O^+ according to the equation

$$H_3O^+(aq) + OH^-(aq) = 2H_2O(l)$$

Hence, the concentration of H_3O^+ is reduced and equilibrium does not exist. To restore equilibrium, the forward reaction must occur so that $[C_9H_7O_4{}^-{}_{(aq)}]$ will increase , $[C_9H_8O_{4(aq)}]$ will decrease, $[H_3O^+{}_{(l)}]$ will decrease, $[OH^-{}_{(aq)}]$ will increase while $[H_2O_{(l)}]$ is constant.

Section A

Question 1

Item 11 ANS D

The equilibrium expression for this equation is $K_c = \dfrac{[C_9H_7O_4{}^-{}_{(aq)}]\,[H_3O^+{}_{(l)}]}{[C_9H_8O_{4(aq)}]\,[H_2O_{(l)}]}$

The value of K_c is constant at constant temperature. If sulfuric acid is added to an aqueous solution of aspirin, H_3O^+ is added to the equilibrium mixture. This destroys the equilibrium. To restore equilibrium, H_3O^+ will react with $C_9H_7O_4^-$(aq) according to the equation

$$H_3O^+(aq) + C_9H_7O_4^-(aq) = C_9H_8O_4(aq) + H_2O(l)$$

Hence, $[C_9H_8O_{4(aq)}]$ will increase, $[C_9H_7O_4{}^-{}_{(aq)}]$will decrease and $[H_3O^+{}_{(l)}]$will still be greater than its original value. The product $K_w = [OH^-] \times [H_3O^+] = 10^{-14}$. This is constant at constant temperature.

Item 12 ANS C

Lipase is a protein which acts as a catalyst for this reaction. A catalyst increases the rate at which equilibrium is achieved by increasing the rate of both the forward and reverse reactions. A catalyst does **not** change the position of equilibrium for the reaction. The lipase binds strongly to the fat molecule, lowers the activation energy for the reaction and thereby increases the rate of reaction.

Item 13 ANS A

The mineral particles are $CuFeS_2$. They contain ions to which the hydrophilic end(charged end) of the surface active molecules (ethyl xanthate) become attached. This leaves the hydrophobic end pointing out and effectively makes the whole mineral particle hydrophobic. These hydrophobic ends becomes attached to air bubbles which carry the mineral particles to the surface.

Item 14 ANS B

In the production of copper, slag is $FeSiO_3$(l)

Item 15 ANS A

The process of ‘roasting’ the $CuFeS_2$ converts the iron into iron(II) oxide and some of the sulfur into sulfur dioxide according to equation **A**. The oxygen is provided from the air coming into the roaster.

Item 16 ANS C

In the converter, ‘blister’ copper is produced by the oxidation of sulfide ions to sulfur dioxide by oxygen gas. Notice the air coming into the converter to suply the oxygen. The copper(I) ions are reduced to copper metal. Equation D could be an intermediate step in the reaction.

Item 17 ANS C

The addition reaction is C_2H_4(g) + HCl(g) = C_2H_5Cl(g) also written CH_3CH_2Cl(g). Ethyl chloride (chloroethane) is produced.

Section A

Question 1

Item 18 ANS D
The addition reaction is $C_2H_4(g) + H_2(g) = C_2H_6(g)$. Ethane is produced.

Item 19 ANS B
The addition reaction is $C_2H_4(g) + H_2O(g) = C_2H_5OH(g)$ also written $CH_3CH_2OH(g)$. Ethanol is produced.

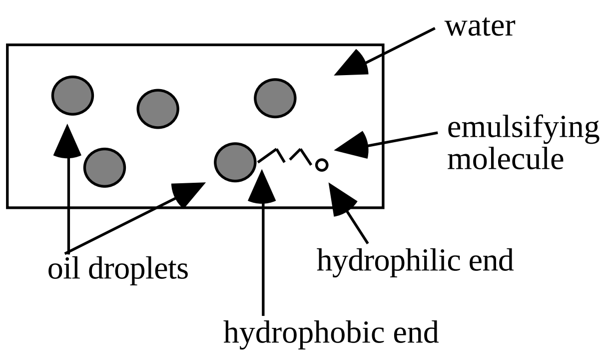
Item 20 ANS D
The addition reaction is $C_2H_4(g) + Cl_2(g) = C_2H_4Cl_2(g)$. Dichloroethane is produced.

Section B

Question 2

(a) Surface tension is the force required to deform a surface (measured in newtons per metre). It is also a measure of the energy required to form a surface. Water (H_2O) has a larger surface tension than octane (C_8H_{18}) because the polar forces of attraction (hydrogen bonding) between the water molecules are greater than the dispersion forces between the octane molecules. Hence, it is more difficult to stretch or deform the surface of water than the surface of octane.

(b) An oil-in-water emulsion has oil droplets suspended in water. The surface of each oil droplet is coated with a molecule that has a hydrophobic (non-polar) end attached to the oil and a hydrophilic (polar) end pointing into the water. This is shown in the diagram below. This molecule is contained in the emulsifier that has been added to the mixture. The emulsifier has thus reduced the surface tension between the two liquids and stopped their natural tendency to separate into layers.



(c) Add a non-polar solvent such as hexane to the emulsion under study. If two layers form, it is an oil-in-water emulsion. If the solvent mixes with the emulsion, it is a water-in-oil emulsion.

Section B

Question 3

(a) As the amount of ethanol increases, the surface tension of the drop decreases and the force of attraction of the surface for the drop causes the drop to spread over a larger area.

(b) Measure the surface areas covered by a drop of fixed volume for varying proportions of ethanol in water. Develop a relationship between the surface area covered and the ethanol content. Alternatively, measure the angle between the drop and the surface or the vertical height of the drop and develop relationships between these and the ethanol content.

Question 4

(a) $K_c = \dfrac{[CH_3OH]}{[CO]\,[H_2]^2}$

(b) (i) The concentration fraction = C.F. $= \dfrac{\frac{2.4 \times 10^{-8}}{5}}{\left(\frac{1.5 \times 10^{-3}}{5}\right) \times \left(\frac{2.0 \times 10^{-3}}{5}\right)^2}$

$= \dfrac{0.48 \times 10}{0.3 \times 0.16} = 100$

Since the concentration fraction is not equal to K_c, the system is not in equilibrium.

(ii) Since the concentration fraction is greater than the equilibrium constant, the system will move towards equilibrium by favouring the reverse reaction, thereby increasing the concentrations of both CO and H_2.

(c) This reaction is exothermic in the forward direction. If the temperature is raised, the equilibrium will shift in favour of the endothermic reaction. This is the reverse reaction in this case. Hence, the value of K_c will decrease.

Question 5 (a)

Use a pipette (first rinsed with the cloudy ammonia solution) to transfer 25.00 mL to a 250 mL volumetric flask.

Make up to the mark with distilled water and mix thoroughly.

Into each of three conical flasks, pipette 20.00 mL aliquots of the diluted solution. The pipette should first have been rinsed with the diluted solution.

Add methyl orange indicator.

Titrate with standard HCl from a burette (first rinsed with the HCl) until three concordant titres have been obtained.

Section B

Question 5 (continued)

(b) $NH_3(g) + HCl(g) = NH_4Cl(g)$

(c) $n(NH_3)$ in the diluted 250 mL sample = $n(NH_3)$ in original 25.00 mL sample

$= c \times V = 2 \times \frac{25}{1000} = 0.05$ **ANS**

(d) From the balanced equation,

n(HCl) used in one titration = $n(NH_3)$ in 20 mL aliquot = $\frac{0.05 \times 20}{250} = 0.004$ **ANS**

(e) If the volume of HCl in a titre is approximately 20 mL, the concentration of the standard HCl solution = $\frac{n}{V} = \frac{0.004}{0.02} = 0.2$ M **ANS**

(f) Safety precautions that should be observed include:

(1) wear safety glasses to prevent splashes of liquid in the eyes.
(2) use fume hood to carry gases away.
(3) do **not** pipette these liquids by mouth.

(g) The original cloudy ammonia solution should be diluted before attempting a titration because the original solution is too concentrated to give a reasonable titre with HCl of a reasonable concentration. Both $NH_3(aq)$ and HCl(aq) are volatile solutions. As their concentrations increase, they tend to give off $NH_3(g)$ and HCl(g) respectively and the their concentrations change. Hence, they should be used in titrations at lower concentrations for more accurate results.

Question 6

(a) (i) $S(s) + O_2(g) = SO_2(g)$

(ii) $2SO_2(g) + O_2(g) \Leftrightarrow 2SO_3(g)$.

(iii) $SO_3(g) + H_2SO_4(l) = H_2S_2O_7(l)$

(iv) $H_2S_2O_7(l) + H_2O(l) = 2H_2SO_4(l)$

(b) (i) The catalyst increases the rate at which equilibrium is attained by increasing the rates of both the forward and reverse reactions by an equal amount.

(ii) A suitable catalyst that is not too expensive is vanadium pentoxide (V_2O_5).

(iii) The recycling process in the converter increases the contact time of the gas mixture with the catalyst , thereby ensuring that equilibrium is reached. Also it enables the mixture to be cooled before coming into contact with the catalyst again. It is critical that the temperature does not rise too much since this would lower the yield of sulfur trioxide.

Section B

Question 6 (continued)

(c) In the converter, sulfur dioxide reacts further with air to produce sulfur trioxide according to the equilibrium equation: $2SO_2(g) + O_2(g) \Leftrightarrow 2SO_3(g)$. This reaction is exothermic and produces a smaller number of mole of gas. Equilibrium principles would suggest that a higher yield of sulfur dioxide would be produced in a given time by:

(1) using a low temperature
(2) using high pressure

However, in practice low temperatures are not used since this would increase the time required to reach equilibrium. A compromise temperature of approximately 450^{o}C and a catalyst are used. High pressures are not used since the yield at atmospheric pressure is high and the extra yield does not justify the use of expensive pressure equipment.

Question 7

(a) The concentration of phosphorus in the solution = 13 mg per litre. Use the graph given to draw a line from the *Y* axis at 0.130 to the straight line graph. Come down to the *X* axis to obtain the answer 13 mg per litre.

(b) m(P) in one litre = 13 mg = 13×10^{-3} g

m(P) in the 500 mL (0.5 L) sample = $13 \times 10^{-3} \times 0.5$ g

% by mass of phosphorus in the detergent (0.500 g) $= \dfrac{13 \times 10^{-3} \times 0.5}{0.5} \times 100$

= 1.3 % **ANS**

(c) The set of standard solutions gives the relationship between absorbance and the concentration of phophorus so that solutions containing unknown amounts of phosphorus can be tested.

END OF 1993 VCE CHEMISTRY CAT 1 SOLUTIONS

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