BE TRUE

TRINITY COLLEGE NABBINGO

ADVANCED LEVEL ANNUAL CHEMISTRY SEMINAR

3RD EDITION HELD ON SATURDAY 24TH SEPTEMBER 2022

1. An organic compound X contains 60% by mass of carbon, 13.3% by mass of hydrogen, the rest being oxygen. 0.0725g of X on Vapourisation occupied 396cm^3 at 290K and 0.0726 atmosphere pressure.

   (a) Calculate:

   (i) The empirical formula formular of X

   (ii) The molecular formula of X

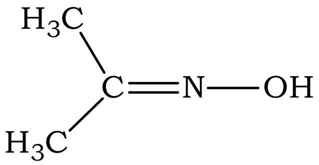
   (b) (i) Write the structural formulae of possible isomers of X

   (iii) Which isomer has the lowest boiling point? Give a reason for your answer

   (c) When X was heated with acidified potassium dichromate(VI) solution compound Y was formed. Y formed a yellow precipitate with iodine solution and sodium hydroxide.

   (i) Name compound X and Y

   (ii) Write equation to show how the compound below can be prepared from Y.



   Outline a mechanism for the reaction

   (d) Starting with ethene, write equations to show how X can be prepared. Indicate reagents and conditions for the reaction.

2. Explain each of the following observations and where applicable illustrate your answer with equation(s)

(a) The molecules of trichloromethane, $CHCl_3$ are much more deflected by a charged rod than those of tetrachloromethane CCl_4
(b) Graphite conducts electricity in solid state but sodium chloride does not
(c) The bond angle in a water molecule is 104° while that in hydrogen sulphide is 92°
(d) When sodium sulphite is added to a solution of aluminium chloride, a white precipitate if formed and effervescence produced.

3. (a) (i) State the distribution law
(ii) State four conditions under which the distribution law is valid

(b) (i) describe an experiment to determine the partition coefficient of ammonia between water and trichloromethane

(ii) State four applications of the distribution law

(c) In an experiment to determine the partition coefficient of ammonia between water and trichloromethane, $50cm^3$ of aqueous ammonia was shaken with $250cm^3$ of trichloromethane until equilibrium was established and the number of moles of ammonia in each layer was determined. The experiment was repeated several times using aqueous ammonia of different concentration and results are given in the table below.

Amount of NH_3 in $50cm^3$ of water (moles)	0.0065	0.0070	0.0095	0.014	0.019	0.025	0.028
Amount of NH_3 in $250cm^3$ of $CHCl_3$ (moles)	0.0005	0.001	0.002	0.003	0.004	0.005	0.006

(i) Plot a graph of molar concentration of ammonia in water against concentration of ammonia in trichloromethane
(ii) Use your graph to determine the partition coefficient of ammonia between water and trichloromethane.

4. (a) Describe how sodium hydroxide is prepared on a large scale
(b) Describe the reactions of sodium hydroxide with:
    (i) Fluorine
    (ii) Silicon(IV) oxide
    (iii) Chromium
(c)Explain the reactions that take place when sodium hydroxide solution is added drop wise until in excess to a solution containing
    (i) Aluminium ions
    (ii) Manganese(II) ions

5. (a) The atomic numbers of calcium and iron are 20 and 26 respectively. Write the electronic configuration of the atom of each element

(b) The melting points of calcium and iron are 842 ^{o}C and 1538 ^{o}C respectively. Explain the difference in melting points

(c) (i) State three properties in which iron differs from calcium

(ii) Describe the reactions that take place during the extraction of iron from spathic iron ore

(d) Discuss the reactions of iron with

  (i) water

  (ii) Sulphuric acid

(e) The rusting of iron is an electro-chemical process which takes place in presence of moist air. Explain the chemical reactions that take place during rusting of iron

6. Write equations for the following reactions and outline a mechanism for the reaction

(a) Phenylethene and bromine in the presence of carbon tetrachloride

(b) Iodoethane and sodium hydroxide under heat

(c) Propanone and 2,4-Dinitrophenylhydrazine in acidic medium

(d) 2-bromo-2-methyl propane and sodium ethoxide in the presence of ethanol under heat

(e) Benzene and chloroethane in the presence of aluminium chloride

7. (a) 1.57g of an organic compound W containing carbon, hydrogen and nitrogen only on complete combustion yielded 3.64g of carbon dioxide gas and 308.80cm^3 of nitrogen gas measured at s.t.p. Determine the empirical formula of W.

(b) When vapourised, 0.2g of W occupied 87.52 cm^3 measured at 100kPa and 27 oC

  (i) Determine the molecular formula of W

  (ii) Write down the structural formula and IUPAC names of all the possible isomers of W

(c) When W was reacted with sodium nitrite and dilute sulphuric acid, a yellow oil was formed.

  (i) Identify W

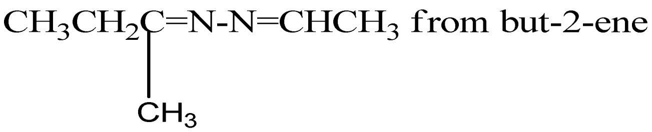
  (ii) Write an equation for the reaction

  (iii) Write equations to show how W can be synthesized from propna-1-ol. Indicate reagents and conditions for the reactions.

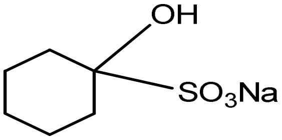
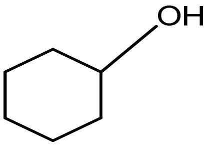
8. Using equations only show how the following conversions can be effected

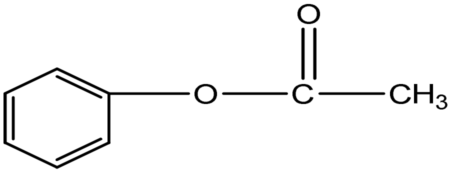
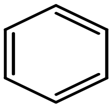
(a) Propyne from but-2-ene

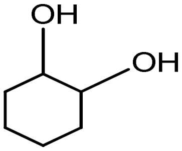
(b) $(CH_3CH_2)_2N\text{-}N{=}O$ from CH_3CH_2COCl

(c) 
$CH_3CH_2\underset{\displaystyle CH_3}{\underset{|}{C}}{=}N\text{-}N{=}CHCH_3$ from but-2-ene

(d) Phenol from benzaldehyde

(e)  from 

(f)  from 

(g)  from Phenol

9. (a) Define the term molar conductivity

(b) The molar conductivities of silver nitrate, potassium nitrate and potassium chloride are 134.0, 143.2 and 140.8 $\Omega^{-1}cm^2mol^{-1}$ respectively at infinite dilution at 25 ^oC. Calculate the

(i) Molar conductivity of silver chloride at infinite dilution

(ii) Solubility product Ksp of silver chloride at 25^oC (The resistances of conductivity water and that of a saturated solution of silver chloride are $8.22x10^6$ and $2.20\ x10^6\ \Omega$ respectively when determined using a cell with a constant $0.425cm^{-1}$).

(c) State two applications of conductance measurements

(d) (i) Define the term standard electrode potential

(ii) Describe how the standard electrode potential of the zinc electrode may be determined

(e) The stand electrode potentials E^o for some half-cell reactions are given below

$$MnO_4^-\,(aq)/Mn_2^+\,(aq) \qquad E^o = 1.52\ V$$
$$VO_2^+\,(aq)/\,VO^{2+}\,(aq) \qquad E^o = 0.98\ V$$

(i) Write equations for the reactions which take place at the cathode and anode of the cell formed by combining the two electrode

(ii) Write a notation for the cell formed in (e) (i) and calculate the e.m.f of the cell.

(iii) State two applications of e.m.f measurements.

10. (a) Define the terms

(i) Activation energy

(ii) Order of reaction

(b) Ethanal decomposes thermally to form methane and carbon monoxide according to the following equation

$$CH_3CHO\ (l) \rightleftharpoons CH_4\ (g) + CO\ (g)$$

Calculate the standard enthalpy of decomposition of ethanal. (The standard enthalpies of combustion of ethanal, methane and carbon monoxide are -1187, -884 and -283.5 $kJmol^{-1}$ respectively).

(c) The activation energy for the catalyzed and uncatalyzed decomposition of ethanal are136 and 190kJmol-1 respectively.

(i) Draw the reaction profiles using the same axes for catalyzed and uncatalyzed reactions

(ii) Explain the effect of the catalyst on the rate of decomposition of ethanal

(d) The table below shows the rates of decomposition of ethanal at different concentrations

Concentration, C ($moldm^{-3}$)	0.20	0.30	0.40	0.50
Rate ($moldm^{-3}S^{-1}$)	$1.5x10^{-3}$	$3.37\ x10^{-3}$	$5.98\ x10^{-3}$	$9.35\ x10^{-3}$

(i) Plot a graph of rate of decomposition against square of concentration

(ii) Deduce the order of reaction

(iii) Write the rate equation and hence calculate the rate constant for the decomposition of ethanal

(e) Explain what happens to the rate of decomposition of ethanal when the concentration of ethanal is tripled.

11. The contact process involves catalytic oxidation of sulphur dioxide according to the following equation

$$2SO_2\ (g) + O_2\ (g) \rightleftharpoons 2SO_3\ (g)$$

(a) Name:

(i) One source of sulphur dioxide and one source of oxygen for use in the contact process

(ii) The catalyst used in the contact process

(b) In a one litre vessel, sulphur dioxide and oxygen were mixed in a molar ratio 2:1at different temperatures. At equilibrium the percentage of sulphur trioxide in the mixture of gases was 64.7% at 732 ^oC and 56.0% at 856 ^oC

(i) Calculate the values of equilibrium constant, Kc at 732 ^oC and 856 ^oC

(ii) Explain whether oxidation of sulphur dioxide to sulphur trioxide is endothermic or exothermic reaction

(c) Write equations to show how sulphur trioxide is converted to sulphuric acid

(d) Describe the reactions of sulphuric acid and
   (i) Ammonium iodide
   (ii) Calcium phosphate
(e) Describe how a named detergent can be prepared from sulphuric acid

12. (a) (i) Define the term vapour pressure
   (ii) State Raoult's law of vapour pressure lowering

(b) The vapour pressure of aqueous solutions of glucose containing 9.0g of water at 27 oC varies with the mass of glucose dissolved as shown in the table below.

Mass of glucose dissolved in 9.0g of water	0.00	0.45	0.90	1.80	3.60	4.50	7.20
Vapour pressure of solution (mmHg)	31.82	31.66	31.50	31.32	30.55	30.23	29.27

(i) Plot a graph of lowering in vapour pressure (ΔP) against mass of glucose dissolved in 9.0g of water
(ii) Use your graph in b(i) above to determine the molar mass of glucose
(iii) State the effect of water on the molecular state of glucose. Give a reason for your answer using the molar mass calculated in b (ii) above.

(c) One of the limitations of the method of determining relative molecular mass by freezing point method is that the solute should not associate or dissociate in solution
(i) State three other limitations of determining molecular mass by freezing point method
(ii) Explain how association of a solute in solution affects the molecular mass determined by freezing point method

(d) Describe an experiment that can be carried out to determine the relative molecular mass of naphthalene in camphor by depression of freezing point method.

(**Diagram not required**)

(e) A solution containing 0.142g of naphthalene in 20.25g of benzene caused a lowering of freezing point of 0.284 °C. Calculate the molar mass of naphthalene. (Cryoscopic constant ***kf*** of benzene is 5.12 $^{o}C\ mol^{-1}\ kg^{-1}$)

13. (a) What is meant by the following?

(i) Common ion effect

(ii) Solubility of a salt

(iii) Solubility product

(b) The solubility product of silver phosphate at 25 ^oC is 1.4 x 10^{-21} mol^{-4} dm^{-12}

Calculate the:

(i) Solubility of silver phosphate in gdm^{-3} at 25 ^oC

(ii) Molar concentration of silver ions in the saturated solution of silver phosphate at 25 ^oC.

(c)(i) Describe an experiment to determine the solubility product of strontium hydroxide in the laboratory at 25 ^oC.

(ii) 25 cm^3 of a saturated solution of strontium hydroxide at 25 ^oC were mixed with 50 cm^3 of 0.2M hydrochloric acid. The resultant solution was diluted to 250cm^3. 20 cm^3 of this solution required 12.55 cm^3 of 0.025M sodium hydroxide solution using phenolphthalein indicator. Calculate the solubility product of strontium hydroxide at 25 ^oC.

(d) State two applications of solubility measurements

14. (a) Define the following terms

(i) Oxo-anion

(ii) Disproportionation

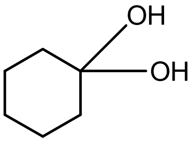
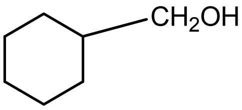
(b) Write an equation for the disproportionation of potassium manganate(VI) in water and state the oxidation states of manganese in each of the species formed

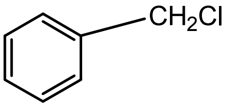
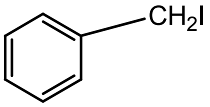
(c) (i) 25cm^3 of a solution made by dissolving 6.4g of Iron(II) oxalate, $FeC_2O_4.nH_2O$ in 1 dm^3 was titrated with 0.02M of acidified potassium manganate(VII) solution. 26.7 cm^3 of the potassium manganate(VII) was required for complete reaction. Determine the value of n.

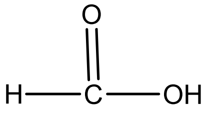
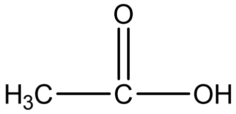
(ii) 25 cm^3 of a solution prepared by dissolving 8.0g of $K_xH_y(C_2O_4)z.nH_2O$ in one litre required 23.80 cm^3 of 0.1M sodium hydroxide for complete reaction. Another 25cm^3 of the same solution required 31.75cm^3 of 0.02M potassium manganate(VII) for complete reaction. Determine the value of x, y, z and n.

(d) Explain the following why during redox titrations, Iron(II) salts are dissolved in a little sulphuric acid before water is added.

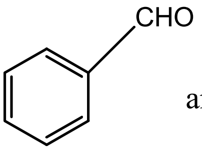
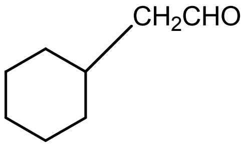
15. Name the reagents which can be used to distinguish between each of the following pairs of organic compounds. In each, state what is observed if each member of the pair is treated with the reagent.

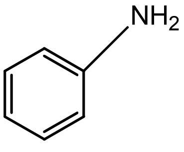
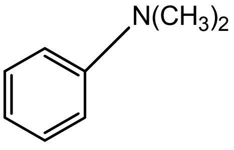
(a)  and 

(b)  and 

(c)  $\mathrm{H{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}OH}$ and  $\mathrm{H_3C{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}OH}$

(d) $C_4H_4O_4$ and CH_3CH_2COOH

(e)  and 

(f)  and 

16. (a) Define the following terms

(i) Transition element

(ii) Complex ion

(b) Explain why Iron(II) ions are readily oxidised to Iron(III) ions whereas manganese(II) ions are not readily oxidised to Manganese(III) ions

(c) Hydrated chromium(III) chloride, $CrCl_3.6H_2O$ exhibits hydrate isomerism

(i) Write down its isomers and give the IUPAC names

(ii) How can the isomers be distinguished

(d) When an aqueous solution of chromium(III) chloride is added to sodium sulphide, a green precipitate and bubbles of a colourless gas that forms a black precipitate when bubbled through lead(II) ethanoate is given off. Explain the observation

(e) Discuss the reactions of chromium with sulphuric acid.

17. (a) Define the following terms

(i) Standard enthalpy of formation of a substance

(ii) Lattice energy

(iii) Bond energy

(b) The standard heat of formation of phosphorus trichloride is -306kJmol^{-1}. The atomization energies of chlorine and phosphorus are 242 and 314 kJmol^{-1} respectively. Draw the Born-Haber cycle and use it to calculate the average bond energy of P-Cl bond.

(c) Describe an experiment to determine the enthalpy of combustion of sulphur

(d) Calculate the standard enthalpy change for the reaction

$$SO_2(g) + 2H_2S(g) \longrightarrow 3S(s) + 2H_2O(l)$$

Given that, the standard enthalpy of combustion of sulphur is -297kJmol^{-1} and the standard enthalpies of formation of hydrogen sulphide and water are -20.2 kJmol^{-1} and -286 kJmol^{-1} respectively

18. (a) The Table 1 below shows the oxo-acids of chlorine. Complete the table and use the table to answer the questions that follow

Oxo-acid	Structure	Shape	Oxidation state of chlorine
HOCl			
$HClO_2$			
$HClO_3$			
$HClO_4$			

(b) Arrange the oxo-acids above in order of increasing acidic strength

(c) Explain your answer in (b) above

(d) Table 2 shows acid dissociation constants, Ka, for some acids at 25 ^{o}C

Acid	Ka (mol dm^{-3})
HCOOH	1.7×10^{-4}
CH_3COOH	1.7×10^{-5}
CH_3CH_2COOH	1.35×10^{-5}

(i) State the trend in acid strength of the acids in Table 2

(ii) Explain your answer in (a)(i)

(iii) Calculate the pH of the solution made by dissolving 7.2g of ethanoic acid and 12g of sodium ethanoate to make one litre. State any assumptions made.

19. (a) When one mole of a compound P was burnt in excess oxygen, 96000cm^3 of carbon dioxide gas was produced at room temperature. If the empirical formula of P is CHO, calculate its molecular mass.

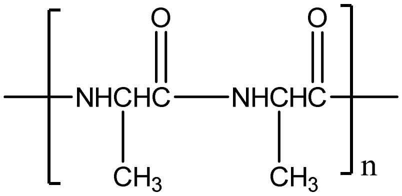
(b) Compound P when treated separately with alkaline potassium manganate(VII) solution and bromine water, both turn colourless. P also liberates an effervescence of a colourless gas when reacted with sodium carbonate solution

(i) Identify compound P

(ii) Write an equation of reaction between P and bromine water and suggest a suitable mechanism for the reaction

(iii) Write an equation for the reaction between P and sodium carbonate

20. The formula of a condensation polymer formed by loss of a water molecule is shown below



$$\left[-NHCH(CH_3)\overset{O}{\overset{\|}{C}}-NHCH(CH_3)\overset{O}{\overset{\|}{C}}-\right]_n$$

(a) (i) Write the structural formula and give the IUPAC name of the monomers

(ii) Given that polymer is formed by combining 50 monomer units. Calculate the relative formula mass of the polymer

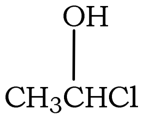
(b) Describe the reactions of the monomers in a (i) above with each of the following reagents. Your answer should include conditions for the reaction and equations of reactions

(i) Sodium hydroxide

(ii) Hydrochloric acid

(iii) Ethanol

(c) Using equations of reactions, show how the monomer in (a)(i) can be:

(i) prepared from 

$CH_3\overset{OH}{\overset{|}{C}}HCl$

(ii) converted to ethane-1,1-diamine

21. (a) The bond energies of halogen acids are given in the table below

H-X	H-F	H-Cl	H-Br	H-I
Bond energy (kJmol^{-1})	556	431	336	299

(i) Explain the variation in bond energy

(ii) State two properties of the halogen acids whose variation is caused by the trend in bond energies

(b) Describe the reaction of the halogen acids with

(i) Concentrated sulphuric acid
(ii) Sodium carbonate

(c) Concentrated hydrochloric acid is an Azeotropic mixture of composition 36.47% w/w. The density of the Azeotropic is 1.108gcm^{-3} at 25 ^{o}C. 4.5 cm^3 of the Azeotropic mixture were transferred into a 250 cm^3 volumetric flask and diluted up to the mark with distilled water. 20 cm^3 of the dilute acid required 20 cm^3 of sodium carbonate solution containing 0.3g of the impure salt. Determine the percentage purity of the impure salt.

END