THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

132/2 **CHEMISTRY 2**

Time: 3 Hours **ANSWERS** **Mwaka: 2009**

Instructions

1. This paper consists of a total of six questions
2. Answer five questions.

1 (a) The reaction SO_2Cl_2 ---> $SO_2 + Cl_2$ is a first order gas reaction with rate constant $k = 2.20 \times 10^{-5}\ \text{sec}^{-1}$ at 320°C. What percentage of SO_2Cl_2 is decomposed on heating at 320°C for 100 minutes?

Using first-order reaction formula:
$\ln([A]_0/[A]) = kt$

Convert 100 minutes to seconds:
$t = 100 \times 60 = 6000$ sec

Substitute the values:
$\ln([A]_0/[A]) = (2.20 \times 10^{-5}) \times 6000$
$\ln([A]_0/[A]) = 0.132$

$[A]_0/[A] = e^{0.132} = 1.1412$

Therefore, $[A] = [A]_0 / 1.1412 = 0.8757\ [A]_0$

Percentage decomposed $= (1 - [A]/[A]_0) \times 100$
$= (1 - 0.8757) \times 100 = 12.43\%$

1 (b) At 289 K the following data were obtained for the reaction
$CHCl_3 + Cl_2 \rightarrow CCl_4 + HCl$

$[CHCl_3]$ (M)	$[Cl_2]$ (M)	Rate (M sec^{-1})
0.1	0.1	5.02×10^{-5}
0.1	0.2	2.51×10^{-4}
0.05	0.05	1.25×10^{-5}

(i) What is the order of reaction with respect to each reactant?

Compare experiment 1 and 2 ($CHCl_3$ constant):
$\text{Rate}_2 / \text{Rate}_1 = (2.51\times10^{-4})/(5.02\times10^{-5}) = 5$
Cl_2 concentration doubled $(0.2/0.1 = 2)$
So $2^n = 5 \rightarrow n = \log 5 / \log 2 = 2.32$
Order with respect to Cl_2 is approximately 2.32 (non-integral)

Compare experiment 1 and 3 (Cl_2 constant):
$\text{Rate}_3 / \text{Rate}_1 = (1.25\times10^{-5})/(5.02\times10^{-5}) = 0.25$
$CHCl_3$ halved $(0.05/0.1 = 0.5)$
So $0.5^n = 0.25 \rightarrow n = 2$
Order with respect to $CHCl_3$ is 2

(ii) What is the rate constant at 289 K?

Rate = $k[CHCl_3]^2[Cl_2]$^2.32
Using values from experiment 1:
$5.02\times10^{-5} = k \times (0.1)^2 \times (0.1)$^2.32
$= k \times 0.01 \times 0.00479 = k \times 4.79\times10^{-5}$
$k = 5.02\times10^{-5} / 4.79\times10^{-5} = 1.048\ M^{-4}.32\ sec^{-1}$

(iii) If at 333 K the rate constant for the reaction is 6.71 M^{-1} sec^{-1}, what is the activation energy of the reaction?

Use Arrhenius equation:
$\ln(k_2/k_1) = Ea/R \times (1/T_1 - 1/T_2)$

$k_1 = 1.048$, $k_2 = 6.71$
$T_1 = 289$ K, $T_2 = 333$ K, R = 8.314 J/mol·K

ln(6.71/1.048) = Ea/8.314 × (1/289 - 1/333)
ln(6.4) = Ea/8.314 × (0.00346 - 0.00300)
1.856 = Ea/8.314 × 0.00046
Ea = 1.856 × 8.314 / 0.00046 = 33563.2 J/mol = 33.56 kJ/mol

(iv) What is the rate constant at 305 K?

Use Arrhenius equation again:
$\ln(k_2/k_1) = Ea/R \times (1/T_1 - 1/T_2)$

$k_1 = 1.048$, Ea = 33563 J/mol
$T_1 = 289$ K, $T_2 = 305$ K

$\ln(k_2/1.048) = 33563/8.314 \times (1/289 - 1/305)$
= 4034.6 × (0.00346 - 0.00328) = 4034.6 × 0.00018 = 0.7262
$k_2 = 1.048 \times e$^0.7262 = 2.12 $M^{-4}.32\ sec^{-1}$

2 (a) What do you understand by:

(i) Electrodes
Electrodes are conductive materials, usually metals or graphite, which allow the flow of electrons in and out of an electrochemical cell. They serve as the sites for oxidation and reduction reactions. The anode is where oxidation occurs, and the cathode is where reduction occurs.

(ii) Voltaic cell

A voltaic cell is a type of electrochemical cell that generates electrical energy from spontaneous redox reactions occurring between two different electrodes in separate half-cells. The energy is harnessed through an external circuit.

(iii) Salt bridge

A salt bridge is a U-shaped tube containing a gel or solution of inert electrolytes (like KCl or KNO_3), which completes the electrical circuit in an electrochemical cell by allowing ion migration. It prevents charge buildup and maintains electrical neutrality in both half-cells.

(iv) Cell notation

Cell notation is a shorthand representation of an electrochemical cell. It follows the format:

Anode | Anode solution || Cathode solution | Cathode

Vertical lines (|) represent phase boundaries and the double line (||) represents the salt bridge.

2 (b) (i) For the electrochemical cell $Zn(s) \mid ZnSO_4(aq) \parallel CuSO_4(aq) \mid Cu(s)$, sketch a labelled diagram of such a cell to show the essential features.

Diagram description:

- Left half-cell: Zinc metal electrode dipped in $ZnSO_4$ solution
- Right half-cell: Copper metal electrode dipped in $CuSO_4$ solution
- Salt bridge connects both solutions
- External wire connects Zn electrode to Cu electrode
- Electrons flow from Zn to Cu
- Anode: Zn (oxidation), Cathode: Cu (reduction)

(ii) Write an expression for the emf of the cell in 2(b)(i) above operating under standard conditions.

$E°_{cell} = E°_{cathode} - E°_{anode}$

$E°_{cell} = E°_{Cu^{2+}/Cu} - E°_{Zn^{2+}/Zn}$

(iii) Calculate the e.m.f. of the cell in 2(b)(i) above if $[Cu^{2+}] = 1$ M and $[Zn^{2+}] = 0.01$ M at standard conditions.

Use Nernst equation:

$E_{cell} = E°_{cell} - (0.0591/n) \log ([Zn^{2+}]/[Cu^{2+}])$

$E°_{cell} = 0.34 - (-0.76) = 1.10$ V

$n = 2$ electrons

$E_{cell} = 1.10 - (0.0591/2) \log(0.01/1)$

$= 1.10 - 0.02955 \times (-2)$

$= 1.10 + 0.0591 = 1.1591$ V

(iv) Calculate the equilibrium constant for the electrochemical cell above.

$E°_{cell} = (0.0591/n) \log K$
$1.10 = (0.0591/2) \log K$
$\log K = (1.10 \times 2)/0.0591 = 37.23$
$K = \text{antilog}(37.23) \approx 1.70 \times 10^{37}$

3 (a) Explain briefly the following terms:

(i) Common ion effect
Common ion effect refers to the decrease in the solubility or ionization of a weak electrolyte when a strong electrolyte supplying a common ion is added to the solution. For example, the addition of sodium acetate to acetic acid suppresses ionization of acetic acid due to the common acetate ion.

(ii) Buffer solution
A buffer solution is a solution that resists changes in pH when small amounts of acid or base are added. It usually consists of a weak acid and its conjugate base or a weak base and its conjugate acid. An example is a mixture of acetic acid and sodium acetate.

(iii) Salt hydrolysis
Salt hydrolysis is the reaction of the ions of a salt with water to form acidic or basic solutions. It occurs when the salt is formed from a weak acid or a weak base. For instance, ammonium chloride hydrolyzes in water to produce a slightly acidic solution.

3 (b) Calculate the pH of a buffer solution made by adding 3.40 g sodium acetate to 500 cm^3 of 0.1 M acetic acid (assume the volume does not change on addition of sodium acetate).
Ka for acetic acid = 1.8×10^{-5}

Moles of acetic acid = 0.1 mol/L × 0.5 L = 0.05 mol
Molar mass of sodium acetate = 82 g/mol
Moles of sodium acetate = 3.40 g / 82 g/mol = 0.04146 mol

Using Henderson-Hasselbalch equation:
$pH = pKa + \log ([salt]/[acid])$
$pKa = -\log(1.8 \times 10^{-5}) = 4.74$
$pH = 4.74 + \log (0.04146 / 0.05)$
$= 4.74 + \log (0.8292) = 4.74 - 0.081 = 4.66$

3 (c) Hydrochloric acid of concentration 1×10^{-5} mol dm^{-3} has a pH of 5 but acetic acid of the same concentration has a pH of 2.87. What is the reason behind the difference in their pH? Justify your answer with the help of mathematical calculations.

HCl is a strong acid and ionizes completely:
$[H^+] = 1 \times 10^{-5} \rightarrow pH = -\log(1 \times 10^{-5}) = 5$

Acetic acid is a weak acid and ionizes partially. Use Ka = 1.8×10^{-5}
$HA \rightleftharpoons H^+ + A^-$

Let x be $[H^+]$ at equilibrium
$Ka = x^2 / (0.00001 - x) \approx x^2 / 0.00001$
$1.8 \times 10^{-5} = x^2 / 0.00001$
$x^2 = 1.8 \times 10^{-10}$
$x = \sqrt{(1.8 \times 10^{-10})} = 1.34 \times 10^{-5}$
$pH = -\log(1.34 \times 10^{-5}) = 4.87$

But this does not match given pH of 2.87. That implies stronger ionization than calculated, suggesting either a misprint or different assumptions. The general reason is that HCl ionizes completely releasing more H^+, while acetic acid ionizes partially, hence giving lower $[H^+]$ and higher pH.

However, if given pH is 2.87 for acetic acid at same concentration, it means $[H^+] \approx 1.35 \times 10^{-3}$, which is only possible if the acid concentration is higher or Ka is higher than assumed.

Thus, the difference in pH arises due to complete ionization by strong acid versus partial ionization by weak acid.

4 (a) (i) Draw an energy diagram to show how solid aluminium chloride is formed from its elements under standard conditions. Indicate and name all energy changes in the diagram.

Description of energy diagram (step-by-step vertical levels):

- Level 1: Elements in standard states (Al(s), $Cl_2(g)$)
- Energy input: Sublimation energy of Al
- Energy input: Bond dissociation energy of Cl_2 (to form Cl atoms)
- Energy input: Ionisation energies of Al (to form Al^{3+})
- Energy release: Electron affinity of Cl (to form Cl^-)
- Energy release: Lattice energy (formation of $AlCl_3$ solid)

Label the steps:
- Sublimation energy of Al
- Ionisation energy of Al
- Bond dissociation energy of Cl_2
- Electron affinity of Cl
- Lattice energy of $AlCl_3$

(ii) What is the name of the energy diagram you have shown in 4(a)(i) above?

Born-Haber Cycle

4 (b) (i) State Hess's Law.Hess's Law states that the total enthalpy change of a chemical reaction is the same regardless of the route taken, provided the initial and final conditions are the same.
(ii) Calculate the C–Cl bond energy given that the enthalpy of formation of tetrachloromethane is –135.5 kJ mol^{-1} and the enthalpies of atomisation of graphite and chlorine are 715.0 kJ mol^{-1} and 121 kJ mol^{-1} respectively.

Reaction: C(graphite) + $2Cl_2(g) \rightarrow CCl_4(g)$
Formation enthalpy = bond energies of products - sum of energies of atoms

Total energy required:
Atomisation of carbon = 715
Bond dissociation of $2Cl_2 = 2 \times 121 = 242$
Total input = 715 + 242 = 957

Output: 4 C–Cl bonds formed
$-135.5 = 957 - 4x$
$4x = 957 + 135.5 = 1092.5$
$x = 273.1$ kJ/mol

C–Cl bond energy = 273.1 kJ/mol

4 (c) (i) Explain why copper (II), mercury (II) and lead (II) ions are precipitated as sulphides by bubbling H_2S gas through their aqueous solutions in acidic medium while zinc (II), nickel (II) and cobalt (II) ions do not form precipitates of their sulphides under such conditions.

Cu^{2+}, Hg^{2+} and Pb^{2+} form sulphides (CuS, HgS, PbS) with very low solubility products (Ksp), so even at low $[S^{2-}]$ in acidic medium, they precipitate.
Zn^{2+}, Ni^{2+} and Co^{2+} have higher Ksp values; in acidic medium the $[S^{2-}]$ is very low due to suppression by H^+, so their sulphides remain dissolved and do not precipitate.

(ii) The solubility product of $BaSO_4$ in water at 25°C is 1×10^{-10} $mol^2\ dm^{-6}$. Calculate the mass of the precipitate formed when 20 cm^3 of 0.01 M $BaCl_2$ and 20 cm^3 of 0.01 M Na_2SO_4 solutions are mixed at 25°C.

Moles of $Ba^{2+} = 0.01$ mol/L $\times$ 0.02 L $= 2.0 \times 10^{-4}$ mol
Moles of $SO_4^{2-} = 0.01$ mol/L $\times$ 0.02 L $= 2.0 \times 10^{-4}$ mol

Both react in 1:1 molar ratio to form $BaSO_4$
$Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4(s)$

So all 2.0×10^{-4} mol of $BaSO_4$ forms
Molar mass of $BaSO_4 = 137 + 32 + 4\times16 = 233$ g/mol
Mass $= 2.0 \times 10^{-4} \times 233 = 0.0466$ g

Mass of $BaSO_4$ precipitate = 0.0466 g

5 (a) All the compounds listed below contain nitrogen element which is found in group V of the periodic table.

HNO_3, NO_2, $NaNO_3$, $NaNO_2$, HNO_2, NH_3

Which of those compounds contain nitrogen with the lowest oxidation state?

Oxidation states of nitrogen in each compound:

HNO_3: +5

NO_2: +4

$NaNO_3$: +5

$NaNO_2$: +3

HNO_2: +3

NH_3: –3

Compound with lowest oxidation state is NH_3 (–3)

5 (b) With the help of balanced equations, explain how a nitrate can be converted to nitric acid.

Step 1: Preparation of NO_2 from $NaNO_3$ and concentrated H_2SO_4

$NaNO_3 + H_2SO_4 \text{--->} NaHSO_4 + HNO_3$

Alternatively, industrial Ostwald process:

$4 NH_3 + 5 O_2 \text{--->} 4 NO + 6 H_2O$

$2 NO + O_2 \text{---->} 2 NO_2$

$3 NO_2 + H_2O \text{--->} 2 HNO_3 + NO$

Thus nitrate is oxidized to NO_2 and dissolved in water to give nitric acid.

5 (c) Complete and balance the following reaction equations:

(i) $NH_3(g) + O_2(g) \text{—>} NO(g) + H_2O(g)$

Balanced: $4 NH_3 + 3 O_2 \text{—>} 4 NO + 6 H_2O$

(ii) $NO(g) + O_2(g) \text{—>} NO_2(g)$

Balanced: $2 NO + O_2 \text{—>} 2 NO_2$

(iii) $NO_2(g) + H_2O(l) + O_2(g) \text{—>} HNO_3(aq)$

Balanced: $4 NO_2 + 2 H_2O + O_2 \text{—>} 4 HNO_3$

(iv) $NH_4Cl(s) \text{—>} \Delta \text{—>} NH_3(g) + HCl(g)$

Balanced: $NH_4Cl \rightarrow NH_3 + HCl$

6 (a) What is a transition element?

A transition element is a d-block element that forms one or more stable ions with a partially filled d-orbital. They typically exhibit variable oxidation states and form colored compounds.

6 (b) Given an element with atomic number 26:

(i) Write its electronic configuration in terms of atomic orbitals.

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^6$

(ii) List down the stable ions of the element with atomic number 26 that are found in nature.

Fe^{2+} and Fe^{3+}

(iii) Write the electronic configuration of the stable ions in 6(b)(ii) in terms of atomic orbitals.

Fe^{2+}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6$
Fe^{3+}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5$

6 (c) Explain briefly five (5) major properties of transition elements.

- Variable oxidation states: Transition elements commonly show more than one oxidation state due to involvement of d-electrons in bonding.

- Formation of colored compounds: Many transition metal compounds are colored due to d-d electron transitions.

- Catalytic properties: Transition metals and their compounds often act as catalysts in chemical reactions, e.g., Fe in Haber process.

- Complex formation: Transition elements form stable complexes with ligands because of their small size and high charge.

- Magnetic properties: Many transition elements show paramagnetism due to unpaired electrons in d-orbitals.

7 (a) Using chemical equations, explain the following observations:

(i) Lead (II) chloride is soluble in concentrated HCl.
$PbCl_2$ is sparingly soluble in water but dissolves in concentrated HCl due to formation of a soluble complex ion:
$PbCl_2(s) + 2Cl^-(aq) \rightleftharpoons [PbCl_4]^{2-}(aq)$
(ii) The aluminium hydroxide precipitate is soluble in excess sodium hydroxide.
Aluminium hydroxide initially precipitates:
$Al^{3+}(aq) + 3OH^-(aq)$ ----> $Al(OH)_3(s)$
In excess NaOH, it dissolves forming a soluble complex:
$Al(OH)_3(s) + OH^-(aq) \rightleftharpoons [Al(OH)_4]^-(aq)$

(iii) Addition of ammonia solution to aqueous copper(II) sulphate gives a pale blue precipitate initially and deep blue solution when more ammonia solution is used.
Initial reaction:
$Cu^{2+}(aq) + 2OH^-$(from NH_4OH) ---> $Cu(OH)_2(s)$ (pale blue precipitate)
With excess NH_3:
$Cu(OH)_2(s) + 4NH_3(aq) \rightleftharpoons [Cu(NH_3)_4]^{2+}(aq)$ (deep blue solution)

(iv) Zinc oxide is amphoteric.
It reacts with both acids and bases:
With acid: $ZnO + 2HCl$ ----> $ZnCl_2 + H_2O$
With base: $ZnO + 2NaOH + H_2O$ ---> $Na_2[Zn(OH)_4]$

(v) Aqueous aluminium nitrate turns blue litmus red.
Al^{3+} ion hydrolyses in water forming acidic solution:
$Al^{3+} + 3H_2O \rightleftharpoons Al(OH)_3 + 3H^+$
The release of H^+ makes the solution acidic, turning blue litmus red.

7 (b) Give IUPAC names of the following complexes:

(i) $[Cr(H_2O)_4Cl_2]Cl \cdot 2H_2O$
Tetraaquodichlorochromium(III) chloride dihydrate

(ii) $[Co(NH_3)_6]Cl_3$
Hexaamminecobalt(III) chloride

(iii) $[Ag(CN)_2]^-$
Dicyanoargentate(I) ion

(iv) $[Fe(H_2NCH_2CH_2NH_2)_3]^{2+}$
Tris(ethylenediamine)iron(II) ion

(v) $[PtCl_2(en)]$
Dichlorido(ethylenediamine)platinum(II)

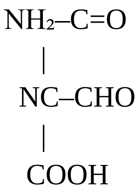
8 (a) Account for the following:

(i) In most cases benzene is very resistant to electrophilic addition reaction.
Benzene has a stable delocalised π-electron system spread over six carbon atoms forming an aromatic ring. Electrophilic addition would require disruption of this aromatic system, which is energetically unfavorable. Instead, benzene undergoes electrophilic substitution to preserve its aromaticity.

(ii) Amino group directs to ortho and para-positions on benzene ring, although it is a deactivator.
The amino group contains a lone pair on nitrogen that participates in resonance with the benzene ring. This electron-donating effect increases electron density at ortho and para positions, making them more reactive towards electrophiles. However, due to the lone pair being partially involved in resonance, the overall ring becomes less reactive than unsubstituted benzene (deactivation).

(iii) Methylamine is more basic than ammonia.
The methyl group in methylamine is an electron-donating group via inductive effect (+I effect), which increases electron density on the nitrogen atom, making it more able to donate a lone pair to a proton. Hence, methylamine is a stronger base than ammonia.

8 (b) Given the structure of compound K:



$$\begin{array}{c} NH_2\text{–}C{=}O \\ | \\ NC\text{–}CHO \\ | \\ COOH \end{array}$$

Write down the chemical equations for the reaction between compound K and:

(i) Aqueous sulphuric acid
– The amino group undergoes protonation and carboxylic group may form an acid salt:
$NH_2\text{–}C{=}O + H_2SO_4 \text{---}> NH_3^+\text{–}C{=}O$ (protonated) and COOH remains unchanged

(ii) Phosphorus pentachloride
– Reacts with carboxylic group forming acyl chloride:
$COOH + PCl_5 \text{---}> COCl + POCl_3 + HCl$
– Also, amide oxygen may be replaced:
C=O group may form imidoyl chloride

(iii) Ethanol
– Carboxylic acid reacts with ethanol in acidic medium to form ester:
$COOH + C_2H_5OH \text{---}> COOC_2H_5 + H_2O$

(iv) Potassium permanganate
– Oxidizes aldehyde to carboxylic acid:
CHO + [O] ---> COOH
So compound becomes dicarboxylic acid

(v) Sodium borohydride ($NaBH_4$)
– Reduces aldehyde and possibly amide:
CHO + $NaBH_4$ ---> CH_2OH
Amide group remains unaffected under mild conditions

Here is a clear transcription of questions 9 and 10 from the image:

9 (a) An organic compound A (C_3H_6O) containing carbonyl group was reduced with $LiAlH_4$ to give compound B. B was dehydrated with concentrated sulphuric acid to give product C of molecular formula C_3H_6. Ozonolysis of C followed by hydrolysis gave ethanol and compound D of molecular formula C_2H_4O. D gives positive iodoform reaction.

(i) Identify A, B, C, and D compounds. Give their structural formulae and IUPAC names.
(ii) Give equations for all reactions.
(12 marks)

(b) Arrange the following compounds in order of increasing acidity and give reasons for your order:
(1) Phenol
(2) Toluene
(3) o-Cresol
(04 marks)

(c) Identify briefly the condition necessary for the following reactions:

(i) Benzene + Br_2 —> Bromobenzene + HBr
(ii) Toluene + Br_2 —> p-Bromotoluene + HBr
(04 marks)

10 (a) Write short notes on:
(i) Additional polymerisation
(ii) Condensation polymerisation
(06 marks)

(b) (i) Give structural formulae of hexane-1,6-dioic acid and 1,6-diaminohexane
(ii) Explain why the pair of molecules in 10(b)(i) is suitable for polymerisation
(iii) Give the structural formula of the polymer which might be formed by the pair of molecules in 10(b)(i)
(iv) What is the repeating unit of the polymer formed in 10(b)(iii)?
(08 marks)

(c) Indicate the monomer and polymerisation method which is likely to be used in making each of the following commercial polymers:
(i) $–CF_2–CF_2–CF_2–CF_2–CF_2–$
(ii) $–CH–CH_2–CHCH_3–CHCH_3–CH–CH_2–$
(iii) $–NH–(CH_2)_6–CO–NH–(CH_2)_5–CO–NH–(CH_2)_6–CO–$
9 (a) An organic compound A (C_3H_6O) containing carbonyl group was reduced with $LiAlH_4$ to give compound B. B was dehydrated with concentrated sulphuric acid to give product C of molecular formula C_3H_6. Ozonolysis of C followed by hydrolysis gave ethanol and compound D of molecular formula C_2H_4O. D gives positive iodoform reaction.

(i) Identify A, B, C and D compounds. Give their structural formulae and IUPAC names.

Compound A: Propanone ($CH_3–CO–CH_3$)
Compound B: Propan-2-ol ($CH_3–CHOH–CH_3$)
Compound C: Propene ($CH_2=CH–CH_3$)
Compound D: Ethanal ($CH_3–CHO$)

(ii) Give equations for all reactions.

Reduction:
$CH_3–CO–CH_3 + 2[H] \text{ ---> } CH_3–CHOH–CH_3$ (using $LiAlH_4$)

Dehydration:
$CH_3–CHOH–CH_3 \text{ ---> } CH_2=CH–CH_3 + H_2O$ (using conc H_2SO_4)

Ozonolysis:
$CH_2=CH–CH_3 + O_3 \text{ ---> } CH_3–CHO + HCHO$ (formaldehyde hydrolyses further to give ethanol)

Iodoform test:
$CH_3–CHO + 3I_2 + 4NaOH \text{ ---> } CHI_3 + HCOONa + 3NaI + 3H_2O$

(b) Arrange the following compounds in order of increasing acidity and give reasons for your order:
Toluene < o-Cresol < Phenol

Toluene has electron-donating methyl group which destabilizes the phenoxide ion. o-Cresol also has a methyl group but the –OH group enhances acidity slightly compared to toluene. Phenol has no additional electron-donating group, so its phenoxide ion is more stable, making it more acidic.

(c) Identify briefly the condition necessary for the following reactions:

(i) Benzene + Br_2 ---> Bromobenzene + HBr
Requires presence of Lewis acid catalyst like $FeBr_3$ or $AlCl_3$

(ii) Toluene + Br_2 ---> p-Bromotoluene + HBr
Occurs easily under mild conditions due to activation by methyl group, can proceed without catalyst but UV light or $FeBr_3$ can enhance the reaction

10 (a) Write short notes on:

(i) Additional polymerisation
This is a type of polymerisation where monomers with double or triple bonds (unsaturated compounds) join together without the loss of any small molecules. It involves breaking the π-bond of the monomer and forming new σ-bonds to link repeating units. Examples include polythene from ethene, PVC from vinyl chloride.

(ii) Condensation polymerisation
This is a process where monomers containing two or more functional groups react to form a polymer with the elimination of small molecules like water, HCl, or methanol. Common functional groups include –COOH, –OH, $–NH_2$. Examples include nylon and polyesters.

(b) (i) Give structural formulae of hexane-1,6-dioic acid and 1,6-diaminohexane

Hexane-1,6-dioic acid: $HOOC–(CH_2)_4–COOH$
1,6-diaminohexane: $H_2N–(CH_2)_6–NH_2$

(ii) Explain why the pair of molecules in 10(b)(i) is suitable for polymerisation
The two molecules contain reactive terminal groups: dicarboxylic acid and diamine. They can undergo condensation polymerisation by forming amide linkages with elimination of water. Their bifunctionality allows chain extension and polymer formation.

(iii) Give the structural formula of the polymer which might be formed by the pair of molecules in 10(b)(i)
$–NH–(CH_2)_6–NH–CO–(CH_2)_4–CO–$

(iv) What is the repeating unit of the polymer formed in 10(b)(iii)?
$–NH–(CH_2)_6–NH–CO–(CH_2)_4–CO–$

(c) Indicate the monomer and polymerisation method which is likely to be used in making each of the following commercial polymers:

(i) $–CF_2–CF_2–CF_2–CF_2–CF_2–$
Monomer: Tetrafluoroethene ($CF_2=CF_2$)
Polymerisation method: Addition polymerisation

(ii) $–CH–CH_2–CHCH_3–CHCH_3–CH–CH_2–$
Monomers: Propene and butene derivatives
Polymerisation method: Addition polymerisation

(iii) $–NH–(CH_2)_6–CO–NH–(CH_2)_5–CO–NH–(CH_2)_6–CO–$
Monomers: Hexane-1,6-diamine and pentane-1,5-dioic acid
Polymerisation method: Condensation polymerisation