Question 1. ANSWERS CAT 1 1993

Item Number	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
Response	B	D	B	D	C	B	C	B	D	A	D	C	A	B	A	C	C	D	B	D

Question2.

(a) At 25 °C, liquid octane (a liquid hydrocarbon) has a surface tension of 0.021 N m^{-1} while water has a surface tension of 0.072 N m^{-1}. Briefly explain what is meant by the term 'surface tension' and give a brief explanation for the *difference* between the surface tensions of the two liquids.

Surface tension is a measure of: – the energy needed to increase the surface area (of a liquid) by unity OR – the inward attraction experienced by molecules in the surface of a liquid* OR – equivalent statement e.g a diagram showing the inward attraction experienced by surface molecules.*

water molecules in the liquid are bonded together by hydrogen bonds; octane molecules are held together by dispersion forces; the hydrogen bonding is stronger* than the bonding due to dispersion forces, hence water has a higher surface tension than octane since its molecules in the surface are attracted inwards more strongly*.*

Note that the mention of dispersion forces & hydrogen bonding attracts half a mark each – hence mention of one of these is sufficient for full marks provided the point is made that the intermolecular attraction is stronger for water than it is for octane. (4 marks total)

(b) You are given a sample of an oil to be used in a medical procedure. The oil is to be used in the form of an emulsion in water. Briefly describe the chemical nature of a substance that might be chosen as the emulsifier and hence explain the nature of an emulsion.

Need a 'surface active' molecule, consisting of a hydrophilic end & a hydrophobic end.*

An emulsion consists of very small particles (in this case oil globules) dispersed in another liquid (in this case water) stabilised by the presence of surface active molecules attached to the surface. Verbal description is sufficient, but an appropriately labelled diagram is acceptable.*

To get the 2 marks for this part, the term 'surface active molecule' must be expanded, at least by a labelled diagram, showing the two different parts of the surface active molecule in their correct appropriate places. The words 'hydrophilic' & 'hydrophobic' need not be mentioned provided the meaning is clear; the description of the nature of an emulsion may thus include the description of a surface active molecule. (2 marks total).

(c) Suggest a simple laboratory means of distinguishing an oil–in–water emulsion from a water–in–oil emulsion.

An electrolyte will dissolve in the water of an oil–in–water emulsion & make the emulsion an electrical conductor. The water–in–oil emulsion would not conduct electricity.

OR

**Use water–soluble & oil–soluble dyes; the water–soluble dye will 'colour' the oil–in–water emulsion* but not the water–in–oil emulsion*

OR

**A water–in–oil emulsion mixes with a non–polar solvent (e.g. hexane) while a water–in–oil emulsion mixes with water*.*

To get 2 marks, the distinction in behaviour between the two sorts of emulsion must be made. You may have to use some judgment here! (2 marks total).

(4 + 2 + 2 = 8 marks) (11 minutes)

Question3

When a drop of water is placed in the palm of a person's hand it takes a shape like that shown in figure 1 (a) below. If the same experiment is repeated with mixtures of water and ethanol, the drops appear as shown in figures 1(b) and 1(c).

1(a)... 1(b)... 1(c)...

Purewater | Water–ethanol mixture 1 (low ethanol content) | Water–ethanol mixture 2 (high ethanol content)

(a) What property of the liquid is responsible for the changes in drop shape as the proportion of ethanol in the mixture is increased?

Surface tension (1 mark total)*

(b) Describe how the change in drop shape shown in the above experiment could be used as the basis of an experimental method for determining the proportion of ethanol in various mixtures of water and ethanol.

**A standard drop (constant volume/mass) will cover a larger surface area, the lower the surface tension*
OR
**The higher the surface tension, the higher will be the contact angle between the drop & a hydrophobic surface.*

**The chosen variable (contact angle; area of drop) can be related to ethanol content by a calibration procedure in which solutions of known ethanol content are used.*

**An unknown solution can then have its ethanol content determined by measuring the chosen variable for an unknown solution & comparing the result with the calibration. (3 marks total)*

3 marks should be awarded for the choice of an appropriate variable & a description of its use – the description of a procedure for calibration may include, by implication, the subsequent use of the calibration in a determination of the alcohol content of an unknown mixture. Use your judgment here, but don't be too lax – the point must be clear for the full 3 marks.

[1 + 3 = 4 marks] (6 minutes)

Question4

Methanol can be prepared industrially by the reaction of carbon monoxide and hydrogen with a suitable catalyst according to the equation:

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g); \quad \Delta H = -90 \text{ kJ mol}^{-1}$$

(a) Write an equation for the equilibrium constant, K_c, for this reaction.

$$K_c = \frac{[CH_3OH]}{[CO][H_2]^2}$$

The expression of the right hand side of the above equation is sufficient to gain the mark. (1 mark total)

(b) At 150 °C the equilibrium constant, K_c, has a value of 2.2 M^{-2}. In a particular reaction mixture at this temperature, in a vessel of volume 5.0 L, the amount of each gas was found to be:

$n(CO) = 1.5 \times 10^{-3}$ mol
$n(H_2) = 2.0 \times 10^{-3}$ mol
$n(CH_3OH) = 2.4 \times 10^{-8}$ mol

(i) Use these numbers to show that, in the reaction mixture described, the reaction is not at equilibrium.

$$\frac{[CH_3OH]}{[CO][H_2]^2} = \frac{(2.4 \times 10^{-8}/5)}{(1.5 \times 10^{-3}/5)(2.0 \times 10^{-3}/5)^2} * = 100 \text{ M}^{-2} *$$

... the value of K_c. *The reaction is thus not at equilibrium*.*

Deduct one mark for omitting to divide the number of mole by 5 in each case. (3 marks total)

(ii) How would the concentration of CO change as the system moves towards equilibrium? Briefly explain your answer.

*Since the reaction quotient calculated in b(i) is greater than 2.2, the reaction must go backwards in order to bring the value of the quotient towards 2.2. It follows that [CO] must increase.**

Note that there must be an explanation to obtain the mark. A bald statement that [CO] will increase is worth nothing. (1 mark total)

(c) Explain how you would tell from the data given how the equilibrium constant would change as the temperature was raised.

K_c will decrease with increasing temperature, since the reaction is exothermic* in the forward direction.*

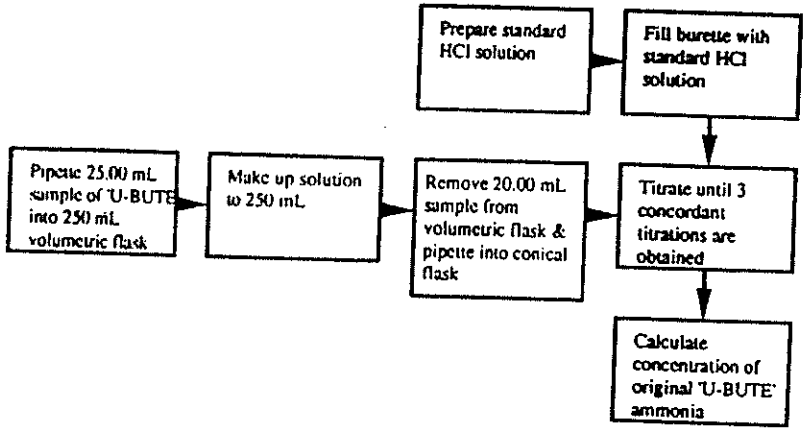
The explanation must accompany the conclusion that K will decrease with increasing temperature. This part will thus normally get 0 or 2 marks. 1 mark might be indicated if the explanation is unclear or imperfect in some way. Judgment! (2 marks total)

[1 + 3 + 1 + 2 = 7 marks] (10 minutes)

Question5

Your employer asks you to check that the concentration of ammonia (NH_3) in a bottle of 'U BUTE' cloudy ammonia is no less than 2.0 M. You decide to dilute a 25.00 mL sample of the cloudy ammonia with water to a volume of exactly 250.00 mL. You then plan to titrate a 20.00 mL sample of the diluted solution with a standard solution of hydrochloric acid so that the volume of the standard HCl used (the titre) will be approximately 20 mL.

(a) Sketch a flow chart showing the procedure you should use.



Above is shown an example of a satisfactory flow chart. Other points might validly be made - e.g. noting that burette readings should be taken before & after a titration; addition of indicator to flask holding the 20.00 mL sample of ammonia; some detail about the means of standardising the HCl (Na_2CO_3 titration). The 3 marks should be awarded for a coherent sequence that includes the taking of the liquid samples, the use of the standard HCl* & the titration itself*. Deduct marks for sequences that omit or do not clearly imply an important basic step in the procedure.* (3 marks total)

$NH_3(aq) + HCl(aq) \longrightarrow NH_4Cl(aq) + H_2O(l)$

OR

$NH_3(aq) + H^+(aq) \longrightarrow NH_4^+(aq)$

$H_3O^+(aq)$ is correct; it is correct to include the Cl^- counter ion in the ionic equation. (1 mark total)

(c) If the ammonia concentration in the original 25 mL sample was approximately 2 M, approximately how many mole of ammonia would there be in the diluted 250.00 mL sample of ammonia?

*(25 x 2)/1000 = 0.05 or 0.050 mole**

(1 mark total)

(d) Approximately how many mole of hydrochloric acid would be used in one titration?

Approximate concentration of NH_3 in the 250 mL volumetric flask is 0.2 M. 20.00 mL of this solution will contain (20 x 0.2)/1000 = 0.004 or 0.0040 mole which must equal the number of mole of HCl used*.

(1 mark total)

(e) What would be the approximate concentration of the standard HCl solution?

Since the titre required is ca. 20 mL, the HCl concentration must be about the same as the NH_3 concentration, i.e. about 0.2 M.*

(1 mark total)

(f) Briefly describe two safety precautions that should be observed when carrying out these titrations.

Any two of:

**Wear safety glasses*
**Wear lab coat*
**Wear gloves*
**Use automatic pipette filler*

(g) Give a reason why the original cloudy ammonia solution should be diluted before attempting a titration.

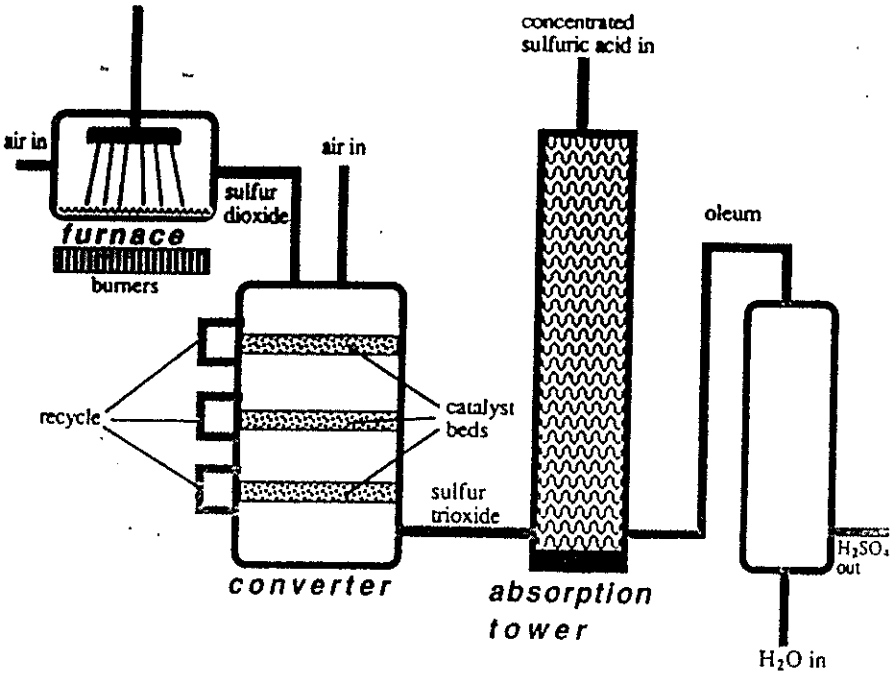
Any one of:

**Dilute solution less likely to lose NH_3 by evaporation than the more concentrated solution.*
**Dilute solution less likely to absorb CO_2 from air than the more concentrated solution.*

[3 + 1 + 1 + 1 + 1 + 2 + 1 = 10 marks] (14 minutes)

Question6

This diagram shows a flow diagram of the industrial production of sulfuric acid.



(a) Write down chemical equations for the following processes that occur during the industrial production of sulfuric acid:

(i) in the furnace.

$S(l) + O_2(g) \rightarrow SO_2(g)$*

(ii) in the converter

$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$*

(iii) in the absorption tower

$SO_3(g) + H_2SO_4(l) \rightarrow H_2S_2O_7(l)$*

(iv) in the production of sulfuric acid from oleum.

$H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(l)$*

(4 marks total)

(b) The chemical process in the converter takes place in the presence of a catalyst.
(i) Explain briefly what the catalyst does.

Speeds up the rate of attainment of equilibrium of the reaction in (ii) above.*

(ii) Name a suitable catalyst

One of: platinised platinum; vanadium pentoxide* ('vanadium oxide' will do).*

(iii) Explain the reason for the recycling process in the Converter.

To increase the contact time between the reactants & the catalyst so that the reaction approaches as closely as possible to equilibrium, thus maximising the yield*.*

Note that the answer 'to increase the yield' can get 1 mark, but the extra mark must be earned by referring to the need to get as close as possible to equilibrium. (4 marks total)

(c) Give a brief explanation of the factors that help determine the exact conditions of temperature and pressure chosen for the reaction occurring in the Converter.

Temperature: To obtain full marks, the student must refer to the fact that the rate of approach to equilibrium is faster as the temperature rises, but that the equilibrium yield decreases with increasing temperature*. In a practical process, the synthesis must occur at a reasonably high rate, but must also have a reasonable yield, so that the actual temperature is the result of a compromise between these two opposing factors.*.*

Pressure: The yield of SO_3 is favoured by an increase in pressure but, in practice, extremely high pressures are not used as the gains from pressure increase are not worth the extra cost of high-pressure plant.*

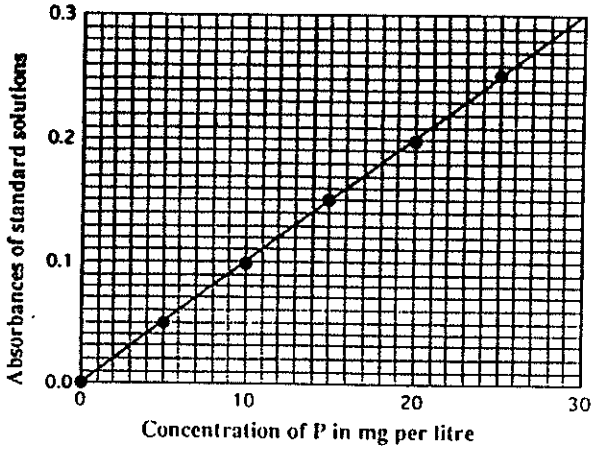
(4 marks total)

[4 + 4 + 4 = 12 marks] (14 minutes)

Question7

Many commercial detergents contain phosphorus in the form of sodium polyphosphate. The amount of phosphorus in a sample of detergent can be determined colorimetrically. 0.500 g of a sample of a solid detergent is dissolved in water and the solution made up to 500 mL. 20.0 mL samples of this solution are mixed with 2.00 mL of a standard molybdate solution. A blue colour develops that gives an absorbance reading of 0.130 in a simple colorimeter.

Five standard solutions of sodium polyphosphate were similarly treated with the standard molybdate solution and their absorbances are shown below. The graph shows the measured absorbance as a function of the *mass of phosphorus* (P) per litre in the standard phosphate solutions.



(a) What is the concentration of phosphorus (as P) in the solution ?

from graph, concentration is 13 mg per litre.* (1 mark total)

(b) What is the percentage by mass of phosphorus (P) in the detergent?

500 mL of solution must contain (500/1000) x 13 = 6.5 mg of phosphorus. The percentage by mass of P in the detergent is thus (0.0065/05) x 100* = 1.3 % P by mass.*
(2 marks total)

(c) Explain why it was necessary to make up a set of standard solutions of sodium polyphosphate?

To provide a calibration curve for the analysis of the unknown solution. (1 mark total)

[1 + 2 + 1 = 4 marks] (6 minutes)