G.C.E.(A.L.) Examination - 2013

Evaluation Report

02 - Chemistry

Research & Development Branch
National Evaluation & Testing Service
Department of Examinations

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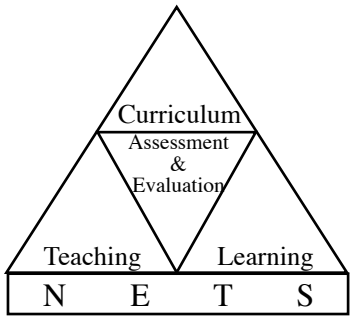

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Evaluation Report - G.C.E.(A.L.) Examination - 2013

Financial Aid

Transforming the School Education System as the Foundation of a Knowledge Hub Project (TSEP-WB)

INTRODUCTION

The General Certificate of Education (Advanced Level) Examination is the final certification examination of the Senior Secondary Education in Sri Lanka. Though certification of t`he students' achievement level at the end of Senior Secondary Education is the major aim of this examination, it bears a momentous position as an achievement test as well as a selection test because the eligible candidates for national universities and other higher education and vocational training institutes and also for the National Colleges of Education are selected on the results of this examination. This has also been accepted as an examination that certifies entry qualifications for the tertiary level employments. New syllubuss in the year 2013, 209906 school candidates and 31723 n private candidates sat this examination.

Much pains are being taken by students to have a high achievement level at this examination and teachers and parents to fulfil their expectations. This evaluation report has been prepared by the Department of Examinations to assist the realization of their goals. It is certain that the information provided by this evaluation report is equally important for candidates, teachers, principals, in-service advisers, subject directors, parents and researchers in education. So it is appropriate to tender this report for wider reference.

This evaluation report comprises of three parts. I, II and III.

Part I of this report consists of information related to aims and achievement of the subject Chemistry in G.C.E. (A.L) Examination. Presented under it are the statistical information on subject achievement, that is number of candidates sat for the subject, how they have obtained grades, how school candidates have obtained grades by district and distribution of marks according to class intervals and a comprehensive analysis of the subject achievement that reveals how candidates have selected questions in Papers I and II in Chemistry and how they have scored marks for the questions in them and the sub parts of each question. Part II of this report presents the questions in Paper I and Paper II of Chemistry in the G.C.E. (A.L) Examination 2013 and information about the candidates' responses to them. It encompasses expected answers for the questions of papers I and II, the mark scheme, observations on answers, conclusions and constructive suggestions.

This evaluation report prepared by the Research and Development Branch of the Department of Examinations is based on the information, observations, ideas and suggestions provided by chief examiners, additional chief examiners and assistant examiners involved in evaluating answer scripts and the information drawn through the analysis of candidates' responses using the Classical Test Theory and the Item Response Theory.

Part III of this report embodies the facts that should be taken into consideration by the candidates when answering each question and opinions and suggestions with regard to the learning teaching process. I think that this report is of immense value in the organization of the learning teaching process to achieve respective competencies and competency levels.

You are kindly requested to direct your productive ideas and suggestions to us to improve the quality of our future evaluation reports.

I wish to extend my sincere thanks to the chief examiners, additional chief examiners and assistant examiners who provided information to prepare this report, the committee members who fervently and actively contributed to the task, the officers and the staff of the Department of Examinations who shouldered the responsibility and the TSEP-WB for providing financial assistance for this task.

W.M.N.J. Pushpakumara
Commissioner General of Examinations

19th January 2015
Research & Development Branch
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Pelawatta, Battaramulla.

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Part I

1. Subject objectives and information on subject achievements

1.1 Subject objectives

After following this course the student will :

* understand the basic concepts in chemistry required to comprehend the physical foundation of scientific explanations of natural phenomena.
* become knowledgeable about the total framework of chemistry including its main concepts, unifying themes and patterns enabling to understand the structure and changes in matter and lay the foundation for students who pursue the study of further chemistry in the future.
* incline to understand and appreciate the nature of the scientific process through direct experiences and inquiring into the historical development of chemistry.
* understand the limits of science and how it is applied in relation to technical, economic, social and personal development.
* understand the physico - chemical foundation of problems relating to the scientific usage and conservation of resources acquiring a general knowledge of them with special attention to the conditions prevailing in Sri Lanka.
* acquire knowledge and skills required for the application of basic concepts in chemistry for technical, social and economic development with special attention to Sri Lanka.
* develop interest for applying the knowledge and skills gained through the course for socio - economic development and conservation and utilization of natural resources.

1.2 Statistical information on subject achievement

1.2.1 Number of candidates sat for the subject

Medium	School	Private	Total
Sinhala	48754	10005	58759
Tamil	7596	957	8553
English	3008	378	3386
Total	**59358**	**11340**	**70698**

Table 1

1.2.2 Grades obtained by the candidates

Grade	School Candidates		Private Candidates		Total	Percentage
	Number	Percentage	Number	Percentage		
A	2240	3.77	580	5.11	2820	3.99
B	4079	6.87	1236	10.90	5315	7.52
C	10038	16.91	2446	21.57	12484	17.66
S	19744	33.26	4015	35.41	23759	33.60
F	23257	39.19	3063	27.01	26230	37.23
Total	**59358**	**100.00**	**11340**	**100.00**	**70698**	**100.00**

Table 2

1.2.3 Grades obtained by school candidates who sat the examination for the first time - Districtwise

District	No. Sat	Distinction (A)		Very Good Pass (B)		Credit Pass (C)		Ordinary Pass (S)		Pass (A+B+C+S)		Failed (F)	
		Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
1. Colombo	5819	343	5.89	468	8.04	1018	17.49	1897	32.60	3726	64.03	2093	35.97
2. Gampaha	3575	92	2.57	153	4.28	505	14.13	1136	31.78	1886	52.76	1689	47.24
3. Kalutara	2204	35	1.59	88	3.99	266	12.07	623	28.27	1012	45.92	1192	54.08
4. Kandy	2940	71	2.41	140	4.76	384	13.06	924	31.43	1519	51.67	1421	48.33
5. Matale	733	6	0.82	19	2.59	66	9.00	209	28.51	300	40.93	433	59.07
6. Nuwara Eliya	868	6	0.69	18	2.07	62	7.14	227	26.15	313	36.06	555	63.94
7. Galle	2439	84	3.44	142	5.82	357	14.64	781	32.02	1364	55.92	1075	44.08
8. Matara	2141	87	4.06	108	5.04	270	12.61	651	30.41	1116	52.13	1025	47.87
9. Hambantota	1636	28	1.71	56	3.42	176	10.76	489	29.89	749	45.78	887	54.22
10. Jaffna	1267	76	6.00	88	6.95	196	15.47	386	30.47	746	58.88	521	41.12
11. Kilinochchi	175	7	4.00	7	4.00	11	6.29	60	34.29	85	48.57	90	51.43
12. Mannar	147	1	0.68	1	0.68	14	9.52	50	34.01	66	44.90	81	55.10
13. Vavuniya	214	9	4.21	7	3.27	36	16.82	63	29.44	115	53.74	99	46.26
14. Mullativu	138	6	4.35	2	1.45	20	14.49	34	24.64	62	44.93	76	55.07
15. Batticaloa	561	34	6.06	52	9.27	105	18.72	184	32.80	375	66.84	186	33.16
16. Ampara	1131	17	1.50	41	3.63	114	10.08	373	32.98	545	48.19	586	51.81
17. Trincomalee	498	21	4.22	28	5.62	57	11.45	169	33.94	275	55.22	223	44.78
18. Kurunegala	3158	50	1.58	99	3.13	321	10.16	976	30.91	1446	45.79	1712	54.21
19. Puttalam	921	17	1.85	31	3.37	105	11.40	296	32.14	449	48.75	472	51.25
20. Anuradhapura	1293	24	1.86	33	2.55	116	8.97	318	24.59	491	37.97	802	62.03
21. Polonnaruwa	517	2	0.39	9	1.74	65	12.57	138	26.69	214	41.39	303	58.61
22. Badulla	1439	31	2.15	54	3.75	164	11.40	472	32.80	721	50.10	718	49.90
23. Monaragala	624	2	0.32	9	1.44	59	9.46	178	28.53	248	39.74	376	60.26
24. Ratnapura	1757	30	1.71	50	2.85	197	11.21	524	29.82	801	45.59	956	54.41
25. Kegalle	1628	20	1.23	56	3.44	190	11.67	512	31.45	778	47.79	850	52.21
All Island	**37823**	**1099**	**2.91**	**1759**	**4.65**	4874	12.89	11670	30.85	19402	51.30	18421	48.70

Table 3

1.2.4 Marks obtained according to class intervals

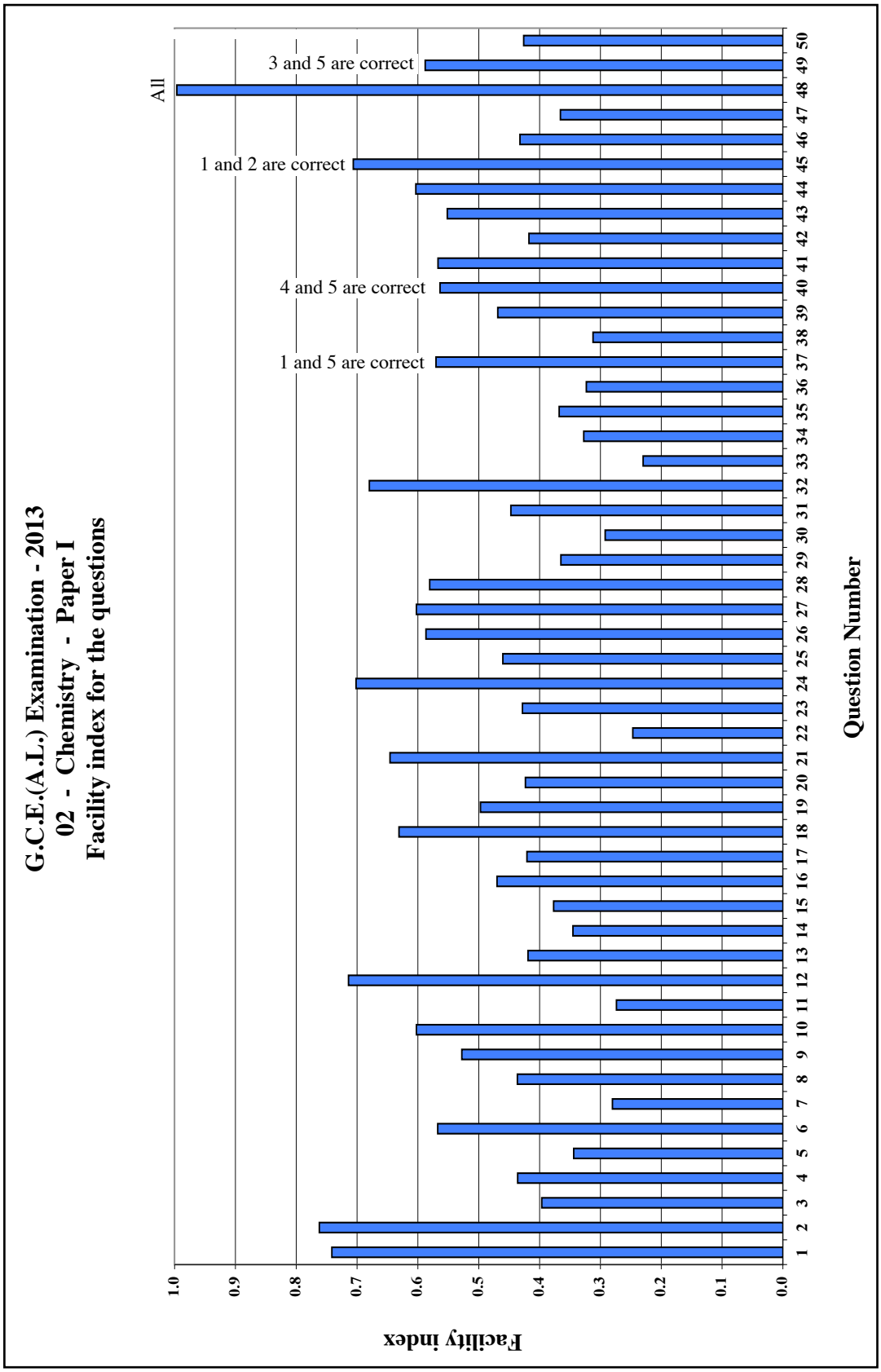
Class Interval	Frequency	Frequency Percentage	Cumulative Frequency	Cumulative Frequency Percentage
91 - 100	47	0.07	70698	100.00
81 - 90	948	1.34	70651	99.93
71 - 80	3620	5.12	69703	98.59
61 - 70	6354	8.99	66083	93.47
51 - 60	8615	12.19	59729	84.48
41 - 50	12005	16.98	51114	72.30
31 - 40	14388	20.35	39109	55.32
21 - 30	15034	21.27	24721	34.97
11 - 20	9309	13.17	9687	13.70
01 - 10	369	0.52	378	0.53
00 - 00	9	0.01	9	0.01

Table 4

Accourding to the above table the number of candidates scoring from 21 - 30 is 15034. As a percentage it is 21.27. The number scoring 30 or below marks is 24721 and as a percentage it is 34.97.

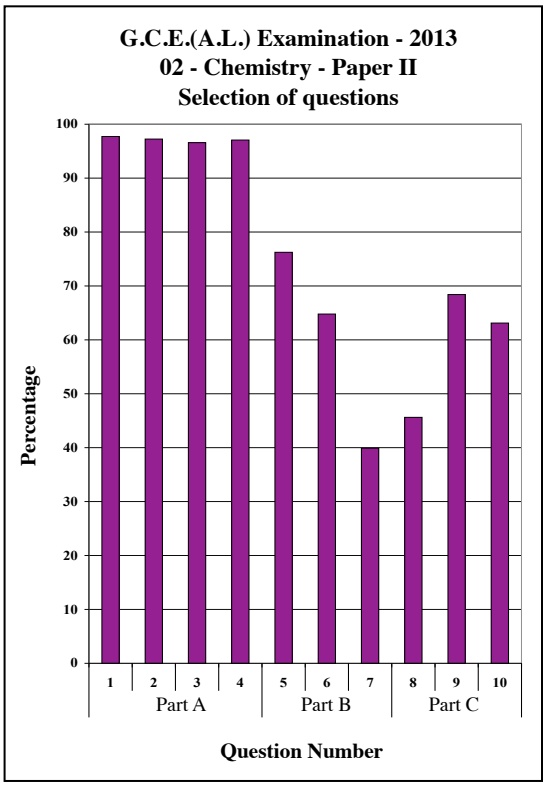
1.3 Analysis of Subject Achievement

1.3.1 Achievement in Paper I



Graph 1 (Prepared using the information collected from form RD/16/05/AL)
According to the above graph highest number of candidates has correctly responded to question 2. Its percentage is 76%. Least number of candidates has correctly responded to question 33. Its percentage is 23%.

1.3.2 Selection of questions in Paper II

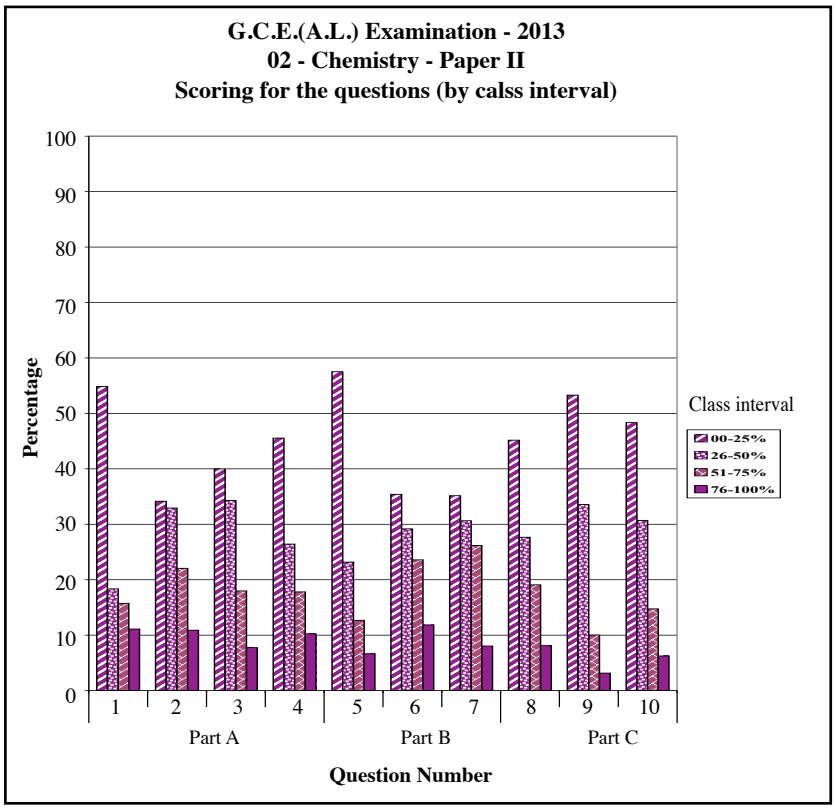


Though questions 1 - 4 were compulsory, a small number has not answered even the compulsory questions. Nearly 98% have answered question 1. The percentage selecting question 3 is about 97%.

Of questions 5 - 10 in Part B, question 5 was the choice of the most and question 7 was the selection of the least. The percentages selecting these two were 76% and 40% respectively.

Graph 2 (Prepared using the information collected from the form RD/16/02/AL)

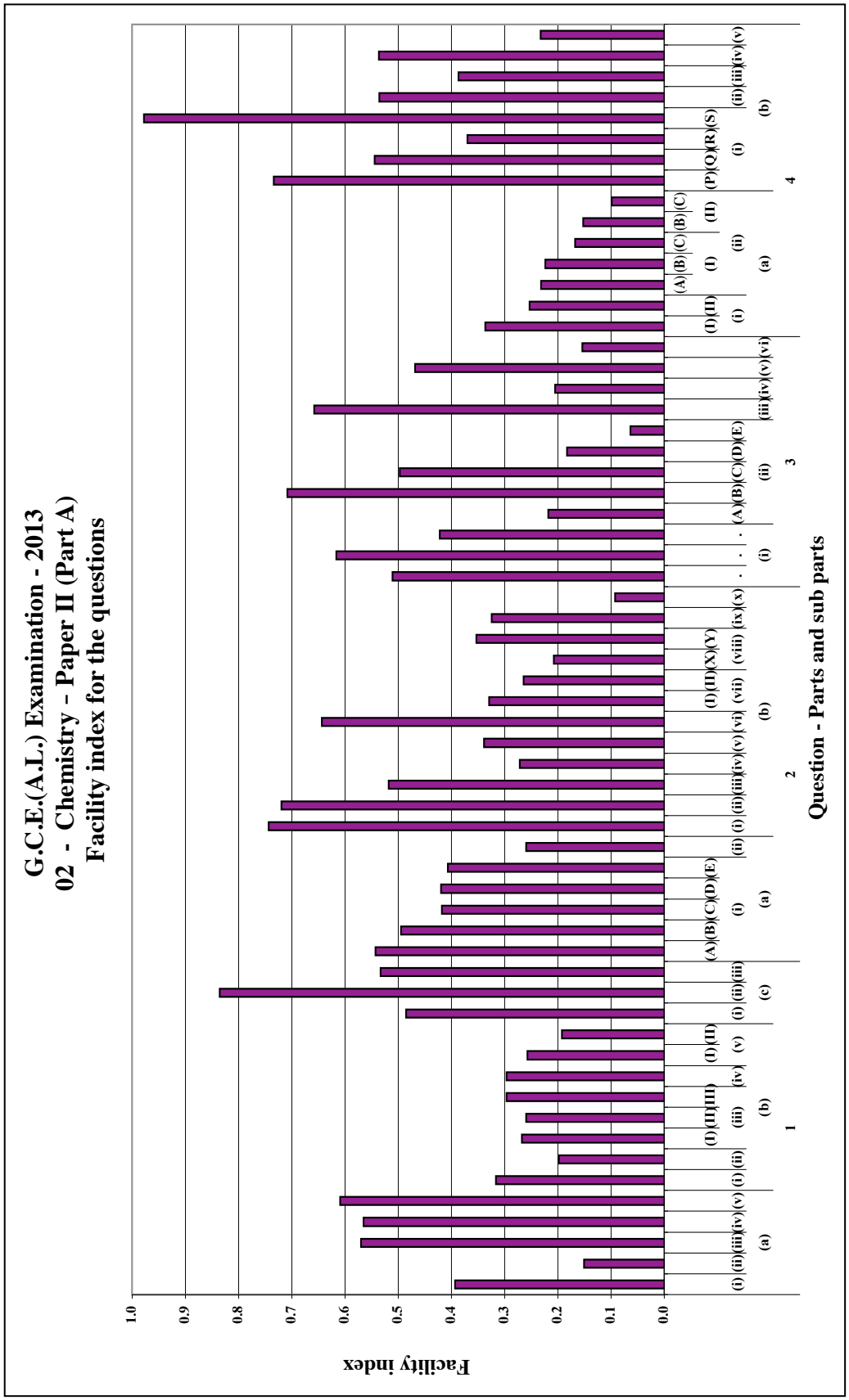
1.3.3 Scoring for the questions in Paper II



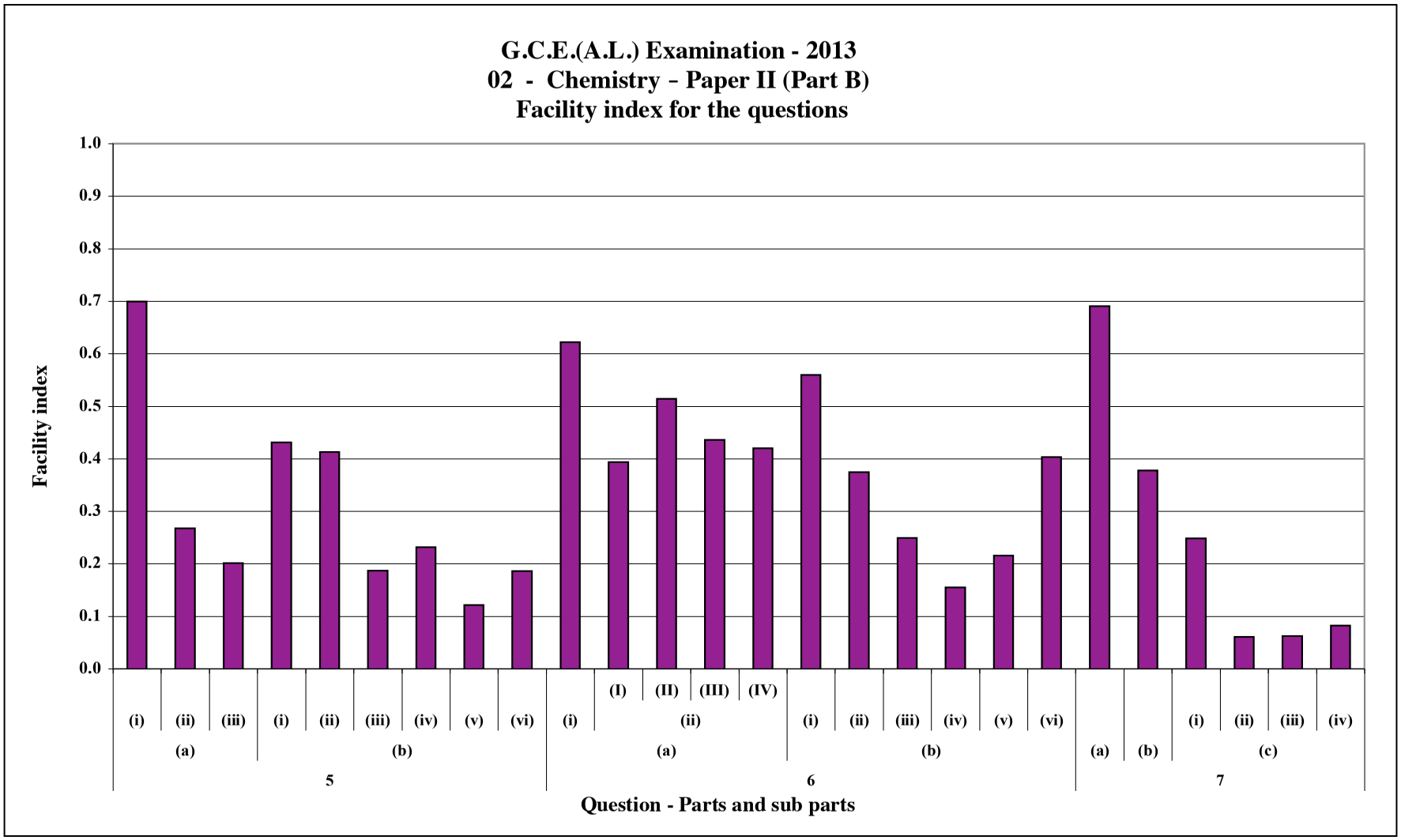
As an example marks allocated for question 1 is 100. The percentage scoring within the range 76% - 100% is 11%. The percentage getting between 00% and 25% of the 100 marks set apart was about 55%.

Graph 3 (Prepared using the information collected from the form RD/16/02/AL)

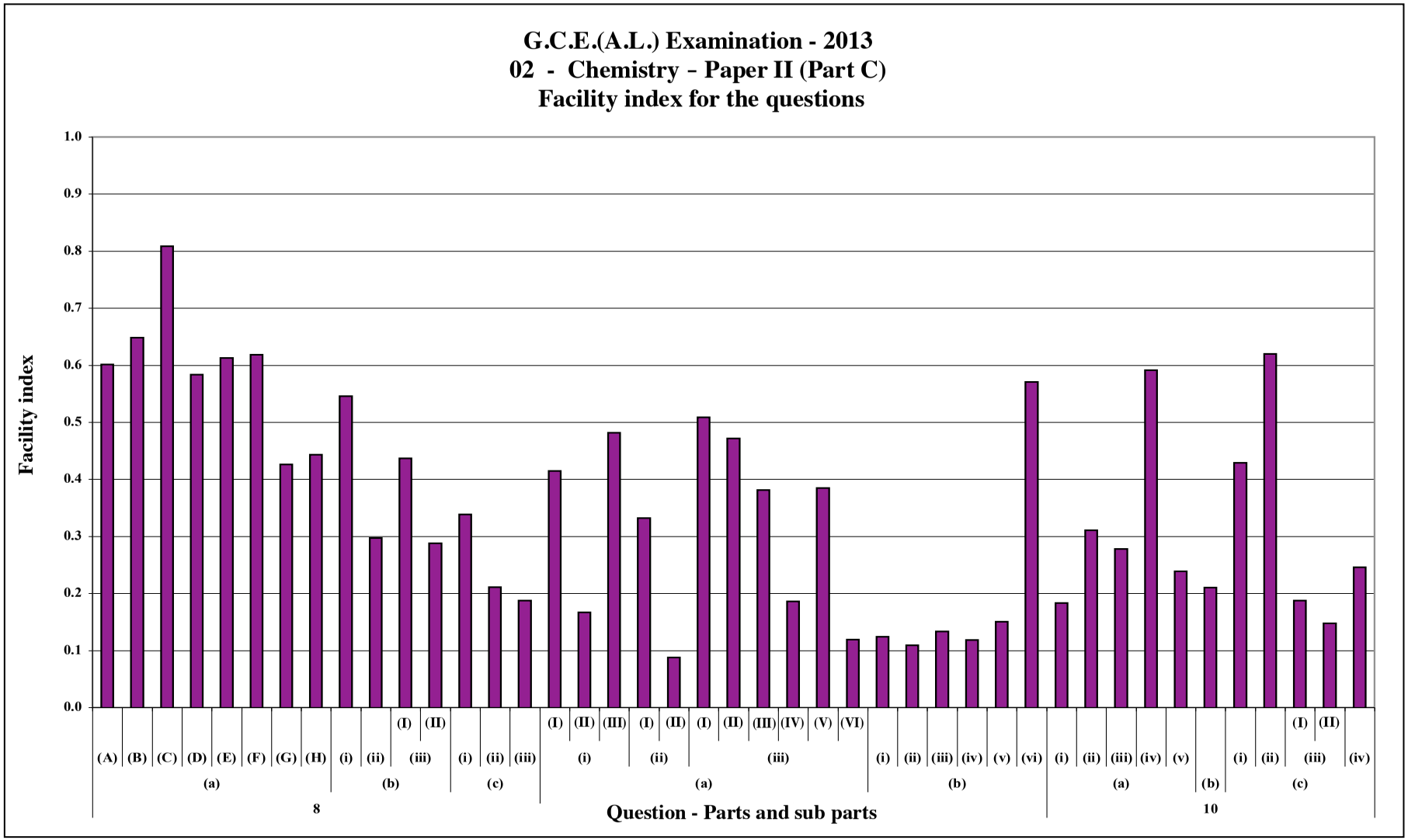
1.3.4 Achievement in Paper II



Graph 4.1 (Prepared using the information collected from the form RD/16/04/AL)


G.C.E.(A.L.) Examination - 2013
02 - Chemistry - Paper II (Part B)
Facility index for the questions
Facility index
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
(i) (ii) (iii) (i) (ii) (iii) (iv) (v) (vi) (i) (I) (II) (III) (IV) (i) (ii) (iii) (iv) (v) (vi) (a) (b) (i) (ii) (iii) (iv)
(a) (b) (a) (b) (c)
5 6 7
Question - Parts and sub parts

Graph 4.2


G.C.E.(A.L.) Examination - 2013
02 - Chemistry - Paper II (Part C)
Facility index for the questions
Facility index
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
(A) (B) (C) (D) (E) (F) (G) (H) (i) (ii) (I) (II) (iii) (i) (ii) (iii) (I) (II) (III) (I) (II) (I) (II) (III) (IV) (V) (VI) (i) (ii) (iii) (iv) (v) (vi) (i) (ii) (iii) (iv) (v) (i) (ii) (I) (II) (iii) (iv)
(a) (b) (c) (i) (a) (iii) (b) (a) (b) (c)
8
Question - Parts and sub parts
10

Graph 4.3

Part II

2. Information on questions and answers

2.1 Question paper I and information on answers to paper I

2.1.1 Structure of Paper I

Time is 02 hours. Total mark is 100.

- This question paper consists of 50 multiple choice questions each with five options. For each question, candidates were expected to select the correct or the most suitable option from the options (1), (2), (3), (4) and (5).

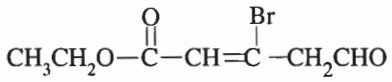
- Responding to all the questions is expected.

2.1.2 Paper I

1. The highest oxidation state and the outer electron configuration of the ground state of chromium respectively are
   (1) +3 and $[Ar]3d^4 4s^2$ (2) +4 and $[Ar]3d^5 4s^1$ (3) +6 and $[Ar]3d^4 4s^2$
   (4) +4 and $[Ar]3d^6 4s^0$ (5) +6 and $[Ar]3d^5 4s^1$

2. The **increasing** order of the first ionization energy of atoms N, Ne, Na, P, Ar and K is
   (1) Na < K < P < N < Ar < Ne (2) Na < K < Ar < N < P < Ne
   (3) P < N < K < Na < Ne < Ar (4) K < Na < N < P < Ne < Ar
   (5) K < Na < P < N < Ar < Ne

3. What is the IUPAC name of the following compound?



   (1) 3–bromo–5–ethoxy–5–oxo–3–pentenal (2) ethyl–3–bromo–5–oxopent–2–enoate
   (3) ethyl 3–bromo–2–en–5–oxopentanoate (4) ethyl 3–bromo–5–oxo–2–pentenoate
   (5) 3–bromo–1–ethoxy–5–oxo–2–pentenal

4. When the compound **X** having C, H, O only was treated with excess acetylchloride a compound having a relative molecular mass 126 units higher than that of **X** was obtained. The number of hydroxyl groups in **X** is
   (1) 1 (2) 2 (3) 3 (4) 4 (5) 5

5. The number of atomic orbitals possible for which the quantum numbers $n = 3$ and $m_l = -1$ is
   (1) 1 (2) 2 (3) 3 (4) 4 (5) 5

6. The electron pair geometry and the molecular shape of XeO_2F_2 respectively, are
   (1) trigonal bipyramid and see-saw. (2) trigonal bipyramid and tetrahedral.
   (3) tetrahedral and see-saw. (4) see-saw and trigonal bipyramid.
   (5) square planar and tetrahedral.

7. A mixture of Fe_2O_3 and FeO is found to contain 72.0% Fe by mass. The mass of Fe_2O_3 in 1.0 g of this mixture is (O = 16, Fe = 56)
   (1) 0.37 g (2) 0.52 g (3) 0.67 g (4) 0.74 g (5) 0.83 g

8. Samples of $F_2(g)$ and Xe(g) are mixed in a container of fixed volume. The partial pressures of $F_2(g)$ and Xe(g) before they react are 8.0×10^{-5} kPa and 1.7×10^{-5} kPa respectively. When all of the Xe(g) has reacted, forming a solid compound, the partial pressure of the remaining $F_2(g)$ was 4.6×10^{-5} kPa. The system was maintained at a constant temperature during the above process. What is the formula of the solid compound formed?
   (1) XeF_2 (2) XeF_3 (3) XeF_4 (4) XeF_6 (5) XeF_8

9. When an inorganic solid **X** was treated with dil. HCl, a colourless solution and a gas that turned a filter paper moistened with lead acetate solution black were produced. When the colourless solution was subjected to the flame test, an apple green coloured flame was observed.
   Solid **X** is
   (1) BaS (2) $CuSO_3$ (3) $BaSO_3$ (4) NiS (5) $CuCO_3$

10. Which of the following statements is **false** with regard to hypochlorous acid (HOCl) ?
    (1) HOCl is a weak acid.
    (2) The oxidation state of chlorine in HOCl is –1.
    (3) I_2 is produced when KI is added to an aqueous solution of HOCl.
    (4) In basic solution HOCl disproportionates on heating.
    (5) HOCl reacts with alkali to form salts called hyprochlorites.

11. A volume of 50.00 cm^3 of 0.01 mol dm^{-3} NaOH solution was added to 50.00 cm^3 of 0.11 mol dm^{-3} solution of the weak acid HA. The pH of the final mixture was found to be 6.2. If K_a is the dissociation constant of the acid, which of the following answers indicates its pK_a value?
    (1) 5.2 (2) 6.0 (3) 6.2 (4) 7.0 (5) 7.2

12. The IUPAC name of $[Co(CN)_2(NH_3)_4]^+$ is
(1) tetraammoniadicyanocobalt(III) ion
(2) tetraamminedicyanocobalt(III) ion
(3) dicyanotetraamminecobalt(III) ion
(4) tetraamminedicyanidecobalt(III) ion
(5) tetraaminedicyanocobalt(III) ion

13. A 50.00 cm^3 sample of a solution containing Fe^{2+} is titrated with 0.02 M $K_2Cr_2O_7$ in acidic medium. The volume of $K_2Cr_2O_7$ required to react all the Fe^{2+} is 25.00 cm^3. If this titration is carried out using 0.02 M $KMnO_4$ instead of 0.02 M $K_2Cr_2O_7$, the volume of $KMnO_4$ required is
(1) 22.00 cm^3 (2) 23.00 cm^3 (3) 25.00 cm^3 (4) 27.00 cm^3 (5) 30.00 cm^3

14. Consider the following elementary reaction.

$$\mathbf{A}(g) + \mathbf{B}(g) \longrightarrow \mathbf{C}(g)$$

The rate constant of the reaction at temperature T is k. n mol of **A** and n mol of **B** were mixed and allowed to react in a rigid container of volume V. If the universal gas constant is R, and the rate of reaction at time t is Q, the pressure (P) of the vessel at time t is given by

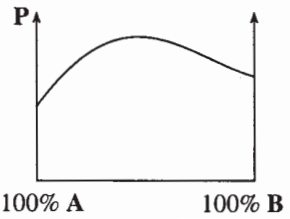
(1) $P = Q^2 \frac{RT}{V}$ (2) $P = \left[\frac{n}{V} + \left(\frac{Q}{k}\right)^{\frac{1}{2}}\right]RT$ (3) $P = \frac{Q}{k}\frac{RT}{V}$

(4) $P = \left(\frac{n}{V} + \frac{Q}{k}\right)RT$ (5) $P = \frac{2n\,RT}{V}$

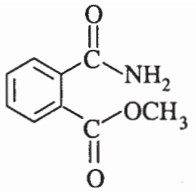
15. Volatile liquids **A** and **B** form an ideal solution when mixed. It was observed that the pressure of the vapour phase, which is in equilibrium with the liquid phase was doubled when the composition in the liquid phase was changed from $X_A = 0.2$, $X_B = 0.8$ to $X_A = 0.6$ and $X_B = 0.4$. The system was maintained at a constant temperature during the above process. The saturated vapour pressures of **A** and **B** at this temperature are P_A° and P_B° respectively. Which of the following relationships is **correct**?

(1) $\frac{P_A^\circ}{P_B^\circ} = 6$ (2) $P_A^\circ + P_B^\circ = \frac{1}{2}$ (3) $\frac{P_A^\circ}{P_B^\circ} = \frac{4}{3}$ (4) $\frac{P_A^\circ}{P_B^\circ} = \frac{3}{4}$ (5) $\frac{P_A^\circ}{P_B^\circ} = \frac{1}{6}$

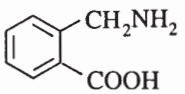
16. The variation of vapour pressure (**P**) with composition of a mixture of two miscible liquids **A** and **B** is shown in the figure.

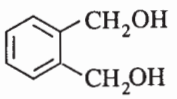


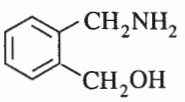
Which of the following answers is **true** about the intermolecular attractive forces?
(1) **A – A < A – B < B – B** (2) **A – A > A – B > B – B**
(3) **A – A < A – B > B – B** (4) **A – A > A – B < B – B**
(5) **A – A = A – B = B – B**

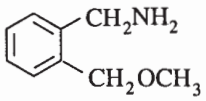
17. 

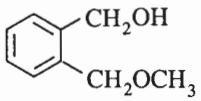
What is the **major** product obtained when the compound above is treated with $LiAlH_4$ and the reaction mixture is neutralized?

(1) 

(2) 

(3) 

(4) 

(5) 

18. Consider the following equilibria with equilibrium constants K_1, K_2 and K_3 respectively.

$$A(g) + B(g) \rightleftharpoons C(g)$$
$$C(g) + A(g) \rightleftharpoons D(g)$$
$$2A(g) + B(g) \rightleftharpoons D(g)$$

Which of the following equations shows the relationship among the three equilibrium constants?

(1) $K_3 = K_1 + K_2$ (2) $K_3 = \sqrt{K_1 K_2}$ (3) $K_3 = \frac{1}{K_1 K_2}$ (4) $K_3 = K_1 K_2$ (5) $K_3 = K_1 - K_2$

19. Which of the following arrangements shows the correct **increasing** order of pH of the following 1 M aqueous solutions?

HCl, KOH, $CaCl_2$, CH_3COOH, $CH_3COO^-Na^+$

(1) $KOH < CaCl_2 < CH_3COO^-Na^+ < CH_3COOH < HCl$
(2) $HCl < CaCl_2 < CH_3COOH < KOH < CH_3COO^-Na^+$
(3) $CH_3COOH < HCl < CaCl_2 < KOH < CH_3COO^-Na^+$
(4) $HCl < CH_3COOH < CH_3COO^-Na^+ < CaCl_2 < KOH$
(5) $HCl < CH_3COOH < CaCl_2 < CH_3COO^-Na^+ < KOH$

20. What is the total number of resonance structures that can be drawn for the HN_3 molecule? (Skeleton of the molecule, H—N—N—N)

(1) 2 (2) 3 (3) 4 (4) 5 (5) 6

21. Which of the following statements with regard to 3*d*-block transition elements is **false**?

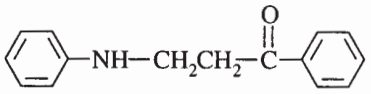
(1) Variable oxidation states result because of the comparable energies of 3*d* and 4*s* atomic orbitals.
(2) The electronegativity gradually decreases across the period from left to right.
(3) They have stronger metallic characteristics than those belonging to the *s*-block of the same period.
(4) Many ionic and covalent compounds of transition metals are coloured.
(5) Their densities are higher than the *s*-block elements of the same period.

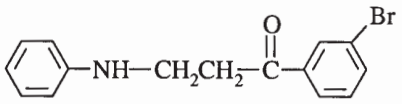
22. $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$

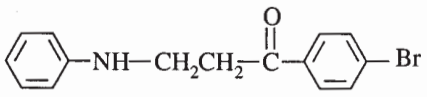
The reaction above is thermodynamically spontaneous at 298 K, but not so at high temperature. Which of the following is **true** about the reaction at 298 K?

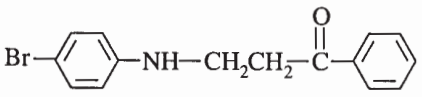
(1) ΔG, ΔH and ΔS all are positive.
(2) ΔG, ΔH and ΔS all are negative.
(3) ΔG and ΔH are negative and ΔS is positive.
(4) ΔG and ΔS are negative and ΔH is positive.
(5) ΔG and ΔH are positive and ΔS is negative.

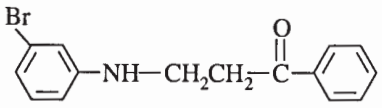
23. Predict the **major** product that will be obtained from the bromination of the following compound with $Br_2/FeBr_3$.

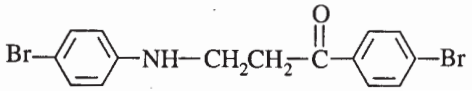


(1) 

(2) 

(3) 

(4) 

(5) 

24. Which of the following reactions is **not** likely to take place during chlorination of methane in the presence of light?

(1) $Cl-Cl \longrightarrow 2\,\dot{Cl}$

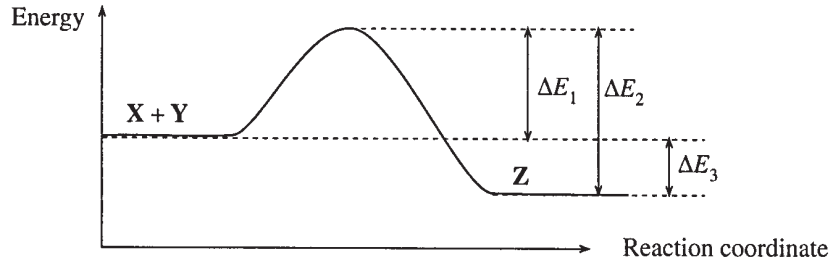
(2) $CH_4 + \dot{Cl} \longrightarrow CH_3Cl + \dot{H}$

(3) $CH_4 + \dot{Cl} \longrightarrow \dot{C}H_3 + HCl$

(4) $\dot{C}H_3 + Cl_2 \longrightarrow CH_3Cl + \dot{Cl}$

(5) $\dot{C}H_3 + \dot{Cl} \longrightarrow CH_3Cl$

25. The energy diagram for the reaction **X** + **Y** → **Z** is shown below.



The rate of this reaction is dependent on

(1) ΔE_1 only. (2) ΔE_2 only. (3) ΔE_3 only.

(4) $\Delta E_1 + \Delta E_2$. (5) $\Delta E_2 + \Delta E_3$.

26. Which of the following statements is **false** with regard to *s*-block elements?

(1) Group I elements are strong oxidizing agents.
(2) Group I elements have the lowest first ionisation energy values in a period.
(3) Group II elements are smaller than the corresponding Group I elements.
(4) In general, Groups I and II elements form ionic compounds.
(5) Group II elements are harder and have higher melting points than those of Group I.

27. Which of the following statements regarding ammonia (NH_3) is **false**?

(1) The oxidation state of N in NH_3 is −3.
(2) NH_3 gives a pink colour with Nessler's reagent.
(3) NH_3 is used as one of the raw materials in the manufacture of nitric acid.
(4) NH_3 is used to remove the acidic constituents in crude oil.
(5) NH_3 is produced on heating $NaNO_3$ with Al powder and aqueous NaOH.

28. Which of the following statements with regard to molecular oxygen (O_2) and ozone (O_3) is **false**?

(1) Molecular oxygen and ozone are allotropes.
(2) In the lower atmosphere photochemical reactions generate ozone from molecular oxygen.
(3) The O—O bond length of ozone is greater than the O—O bond length of molecular oxygen.
(4) Both molecular oxygen and ozone are greenhouse gases.
(5) Since molecular oxygen and ozone absorb UV radiation in the upper atmosphere, human life on earth is protected.

29. A 25.00 cm^3 volume of aqueous $CuSO_4$ solution is electrolysed using two platinum electrodes. The current during the electrolysis was kept at 10^{-2} A and it took 9.65 seconds to deposit all the Cu^{2+} as Cu on the cathode. What is the concentration of Cu^{2+} in the solution? (1 F = 96 500 C mol^{-1})

(1) 1×10^{-5} M (2) 2×10^{-5} M (3) 4×10^{-5} M (4) 5×10^{-5} M (5) 1×10^{-4} M

30. A solid sample contains only $CaCO_3$ and $MgCO_3$. To completely react the $CaCO_3$ and $MgCO_3$ present in the sample, 42.00 cm^3 of 0.088 M HCl were required. The anhydrous chloride salts from the reaction, obtained by evaporation of the filtrate weighed 0.19 g. The mass of $CaCO_3$ present in the solid sample is
(C = 12, O = 16, Mg = 24, Ca = 40, Cl = 35.5)

(1) 0.05 g (2) 0.07 g (3) 0.09 g (4) 0.11 g (5) 0.12 g

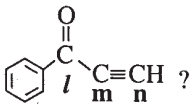
- For each of the questions **31** to **40**, one or more responses out of the four responses (*a*), (*b*), (*c*) and (*d*) given is/are correct. Select the correct response/responses. In accordance with the instructions given on your answer sheet, mark

(1) if only (*a*) and (*b*) are correct.
(2) if only (*b*) and (*c*) are correct.
(3) if only (*c*) and (*d*) are correct.
(4) if only (*d*) and (*a*) are correct.
(5) if **any other** number or combination of responses is correct.

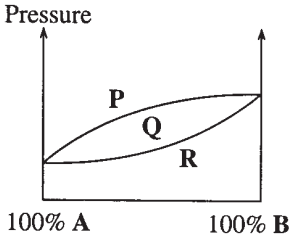
Summary of above Instructions

(1)	(2)	(3)	(4)	(5)
Only (*a*) and (*b*) are correct	Only (*b*) and (*c*) are correct	Only (*c*) and (*d*) are correct	Only (*d*) and (*a*) are correct	**Any other** number or combination of responses is correct

31. Values of E° for the Ce^{4+}/Ce^{3+} and Fe^{2+}/Fe are +1.72 V and –0.44 V respectively. According to these data which of the following statements is/are **true**?
(*a*) Ce^{4+} is a weaker oxidizing agent than Fe^{2+}.
(*b*) Ce^{4+} will reduce Fe^{2+}.
(*c*) Ce^{4+} is a better oxidizing agent than Fe^{2+}.
(*d*) Ce^{4+} will oxidize Fe.

32. Which of the following statements is/are **true** regarding the molecule  ?
(*a*) All carbon atoms are sp^2 hybridized.
(*b*) Carbon atoms labelled as ***l***, **m** and **n** and the oxygen atom lie in the same plane.
(*c*) All C—H bonds are equal in length.
(*d*) Carbon atoms labelled as ***l***, **m** and **n** lie in a straight line.

33. Shown below is the constant temperature phase diagram of **A** and **B**, which form an ideal solution.



Which of the following statements is/are **true**?
(*a*) The boiling point of compound **A** is higher than the boiling point of compound **B**.
(*b*) The vapour phase and liquid phase exist in equilibrium in the region **Q**.
(*c*) Only the vapour phase exists in the region **P**.
(*d*) Only the liquid phase exists in the region **R**.

34. Which of the following statements is/are **true** regarding polymers?
(*a*) Natural rubber has double bonds with *cis* configuration.
(*b*) Polyvinyl Chloride (PVC) is formed by addition polymerization of CHCl=CHCl.
(*c*) Polystyrene and nylon are both prepared by condensation polymerization.
(*d*) Both urea-formaldehyde and phenol-formaldehyde polymers contain $\rangle C=O$ groups in their structures.

35. The gases **A** and **B** react to form the product **P**. The material **X** in fine particle form, has been suggested for use as a catalyst for this reaction. The material **X** provides an alternative mechanism consisting of three steps. The activation energies for the three steps and for the reaction without **X** are given below.

	Activation energy / kJ mol^{-1}
Without **X**	50
With **X** step I	10
With **X** step II	5
With **X** step III	50

Which of the following statements is/are **true**?

(*a*) Use of **X** will not change the reaction rate significantly.
(*b*) Activation energy in step III can be lowered by using more **X**.
(*c*) Use of **X** increases the rate of the reaction because **X** is a material with a large surface area.
(*d*) Increasing of temperature will increase the reaction rate, regardless of whether **X** is used or not.

36. Which of the following statements is/are **true** regarding phenol?

(*a*) Phenol reacts readily with formaldehyde in acidic or basic medium.
(*b*) Phenol is less acidic than ethanol.
(*c*) Phenol reacts with aq. $NaHCO_3$ and gives CO_2.
(*d*) Phenol undergoes a substitution reaction with Br_2.

37. Which of the following statements is/are **true** regarding the compound represented by the structure given below?

$$CH_3CH_2\underset{\displaystyle Br}{\underset{|}{C}}H-CH=CH_2$$

(*a*) It can exist in two stereoisomeric forms.
(*b*) Catalytic hydrogenation of it gives a compound which does not show stereoisomerism.
(*c*) Treatment of it with alcoholic KOH gives a compound which does not show stereoisomerism.
(*d*) Treatment of it with aqueous KOH gives a compound which does not show stereoisomerism.

38. ΔH and ΔG data at temperature T are provided for the following reactions.

I. $2CH_4(g) \longrightarrow C_2H_4(g) + 2H_2(g)$ $\quad \Delta H = 201.88$ kJ mol^{-1}; $\Delta G = 169.62$ kJ mol^{-1}

II. $2CH_4(g) + O_2(g) \longrightarrow C_2H_4(g) + 2H_2O(g)$ $\quad \Delta H = -281.76$ kJ mol^{-1}; $\Delta G = -287.56$ kJ mol^{-1}

III. $2CH_4(g) + 2C(s) \longrightarrow 2C_2H_4(g)$ $\quad \Delta H = 254.14$ kJ mol^{-1}; $\Delta G = 237.74$ kJ mol^{-1}

Which of the following statements is/are **true** at temperature T?

(*a*) All three reactions I, II and III could be used to produce C_2H_4 from CH_4.
(*b*) Reaction I has a negative entropy change.
(*c*) Reaction II is the only feasible reaction for producing C_2H_4 from CH_4.
(*d*) Reaction III has a positive entropy change.

39. During cation analysis, Group I metal ions are precipitated as chlorides. Which of the following statements is/are **true** regarding the Group I analysis?

(*a*) Ag^+, Hg^{2+}, Hg_2^{2+} and Pb^{2+} form insoluble chlorides with the addition of dil. HCl.
(*b*) Only AgCl and $PbCl_2$ dissolve in aqueous NH_3 and will not reprecipitate with the addition of dil. HCl.
(*c*) Only Ag^+, Hg_2^{2+} and Pb^{2+} form insoluble chlorides with the addition of dil. HCl.
(*d*) Pb^{2+} does not precipitate in hot conc. HCl.

40. Which of the following statements is/are **false** with regard to H_2O_2?

(*a*) In the H_2O_2 molecule, the two hydroxyl groups lie in the same plane.
(*b*) H_2O_2 can act both as an oxidizing agent and a reducing agent in both acidic and basic media.
(*c*) Pure H_2O_2 is a colourless, strongly hydrogen bonded liquid.
(*d*) The oxygen atoms in H_2O_2 are *sp* hybridized.

- In question Nos. **41** to **50**, two statements are given in respect of each question.
  From the Table given below, select the response out of the responses (1), (2), (3), (4) and (5) that **best** fits the two statements and mark appropriately on your answer sheet.

Response	First Statement	Second Statement
(1)	True	True, and correctly explains the first statement.
(2)	True	True, but does **not** explain the first statement correctly.
(3)	True	False
(4)	False	True
(5)	False	False

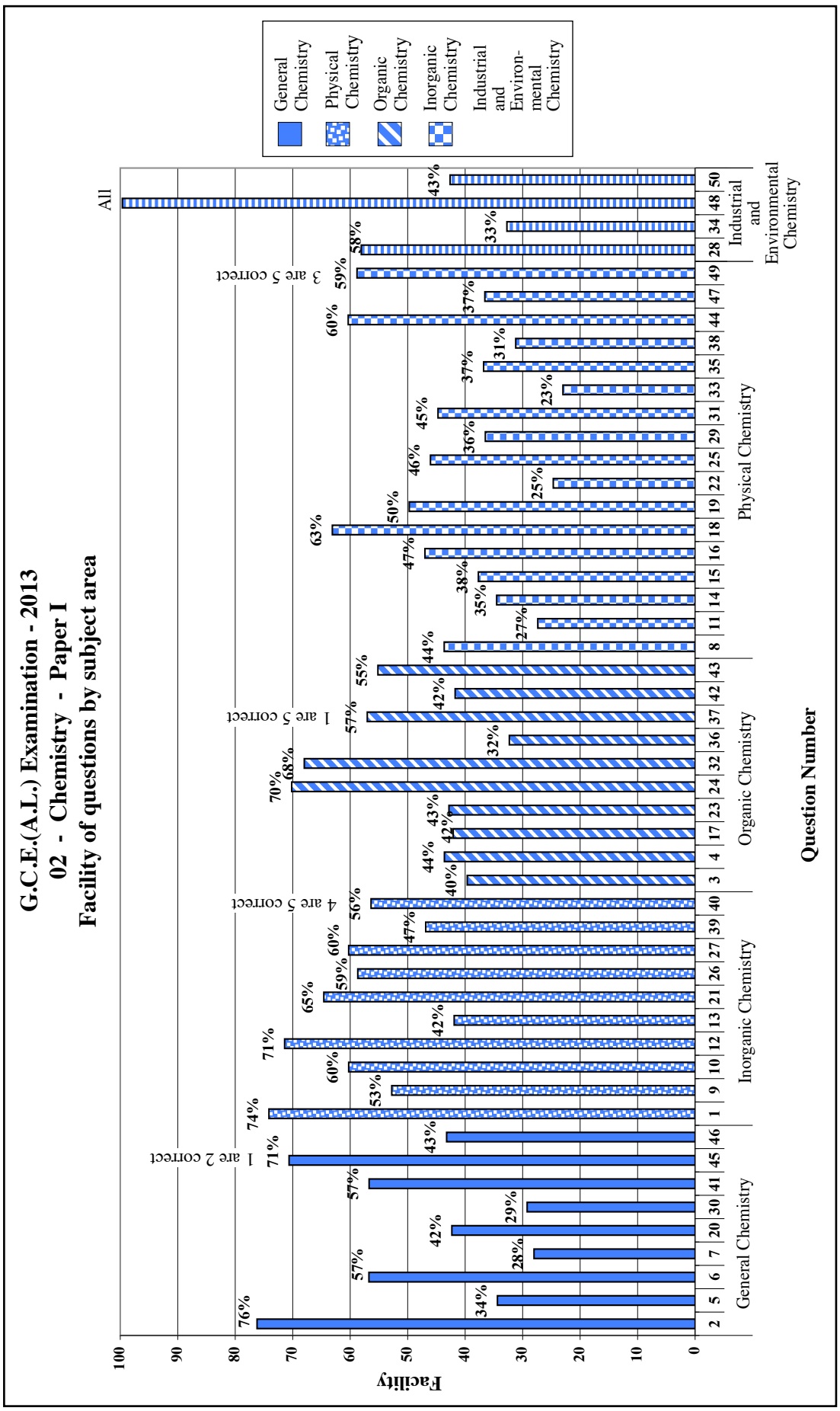
	First Statement	Second Statement
41.	All emissions end up at $n = 1$ for the Balmer series in the hydrogen spectrum.	The Bohr model is used to explain the origin of the hydrogen spectrum.
42.	2–Butanone (MW 72) has a higher boiling point than that of pentane (MW 72).	There are no hydrogen bonds between pentane molecules.
43.	2–Methyl–1–propanol gives a turbidity with conc. $HCl/ZnCl_2$ much faster than does 2–methyl–2–propanol.	Tertiary carbocations are more stable than primary carbocations.
44.	$CaCO_3(s)$ does not decompose to $CO_2(g)$ and $CaO(s)$ at room temperature, but it could be decomposed by increasing the temperature.	Gibbs energy change of a reaction can always be made negative by increasing the temperature.
45.	Intermolecular forces between SO_2 molecules are stronger than those between CO_2 molecules.	Intermolecular forces between polar molecules are stronger than those between non-polar molecules of similar mass.
46.	$CH_3-\overset{\overset{O}{\|}}{C}-CH_2CH_3$ and $CH_2=\overset{\overset{OH}{\|}}{C}-CH_2CH_3$ are two reasonance structures of the same compound.	The number of double bonds in resonance structures of a given compound should be the same.
47.	At constant temperature, doubling the concentration of all the reactants in the elementary reaction $2\mathbf{A} + \mathbf{B} \longrightarrow 3\mathbf{D} + \mathbf{E}$ increases the rate by a factor of 8.	In an elementary reaction, the order with respect to a reactant is equal to its stoichiometric coefficient.
48.	In the extraction of iron, the reduction of haematite by CO takes place in three stages.	The temperature of the blast furnace used in the extraction of iron decreases from top to bottom.
49.	Increasing the temperature will always increase the reaction rate.	The activation energy of a reaction decreases when the temperature is increased.
50.	Ammonia and carbon monoxide are used as raw materials in the manufacture of urea.	Ammonium carbonate formed by the reaction of ammonia and carbon monoxide, decomposes to give urea.

2.1.3 Expected answers and the marking scheme for Paper I

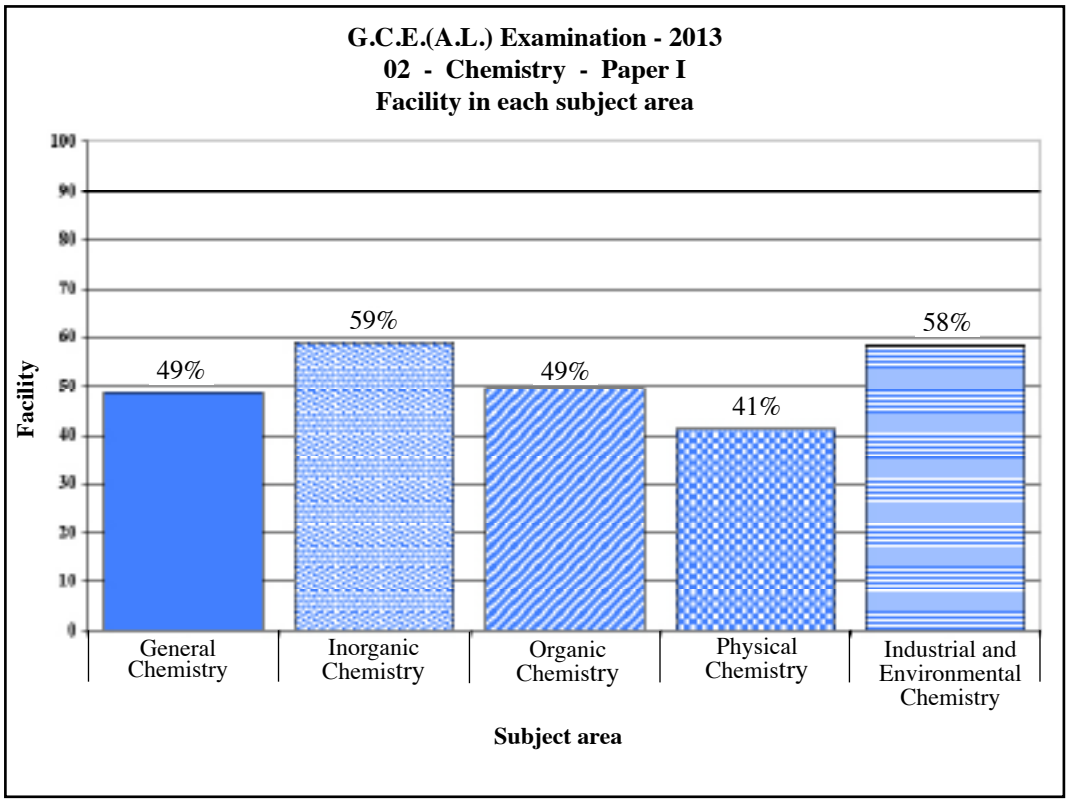
Question No.	Answer	Question No.	Answer
01.	5	26.	1
02.	5	27.	2
03.	4	28.	4
04.	3	29.	2
05.	2	30.	3
06.	1	31.	3
07.	4	32.	5
08.	3	33.	1
09.	1	34.	5
10.	2	35.	4
11.	5	36.	4
12.	2	37.	1 and 5
13.	5	38.	3
14.	2	39.	3
15.	1	40.	4 and 5
16.	4	41.	4
17.	3	42.	2
18.	4	43.	4
19.	5	44.	3
20.	2	45.	1 and 2
21.	2	46.	5
22.	2	47.	1
23.	3	48.	All
24.	2	49.	3 and 5
25.	1	50.	5

Each correct answer carries 02 marks, amounting the total to 100.

2.1.4 Observations on the responses to Paper I (by subject area) :



Subject area	The question of highest facility and its facility	The question of lowest facility and its facility
General Chemistry	2 (76%)	7 (28%)
Physical Chemistry	18 (63%)	33 (23%)
Organic Chemistry	24 (70%)	36 (32%)
Inorganic Chemistry	1 (74%)	13 (42%)
Industrial and Environmental Chemistry	28 (58%)	34 (33%)



Of the five subject areas used to set Paper I, the facility of Organic Chemistry was 59% while the facility of Industrial and Environmental Chemistry was 58%. Physical Chemistry was the most difficult area in Paper I. Its facility was 41%. The overall facility of Paper I was 49%.

2.1.5 Responses to the options in Paper I - as a percentage

Question Number	Correct Answer	Percentage of students selecting each option					
		1	2	3	4	5	Missing
1	5	4%	6%	13%	3%	**74%**	-
2	5	9%	3%	3%	9%	**76%**	-
3	4	16%	27%	10%	**40%**	7%	-
4	3	5%	15%	**43%**	26%	10%	1%
5	2	12%	**34%**	33%	11%	10%	-
6	1	**57%**	13%	13%	9%	8%	-
7	4	11%	19%	33%	**28%**	8%	1%
8	3	29%	12%	**44%**	12%	3%	-
9	1	**53%**	11%	26%	8%	2%	-
10	2	9%	**60%**	13%	11%	7%	-
11	5	20%	12%	31%	9%	**27%**	1%
12	2	4%	**71%**	5%	6%	14%	-
13	5	7%	10%	27%	14%	**42%**	-
14	2	4%	**34%**	18%	21%	22%	1%
15	1	**38%**	12%	20%	19%	11%	-
16	4	7%	11%	31%	**47%**	4%	-
17	3	11%	8%	**42%**	30%	9%	-
18	4	14%	10%	10%	**63%**	3%	-
19	5	9%	10%	6%	25%	**50%**	-
20	2	21%	**42%**	22%	9%	5%	1%
21	2	11%	**65%**	13%	6%	5%	-
22	2	6%	**25%**	42%	13%	14%	-
23	3	20%	10%	**43%**	12%	15%	-
24	2	6%	**70%**	10%	7%	7%	-
25	1	**46%**	23%	16%	11%	4%	-
26	1	**59%**	9%	17%	7%	8%	-
27	2	5%	**60%**	7%	12%	16%	-
28	4	5%	9%	17%	**58%**	11%	-
29	2	13%	**36%**	32%	10%	9%	-
30	3	8%	16%	**29%**	25%	21%	1%
31	3	14%	18%	**45%**	13%	10%	-
32	5	4%	14%	9%	5%	**68%**	-
33	1	**23%**	6%	7%	4%	60%	-
34	5	16%	9%	11%	31%	**33%**	1%
35	4	5%	10%	26%	37%	22%	-
36	4	8%	11%	20%	32%	29%	-
37	1 and 5	**24%**	22%	10%	9%	**33%**	-
38	3	11%	15%	**31%**	23%	20%	-
39	3	7%	15%	**47%**	13%	18%	-
40	4 and 5	12%	22%	10%	**24%**	**32%**	-
41	4	7%	16%	9%	**57%**	11%	-
42	2	24%	**42%**	18%	9%	7%	-
43	4	18%	13%	8%	**55%**	6%	-
44	3	14%	15%	**60%**	5%	6%	-
45	1 and 2	**47%**	**24%**	8%	14%	7%	-
46	5	7%	10%	14%	26%	**43%**	-
47	1	37%	14%	7%	32%	10%	-
48	All	5%	21%	48%	8%	18%	-
49	3 and 5	18%	8%	**40%**	15%	**19%**	-
50	5	28%	9%	13%	7%	**43%**	-

* Under each question the student percentage selecting the correct option is shaded.
* 'Missing' indicates the percentage of students selecting more than one option or none.

2.1.6 Overall observations, conclusions and suggestions regarding the answers to Paper I :

Of the first 30 questions, the number of questions correctly responded by less than 40% of the candidates was 9 (30%). For the questions from 31 to 40, the number of questions receiving less than 40% correct answers was 5 (50%). For the questions 41 - 50, more than 40% have given correct answers for 9 questions. However of these, all options of one question and two options of another question were considered correct.

The question numbers with a percentage of less than 40% correct responses and the subject areas relevant to them were as follows.

Subject area	Question number	Number of question
Physical Chemistry	11, 14, 15, 22, 29, 33, 35, 38, 47	9
General Chemistry	5, 7, 30	3
Organic Chemistry	3, 36	2
Industrial and Environmental Chemistry	34	1

From this, it is clear that the most difficult subject area for students had been Physical Chemistry. Of those question, only 23% and 25% were able to provide correct answers for questions 22 and 33 respectively which were based on the principles of energetics and gaseous state in Physical Chemistry. It can be thought that the inability of students to analyse data in questions in relation to relevant physico-chemical principles and convert them into mathematical symbols and insufficiency of the skill of combining those symbols appropriately are the reasons for this.

The percentage selecting correct option (4) for question 3 was 40%. 27% have selected the option (2). This question is based on IUPAC nomenclature in Organic Chemistry. In this, it should be stressed that there shouldn't be a dash following the name of the alkyl group.

43% have correctly responded for question 4. A majority have not been able to understand that on treatment with acetyl chloride, the hydrogen atom of an – OH group is replaced by a CH_3CO- group, so the relative molecular mass increases by 42.

Question 5 is related to General Chemistry. 34% have selected the correct option (2) for this question. Option (3) had been choosen by 33%. This question deals with quantum number designations of electrons. Lack of proper understanding of this newly introduced topic seems to be the reason for low facility. So, involvement of the students in simple exercises relating to sets of quantum numbers is recommended.

Question 7 is a chemical calculation under General Chemistry. Option (4) is the correct response for this question. 28% have selected the correct answer whereas 33% have had the choice of (3). The difficulty in interrelating data correctly had made the solution difficult. The students should understand that the correct method of selecting the answer for this type of questions is solving the problem and matching the answer but not begining with a selected answer and checking whether it is correct.

The percentage responding correctly to question 8 was 44%. A majority has not understood that the partial pressures of the gaseous reactants is proportional to their amount of moles and as fluorine is diatomic, the number should be doubled when taking the atomic ratio.

53% have selected correct option (1) for question 9. 23% selecting option (3) indicates that they are unaware of the fact that lead acetate is blackened by hydrogen sulphide gas. Or else, they are ignorant of the products of sulphite - acid reactions. These are indoctrinated only through practical work. Therefore, it is the responsibility of teachers to involve students in prescribed practical work whenever possible.

Question 11 is related to Physical Chemistry. The correct response for this question is 5. The facility for this option was 27%. In this type of problems the stoichiometry of the basic equation has to be taken into consideration but apparently the students have failed to understand that a partial neutralization had taken place. The answer can be easily deduced using the relationship formulated on the fact that the species produced here are in equilibrium related to Ka. This basic understanding should be inculcated in students when they solve stoichiometry - related problems. Students should necessarily understand that what is stoichiometrically less in amount becomes the limiting reactant which determines the amount of the product.

In the case of question 12, 71% were able to select the correct response (2). However, 14% have opted (5) due to ignorance or inadvertence of the difference between amine and ammine. Students should be emphasized that even very subtle differences need to be given attention in nomenclature.

Fourteen is a Physical Chemistry question. The correct option of this is 2 and its facility was 34%. This question is based on a new relationship founded on the combination of reation rates and ideal gas equation. The student is required to understand that the amounts of reactants change with time and it is the new concentration of reactants at time 't' that is relevant to rate equation. Moreover, when using the ideal gas equation, it should be stressed that 'n' symbolises the total amount of moles of the gas in the mixture. The student should understand that if x is the amount of moles of A reacted at t, $Q = k\left(\frac{n-x}{v}\right)\left(\frac{n-x}{v}\right)$ which gives the total amount of moles of the gases in the mixture and that P can be determined using the ideal gas equation. The competencies of deriving new relationships from fundamental equations should be developed during the learning - teaching process.

The facility of question 15 is 38%. This Physical Chemistry question stems from the concepts of Raoult's law and Dalton's law of partial pressures. Seemingly students have failed to disclose that the following equations can be obtained if the data are translated into mathematical expressions according to the above laws.

$$P_T = P^\circ_A \times 0.2 + P^\circ_B \times 0.8 \quad \text{——— (1)}$$
$$2P_T = P^\circ_A \times 0.6 + P^\circ_B \times 0.4 \quad \text{——— (2)}$$

Thus it is reiterated here, the need of promoting the skills of identifying the relevant scientific concepts correctly, analysing data and expressing as mathematical equations the relationships leading to the solutions when solving Physical Chemistry problems.

(3) is the correct option of question 17. When 42% respond correctly to it, 30% have choosen option (4) for not having a proper understanding of the action of $LiAlH_4$. Hence it is important to pay attention to reagents as well as the reactions of the functional groups.

In spite of that 50% have selected the correct option (5) for question 19, 25% have selected the distractor (4) implying the latter opine that calcium chloride hydrolyses giving an alkaline solution. This shows that the ability of deducing the properties of a salt through the nature of the

acid and the base from which it is derived has to be developed in students.

Question 22 is related to Physical Chemistry. The correct response for this question is (2). The percentage responding correctly was 25%. But 42% have gone for the option (3). Students have failed to understand that the entropy decreases when the number of gaseous molecules decreases. It is seen that students are less skilled in applying the thermodynamic properties enthalpy, entropy and Gibbs' energy logically and correctly as regards a given reaction. During the learning teaching process, students should be given exercises involving the variation of ΔH, ΔS and ΔG in a reaction at a given temperature.

For question 23, the percentage selecting the correct option (3) was 43%. However, twenty percent have selected the incorrect option (1) with the misconception that substitution occurs at the deactivated position.

The correct option (1) was the choice of 46% in question 25. Though 25 was an easy question, 23% have taken the distractor (2) as correct. The reason for this would be the misunderstanding that the largest energy gap was the activation energy or not taking into consideration the required quantity was the activation energy of the forward reaction.

Question 29 comes under the purview of Physical Chemistry. The correct option (2) was selected by 36%. But 32% of the candidates have choosen option (3). This is an easy question based on electrolysis. Not paying attention to the charge of the relevant ion (Cu^{2+}) have misled the student to opt for the distractor (3). The ability of obtaining the relationship between the quantity of electricity and the quantity of matter discharged by half equations should be improved. Faraday's laws, which are only of historical importance today are not a must for this type of calculations.

30 is a question consisting of several steps. Solving the quantitative problem using the relavent stoichiometric relationships and matching the answer with the given options is the course of action that should be followed when answering the questions of this kind.

Question 33 is related to Physical Chemistry. The correct option (1) for this had been selected by 23% but 60% has gone for the option (5). Though this was an easy question based on phase equilibrium, not paying attention to the naming of axes and mistaking this as a temperature - composition graph has misguided students to select a distractor.

Question 34 is connected with Industrial Chemistry. Its correct response is (5) and records a facility of 33%. Thirty one percent have selected the distractor (4). In this, only the statement (a) is correct. Reading and understanding statement (d) reminds the >C=O group of the reactant formaldehyde. Nevertheless the question seeks information related to polymers. When phenol formaldehyde is formed >C=O group gets removed by the condensation reaction, so the polymer does not contain the >C=O group. Therefore, (d) is an incorrect statement. What is required is reading and understanding the entire question well, analysing words and seeking the solution.

Question 35 is a Physical Chemistry question. The correct option is (4), so (a) and (d) happen to be the correct statement. 37% of the candidates have selected this option. 29% have selected option (5). The question deals with reaction rates. Reason for selecting (c) as the correct statement by a considerable fraction of candidates is the misapprehension that increase in surface area of *x* which may not be a catalyst would invariably increase the reaction rate. This has made the selection of the correct response difficult.

When answering question 36, 32% have selected the correct option (4) while 29% have picked option (5). Not knowing that phenol reacts with formaldehyde both in acidic and basic media has led 29% of the candidates for a wrong option. Therefore, the reactions and condition for the formation of phenol formaldehyde needs to be accentuated.

In question 37, selection of option (3) and (4) by 19% of the students as correct implies that they have not understood that the compound obtained after replacing the bromine atom by a $-OH$ group too is optically active. Also, there seems to be a difficulty in determining the product after treating the compound with alcoholic KOH and visualizing stereoisomerism of the product. The students selecting option (3) and (4) have failed to understand the concept of optical isomerism.

Only 31% have succeeded in selecting the correct answer for question 38. Though even all the reactions could be spontaneously carried out by changing temperature T, the question relates only to temperature T. overlooking this has made the failures select the distractors.

42% have answered question 42 correctly. Selection of option (1) by 24% shows that a considerable number of candidates have not clearly understood the reason for the greater strength of the intermolecular forces in butanol. Discussion with examples illustrating how structural features of molecules affect intermolecular forces are suggested to overcome this kind of weaknesses.

In question 43, options (1) and (2) have been taken as correct by 18% and 13% respectively indicating that they lack correct understanding about the rates of the reactions of primary and tertiary alcohols with conc.HCl/ $ZnCl_2$. The reason for the differences between the rates should also be stressed to the students.

A fair percentage (42%) has selected the correct option for question 46. Nonetheless, selection of option (4) by 26% connotes that they think the number of double bonds of the canonical structures should be equal. The falseness of this idea should be explained to the students and they should be enlightened as regards the compulsory similarities among the canonical structures.

A substantial number has misjudged the second statement of question 47 as false for not paying attention to the phrase elementary reaction.

Through 50 is a simple question based only on recall, 28% have taken (2) as a correct option for not taking difference between carbon dioxide and carbon monoxide into consideration.

2.2 Paper II and information on answers

2.2.1 Structure of the Paper II

Time is 03 hours. Total mark is 100.

This paper consists of three parts **A, B** and **C**.

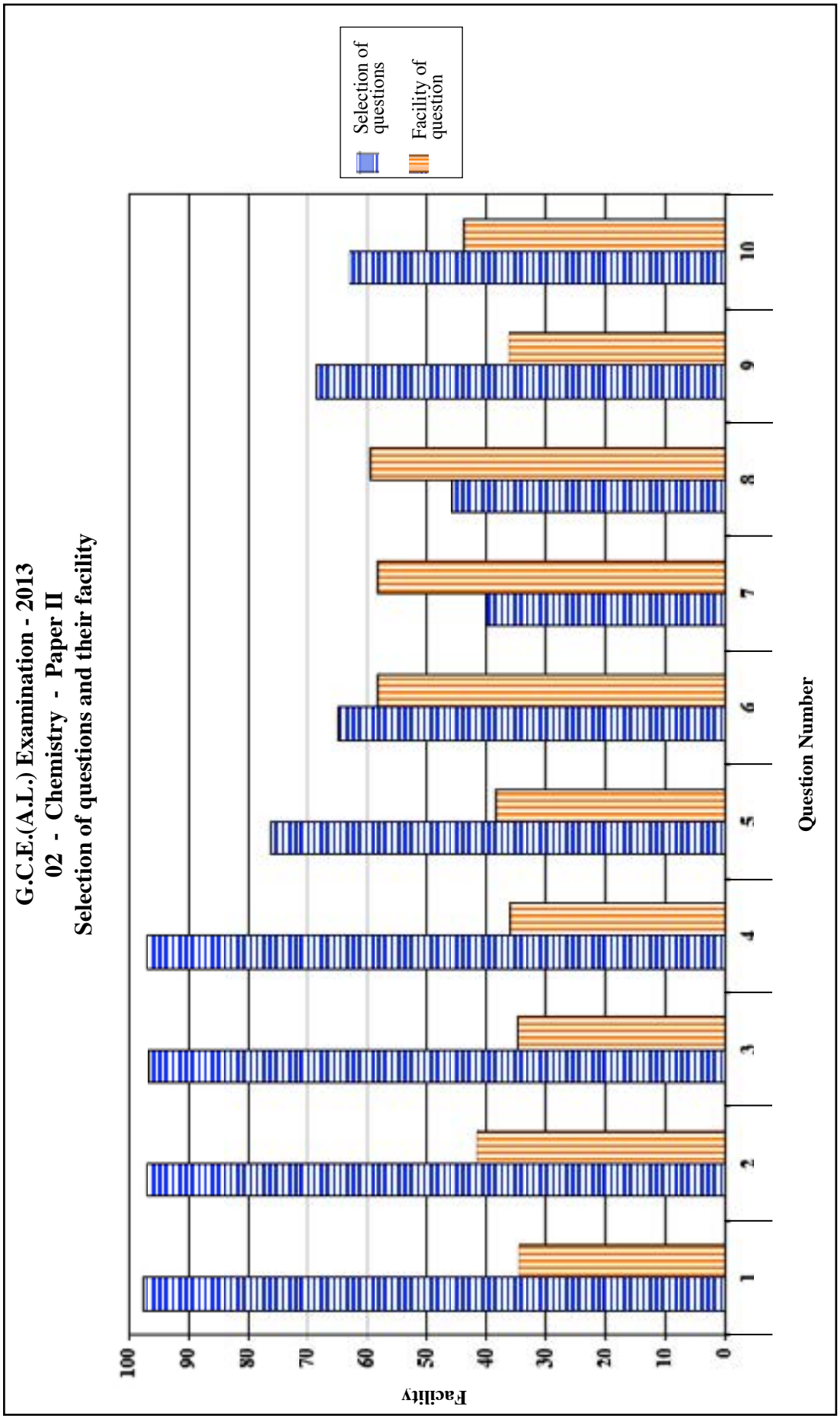
Part **A** – This contains **four structured essay** questions. All the questions should be answered. Each question carries 100 marks, so the total mark is 400.

Part **B** – This comprises **three essay** type questions of which **two** should be answered. Marks allocated for each question is 150. The total mark is 300.

Part **C** – This comprises **three essay** type questions of which **two** should be answered. Marks allocated for each question is 150. The total mark is 300.

Total mark for Paper II is 1000 ÷ 10 = 100

2.2.2 Selection and facility of questions in Paper II



2.2.3 Expected answers, marking scheme and observations and conclusions related to paper II

★ **The observations related to the answers for Paper II have been presented by the graphs 2, 3, 4.1, 4.2 and 4.3.**

PART A — STRUCTURED ESSAY

Answer ***all four*** *questions on this paper itself. (Each question carries* **10** ***marks.)***

Question 1

1. (*a*) Arrange the following in the **increasing** order of the property indicated in parenthesis. Reasons are **not** required.

(i) CO, CO_2, CO_3^{2-} (C—O bond distance)

CO < CO_2 < CO_3^{2-}

(ii) NO_2^+, NO_3^-, NH_3 (electronegativity of N atom)

NH_3 < NO_3^- < NO_2^+

(iii) $BeSO_4$, $MgSO_4$, $CaSO_4$ (decomposition temperature, $MSO_4 \longrightarrow MO + SO_3$, M = metal)

$BeSO_4$ < $MgSO_4$ < $CaSO_4$

(iv) Ne, Ar, Kr (boiling point)

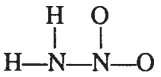
Ne < Ar < Kr

(v) S, F, Si, Cl (atomic radius)

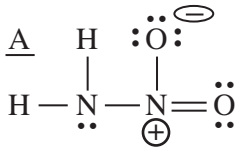
F < Cl < S < Si (05 × 5)

1(a) 25 marks

(*b*) Nitramide ($H_2N—NO_2$) is a weak acid. It decomposes to N_2O and H_2O in the presence of a base. Answer the parts (i) to (v) which are based on nitramide. Its skeleton is given below:

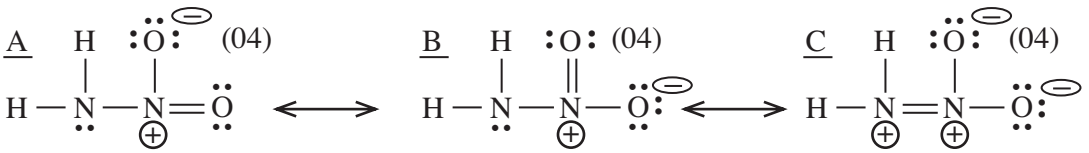


(i) Draw the **most** acceptable Lewis structure for this molecule.



(10)

(ii) Draw the resonance structures for this molecule. Giving reasons, comment on their stabilities.



A stable (01)

opposite charges on adjacent atoms (01) negative charge on more electronegative oxygen (01)

B stable (01)

opposite charges on adjacent atoms (01) negative charge on more electronegative oxygen (01)

C unstable (01)

two positive charges on adjacent atoms (02)

(21)

(iii) State the following:

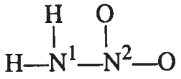
I. electron pair geometry (arrangement of electron pairs) around the atoms
II. shape around the atoms
III. hybridization of the atoms

given in the table below.

		The **N** attached to two **H** atoms	The **N** attached to two **O** atoms	
I.	electron pair geometry	tetrahedral	trigonal planar	(03 + 03)
II.	shape	pyramidal	trigonal planar	(03 + 03)
III.	hybridization	sp^3	sp^2	(03 + 03)

(iv) Is this molecule polar or non-polar? ..... polar ..... (04 marks)

(v) Identify the atomic/hybrid orbitals involved in the formation of the following bonds in the Lewis structure drawn in part (i) above. **N** atoms are labelled 1 and 2 as given below:



I. N^1 and N^2 ..... sp^3 (hybrid orbital) + sp^2 (hybrid orbital) ..... (03 + 03)

II. N^1 and H ..... sp^3 (hybrid orbital) + 1*s* (atomic orbital) ..... (03 + 03)

1 (b) 65 marks

(*c*) Xe, CH_3Cl, HF

Of the substances given above, which one/ones will have the forces given below?

(i) dipole - dipole forces ..... CH_3Cl, HF ..... (02 + 02)

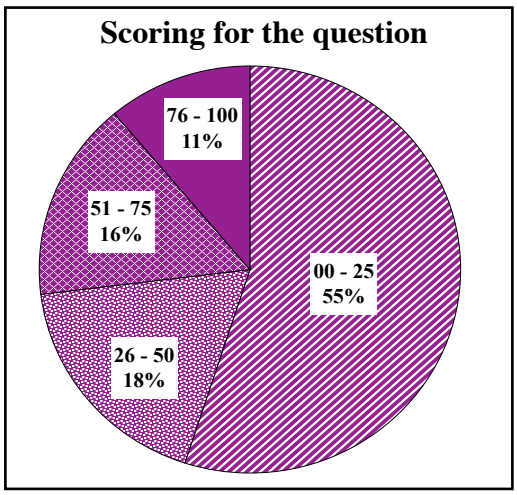
(ii) hydrogen bonding forces ..... HF ..... (02)

(iii) London dispersion forces ..... Xe, CH_3Cl, HF (in any order) ..... (02 + 01 + 01)

1 (c) 10 marks

***Total* : 100 marks**

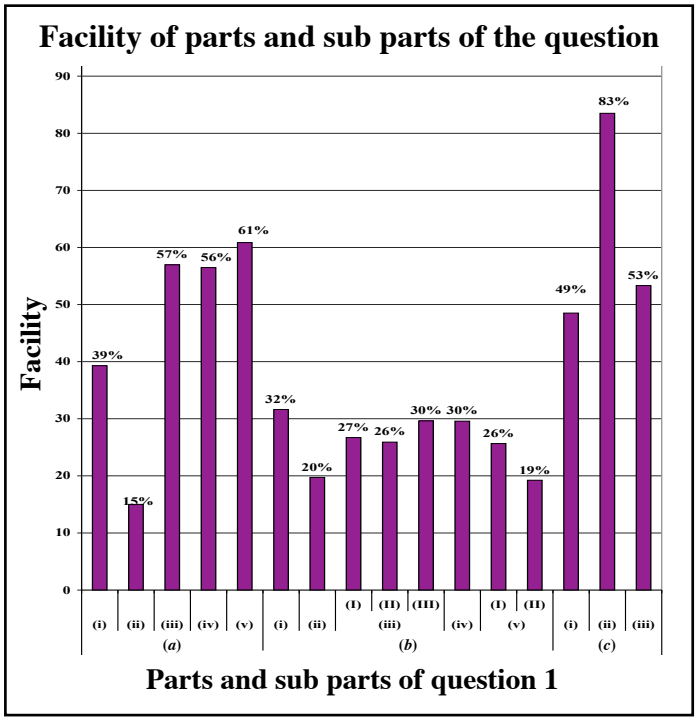
Overall observations, conclusions and suggestions regarding the answers to Question 1 :



Though question 1 was compulsory, 98% have answered it. The question carries 100 marks. The distribution of candidates scoring marks in the four intervals considered were as follows.

00	–	25	–	55%
26	–	50	–	18%
51	–	75	–	16%
76	–	100	–	11%

For this question 11% have scored above 76 or whereas 55% have scored 25 or below.



* The question comprises 16 sub parts. Of them, the facility of 6 sub parts was above 40%. The sub part with lowest facility was (*a*)(ii) and its facility was 15%. (*c*)(ii) has turned out to be the easiest sub part with the facility of 83%.

On the whole, the overall facility of part (*a*) of the first question was about 46%. It consists of 5 sub parts of which the facility of sub part (*a*)(ii) was about 15%. The students should be made well aware of the factors, that should be considered when deducing the electronegativity of an atom of an element contained in a molecule or ion. How the electronegativity of an element changes with hybridization, charge and oxidation state should be illustrated with further examples.

The total facility of part (*b*) was about 30%. It comprises five sub parts and the facility of all the five parts was below 35%. This indicates that the students' understanding of the Lewis structure of a molecule and its canonical structures is at a very low level. So, the teachers need to engage students in the exercises of drawing canonical structures and diciding on their stabilities.

The overall facility of part (*c*) was about 62%. The highest facility for part (*c*)(ii) points to a good understanding of the hydrogen bond in statement. But weakness in distinguishing other secondary bonds is evident. The ability of identifying London dispersion forces as the most common type of bonds existing among molecules is low. Imparting a clear understanding about the secondary interactions among molecules during the learning teaching process is thus essential.

Question 2

2. (*a*) Element **A** belongs to the *s*-block. Its first ionization energy is the highest in the group. **A** reacts with water liberating a gas **B**. The resulting solution from this reaction gives a red colouration to a Bunsen burner flame and the metal oxide on evaporation. **A** reacts with $N_2(g)$ to give compound **C**. The reaction of **A** with $H_2(g)$ gives a salt-like basic compound **D**. On treatment with H_2O, **C** gives a gas **E** which turns red litmus blue.

(i) Identify **A**, **B**, **C**, **D** and **E** giving their chemical formulae.

* **A** = Li **B** = H_2 **C** = Li_3N **D** = LiH **E** = NH_3

(03 × 5 = 15)

(ii) Give balanced chemical equations for the reactions described above.

$2Li + 2H_2O \longrightarrow 2LiOH + H_2$

$2LiOH \xrightarrow{\Delta} Li_2O + H_2O$

$6Li + N_2 \longrightarrow 2Li_3N$

$2Li + H_2 \longrightarrow 2LiH$

$Li_3N + 3H_2O \longrightarrow 3LiOH + NH_3$ (03 × 5 = 15)

2 (a) 30 marks

* Note : No marks for B, C, D, E if the answer for A in 2(*a*)(i) is wrong.

(*b*) The following questions are based on the transition metals, V and Cr and their compounds.

(i) Give the ground state electronic configuration of V. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$ or $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3$

(5)

(ii) State the positive oxidation states of V. +2, +3, +4, +5 or +II, +III, +IV, +V or 2, 3, 4, 5 or II, III, IV, V

(02 × 4)

(iii) Give the chemical formulae of the oxides formed by V in the positive oxidation states given in (ii) above. Indicate whether each of these oxides is acidic, amphoteric or basic.

VO - basic

V_2O_3 - basic

VO_2 - amphoteric

V_2O_5 - acidic (amphoteric) (02 × 8)

(iv) Write the chemical formulae of **two** oxocations formed by V. State their colours in aqueous acidic medium.

VO_2^+ - yellow VO^+ - green (very rare)

VO^{2+} - blue (01 × 4)

(v) What is the simplest ion that chromium forms in aqueous solution? State its colour. Predict what you would expect to observe when solid Na_2CO_3 is added to an aqueous solution of this ion.

$[Cr(H_2O)_6]^{3+}$ - Violet / blue violet or $Cr^{3+}(aq)$ or Cr^{3+} - Green/blue violet (04 + 04)

Evolution of CO_2 or evolution of bubbles or green precipitate/green solution (04)

(vi) Give **one** use of the metal V.

as an ingredient in steel or in alloys or as a catalyst (V_2O_5 accepted), making aircrafts (04)

(vii) What would you **observe** when a green coloured aqueous solution of $CrCl_3$ is subjected to the following?

I. Addition of a few drops of dilute NaOH.

green precipitate (03)

II. Addition of excess dilute NaOH followed by H_2O_2, and then heated.

yellow solution (03)

(viii) When a concentrated solution of $K_2Cr_2O_7$ is treated with conc. H_2SO_4, the bright red acidic oxide **X** of chromium is precipitated. On heating **X**, the green amphoteric oxide **Y** is obtained. **Y** could also be obtained on heating $(NH_4)_2Cr_2O_7$.
Give the chemical formulae of **X** and **Y**.

X = CrO_3 **Y** = Cr_2O_3 (03 + 03)

(ix) What would you observe when dil. NaOH is added to a solution of $K_2Cr_2O_7$?

solution turns yellow or orange solution turns yellow (03)

(x) Give **one** advantage and **one** disadvantage of using $K_2Cr_2O_7$ in titrations.

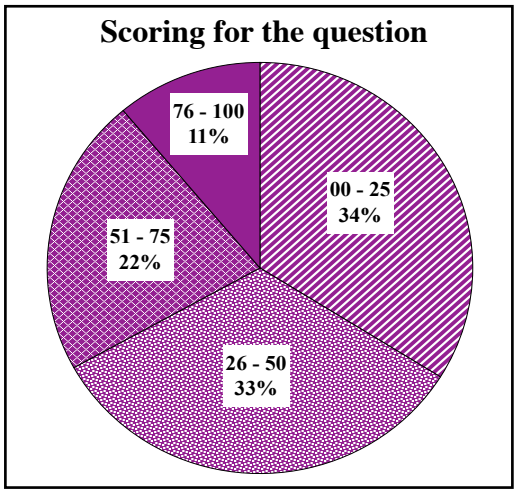
Advantage: it's a primary standard or titration can be done in the presence of chloride ions. (03)

Disadvantage: difficult to observe colour change at end point or not a self - indicator (03)

2 (b) 70 marks

***Total* : 100 marks**

Overall observations, conclusions and suggestions regarding the answers to Question 2 :

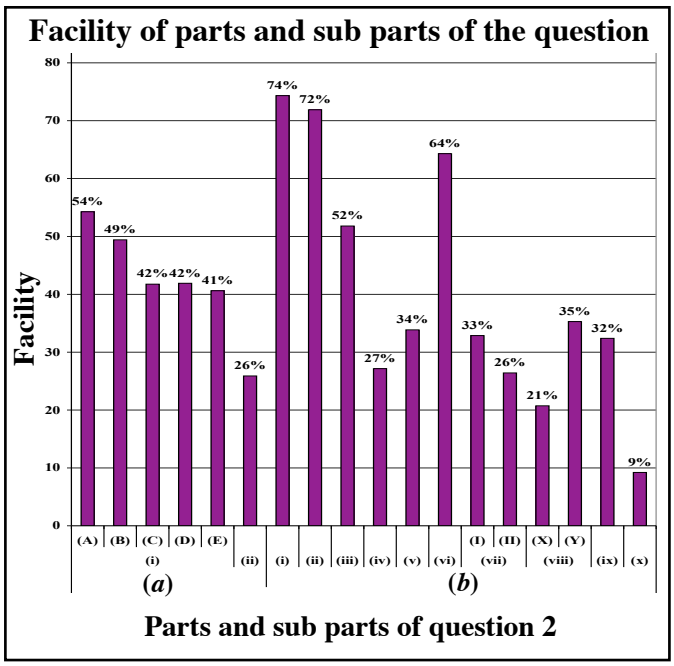


Despite question 2 was compulsory, only 98% had answered it. Marks allocated for this question was 100.

The distribution of candidates among the four selected class intervals were as follows.

00	–	25	–	34%
26	–	50	–	33%
51	–	75	–	22%
76	–	100	–	11%

For this question 11% had scored 76 or above but 34% had obtained 25 or below.



* This question comprises 18 sub parts of which the facility of 5 sub parts stands above 50%. The most difficult sub part had been (*b*)(x) for which the facility was 9%. The easiest sub part (*b*)(i) records a facility of 74%.

The facility of part (*a*)(ii) was 26%. The ability of writing balanced chemical equations for the identified chemical reactions is not adequate. The skill of writing balanced chemical equations for reactions should be developed during the learning teaching process. For this, students should be involved in relevant exercises.

The number of sub parts in part (*b*) is 12. Its total facility was nearly 40%. Seemingly the knowledge the complexes formed by the ions of the 'd' block elements and their colours is at a very low level. The facility of sub part (*b*)(x) was 9%. It appears the practical knowledge of how potassium dichromate is used in a titration and the colour changes occurring in it is very low. Therefore, directing students to carry out practical experiments for consolidating correct understanding is imperative during the learning teaching process.

Question 3

3. Chlorine gas is used as an oxidizing agent to oxidize the metal ion, $M^{2+}(aq)$ to $M^{3+}(aq)$. The following data are given.

Reaction	Standard enthalpy change $\Delta H°$ at 25 °C (kJ mol^{-1})
$M(s) \longrightarrow M^{+}(aq) + e$	– 32.5
$M(s) \longrightarrow M^{2+}(aq) + 2e$	– 48.5
$M(s) \longrightarrow M^{3+}(aq) + 3e$	– 82.5
$Cl_2(g) + 2e \longrightarrow 2Cl^{-}(aq)$	– 334.0

$E°_{M^{3+}/M^{2+}} = +0.77$ V $E°_{Cl_2/Cl^-} = +1.36$ V

The above oxidation is carried out electrochemically.

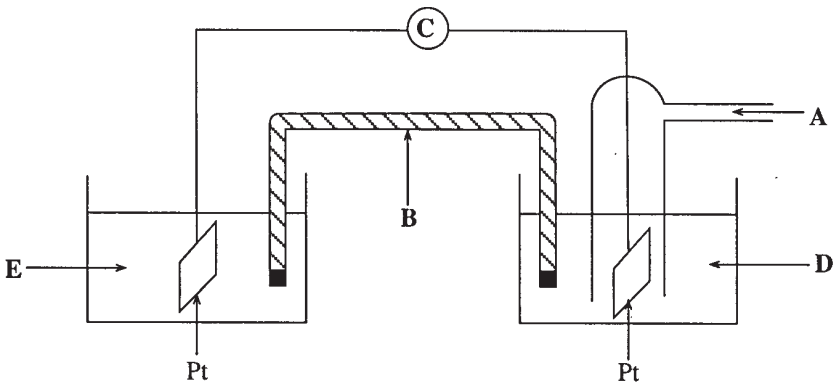
(i) Write half reactions for oxidation and reduction processes and derive the cell reaction.

Oxidation reaction : $M^{2+}(aq) \longrightarrow M^{3+}(aq) + e$ (05)

Reduction reaction : $Cl_2(g) + 2e \longrightarrow 2Cl^{-}(aq)$ (05)

Cell reaction : $2M^{2+}(aq) + Cl_2(g) \longrightarrow 2M^{3+}(aq) + 2Cl^{-}(aq)$ (05)

(ii) The following diagram shows the experimental setup needed to measure $E°_{cell}$ of the above reaction. Identify **A – E,** giving physical state, concentration / pressure where applicable.



A : Cl_2 (g, 1 atm) B : Salt bridge

C : Voltmeter (Potentiometer) D : Cl^- (aq, 1.0 mol dm^{-3})

E : Mixture of M^{2+} (aq, 1.0 mol dm^{-3}) and M^{3+} (aq, 1.0 mol dm^{-3})

(05 × 5)

(iii) Calculate E°_{cell} for the above cell.

$E^\circ_{Cell} = E^\circ_{Cl_2/Cl^-} - E^\circ_{M^{3+}/M^{2+}}$ or $E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$

or $E^\circ_{cell} = E^\circ_{RHS} - E^\circ_{LHS}$ (05)

or 1.36 V – 0.77 V

= 0.59 V (04 + 01)

(iv) Calculate the standard enthalpy change (ΔH°) at 25 °C, for the cell reaction given in part (i).

(02) **(02)**

$2\,M^{2+}(aq) + Cl_2(g) + (4e) \xrightarrow{\Delta H^\circ} 2\,M^{3+}(aq) + 2\,Cl\,(aq) + (4e)$

$2 \times (-48.5\ kj\ mol^{-1})$ **(04 + 01)**

$2 \times (-82.5\ kJ\ mol^{-1}) - 334\ kj\ mol^{-1}$ **(04 + 01)** **(04 + 01)**

$2\,M(s) + Cl_2(g)$ **(02)**

Note : If the thermodynamic cycle is not shown but the calculation in equation eq(1) is correct, award (18 + 03) marks.

$\Delta H^\circ = 2 \times (-82.5\ kJ\ mol^{-1}) - 2 \times (-48.5\ kJ\ mol^{-1}) + (-334\ kJ\ mol^{-1})$ (eq - 1)

$\Delta H^\circ = -402\ kJ\ mol^{-1}$ (03 + 01)

(v) The relationship between standard Gibb's energy change, ΔG° for the cell reaction and E°_{cell} is given by

$\Delta G^\circ = -k E^\circ_{cell}$

where, $k = 1.93 \times 10^5\ J\ mol^{-1}\ V^{-1}$

Calculate the standard Gibbs energy change (ΔG°) at 25 °C, for the above cell reaction.

$\Delta G^\circ = -k E^\circ_{cell}$

$= -1.93 \times 10^5\ (J\ mol^{-1} V^{-1}) \times 0.59\ (V)$ (04 + 01)

$= -113.87\ kJ\ mol^{-1}$ (04 + 01)

(vi) Calculate the standard entropy change (ΔS°) at 25 °C, for the above cell reaction.

$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ (No marks if standard states are not shown) (05)

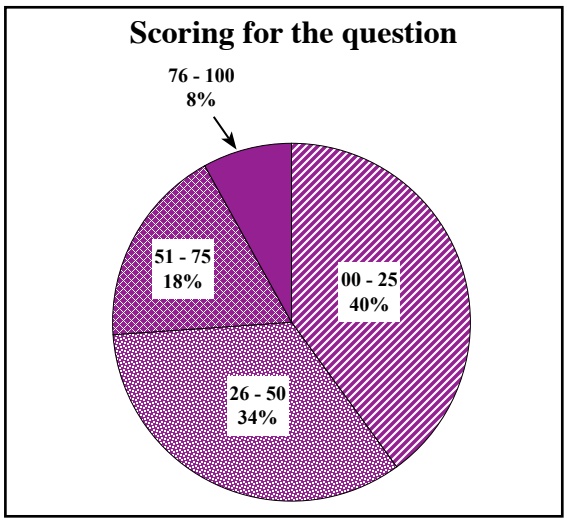
$-113.87\ kJ\ mol^{-1} = -402\ (kJ\ mol^{-1}) - 298\ (K)\ \Delta S^\circ$ (04 + 01)

$\Delta S^\circ = 288\ kJ\ mol^{-1} / (-298\ K)$

$\Delta S^\circ = 0.97\ kJ\ mol^{-1}\ K^{-1}$ (04 + 01)

***Total* : 100 marks**

Overall observations, conclusions and suggestions regarding the answers to Question 3 :

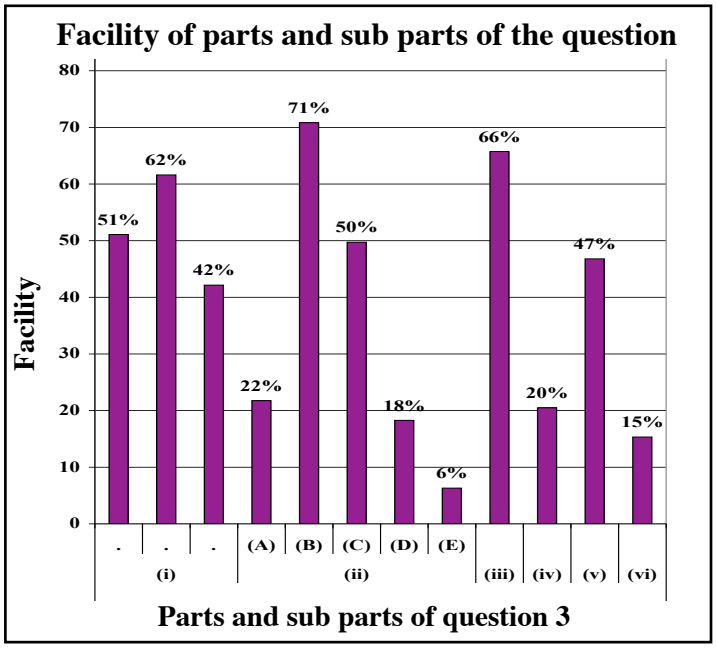


Being compulsory notwithstanding, question 3 had been answered by 97%. The question carries 100 marks.

The approximate percentages falling into the respective class intervals were ;

00	– 25	–	40%
26	– 50	–	34%
51	– 75	–	18%
76	– 100	–	8%

The percentage obtaining 76 marks or above for this question was 8%. Forty percent have scored 25 or below for this question.



* There are 12 sub parts in this question. Of them, the facility of seven sub parts was above 40%. The most facile part had been (ii)(B) and its facility was 71%. The sub part of last facility (ii)(E) had a facility of 6%.

Question 3 has 12 sub parts. Of these, four sub parts showed a facility above 50%. The facility of sub parts (ii)(A), (ii)(D), (ii)(E), (iv) and (vi) was less than 40%. Noticeably, the ability of representing anodic and cathodic components, standard conditions and physical states of substances in the notation of an electrochemical cell is at a low level. Some students have not understood that symbol θ of E^{θ} reflects standard states.

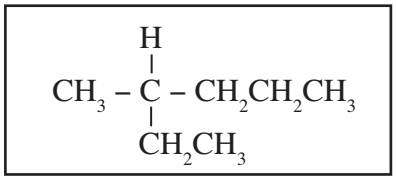
The facility of sub part (iv) was 20%. Inability to give the cell reaction correctly had led to an incorrect thermochemical cycle bringing down the facility.

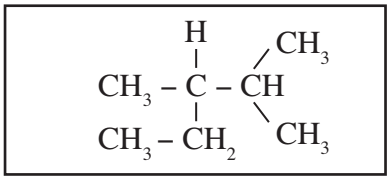
The facility of subpart (iv) was 15%. Marks were denied for not stating standard conditions in the equation $\Delta G = \Delta H - T\Delta S$. It should be considered that if the answer for sub part (v) was wrong, no marks could be given for sub part (vi).

Question 4

4. (*a*) (i) Compound **A** exhibits optical isomerism and has the molecular formula C_7H_{16}.

I. Draw **two** possible structures for **A** which are not enantiomers of each other, in the boxes given below.





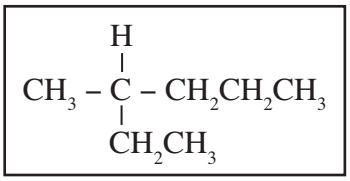
(10 + 10)

II. State the isomeric relationship between the two structures you have drawn.

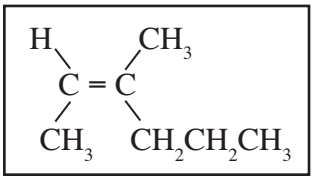
structural isomers **or** constitutional isomers **or** chain isomers ..... (03)

(ii) **B** and **C** are optically inactive compounds with the molecular formula C_7H_{14}. Both **B** and **C** exhibit geometric isomerism. **B** and **C** are **not** geometric isomers of each other. Catalytic hydrogenation of either **B** or **C** yields the same compound **A**.

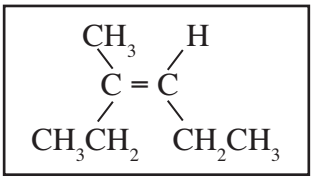
I. Draw the structures of **A**, **B** and **C** in the boxes given below (It is **not** necessary to draw the stereoisomeric forms).



A



B



C

(10 + 10 + 10)

II. Write the IUPAC names of **B** and **C**.

B : 3-methyl-2-hexene or 3-methylhex-3-ene ..... (01)

C : 3-methyl-3-hexene ..... (01)

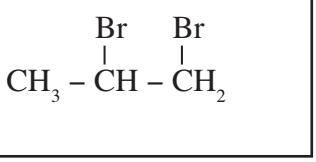
Note : B and C can be interchanged. Accordingly, the correct IUPAC names should be written.

4 (a) 55 marks

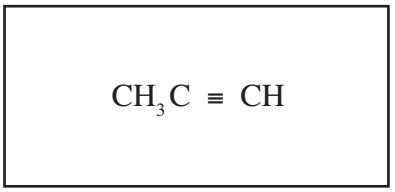
(*b*) Consider the following reaction sequence:

Reaction 1 **Reaction 2** **Reaction 3** **Reaction 4**

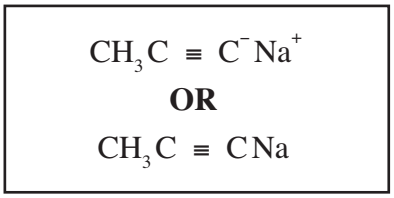
(i) Draw the structures of **P**, **Q**, **R** and **S** in the boxes given below.



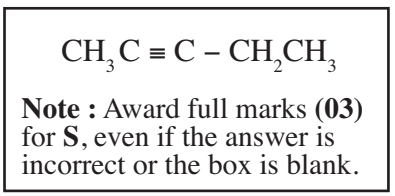
P



Q



R



Note : Award full marks **(03)** for **S**, even if the answer is incorrect or the box is blank.

S

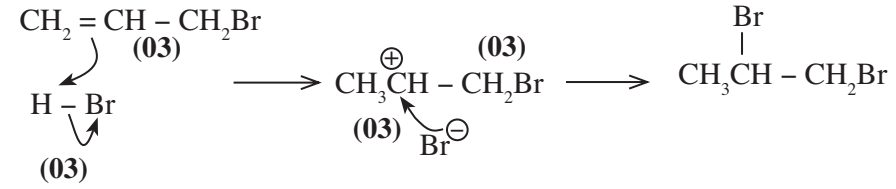
(03 × 4)

(ii) Classify each of the reactions in the above sequence as nucleophilic addition (A_N), electrophilic addition (A_E), nucleophilic substitution (S_N), electrophilic substitution (S_E), elimination (E) or acid-base (AB), by writing A_N, A_E, S_N, S_E, E, AB in the appropriate cages.

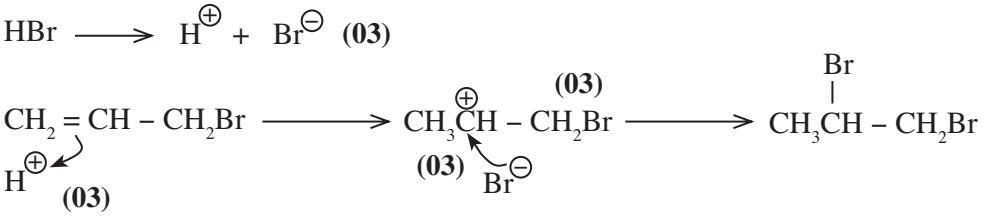
Reaction	1	2	3	4
Reaction type	A_E	E	AB	S_N

(03 × 4)

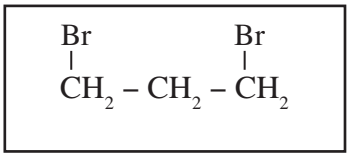
(iii) Write the mechanism for **Reaction 1.**



Alternate answer



(iv) Draw the structure of the product **T** obtained when **Reaction 1** is carried out in the presence of peroxide.



T

(03)

(v) It has been found that **T** is also formed in **Reaction 1**, as a minor product. By considering the mechanism of the reaction, explain why the major product in **Reaction 1** is **P** and not **T**.

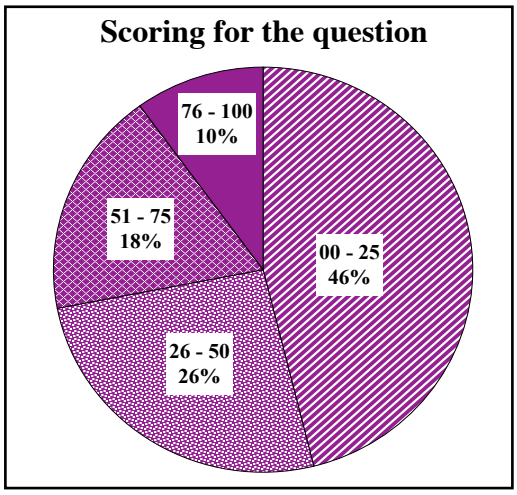
Intermediate carbocation for P $CH_3 - \overset{\oplus}{C}H - CH_2Br$	Intermediate carbocation for T $\overset{\oplus}{C}H_2 - CH_2 - CH_2Br$	} (03)
Secondary carbocation, more stable (**P** is formed faster)	Primary carbocation, less stable	} (03)

Note : Award full marks for mentioning that it is a secondary carbocation without giving the structure, if the structure is drawn in part (iii).

4 (b) 45 marks

***Total* : 100 marks**

Overall observations, conclusions and suggestions regarding the answers to Question 4 :

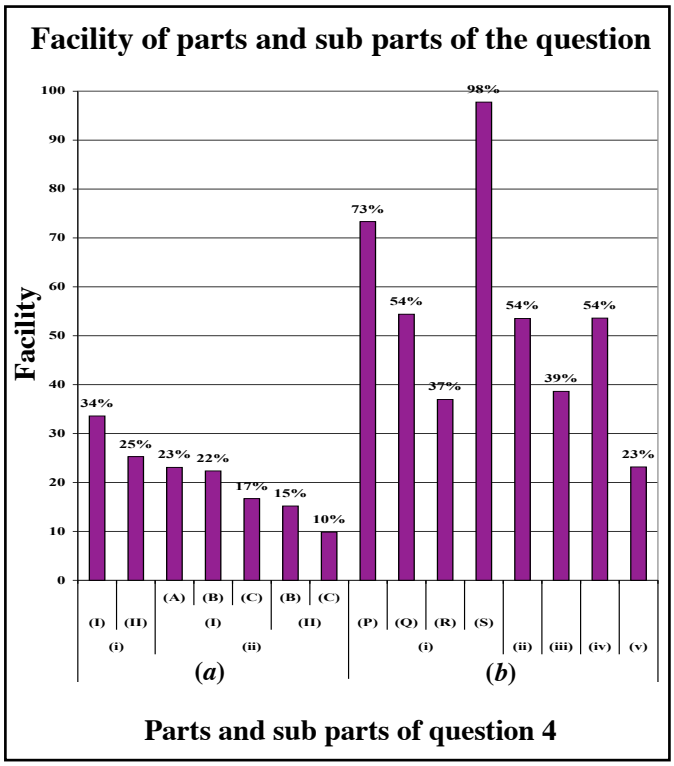


In spite of the fact that question 4 was compulsory, only 94% have answered it. The total mark for the question was 100.

The percentage of candidates scoring within the four class intervals were ;

00	–	25	–	46%
26	–	50	–	26%
51	–	75	–	18%
76	–	100	–	10%

So, 10% have scored 76 or above while 46% have scored 25 or below for this question.



* The question consisting of 15 sub parts has 8 sub parts with a facility less than 35%. The most facile sub part (*b*)(i)(S) held a facility of 98% while the least facile sub part (*a*)(ii)(II)(C) sustained a facility of 10%.

The facility of all the seven sub part in 4(*a*) was below 35%. (*a*)(i) examines the students' understanding of building up structured formulae through isomerism for which marks stand at a lower level. The student have not understood the meaning of enantiomers. Students have lost marks for not displaying the groups in an extended manner in instances where it is required. (e.g. writing C_3H_7 – where it should be written as $CH_3CH_2CH_2$–). In the learning teaching process, the ability of drawing the structures for a compound using different types of isomerism needs to be developed.

The facility of sub part (*b*)(v) was 23%. The concept of the stability of intermediate carbocation during the formation of the main product has not been established in students. Therefore it had become difficult for some to understand that the stability of the carbocation increases in the order primary, secondary, tertiary, so in the first step of this, a secondary carbocation forms as a product.

Question 5

PART B — ESSAY

*Answer **two** questions only.* (*Each question carries* **15 *marks.***)

---

5. (*a*) **A** and **B** are volatile and completely miscible liquids which form an ideal solution when mixed. A mixture containing 1.0 mol of liquid **A** and 1.0 mol of liquid **B** was placed in a closed container. When the system reached equilibrium, the pressure and volume of the gaseous phase, and the mole ratio of **A/B** in this phase were found to be 1.0×10^3 Pa, 0.8314 m^3 and 2/3 respectively. The system was maintained at 200 K.

Calculate the following.

(i) the total number of moles in the gas phase.

(ii) the mole fractions of **A** and **B** in the liquid phase.

(iii) the saturated vapour pressures of **A** and **B**.

(5.0 *marks*)

(*b*) In a saturated solution of $Mn(OH)_2$ at 25 °C, the concentration of Mn^{2+} is 1.0×10^{-5} mol dm^{-3}. The solubility product of $Mg(OH)_2$ at 25 °C is 1.0×10^{-10} mol^3 dm^{-9}. K_b of NH_4OH at 25 °C is 1.6×10^{-5} mol dm^{-3}.

(i) Calculate the solubility product of $Mn(OH)_2$ at 25 °C.

(ii) Calculate the concentration of hydroxide ions in a 0.01 mol dm^{-3} NH_4OH solution at 25 °C.

(iii) Determine the concentration of NH_4OH necessary to start precipitation of $Mn(OH)_2$ from a 0.001 mol dm^{-3} solution of $MnSO_4$.

(iv) If 5.35 g of NH_4Cl is dissolved in 1.00 dm^3 of 1.00 mol dm^{-3} NH_4OH solution, calculate the concentration of hydroxide ions in the solution. (H = 1.0, N = 14.0, Cl = 35.5)

(v) Calculate the number of moles of solid NH_4Cl required to prevent the precipitation of $Mg(OH)_2$ in a solution to be made by mixing 0.50 dm^3 of a 0.02 mol dm^{-3} solution of $Mg(NO_3)_2$ and 0.50 dm^3 of a 0.20 mol dm^{-3} solution of NH_4OH.

(vi) Explain the use of NH_4Cl in group analysis.

5. (*a*) **(i)**

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$n = \frac{1.0 \times 10^3\,\text{Pa} \times 0.8314\,\text{m}^3}{8.314\,\text{J mol}^{-1}\,\text{K}^{-1} \times 200\,\text{K}} \qquad (04 + 01)$$

$$n = 0.5\,\text{mol} \qquad (04 + 01)$$

5 (a)(i) 10 marks

(ii)

Number of moles of A in gas phase = $n_{A,}$ Number of moles of B in gas phase = $n_{B,}$

mole fraction of A in gas phase = $X_{A,}$ mole fraction of B in gas phase = X_B,

mole fraction of A in liquid phase = $X'_{A,}$ mole fraction of B in liquid phase = X'_A

$$\frac{X_A}{X_B} = \frac{n_A}{n_B} = \frac{2}{3} \quad (03)$$

$$n = n_A + n_B = 0.5 \quad (03)$$

$$n_A = 0.2\,\text{mol} \quad (01 + 01)$$

$$n_B = 0.3\,\text{mol} \quad (01 + 01)$$

Amount of A left in the liquid phase $= (1.0 - 0.2)\,\text{mol} = 0.8\,\text{mol}$ (01 + 01)

Amount of B left in the liquid phase $= (1.0 - 0.3)\,\text{mol} = 0.7\,\text{mol}$ (01 + 01)

$$X'_A = \frac{0.8\,\text{mol}}{(0.8 + 0.7)\,\text{mol}} = \frac{8}{15} = 0.533 \quad (03)$$

$$X'_B = \frac{0.7\,\text{mol}}{(0.8 + 0.7)\,\text{mol}} = \frac{7}{15} = 0.467 \quad (03)$$

(If the steps are combined award marks accordingly)

5 (a)(ii) 20 marks

(iii)

Partial pressure of A = P_A, Partial pressure of B = P_B,

Saturated vapour pressure of A = $P°_{A,}$ Saturated vapour pressure of B = $P°_B$.

Applying Daltons law,

$$P_A = P \times X_A = 1.0 \times 10^3\,\text{Pa}\ \frac{0.2\,\text{mol}}{0.5\,\text{mol}} \quad (02)$$

$$P_A = 4.0 \times 10^2\,\text{Pa} \quad (01)$$

similarly

$$P_B = P \times X_B = 1.0 \times 10^3\,\text{Pa}\ \frac{0.3\,\text{mol}}{0.5\,\text{mol}} \quad (02)$$

$$P_B = 6.0 \times 10^2\,\text{Pa} \quad (01)$$

Applying Raoults law,

$$P°_B = \frac{P_A}{X'_A} = \frac{4.0 \times 10^2\,\text{Pa}}{8/15} \quad (03 + 01)$$

$$= 7.5 \times 10^2\,\text{Pa} \quad (02 + 01)$$

$$P°_B = \frac{P_B}{X'_B} = \frac{6.0 \times 10^2\,\text{Pa}}{7/15} \quad (03 + 01)$$

$$= 1.286 \times 10^3\,\text{Pa} \quad (02 + 01)$$

5 (a)(iii) 20 marks

***Total for* 5(a) 50 marks**

(*b*) (i)

$Mn(OH)_2(s) \rightleftharpoons Mn^{2+}(aq) + 2OH^-(aq)$ (physical states required) (02)

$K_{sp} = [Mn^{2+}(aq)]\,[OH^-(aq)]^2$ (physical states required) (02)

$K_{sp} = 1 \times 10^{-5}\,mol\,dm^{-3} \times (2 \times 10^{-5}\,mol\,dm^{-3})^2$ (02 + 01)

$K_{sp} = 4 \times 10^{-15}\,mol^3\,dm^{-9}$ (02 + 01)

5 (b)(i) 10 marks

(ii)

$NH_4OH(aq) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ (physical states required) (01)

$K_b = \dfrac{[NH_4^+(aq)]\,[OH^-(aq)]}{[NH_4OH(aq)]}$ (physical states required) (01)

Since NH_4OH is a weak base, amount dissociated is very small.

$[NH_4^+(aq)] = [OH^-(aq)]$ and $[NH_4OH] = 0.01\,mol\,dm^{-3}$ (02)

$1.6 \times 10^{-5}\,mol\,dm^{-3} = \dfrac{[OH^-(aq)]^2\,(mol\,dm^{-3})^2}{0.01\,mol\,dm^{-3}}$ (02 + 01)

$[OH^-(aq)] = 4.0 \times 10^{-4}\,mol\,dm^{-3}$ (02 + 01)

5 (b)(ii) 10 marks

(iii)

$K_{sp} = [Mn^{2+}(aq)]\,[OH^-(aq)]^2$

$4 \times 10^{-15}\,(mol^3\,dm^{-9}) = 10^{-3}\,(mol\,dm^{-3}) \times [OH^-(aq)]^2$

$[OH^-(aq)]^2 = \dfrac{4 \times 10^{-15}\,(mol^3\,dm^{-9})}{10^{-3}\,(mol\,dm^{-3})} = 4 \times 10^{-2}\,(mol\,dm^{-3})^2$ (04 + 01)

$[OH^-(aq)] = 2 \times 10^{-6}\,mol\,dm^{-3}$ (04 + 01)

The $[OH^-(aq)]$ necessary to just precipitate $Mn(OH)_2 = 2 \times 10^{-6}\,mol\,dm^{-3}$. Assuming the concentration of NH_4OH necessary to provide $[OH^-(aq)] = 2 \times 10^{-6}\,mol\,dm^{-3}$ is x.

$NH_4OH(aq) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

$x - 2 \times 10^{-6}\,mol\,dm^{-3}$ $\quad 2 \times 10^{-6}\,mol\,dm^{-3}$ $\quad 2 \times 10^{-6}\,mol\,dm^{-3}$

$1.6 \times 10^{-5}\,mol\,dm^{-3} = \dfrac{[2 \times 10^{-6}]^2\,(mol\,dm^{-3})^2}{x - 2 \text{ x } 10^{-6}\,mol\,dm^{-3}}$ (04 + 01)

$x = 2.25 \times 10^{-6}\,mol\,dm^{-3}$ (04 + 01)

or

$1.6 \times 10^{-5}\,mol\,dm^{-3} = \dfrac{[2 \times 10^{-6}]^2\,(mol\,dm^{-3})^2}{x}$ (04 + 01)

$x = 2.2 \times 10^{-7}\,mol\,dm^{-3}$ (04 + 01)

5 (b)(iii) 20 marks

(iv)

Molar mass of NH_4Cl $= 14.0 + 1.0 \times 4 + 35.5 = 53.5\,g\,mol^{-1}$

Therefore the amount of $NH_4Cl = 5.35\,g / 53.5\,g\,mol^{-1} = 0.1\,mol$ (01 + 01)

Since NH_4Cl is completely dissociated in aqueous medium

$[NH_4^+(aq)] = 0.1\,mol\,dm^{-3}$ (01 + 01)

Let's take the concentration of NH_4OH as c $mol\,dm^{-3}$ and the degree of dissociation as $\propto$.

$NH_4OH\,(aq) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

at equlibrium

$c\,(1 - \propto)\,mol\,dm^{-3}$ $\quad c \propto mol\,dm^{-3}$ $\quad c \propto mol\,dm^{-3}$

$[NH^+_4(aq)] = (0.1 + c \propto)\,mol\,dm^{-3} = 0.1\,mol\,dm^{-3}$ (03 + 01)

$[NH_4OH\,(aq)] = (0.1 - c \propto)\,mol\,dm^{-3} = 1.0\,mol\,dm^{-3}$ (03 + 01)

Note : If written as statements award (04) + (04) marks.

$$1.6 \times 10^{-5}\,mol\,dm^{-3} = \frac{0.1\,mol\,dm^{-3} \times [OH^-(aq)]}{1.0\,mol\,dm^{-3}}$$ (03 + 01)

$[OH^-(aq)] = 1.6 \times 10^{-4}\,mol\,dm^{-3}$ (03 + 01)

5 (b)(iv) 20 marks

Alternate Answer

Mol. Wt. of $H_4Cl = 14.0 + 1.0 \times 4 + 35.5 = 53.5\,g\,mol^{-1}$

Therefore the amount of $NH_4Cl = 5.35\,g / 53.5\,g\,mol^{-1} = 0.1\,mol$ (01 + 01)

Since NH_4Cl is completely dissociated in aqueous medium.

$[NH_4^+(aq)] = 0.1\,mol\,dm^{-3}$ (01 + 01)

$[NH^+_4(aq)] = (0.1 + c\propto)\,mol\,dm^{-3} = 0.1\,mol\,dm^{-3}$ (03 + 01)

$[NH_4OH\,(aq)] = (0.1 - c\propto)\,mol\,dm^{-3} = 1.0\,mol\,dm^{-3}$ (03 + 01)

Note : If written as statements award (04) + (04) marks.

$$pOH = pK_b + \log\left(\frac{[salt]}{[base]}\right)$$ (03 + 01)

$$pOH = -\log(1.6 \times 10^{-5}) + \log\left(\frac{[0.1\,mol\,dm^{-3}]}{[1.0\,mol\,dm^{-3}]}\right)$$ (03 + 01)

$pOH = 3.796$

$[OH^-] = 1.6 \times 10^{-4}\,mol\,dm^{-3}$ (03 + 01)

5 (b)(iv) 20 marks

(v)

The $[Mg(NO_3)_2(aq)]$ in the final solution

$$= \frac{0.2\,mol\,dm^{-3} \times 0.50\,dm^3}{1.0\,dm^3} = 0.01\,mol\,dm^{-3} \qquad (04 + 01)$$

To avoid the precipitation of $(OH)_2(s)$ in the final mixture, the following criteria should be satisfied.

$Mg(NO_3)_2$ is completely dissociated to Mg^{2+} and NO_3^- ions.

Therefore $[Mg^{2+}(aq)]$ in the final solution = $0.01\,mol\,dm^{-3}$

In order to prevent precipitation of $Mg(OH)_2$.

$K_{sp} \geq [Mg^{2+}(aq)]\,[OH^-(aq)]^2$

$1 \times 10^{-10}\,(mol^3\,dm^{-9}) \geq 10^{-2}\,(mol\,dm^{-3}) \times [OH^-(aq)]^2$

$$[OH^-(aq)]^2 \leq \frac{1 \times 10^{-10}\,(mol^3\,dm^{-9})}{10^{-2}\,(mol\,dm^{-3})} = 1 \times 10^{-8}\,(mol\,dm^{-3})^2 \qquad (04 + 01)$$

$$[OH^-(aq)] \leq 1 \times 10^{-4}\,mol\,dm^{-3} \qquad (04 + 01)$$

The $[NH_4OH(aq)]$ in the final solution

$$= \frac{0.2\,mol\,dm^{-3} \times 0.50\,dm^3}{1.0\,dm^3} = 0.01\,mol\,dm^{-3} \qquad (04 + 01)$$

Let the required concentration of NH_4Cl to keep $[OH^-(aq)]$ at $1 \times 10^{-4}\,mol\,dm^{-3}$ be x.

Since amount dissociated is very small, $[NH^+_4(aq)] = [NHCl(aq)] = x$.

$$1.6 \times 10^{-5}\,mol\,dm^{-3} = \frac{x\,(mol\,dm^{-3}) \times 1 \times 10^{-4}\,(mol\,dm^{-3})}{0.1\,mol\,dm^{-3}} \qquad (04 + 01)$$

$$x = 1.6 \times 10^{-2}\,mol\,dm^{-3} \qquad (04 + 01)$$

The amount of NH_4Cl neccessary to prevent precipitation of $Mg(OH)_2$,

$= 1.6 \times 10^{-2}\,mol\,dm^{-3} \times 1.0\,dm^3 = 1.6 \times 10^{-2}\,mol$ (04 + 01)

5 (b)(v) 35 marks

(vi)

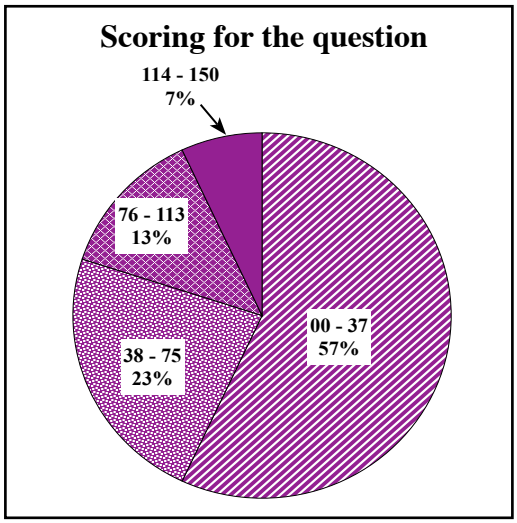
In group separation to avoid the precipitation of $Mg(OH)_2$ in group III (or other cations that may precipitate as hydroxides), NH_4Cl is added before adding NH_4OH. (05)

5 (b)(vi) 05 marks

***Total for* 5(b) 100 marks**

***Total for* 5 : 150**

Overall observations, conclusions and suggestions regarding the answers to Question 5 :

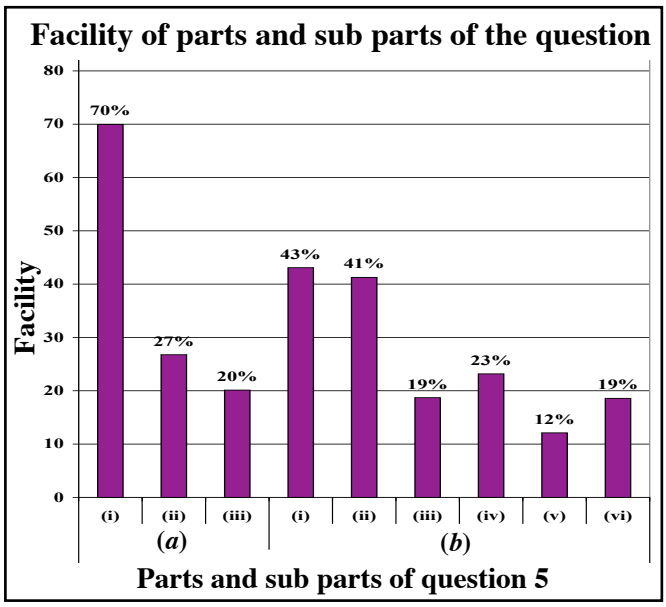


About 77% had chosen this question. Of the two physical chemistry questions in a part B, this was the one answered by a majority.

The question carries 150 marks. The distribution of candidates was as follows in the four class intervals.

00	– 37	–	57%
38	– 75	–	23%
76	– 113	–	13%
114	– 150	–	7%

The percentage scoring 114 or above was 7% while 57% had scored 37 or below.



* Of the nine sub parts of this question (*a*)(i) had been the easiest. Its facility was 70%. The facility of all the other eight sub parts was below 43%. The sub part of least facility was (*b*)(v). Its facility was 12%.

This had been a popular question selected by many (77%). But, of the three essay questions in part B, this was the one of lowest facility (38%). Of the candidates, 57% have obtained less than 37 marks out of 150. Student should understand that the first question in the essay section is always not the easiest to answer, so it would be more productive it they read the question paper first and select questions.

Object of sub part (*a*)(i) was to examine the ability of solving problems applying the ideal gas equation, Raoult's law and Dalton's law of partial pressures. Though candidates were able to achieve the aim of applying ideal gas equation, less than 22% were able to realize the other objectives. Lack of the ability to analyse a problem critically and seeking the solution is the reason for this. Part (*b*) of the question has examined the application and solving of problems related to solubility product and its expression, common ion effect and group analysis. To some extent, candidates were able to achieve the first of the above objectives but were not so successful in realizing the rest. Difficulty in writing the equations correctly and not balancing them, omission of physical states and not calculating with correct units were some of the reasons for this. Although sub parts (*b*)(i) and (ii) were very easy parts that examine the basic knowledge, inability to exceed the level of 43% for them reflects that a substantial section of the candidates are unaware of even them.

This situation can be remedied by developing in students the ability of solving problems logically rather than learning by rote.

Question 6

6. (*a*) Consider the reaction,

$$mM + nN \longrightarrow cC$$

where m, n and c are stoichiometric coefficients of **M**, **N** and **C** respectively.

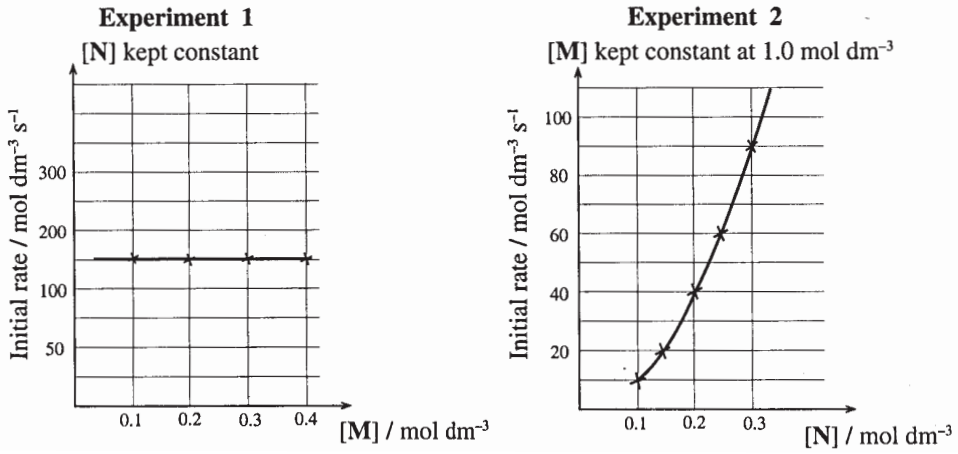
(i) Considering the above reaction to be an elementary reaction, write an expression for the rate of reaction. (The rate constant of the reaction = k.)

(ii) Two experiments were conducted to find the order of the reaction.

Experiment 1 : Initial rate was measured varying the concentration of **M** while keeping the concentration of **N** constant.

Experiment 2 : Initial rate was measured varying the concentration of **N** while keeping the concentration of **M** constant at 1.0 mol dm^{-3}.

Both experiments were conducted at the same temperature. The results of the experiments are shown in the graphs below.



I. Find the order of the reaction with respect to **M**.

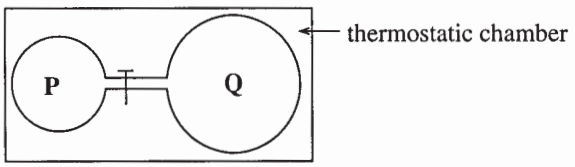
II. Find the order of the reaction with respect to **N**.

III. What is the overall order of the reaction?

IV. Find the rate constant, k of the reaction.

(6.0 *marks*)

(*b*) Two rigid bulbs **P** (volume = V) and **Q** (volume = 2V) connected by a tap are placed in a thermostatic chamber as shown below.



Initially the tap is closed. **P** contains 1.0 mol of gas **AB** and **Q** is empty. When the temperature of the system was increased to 400 K, **AB**(g) dissociated into **A**(g) and **B**(g) according to the equilibrium reaction given below.

$$AB(g) \rightleftharpoons A(g) + B(g)$$

The equilibrium constant for the above equilibrium is K_c. When the system has reached equilibrium (first equilibrium) the amount of **A**(g) was found to be x mol. The tap was opened and the system was allowed to reach equilibrium again (second equilibrium). The amount of **A**(g) formed was found to be y mol.

(i) Show that $K_cV\ (1 - x) = x^2$ and $3K_cV\ (1 - y) = y^2$.

(ii) If $y = 0.5$ mol, calculate the value of x.

(iii) Explain your answer in (ii) above using the Le Chatelier's principle.

(iv) The temperature of the system was increased to 600 K. When the system reached equilibrium (third equilibrium) the pressure of the system was 1.7 times that at the second equilibrium. The amount of **A**(g) at the third equilibrium was z mol. Calculate the value of z.

(v) Show that the decomposition of **AB**(g) is endothermic.

(vi) State any assumption/s made in your calculations.

6. **(*a*)** **(i)** Rate = $k [M]^m [N]^n$ (10)

(ii) I. According to the first graph, the rate of the reaction is independent of [M]. Therefore, the order to the reaction with respect to M must be zero (m = 0).

(10)

Therefore, Rate = $k [N]^n$ (05)

II. From second graph, when N = 0.1 mol dm^{-3} ; Rate = 10 mol dm^{-3} s^{-1},
When N = 0.2 mol dm^{-3} ; Rate = 40 mol dm^{-3} s^{-1}.

When the concentration is doubled, rate increased four times, therefore the order with respect N is 2. (20)

Or

Using data for any two points,

10 mol dm^{-3} s^{-1} = $k(0.1 \text{ mol dm}^{-3})^n$ ———— (1) (04 + 01)

40 mol dm^{-3} s^{-1} = $k(0.2 \text{ mol dm}^{-3})^n$ ———— (2) (04 + 01)

$$\frac{(2)}{(1)} \quad \frac{40 \text{ mol dm}^{-3} \text{ s}^{-1}}{10 \text{ mol dm}^{-3} \text{ s}^{-1}} = \frac{(0.2 \text{ mol dm}^{-3})}{(0.1 \text{ mol dm}^{-3})^n} \quad (04 + 01)$$

$4 = 2^n$

$n = 2$ (05)

Note : For obtaining n = 2 only by argument, e.g. curved shape of the graph means order = 2, award **only 10 marks.**

III. Overall order = n + m = 2 + 0 = 2 (05)

IV. From equation (1),

$$k = \frac{10 \text{ mol dm}^{-3} \text{ s}^{-1}}{(0.1 \text{ mol dm}^{-3})^2} \quad (04 + 01)$$

= 1000 mol^{-1} dm^3 s^{-1} (04 + 01)

6 (a)(ii) 50 marks

***Total for* 6(a) 60 marks**

(*b*) (i)

	$AB(g) \rightleftharpoons$	$A(g)$	+	$B(g)$	
At $t = 0$	$1.0\,mol$	0		0	
at equlibrium	$(1-x)\,mol$	$x\,mol$		$x\,mol$	(05)
or					
concentration at equlibrium	$\frac{1-x}{V}$	$\frac{x}{V}$		$\frac{x}{V}$	

$$K_C = \frac{\left(x/V\right)\left(x/V\right)}{\left((1-x)/V\right)} = \frac{x^2}{(1-x)V} \qquad (05)$$

$$K_C V(1-x) = x^2$$

After opening the tap the volume is increased to $3V$. The amount dissociated is y mol.

	$AB(g) \rightleftharpoons$	$A(g)$	+	$B(g)$	
at equlibrium	$(1-y)\,mol$	$y\,mol$		$y\,mol$	(05)
or					
concentration at equlibrium (mol dm^{-3})	$\frac{1-y}{3V}$	$\frac{y}{3V}$		$\frac{y}{3V}$	

$$K_C = \frac{\left(y/3V\right)\left(y/3V\right)}{\left((1-y)/3V\right)} = \frac{y^2}{(1-y)3V} \qquad (05)$$

$$3K_C V(1-y) = y^2$$

6 (b)(i) 20 marks

(ii) Equilibrium constant K_C in both occasions is the same because there is no change in temperature. (05)

$$K_C = \frac{x^2}{(1-x)\,V} = \frac{y^2}{(1-y)\,3V} \qquad (05)$$

If $y = 0.5\,mol$

$$\frac{x^2}{(1-x)\,V} = \frac{(0.5\,mol)^2}{(1.0\,mol - 0.5\,mol)\,3V} \qquad (05)$$

$$\frac{x^2}{(1-x)\,V} = \frac{(0.5\,mol)^2}{3(0.5\,mol)} = \frac{0.5\,mol}{3}$$

$$3x^2 - 0.5\,mol\,(1-x) = 0$$

$$(3x - 1\,mol)\,(2x + 1\,mol) = 0$$

$$x = \frac{1}{3}\,mol \quad \text{or} \quad x = -\frac{1}{2} \quad \text{(can not be accepted)}$$

$$x = 0.33\,mol \qquad (05)$$

6 (b)(ii) 20 marks

(iii) When volume is V, the amount dissociated = 0.33 mol. When the volume is increased to $3V$ the amount dissociated = 0.50 mol. Increasing of volume decreases the pressure of the system, 50 more AB(g) is dissociated to counter this change.

(10)

6 (b)(iii) 10 marks

(iv) Applying $PV = nRT$ to second equilibrium,

$y = 0.5$

$n = 1 + y = 1.5\,\text{mol}$ (04 + 01)

Volume $= 3V$ and $T = 400\,\text{K}$

$$P_2 = 1.5\ \frac{R \times 400\,\text{K}}{3\text{V}}$$ (05)

When the temperature is increased to 600 K

Pressure = $P_3 = 1.7\ P_2$

Applying $PV = nRT$ for third equilibrium

$n = (1 + z)\,\text{mol}$ (04 + 01)

$V = 3V$ and $T = 600\ \text{K}$

$$P_2 = 1.7\left(1.5\ \frac{R \times 400\,\text{K}}{3V}\right) = \frac{(1+z)\ R \times 600\ \text{K}}{3V}$$ (05)

$$1+z = \frac{1.5 \times 400\,\text{K} \times 1.7}{600\,\text{K}} = 1.7$$

$z = 0.7\,\text{mol}$ (04 + 01)

6 (b)(iv) 25 marks

(v) Increasing of temperature from 400 K to 600 K (at constant volume) has increased the amount dissociated. Therefore, supply of heat has driven the reaction forward. Therefore, the forward reaction must be endothermic.

(10)

6 (b)(v) 10 marks

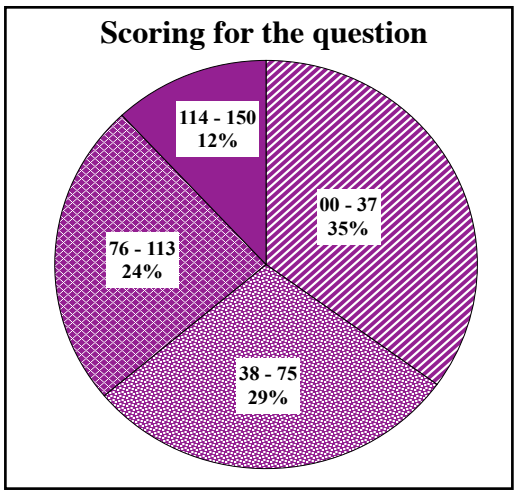
(v) All the gasses behave as ideal gasses. (05)

6 (b)(vi) 05 marks

***Total for* 6(b) 90 marks**

***Total for* 6 : 150**

Overall observations, conclusions and suggestions regarding the answers to Question 6 :

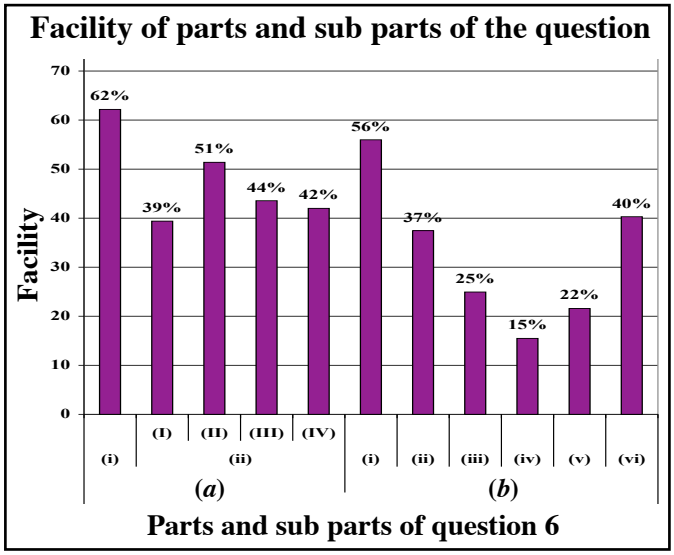


About 65% had selected question 6. The question carries 150 marks.

Given below were the percentages scoring within four class intervals adopted.

00	– 37	–	35%
38	– 75	–	29%
76	– 113	–	24%
114	– 150	–	12%

Candidates scoring 114 or above for this question constitute 12% whereas 35% had obtained 37 or below.



* The question embodies 11 sub parts of which the facility of five stands below 40%. The easiest sub part had been (*a*)(i) and its facility was 62%. (*b*)(iv) had been the most difficult sub part. Its facility was 15%.

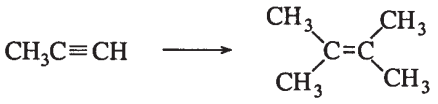
This question was of 58% overall facility and was answered by 65% of the students. Part (*a*) is based on kinetics and all its sub parts had a facility greater than 35%. Many (62%) had successfully answered the direct question (*a*)(i). But a considerable number of candidates were denied the due mark for giving the expression as $R \propto [M]^m[N]^n$ rather than $R = k[M]^m[N]^n$. The question asks to 'write an expression for the rate of reaction'. Expression means a complete mathematical relationship. It consists of constants and variables and after the substitution of data, the required quantity can be directly calculated. Yet $R \propto [M]^m[N]^n$ is only a relationship leading to a mathematical expression.

Only 39% had answered (*a*)(ii)(I) satisfactorily. Many were unable to deduce that the order with respect to M is zero. Even those who knew the answer could not get full marks for not showing how the answer was arrived at. Therefore, when answering questions, the students should thoroughly discern what is expected by the question and it is stressed by the action verb. Both students and teachers should strongly understand that the most important aspect of scientific study is the imagination leading to a logical idea and the skill of presenting it verbally.

Part (*b*) of the question is based on the equilibrium in gaseous systems. The facility of three sub parts of this lies below 35%. The successive decrease in marks in first four parts implies that students have little understanding in the application of equilibria and how a system adjusts according to Le Chatelier's principle with the change in temperature and pressure. Skills of computation also seem to be at the low ebb. Hence, students should practice exercises relating to the behaviour of an equilibrium system under external constraints.

Question 7

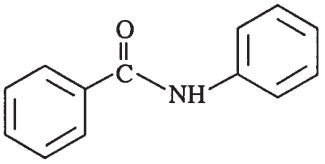
7. (*a*) Using **only** the chemicals given in the list, show how you would carry out the following conversion.



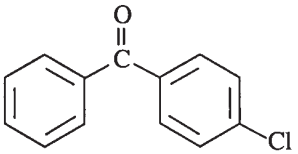
List of chemicals
$NaBH_4$, $HgSO_4$, dil. H_2SO_4,
conc. H_2SO_4, PCl_5, Mg, ether

(4.0 *marks*)

(*b*) Show how you would synthesize compound **B** using compound **A** as the **only** organic starting material.



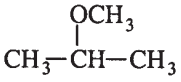
A



B

(6.0 *marks*)

(*c*) It is possible to synthesize the following compound **X** using two different pathways. Each pathway can be written as a nucleophilic substitution reaction.



X

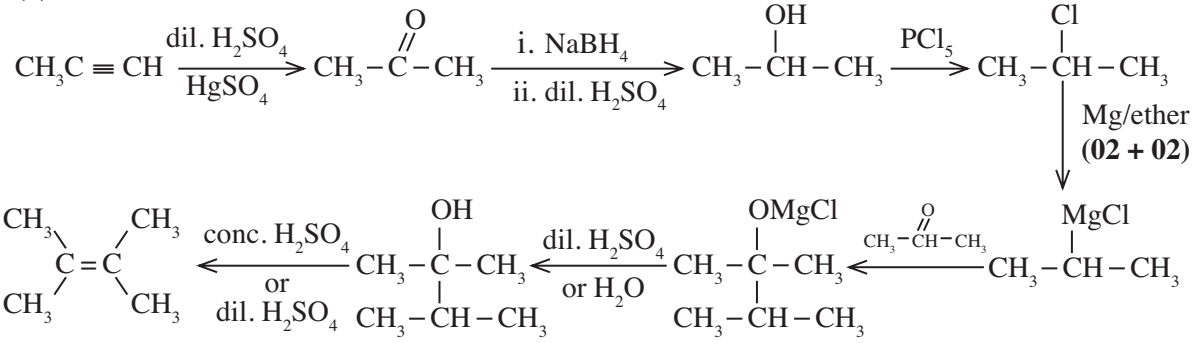
(i) Write the reactants for each pathway.

(ii) One of the above pathways will result in the formation of another compound **Y** in additon to **X**. Identify the reactants involved in this pathway and write the structure of **Y**.

(iii) State what **type of reaction** is involved in the formation of **Y**.

(iv) Assume that the reactants identified in (ii) above, form **X**, by a two step reaction. Show how **X** is formed by writing these two steps. Use curved arrows to indicate movement of electrons.

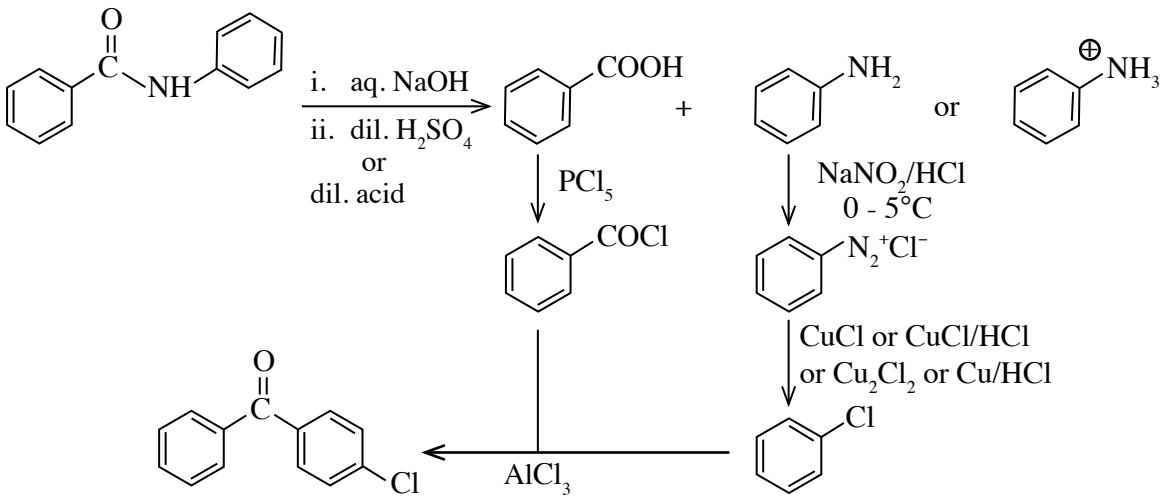
7. (*a*)



(03 × 12 + 04)

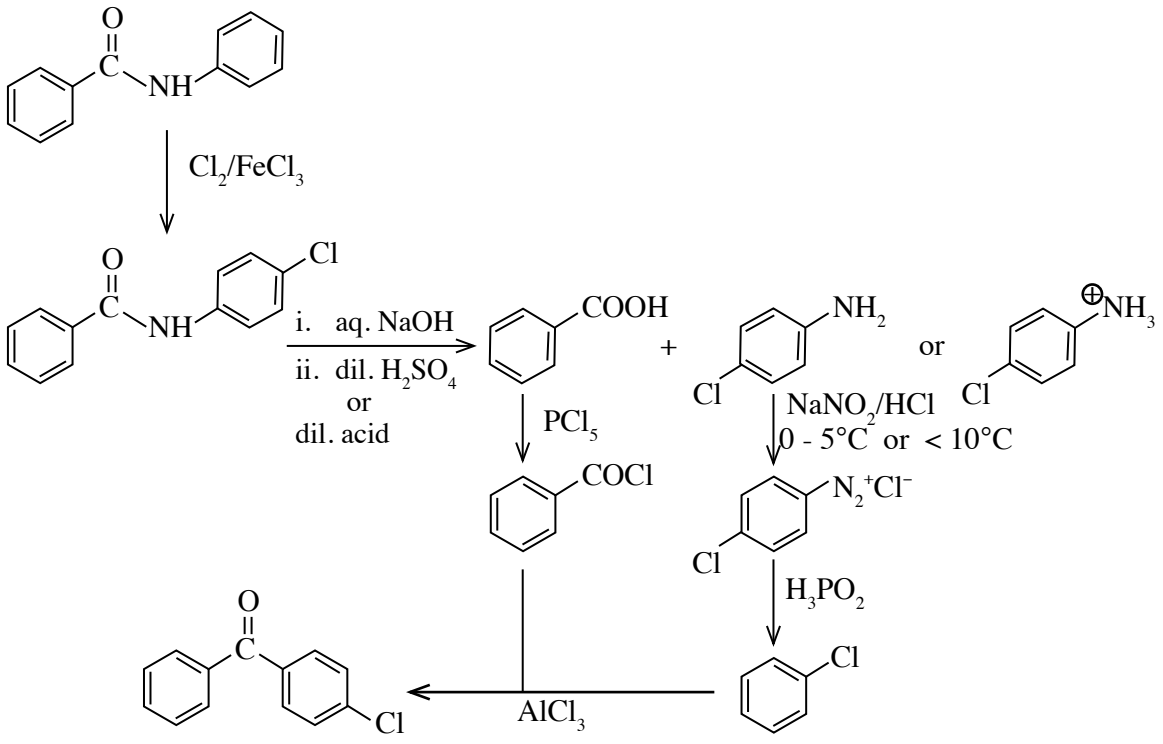
***Total for* 7(a) 40 marks**

(***b***)



(06 × 10)

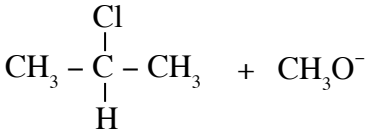
Marks may be awarded for the following alternate scheme as well.



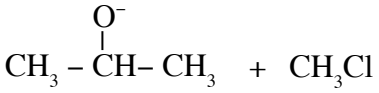
(05 × 12)

***Total for* 7(*b*)**	**60 marks**

(*c*) (i)



(06 + 06)

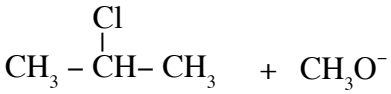


(06 + 06)

Note : CH_3OH with Na is acceptable for CH_3O^-. In place of Cl there can be Br or I.

7 (c)(i) 24 marks

(ii)



(02 + 02)

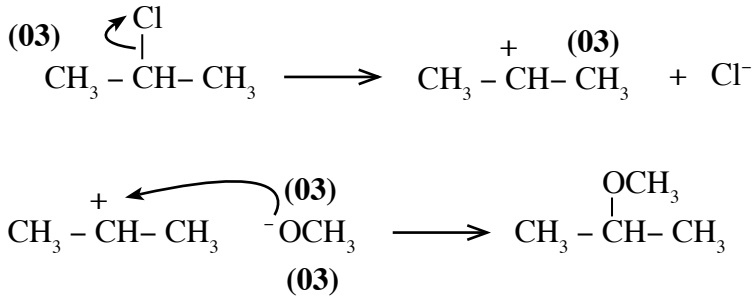
Y = $CH_3CH{=}CH_2$ (04)

7 (c)(ii) 08 marks

(iii) Elimination (06)

7 (c)(iii) 06 marks

(iv)

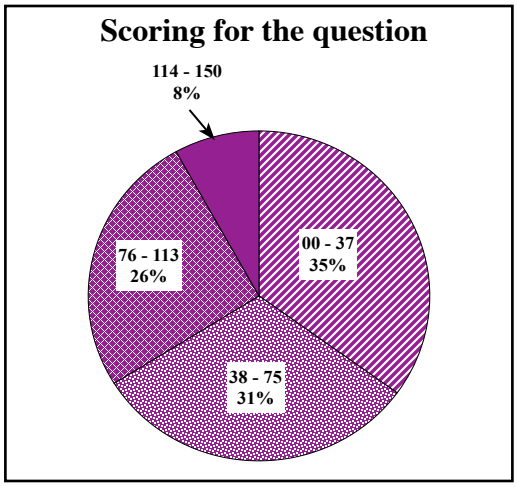


7 (c)(iv) 12 marks

***Total for* 7(*c*) 50 marks**

***Total for* 7 : 150**

Overall observations, conclusions and suggestions regarding the answers to Question 7 :

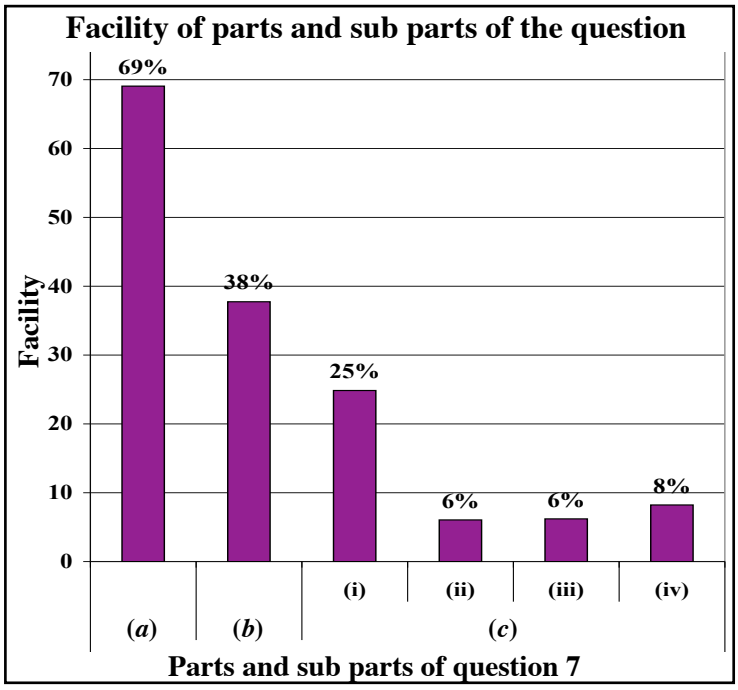


The percentage opting for question 7 was 40%. Of the three question in part B, this was the question is worth 150 marks.

The percentages scoring within the four selected class intervals were;

00	–	37	–	35%
38	–	75	–	31%
76	–	113	–	26%
114	–	150	–	8%

The percentage scoring 114 or above for this question was 8% while 35% had rated 37 or below.



* The question comprises six sub parts. The sub part of highest facility (*a*) had the facility of 69%. (*c*)(ii) and (*c*)(iii) being the most difficult parts registered a facility of 6%.

About 40% of the candidates had answered this question. So, this happened to be a question selected by a minimum percentage but was one of the two question of highest facility in part B.

Facility of sub part (*a*) was 69% but in all the other sub parts, it was below 40%. Sub part (*b*) holds a facility of 38%. From this it can be concluded that deciding the correct synthetic path to convert a given organic compound to another had become more difficult for students in an open instance compared to an instance where the reagents are given. In an organic synthesis, the student has to line up several reactions learnt in different occasions as a sequential series targeting the relevant product. In instances in which this process appears difficult, it can be reversed starting from the product and identifying the next immediate substance giving rise to it till the starting material is met. These competencies may further be developed by drilling through organic synthesis exercises which involve these strategies.

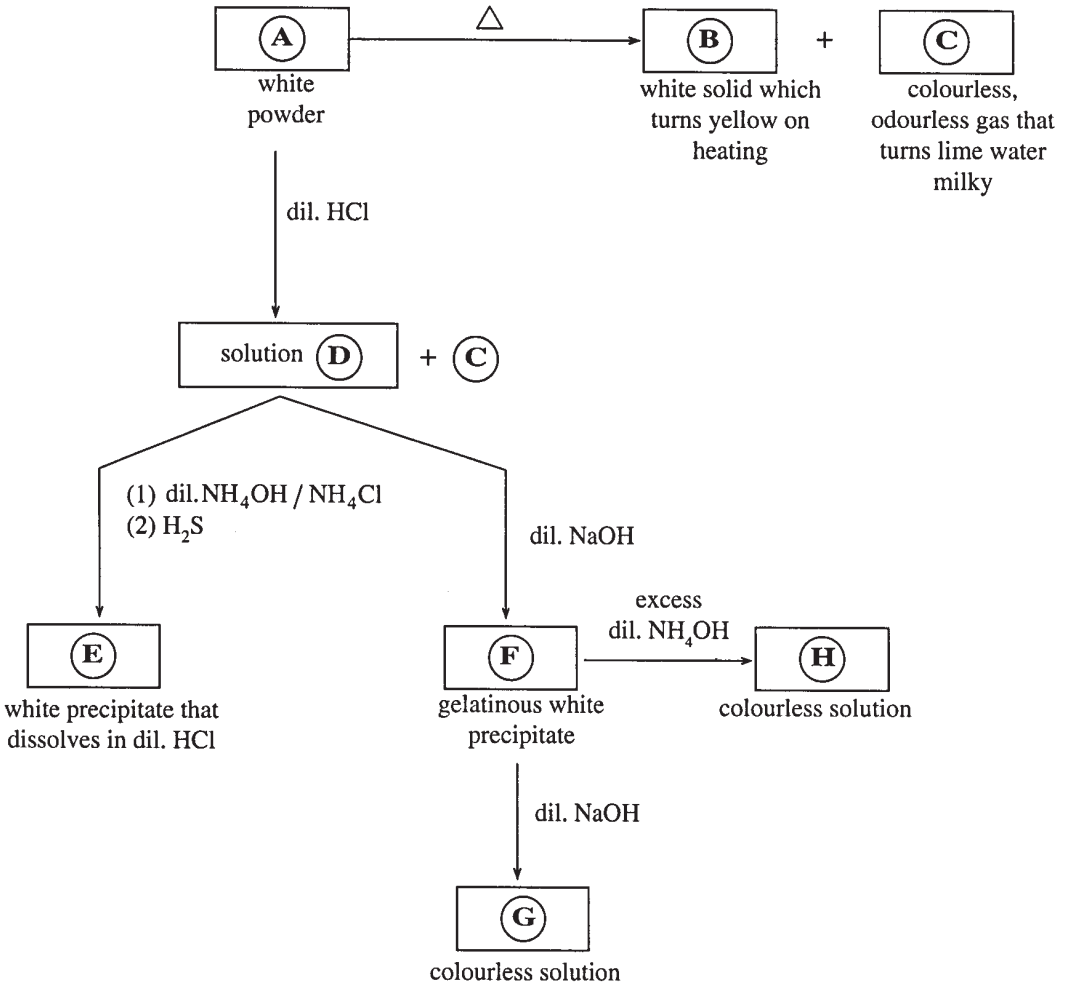
The facility of all the sub parts of (*c*) was at a minimum level. The facility of all the sub parts was below 10%. Apparently, the competency of applying the synthetic methods and reaction mechanisms studied in organic chemistry to an unfamiliar situation appropriately is very low in students. One of the two reactions tested by this section, merely examines the knowledge (recall) while the other assesses the skill of application. The low level of marks obtained by students for this section mirrors that the substitution of the nucleophile RO^- is not adequately discussed when the nucleophilic substitution of haloalkanes is taught.

Question 8

PART C — ESSAY

*Answer **two** questions only. (Each question carries **15** **marks**.)*

8. (*a*) Reactions of compounds of an element in the 3*d* block of the Periodic Table are given below. Identify the species **A**, **B**, **C**, **D**, **E**, **F**, **G** and **H**.



(5.0 *marks*)

(*b*) Tests (1) and (2) were carried out with an aqueous solution **Z** produced by passing the colourless gas **P** into water. The tests and observations are given below.

Test	Observation
(1) Added an acidified solution of $K_2Cr_2O_7$ to the solution.	A clear green solution was obtained.
(2) Added H_2O_2 to the solution and warmed. Then added a solution of $BaCl_2$.	A white precipitate insoluble in dil. HCl was formed.

(i) Identify gas **P**. (Reasons are **not** required.)

(ii) Give balanced chemical equations for the reactions that occur in tests (1) and (2).

(iii) When gas **Q** was passed through solution **Z**, a pale yellow (could be seen as white) turbidity resulted.

I. Identify gas **Q**. (Reasons are **not** required.)

II. Give the balanced chemical equation for this reaction.

(5.0 *marks*)

(*c*) A sample given for analysis was found to contain NaOH, Na_2CO_3 and an inert water soluble substance. The following procedure was used to determine the percentage of Na_2CO_3 in the sample.

Note: The inert substance **does not** participate in the reactions in the procedure given below.

Procedure:

A weight of 42.40 g of the sample was transferred quantitatively to a 500 cm^3 volumetric flask and made upto the mark with distilled water. The flask was shaken thoroughly (**solution X**).

(1) A 25.00 cm^3 portion of **solution X** was titrated with dil. HCl solution using methyl orange as the indicator, until the colour changed from orange to red. The burette reading at the end point was 32.00 cm^3.

(2) A 25.00 cm^3 portion of **solution X** was warmed to 70 °C and 1% $BaCl_2$ solution was added in slight excess. The $BaCO_3$ precipitate formed was filtered, and the filtrate was titrated with dil. HCl solution using phenolphthalein as the indicator until the colour changed from pink to colourless. The burette reading at the end point was 24.00 cm^3.

(3) To a 25.00 cm^3 volume of the dil. HCl solution, 5% KIO_3 and 5% KI solutions were added in excess. The liberated I_2 was titrated with a 0.50 mol dm^{-3} $Na_2S_2O_3$ solution using starch as the indicator. The burette reading at the end point was 12.50 cm^3.

(i) Determine the concentration of the HCl solution.

8. (*a*) **(i)** A = $ZnCO_3$ B = ZnO C = CO_2

D = $ZnCl_2$ or Zn^{2+} or $[ZnCl_4]^{2-}$ or $[Zn(H_2O)_6]^{2+}$

E = ZnS F = $Zn(OH)_2$

G = Na_2ZnO_2 or $(Na_2Zn(OH)_4$ or $Zn(OH)_4^{2-}$ or ZnO_2^{2-}

H = $[Zn(NH_3)_4]^{2+}$ or $[Zn(NH_3)_6]^{2+}$ (06 × 08)

If **all** answers are correct (02)

Total for **8(*a*)** **50 marks**

(*b*) **(i)** SO_2 (10)

8 (b)(i) 10 marks

(ii)

$2(SO_2 + 2H_2O \longrightarrow SO_4^{2-} + 4H^+ + 2e)$ (03)

$Cr_2O_7^{2-} + 14H^+ + 6e \longrightarrow 2Cr^{3+} + 7H_2O$ (03)

$Cr_2O_7^{2-} + 2H^+ + 3SO_2 \longrightarrow 2Cr^{3+} + 3SO_4^{2-} + H_2O$ (04)

$H_2O_2 + 2H^+ + 2e \longrightarrow 2\,H_2O$ (03)

$SO_2 + 2H_2O \longrightarrow SO_4^{2-} + 4H^+ + 2e$ (03)

$SO_2 + H_2O_2 \longrightarrow SO_4^{2-} + 2H^+$ or $SO_2 + H_2O_2 \longrightarrow H_2SO_4$ (04)

$H_2SO_4 + BaCl_2 \longrightarrow BaSO_4\downarrow + 2HCl$ or $SO_4^{2-} + BaCl_2 \longrightarrow BaSO_4\downarrow + 2Cl^-$ (04)

Alternate answer (I)

$3(H_2SO_3 + 2H_2O \longrightarrow SO_4^{2-} + 4H^+ + 2e)$ (03)

$Cr_2O_7^{2-} + 14H^+ + 6e \longrightarrow 2Cr^{3+} + 7H_2O$ (03)

$Cr_2O_7^{2-} + 2H^+ + 3H_2SO_3 \longrightarrow 2Cr^{3+} + 3SO_4^{2-} + 4H_2O$ (04)

$H_2O_2 + 2H^+ + 2e \longrightarrow 2H_2O$ (03)

$H_2SO_3 + H_2O \longrightarrow SO_4^{2-} + 4H^+ + 2e$ (03)

$H_2SO_3 + H_2O_2 \longrightarrow SO_4^{2-} + 2H^+ + H_2O$ (04)

$H_2SO_4 + BaCl_2 \longrightarrow BaSO_4\downarrow + 2HCl$ or $SO_4^{2-} + BaCl_2 \longrightarrow BaSO_4\downarrow + 2Cl^-$ (04)

Alternate answer (II)

$3(SO_3^{2-} + H_2O \longrightarrow SO_4^{2-} + 2H^+ + 2e)$ (03)

$Cr_2O_7^{2-} + 14H^+ + 6e \longrightarrow 2Cr^{3+} + 7H_2O$ (03)

$Cr_2O_7^{2-} + 8H^+ + 3SO_3^{2-} \longrightarrow 2Cr^{3+} + 3SO_4^{2-} + 4H_2O$ (04)

$H_2O_2 + 2H^+ + 2e \longrightarrow 2H_2O$ (03)

$SO_3^{2-} + H_2O \longrightarrow SO_4^{2-} + 2H^+ + 2e$ (03)

$SO_3^{2-} + H_2O_2 \longrightarrow SO_4^{2-} + H_2O$ (04)

$H_2SO_4 + BaCl_2 \longrightarrow BaSO_4\downarrow + 2HCl$ or $SO_4^{2-} + BaCl_2 \longrightarrow BaSO_4\downarrow + 2Cl^-$ (04)

Note :

If equations are not balanced - No marks

If the half reactions are not given but the correct complete reaction is given, award full marks, i.e. (03 + 03 + 04)

8 (b)(ii) 24 marks

(iii) I. $Q = H_2S$ (10)

II. $2H_2S + SO_2 \longrightarrow 3S\downarrow + 2H_2O$

or

$2H^+ + 2H_2S + SO_3^{2-} \longrightarrow 3S + 3H_2O$

$3H_2S + H_2SO_4 \longrightarrow 4S + 4H_2O$ (06)

8 (b)(iii) 16 marks

***Total for* 8(*b*) 50 marks**

(*c*) (i) $IO_3^- + 5I^- + 6H^+ \longrightarrow 3I_2 + 3H_2O$ --------- (1) (04)

$I_2 + 2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2I^-$ --------- (2) (02)

Amount of moles of $S_2O_3^{2-}$ = $\frac{0.50}{1000} \times 12.50$ (02)

Amount of moles of I_2 = $\frac{0.50}{1000} \times 12.50 \times \frac{1}{2}$ (02)

Amount of moles of H^+ = $\frac{0.50}{1000} \times 12.50 \times \frac{1}{2} \times 2$ (02)

$[H^+]$ = $\frac{0.50}{1000} \times 12.50 \times \frac{1}{2} \times 2 \times \frac{1000}{25.0}$ (02)

= **0.25 mol dm^{-3}** (02)

Note : The relationship $H^+ \equiv S_2O_3^{2-}$ can also be used in the above calculation.

8 (c)(i) 16 marks

(ii)

$NaOH + HCl \longrightarrow NaCl + H_2O$ (01)

$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2$ (01)

Amount of moles of HCl required to react with NaOH and Na_2CO_3 = $\frac{0.25}{1000} \times 32.0$ (03)

Amount of moles of HCl required to react with NaOH = $\frac{0.25}{1000} \times 24.0$ (03)

Therefore, amount of moles of HCl required to react with Na_2CO_3

= $\frac{0.25}{1000} \times 32.0 - \frac{0.25}{1000} \times 24.0$ (03)

= 0.008 – 0.006

= 0.002 (03)

Therefore, amount of moles of Na_2CO_3 in 25.0 cm^3 = $\frac{0.002}{2}$ (03)

Amount of moles of Na_2CO_3 in 500.0 cm^3 = $\frac{0.002 \times 20}{2}$

= 0.02 (03)

Molecular mass of Na_2CO_3 = 106 g mol^{-1}

Mass of Na_2CO_3 = $0.02 \times 106 = 2.12$ g (03)

% Na_2CO_3 in sample = $\frac{2.12}{42.4} \times 100$ % (03)

= **5.0 %** (03)

8 (c)(ii) 29 marks

(iii) Assumption/s - All the carbonate in the solution is precipitated as $BaCO_3$ on the addition of excess $BaCl_2$.

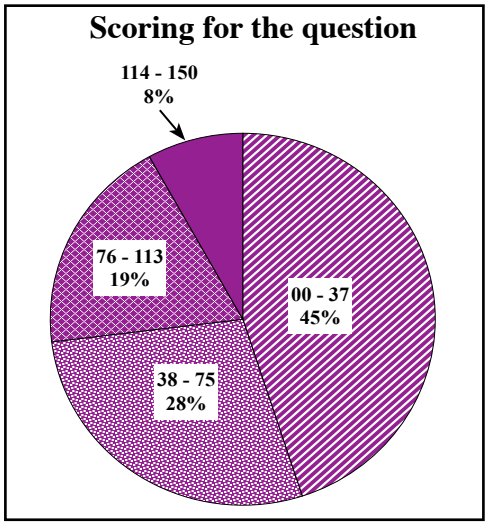
(03)

8 (c)(iii) 05 marks

***Total for* 8(*c*) 50 marks**

***Total for* 8 : 150**

Overall observations, conclusions and suggestions regarding the answers to Question 8 :

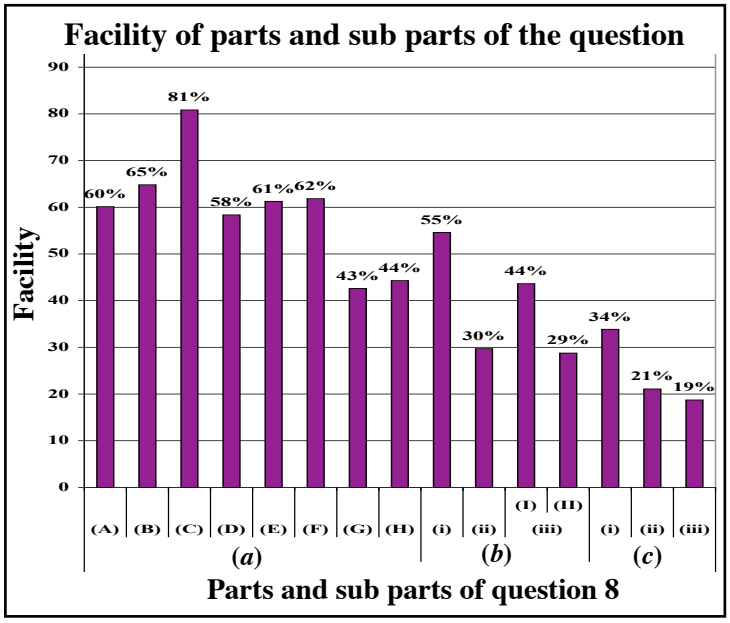


The percentage selecting question 8 was 46%. The question holds a total of 150 marks.

The percentages scoring within the four class intervals concerned were as follows.

00	– 37	–	45%
38	– 75	–	28%
76	– 113	–	19%
114	– 150	–	8%

The percentage scoring 114 or above for this question was 8% whereas 45% had scored 37 or below.



* Of the 15 sub parts in this question, the facility of 5 sub parts was below 35%. The easiest sub part was (*a*)(C) and its facility was 81%. Sub part (*c*)(iii) had the lowest facility.

The total facility of the question was 60% and was responded by 46%. Part 8 (*a*) inquires into the ability of identifying elements in the d block of the periodic table. The facility of identifying species from (A) to (H) in sub part (*a*) was above 40% showing a high level of students' achievements in this section. Though sub part (*b*)(ii) examines writing balanced equations, its total facility stands at 29%.

Answers witnessed a weaker level of writing and balancing ionic half equations for redox reactions. In this area, the achievements can be raised by engaging students often in such exercises. The mixing of ion- electron half reaction method and oxidation number method when balancing redox equations had also affected the nonsuccess of answers. There is a need to reinforce the skill of writing half equations in students when doing exercises in this area.

The facility of all the three sub parts in 8 (*c*) was below 35%. The question was a chemical calculation related to a titration. It should be imbued in students that the titration between Na_2CO_3 and HCl depends on the indicator and in the presence of phenolphthalein, Na_2CO_3 : HCl stoichiometry is 1 : 1 whereas with methyl orange it is 1:2. Scoring seemed to be low also in calculations involving concentrations. In order to improve achievement in this area, involvement of students in problems solving exercises and conducting practical works whenever relevant are highly recommended.

Question 9

9. (*a*) (i) I. With the aid of balanced chemical equations list the steps involved, along with the reaction conditions, in the manufacture of H_2SO_4 using the Contact Process.

II. Briefly describe the physicochemical principles related to this process.

III. Give **two** uses of H_2SO_4.

(ii) Using balanced chemical equations, indicate how the following conversions could be carried out industrially:

I. limestone $\longrightarrow C_2H_2$

II. $N_2 \longrightarrow NaNO_2$

Note: Where applicable give the reaction conditions and indicate how the reagents/reactants are obtained industrially.

(iii) The following questions are based on the manufacture of Na_2CO_3 using the Solvay Process.

I. State the starting materials used in this process.

II. Indicate how the materials stated in I are obtained.

III. Give the **final** by-product of this process.

IV. Give **two** reasons as to why low temperatures are used in this process.

V. Give **two** uses of Na_2CO_3.

VI. Propose a method to convert the final by-product stated in III to gypsum, using sea water as a natural resource. **(7.5 *marks*)**

(*b*) As an alternative to chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) were introduced to reduce the ozone layer depletion. However, both these groups of compounds not only deplete the ozone layer but also contribute to other environmental problems.

(i) Draw the chemical structures of all the CFCs and HCFCs with a single C atom. Label each of them as a CFC or HCFC.

(ii) "Under normal atmospheric conditions, HCFCs are more reactive than CFCs." Comment on this statement.

(iii) Name another environmental problem that is associated with CFCs and HCFCs. Comment on their relative contribution towards this environmental problem.

(iv) Identify **three** properties of CFCs that make them suitable for use as refrigerants.

(v) Explain how CFCs contribute to the depletion of the ozone layer.

(vi) Briefly describing the consequence of the depletion of the ozone layer, identify **three** problems associated with it. **(7.5 *marks*)**

9. (*a*) **(i) I.**

$$S(s) + O_2(g) \xrightarrow{\Delta \ \textbf{(01)}} SO_2(g) \qquad (02)$$

$$2\,SO_2(g) + O_2(g) \underset{\text{1 – 2 atm } \textbf{(01)}}{\overset{\text{450 °c } \textbf{(01)}}{\rightleftharpoons}} 2SO_3(g) \qquad (02)$$

V_2O_5 **(01)**

$$SO_3(g) + H_2SO_4(l) \longrightarrow H_2S_2O_7(l) \qquad (02)$$

$$H_2SO_4(l) + H_2O(l) \longrightarrow 2H_2SO_4(aq) \qquad (02)$$

Other methods of producing SO_2 are also acceptable :

eg : $2PbS(s) + 3O_2(g) \xrightarrow{\Delta} 2PbO(s) + 2SO_2(g)$

$2ZnS(s) + 3O_2(g) \xrightarrow{\Delta} 2ZnO(s) + 2SO_2(g)$

$2H_2S(g) + 3O_2(g) \xrightarrow{\Delta} 2H_2O(g) + 2SO_2(g)$

(H_2S in crude oil burned in air)

$$2CuFeS_2(s) + 4O_2(g) \xrightarrow{\Delta} Cu_2S(s) + 2FeO(s) + 3SO_2(g)$$
(copper pyrites)

$$4CuFeS_2(s) + 11O_2(g) \xrightarrow{\Delta} 2Cu_2O(s) + 4FeO(s) + 8SO_2(g)$$
$$4FeS_2(s) + 11O_2(g) \xrightarrow{\Delta} 2Fe_2O_3(s) + 8SO_2(g)$$

Note : Physical states are not required.

9 (a)(i)(I) 12 marks

II.

The reaction between SO_2 and O_2 is reversible **(01)** and exothermic **(01)** and the number of molecules decreases in the forward reaction **(01).** According to the Le Chatelier's principle **(01) the forward reaction will be favoured by low temperature (01) and high pressure (01).**

The small advantage gained in this reaction by using high pressure is more than offset by the greater cost of equipment that would be needed **(01).** Hence, 1 - 2 atm pressure is used.

At tow temperatures, the rate of reaction is low **(01).** Hence, a temperature of 450°C is used to get an acceptable rate. A catalyst, (V_2O_5), is used **(01)** to speed up the rate of the reaction **(01)** and achieve the equilibrium condition faster **(01)**.

9 (a)(i)(II) 11 marks

III.

Manufacture of fertilizers	Manufacture of chemicals
Production of dyes	Production of drugs
Production of explosives	In automobile batteries/battery acid
Production of detergents	Extracting metals from metal ores
Oxidizing agent	Dehydrating agent
Manufacture of synthetic fibers	Manufacture of plastics
Manufacture of paints & pigments	Used in petroleum refining
Drying agent (gases)	

(any two) (01 × 2)

9 (a)(i)(III) 02 marks

Total for **9(*a*)(i)**	**25 marks**

(ii) I. $CaCO_3(s) \xrightarrow{\Delta\ (01)} CaO(s) + CO_2(g)$ (02)

$CaO(s) + 3C(s) \xrightarrow{\Delta\ (01)} CaC_2(s) + CO(g)$ (02)

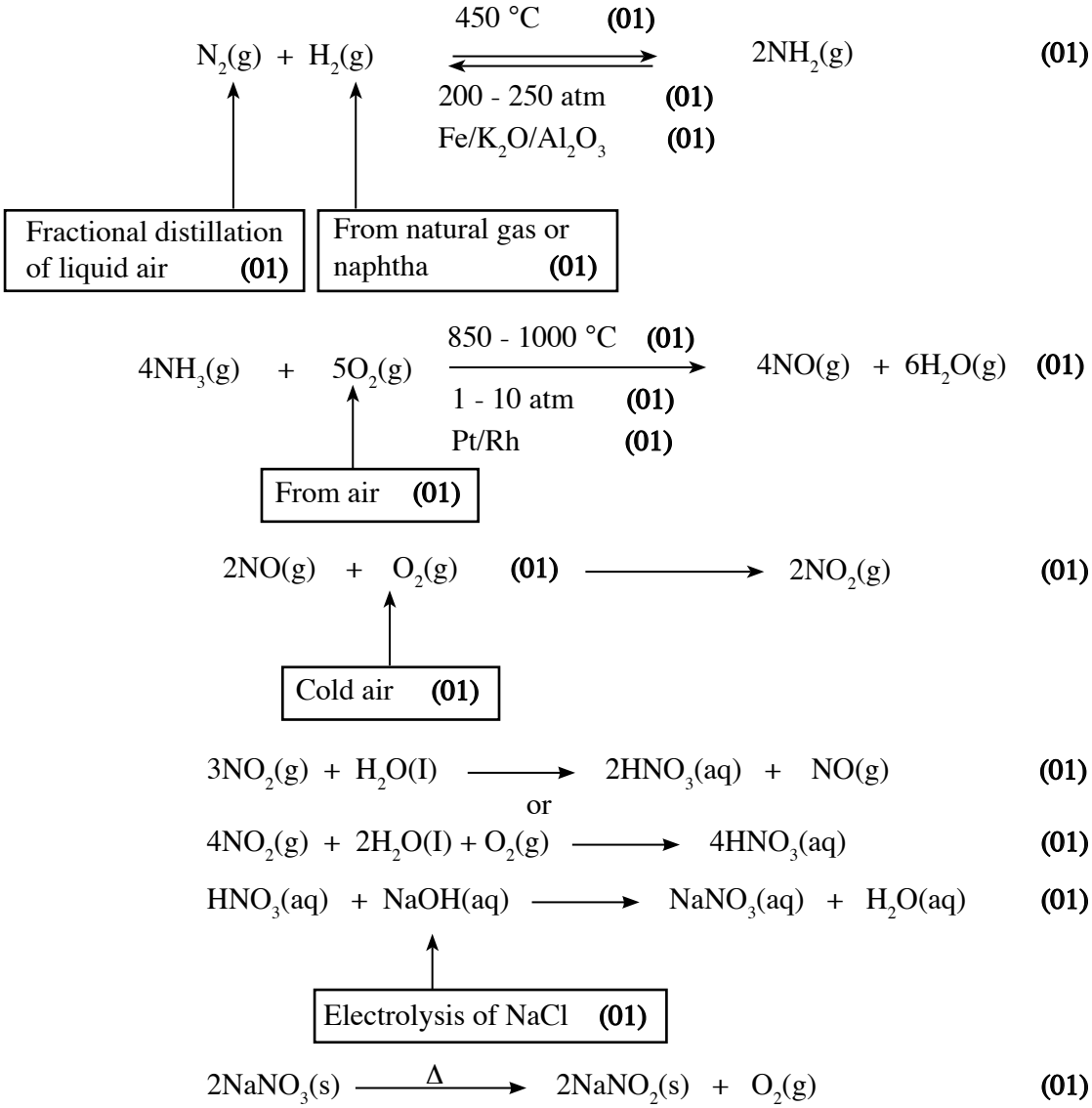
or

$2CaO(s) + 5C(s) \xrightarrow{\Delta} 2CaC_2(s) + CO_2(g)$

$CaC_2(s) + 2H_2O(l) \longrightarrow Ca(OH)_2(aq) + C_2H_2(g)$ (02)

9 (a)(ii)(I) 08 marks

II.



Note : Physical states are not required. **9 (a)(ii)(II) 17 marks**

***Total for* 9(*a*)(ii) 25 marks**

(iii) I. Brine (concentrated NaCl solution), NH_3 and CO_2 (02 + 02 + 02)

II. Brine - from sea water (02)
NH_3 - from the Haber process (02)
CO_2 - from limestone (02)

III. $CaCl_2$ (02 marks)

IV. to precipitate $NaHCO_3$ (02)
to dissolve gases in brine (02)

V. manufacture of glass, detergents, soap, sodium silicate and paper, to soften hard water, as washing soda in detergents, extinguishing fires

(any two) (02 + 02)

VI. $CaCl_2$ is added to remaining mother liquor after precipitating NaCl from sea water. (01)

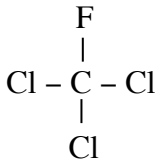
Good source of SO_4^{2-} (01)

$CaCl_2(s) + SO_4^{2-} \longrightarrow CaSO_4 . 2H_2O$ (gypsum) (01)

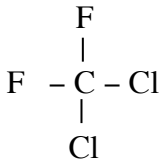
9 (a)(iii) 25 marks

Total for **9(*a*)**	**75 marks**

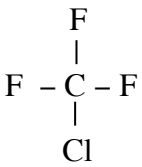
(*b*) (i)



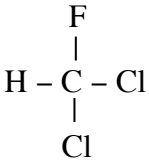
CFC



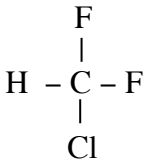
CFC



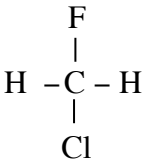
CFC



HCFC



HCFC



HCFC

(03 × 6)

(2 for structure only, 3 for structure and identification)

9 (b)(i) 18 marks

(ii) Statement is correct. **(03)** Compared to C – F and C – Cl bonds C – H bonds are weaker **(03)** and subjected to reaction with environmental chemicals **(03)**.

9 (b)(ii) 09 marks

(iii) Global warming. **(03)** Both the CFCs and HCFCs are greenhouse gases **(03)** that contribute to the elevation of atmospheric temperatures **(03)**. Since HCFCs are more reactive their atmospheric lifetime is shorter **(03)** and hence the contribution to the global warming is less than that of CFCs **(03)**.

9 (b)(iii) 15 marks

(iv)

chemically inert	-	no damage to the food
physiologically inert	-	no health problems even if consumed
nonflammable	-	safety
easily compressible and expandable	-	effective coolant
less viscous	-	easily mobile
low boiling points	-	gaseous at room temperature
high specific heat		

(any three) (03 × 3)

9 (b)(iv) 09 marks

(v) At the higher elevations, CFCs are exposed to UV radiation. UV radiation cleaves C – Cl (or C – F) bonds **(03)** and generates chlorine (or fluorine) free radicals **(03)**. These radicals catalyze the destruction of ozone molecules **(03)** and deplete the levels of ozone in the upper atmosphere **(03)**.

$$CFCl_3 \xrightarrow[(03)]{UV\ (or\ h\upsilon)} {}^{\bullet}CFCl_2 + {}^{\bullet}Cl \quad \text{(any CFC can be used)}$$
(03)

$${}^{\bullet}Cl + O_3 \longrightarrow {}^{\bullet}OCl + O_2 \qquad (01)$$

$$O_2 \xrightarrow{h\upsilon} 2O \qquad (01)$$

$${}^{\bullet}OCl + O \longrightarrow {}^{\bullet}Cl + O_2 \qquad (01)$$

9 (b)(v) 12 marks

(vi) Depletion of ozone layer allows the penetration of high energy UV to the ground **(03)**. Penetrated UV can cause to following problems.

Elevates the atmospheric temperature

Produces ozone at the grouns level

Cataract in eyes

Skin carcinoma

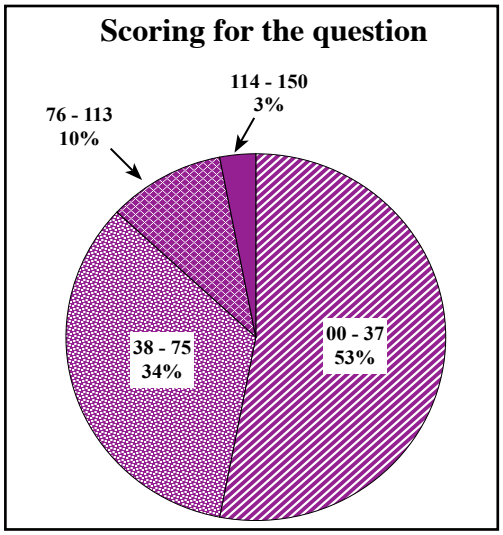
Adversely affects vegetation **(any three, 03 marks each)**

9 (b)(vi) 12 marks

***Total for* 9(*b*) 75 marks**

***Total for* 9 : 150**

Overall observations, conclusions and suggestions regarding the answers to Question 9 :

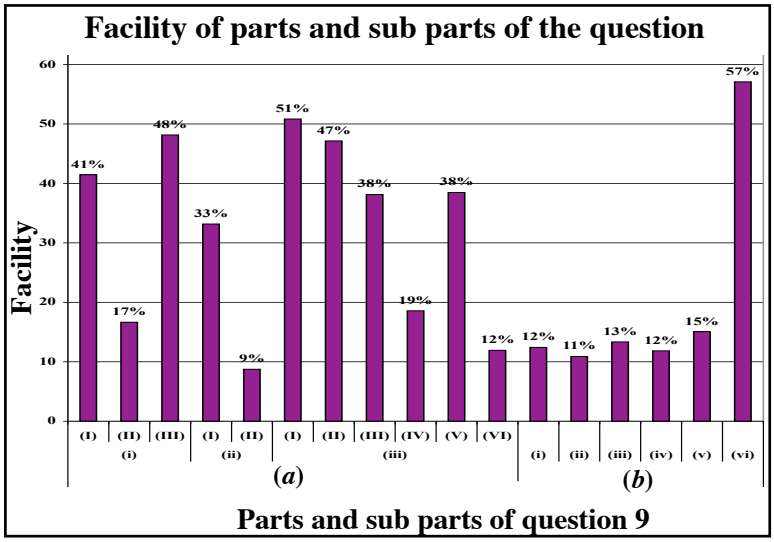


68% had answered question 9. The question is worth 150 marks. This was the most popular question out of the three questions in part C.

The percentages falling into the four class intervals were:

00	–	37	–	53%
38	–	75	–	34%
76	–	113	–	10%
114	–	150	–	3%

As regards this question, the number exceeding 114 or above was 31% by percentage and those scoring 37 or below constitute 53%.



* The question comprises 17 sub parts. Of them, the facility of 10 sub parts was below 33%. The sub part (*a*)(ii)(II) being the most difficult had the facility of 9%. The easiest sub part had been (*b*)(vi). Its facility was 82%.

The percentage selecting question 9 was 68% and its total facility was 36%. Part (*a*) is sub divided into 11 sub parts. The facility of (*a*)(iii) (I) was 51%. The facility of (*a*)(iii)(II) had dropped to 47%. Part (*a*)(i) is based on the manufacture of sulphuric acid by the contact process. Writing reactions and conditions relating to the production of sulphuric acid had been successful to some extent (facility 41%), yet the ability of explaining physico-chemical principles seemed low (facility 17%). The candidates were unable to get the full quota of marks for not giving relevant conditions, not balancing equations, not knowing the specific meaning of some words and the shortcomings in the expression. Some had considered reaction conditions as the physico-chemical principles. Students should be convinced that basic linguistic skills is a compulsory part in answering essay type questions. However , facility has increased when stating the uses of sulphuric acid.

The facility for writing reaction connected with the production of acetylene from limestone in (*a*)(ii) was 48% but 9% was the facility for converting nitrogen to $NaNO_2$. This shows that though students are capable of writing answered by memorizing facts, their ability to apply learned facts analytically is minimal.

Despite the facility of (*a*)(iii) was greater than 36%, the facilities of (*a*)(iii)(IV) and (*a*)(iii)(VI) had slumped to 19% and 12% respectively. So, it seems that students are less capable of producing answers applying the facts with reasoning. The low scores for sub part (*a*)(iii)(VI) is due to the fact that many were unaware that the mother liquor is a source of sulphate ions.

Facility of part (*b*) was less than that of (*a*). Answering questions related to the understanding of global environment had become difficult for students. Not paying adequate attention to last lessons and not covering the entire syllabus would have caused this situation. Hence, it is stressed that in order to answer the chemistry paper successfully, full coverage of the syllabus is essential and the students should be prepared to answer the questions set on all the topics.

Question 10

10. (*a*) Predict the products and give balanced chemical equations for the following reactions. State the action of the species underlined, in the reaction.

(i) $\underline{H_2O_2}(aq) + PbS(s) \longrightarrow$

(ii) $MnO_4^-(aq) + \underline{H_2O_2}(aq) + H^+(aq) \longrightarrow$

(iii) $Cr_2O_7^{2-}(aq) + \underline{H_2S}(aq) + H^+(aq) \longrightarrow$

(iv) $Cu(s) + \underline{H_2S}(g) \xrightarrow{\Delta}$

(v) $C(s) + \underline{\text{conc. } HNO_3} \xrightarrow{\Delta}$

(2.5 *marks*)

(*b*) A solution **T** has been prepared by dissolving 0.300 g of FeC_2O_4 in dilute H_2SO_4. The solution was heated to 65 °C. Calculate the volume of 0.025 mol dm^{-3} $KMnO_4$ solution required to react completely with FeC_2O_4 under these conditions.

(C = 12, O = 16, Fe = 56)

Note : Consider FeC_2O_4 to exist as Fe^{2+} and $C_2O_4^{2-}$ in solution **T**.

(5.0 *marks*)

(*c*) Liquefied-petroleum gas (LP gas) is commonly used as a fuel for cooking purposes in Sri Lanka. It is a mixture of liquefied propane and butane, under high pressure. The following data are provided.

Substance	Standard enthalpy of formation ΔH_f° at 25 °C (kJ mol^{-1})
$H_2O(l)$	– 286
$CO_2(g)$	– 394
$C_3H_8(g)$	– 104
$C_4H_{10}(g)$	– 126

(i) Calculate the standard enthalpies of combustion of propane and butane gases at 25 °C.

(ii) Calculate the amount of heat needed to increase the temperature of 400 g of water from 25 °C to 85 °C. (Heat capacity of water is 4.2 J g^{-1} $°C^{-1}$).

(iii) Assuming complete combustion would take place, calculate the mass of CO_2 emitted in each case when the above process (ii) is carried out using:

I. propane as the fuel.

II. butane as the fuel.

(iv) Based on your calculations in (iii) above, identify which fuel is more environmentally friendly and explain why it is so.

(7.5 *marks*)

10.(*a*) (i) $\underline{4H_2O_2} + PbS \longrightarrow PbSO_4 + 4H_2O$ (04)

Oxidizing agent **or** undergoes reduction (01)

(ii) $2MnO_4^- + \underline{5H_2O_2} + 6H^+ \longrightarrow 2Mn^{2+} + 8H_2O + 5O_2$ (04)

Reducing agent **or** undergoes oxidation (01)

(iii) $Cr_2O_7^{2-} + \underline{3H_2S} + 8H^+ \longrightarrow 2Cr^{3+} + 3S + 7H_2O$ (04)

Reducing agent **or** undergoes oxidation (01)

(iv) $Cu(s) + \underline{H_2S} \xrightarrow{\Delta} CuS + H_2$ (04)

Oxidizing agent **or** undergoes reduction **or** acts as an acid (01)

(v) $C + \underline{4HNO_3} \xrightarrow{\Delta} CO_2 + 4NO_2 + 2H_2O$ (04)

Oxidizing agent **or** undergoes reduction (01)

***Total for* 10(*a*) 25 marks**

(*b*)

Method 1

Half reactions taking place :

$5(Fe^{2+} \longrightarrow Fe^{3+} + e)$ (02)

$5(C_2O_4^{2-} \longrightarrow 2CO_2 + 2e)$ (02)

$3\,(MnO_4^- + 8H^+ + 5e \longrightarrow Mn^{2+} + 4H_2O)$ (02)

$3\,MnO_4^- + 5C_2O_4^{2-} + 5Fe^{2+} + 24H^+ \longrightarrow 5Fe^{3+} + 10CO_2 + 12H_2O + 3Mn^{2+}$ (08)

Molar mass of $FeC_2O_4 = 144\,g$

Amount of moles of $FeC_2O_4 = \dfrac{0.300\,g}{144\,g}$ (03)

Amount of moles of Fe^{2+} = Amount of moles of $C_2O_4^{2-} = \dfrac{0.300\,g}{144\,g} = 2.08 \times 10^{-3}$ (03)

Let the volume of $KMnO_4$ be V cm^3

Amount of moles of $MnO_4^- = \dfrac{0.025}{1000} \times V$ (03)

Therefore, amount of moles of Fe^{2+} = Amount of moles of $C_2O_4^{2-} = \dfrac{0.025}{1000} \times V \times \dfrac{5}{3}$

(03 + 03 + 09)

$= \dfrac{0.025}{1000} \times V \times \dfrac{5}{3} = 2.08 \times 10^{-3}$ (07)

V = **50.0 cm^3** (04 + 01 = 05 marks)

Method 2

$5\ (Fe^{2+} \longrightarrow Fe^{3+} + e)$ (02)

$MnO_4^- + 8H^+ + 5e \longrightarrow Mn^{2+} + 4H_2O$ (02)

$5Fe^{2+} + MnO_4^- + 8H^+ \longrightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$ ---------- (1) (04)

$5(C_2O_4^{2-} \longrightarrow 2CO_2 + 2e)$ (02)

$2\ (MnO_4^- + 8H^+ + 5e \longrightarrow Mn^{2+} + 4H_2O)$ (02)

$2\ MnO_4^- + 5C_2O_4^{2-} + 16H^+ \longrightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$ ---------- (2) (04)

Amount of moles of Fe^{2+} = Amount of moles of $C_2O_4^{2-} = \frac{0.300\ g}{144\ g} = 2.08 \times 10^{-3}$ (03 + 03)

Let the volume of MnO_4^- for reaction (1) be $V_1\ cm^3$

Amount of moles of $MnO_4^- = \frac{0.025}{1000} \times V_1$ (03)

Therefore, amount of moles of $Fe^{2+} = \frac{0.025}{1000} \times V_1 \times 5$ (03)

$= \frac{0.025}{1000} \times V_1 \times 5 = 2.08 \times 10^{-3}$ (03)

$V_1 = 16.67\ cm^3 \approx 16.7\ cm^3$ (03)

Let the volume of MnO_4^- for reaction (2) be $V_2\ cm^3$

Amount of moles of $MnO_4^- = \frac{0.025}{1000} \times V_2$ (03)

Amount of moles of $C_2O_4^{2-} = \frac{0.025}{1000} \times V_2 \times \frac{5}{2}$ (03)

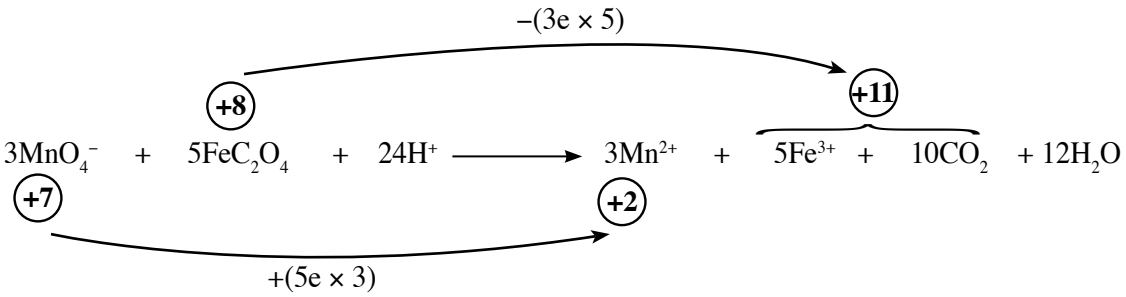
$= \frac{0.025}{1000} \times V_2 \times \frac{5}{2} = 2.08 \times 10^{-3}$ (03)

$V_2 = 33.28\ cm^3 \approx 33.3\ cm^3$ (03)

Total volume = $16.67\ cm^3 + 33.28\ cm^3$ (01)

= **$50.0\ cm^3$** (04 + 01)

Method 3



(02 + 02 + 02 + 08)

Amount of moles of FeC_2O_4 = $\frac{0.300\,g}{144\,g}$ = 2.08×10^{-3} (03)

Let the volume of MnO_4^- for the reaction be V cm^3

Amount of moles of MnO_4^- = $\frac{0.025}{1000} \times V$ (03)

5 moles of FeC_2O_4 ≡ 3 moles of $KMnO_4$ (09)

$\frac{0.300\ g}{144\ g} \times 3 = \frac{0.025 \times V \times 5}{1000}$ (16)

V = **50.0 cm^3** (04 + 01)

Total for **10(*b*)**	**50 marks**

(*c*) (i)

Burning of propane

$H_2(g) + 1/2O_2(g) \longrightarrow H_2O(l)$ $\Delta H_1 = -286\,kJ\,mol^{-1}$ ---- (1) (01)

$C(graphite) + O_2(g) \longrightarrow CO_2(g)$ $\Delta H_2 = -394\,kJ\,mol^{-1}$ ---- (2) (01)

$3C\ (graphite) + 4H_2(g) \longrightarrow C_3H_8(g)$ $\Delta H_3 = -104\,kJ\,mol^{-1}$ ---- (3) (02)

$C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(l)$ ΔH_4 ---- (4) (02)

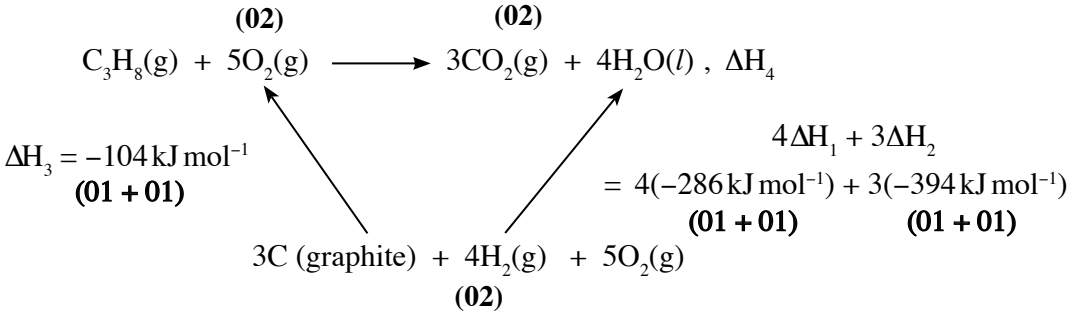
$\Delta H_4 = 4\Delta H_1 + 3\Delta H_2 - \Delta H_3$

$\Delta H_4 = 4(-286\,kJ\,mol^{-1}) + 3\,(-394\,kJ\,mol^{-1}) - (-104\,kJ\,mol^{-1})$

(01 + 01) **(01 + 01)** **(01 + 01)**

$= -2222\,kJ\,mol^{-1}$ (02 + 01)

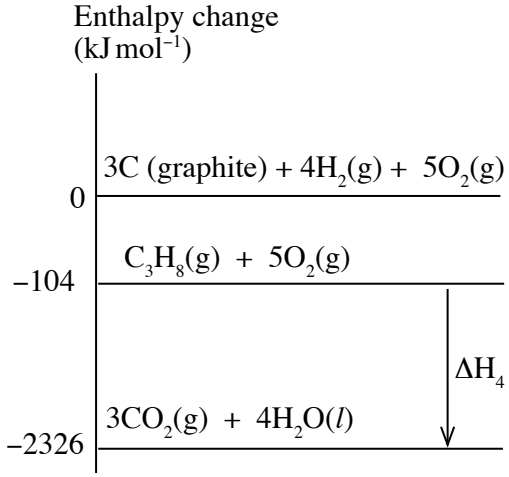
OR



$\Delta H_4 = 4\Delta H_1 + 3\Delta H_2 - \Delta H_3$

$= -2222\,kJ\,mol^{-1}$ (02 + 01)

OR



(02)

(02)

(02)

$\Delta H_4 = 4(-286\,kJ\,mol^{-1}) + 3(-394\,kJ\,mol^{-1}) - (-104\,kJ\,mol^{-1})$

(01 + 01) (01 + 01) (01 + 01)

(or correct enthalpy changes on the diagram)

$= -2222\,kJ\,mol^{-1}$ (02 + 01)

<u>Burning of butane</u>

$H_2(g) + 1/2O_2(g) \longrightarrow H_2O(l)$ $\Delta H_1 = -286\,kJ\,mol^{-1}$ ---- (1) (01)

$C(graphite) + O_2(g) \longrightarrow CO_2(g)$ $\Delta H_2 = -394\,kJ\,mol^{-1}$ ---- (2) (01)

$4C\,(graphite) + 5H_2(g) \longrightarrow C_4H_{10}(g)$ $\Delta H_3 = -126\,kJ\,mol^{-1}$ ---- (3) (02)

$C_4H_{10}(g) + 13/2O_2(g) \longrightarrow 4CO_2(g) + 5H_2O(l)$ ΔH_4 ---- (4) (02)

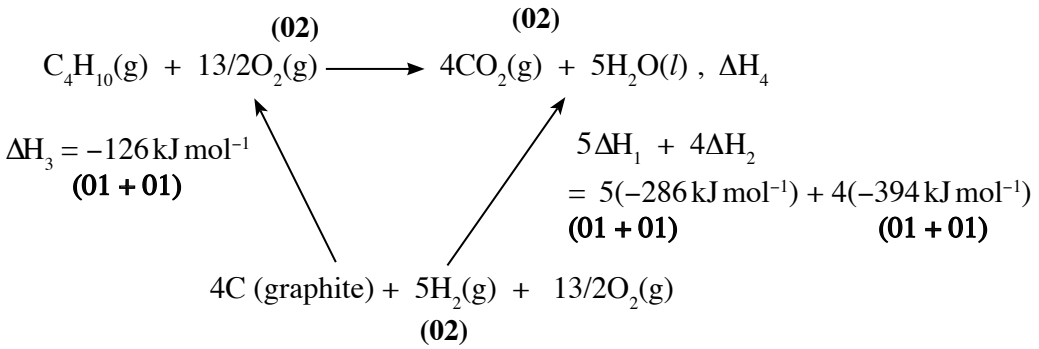
$\Delta H_4 = 5\Delta H_1 + 4\Delta H_2 - \Delta H_3$

$\Delta H_4 = 5(-286\,kJ\,mol^{-1}) + 4(-394\,kJ\,mol^{-1}) - (-126\,kJ\,mol^{-1})$

(01 + 01) (01 + 01) (01 + 01)

$= -2880\,kJ\,mol^{-1}$ (02 + 01)

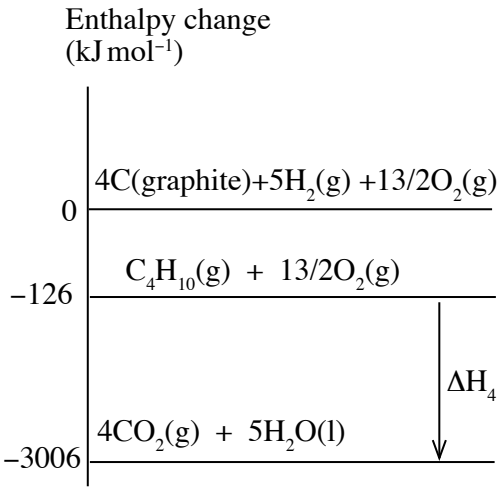
OR



$\Delta H_4 = 5\Delta H_1 + 4\Delta H_2 - \Delta H_3$

$= -2880\,kJ\,mol^{-1}$ (02 + 01)

OR



(02)

(02)

(02)

$\Delta H_4 = 5\,(-286\,kJ\,mol^{-1}) + 3\,(-394\,kJ\,mol^{-1}) - (-126\,kJ\,mol^{-1})$

(01 + 01) (01 + 01) (01 + 01)

(or correct enthalpy changes on the diagram)

$= -2880\ kJ\ mol^{-1}$ (02 + 01)

10 (c)(i) 30 marks

(ii) Heat needed to increase the temperature of 400 g of water from 25 °C to 85 °C.

$q = 400\,g \times 4.2\,J\,g^{-1}\,°C^{-1}\,(85 - 25)\,°C$ (04 + 01)

$= 100.8\,kJ$ (04 + 01)

10 (c)(ii) 10 marks

(iii) Amount of propane needed to produce the amount of heat in (ii).

$= 1/2222\,kJ\,mol^{-1} \times 100.8\,kJ = 4.54 \times 10^{-2}\,mol$ (04 + 01)

Amount of CO_2 emitted

$= 4.54 \times 10^{-2}\,mol \times 3$

$= 1.36 \times 10^{-1}\,mol$ (04 + 01)

Mass of CO_2 emitted

= 1.36×10^{-1} mol $\times$ 44 g mol^{-1}

= 5.98 g (04 + 01)

Amount of butane needed to produce the amount of heat in (ii).

= 1/2880 kJ mol^{-1} $\times$ 100.8 kJ

= 3.50×10^{-2} mol (04 + 01)

Amount of CO_2 emitted

= 3.50×10^{-2} mol $\times$ 4

= 1.40×10^{-1} mol (04 + 01)

Mass of CO_2 emitted

= 1.40×10^{-1} mol $\times$ 44 g mol^{-1}

= 6.16 g (04 + 01)

10 (c)(iii) 30 marks

(iv) Propane is a more environmental friendly fuel because it emits less CO_2 compared to butane when the same amount of heat is produced.

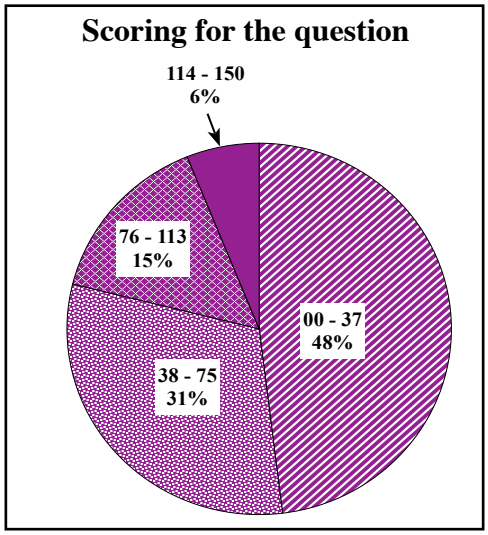
(05)

10 (c)(iv) 05 marks

Total for **10(*c*) 75 marks**

Total for **10 : 150**

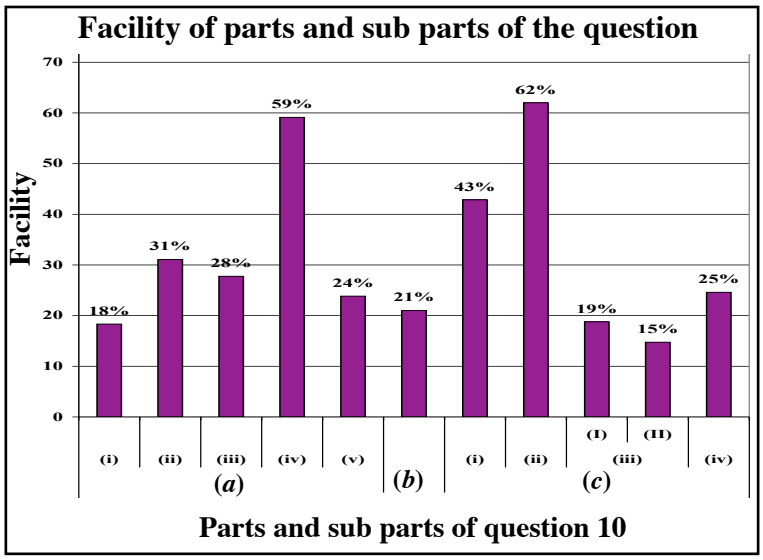
Overall observations, conclusions and suggestions regarding the answers to Question 10 :



About 42% had selected question 10. The question is worth 150 marks. The distribution of the percentages of candidates scoring marks within the four selected class intervals was as follows.

00	–	37	–	48%
38	–	75	–	31%
76	–	113	–	15%
114	–	150	–	6%

The percentage constituting the scores of 114 or above for this question was 6%. 48% had received less than 37 or below for this question.



* Question 10 embodies 11 sub parts of which three sub parts had a facility greater than 40%. Sub part (*c*)(iii)(II) was the most difficult sub part in this question. Its facility was 15%. (*c*)(ii) being the most facile part had a facility of 62%.

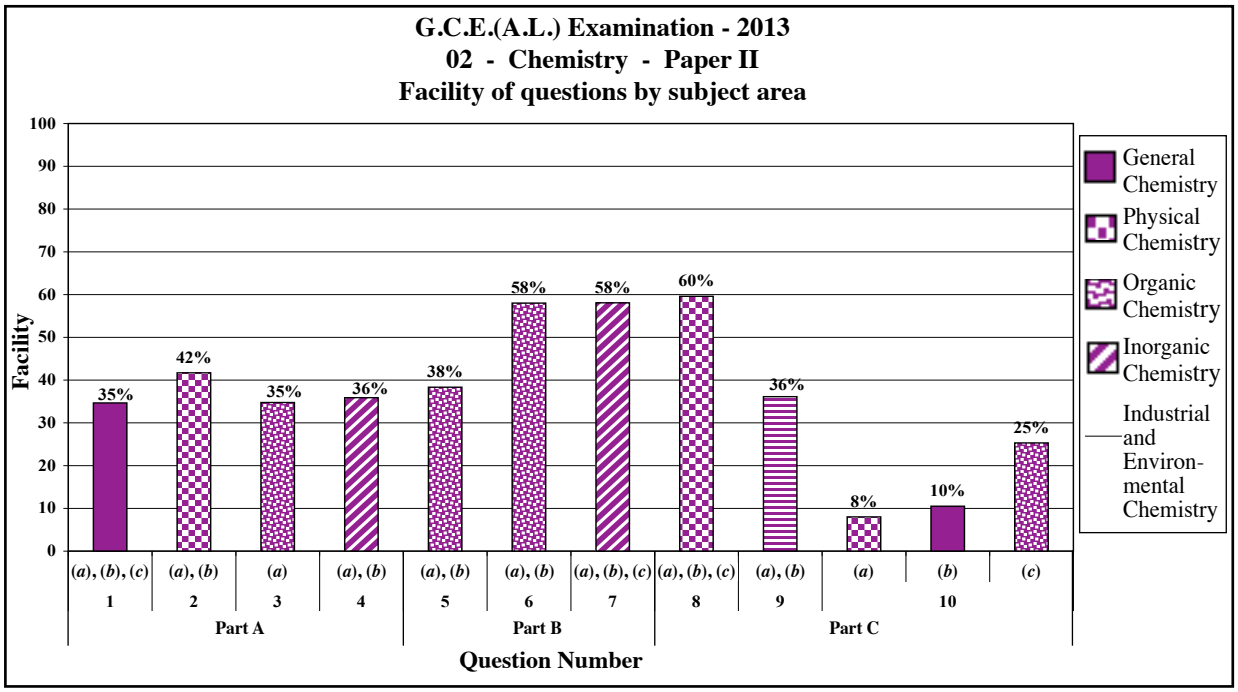
Of the students who opted to answer question 10, about 48% had scored 37 marks or less than that. The total facility of this question was 44%.

Sub part (*a*) subsumes questions in inorganic chemistry where (*a*)(i) records a minimum facility (18%) and (*a*)(iv) holds a maximum facility (59%). It was evident that the students lack a clear understanding about the oxidizing behaviour of hydrogen peroxide with lead sulphide and had little inclination to write simple equations and apply knowledge gained through exercises.

Sub part (*b*) is based on general chemistry and it too marks a low facility (21%). This kind of problems can be overcome through exercise of writing ionic equation and use of short but correct methods of simplification.

Sub part (*c*) is related to physical chemistry. Facilitywise, (*c*)(ii) was placed at the maximum (62%) whereas (c) (iii)(II) had slumped to the minimum (15%). This part had aimed to gauge the problem solving skills using the simple concepts of thermochemistry. But many had failed to achieve the expected level. At times it was seen that some have failed to understand what was meant by 'above process (ii)' in sub part c(iii). The apposite methodology is the formation of concepts related to Hess's law by way of practical experiments.

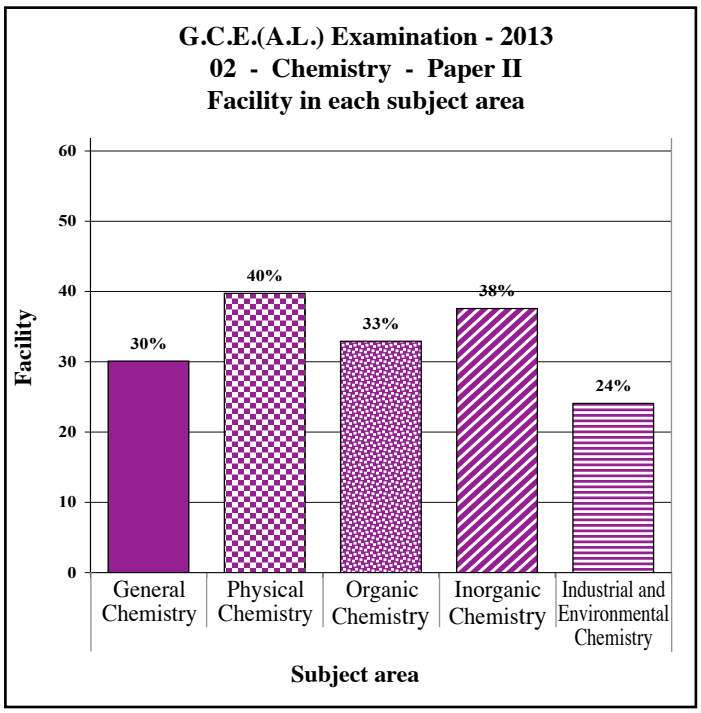
2.2.4 Overall observations, conclusions and suggestions regarding the answers to Paper II



Of the four compulsory structured questions, second question shows the highest facility. Of the essay questions in part B, and 7 show highest facility. Question 7 comes under organic chemistry. Though this was the question of minimum choice, those who opted for it recorded a facility of about 58%.

Of the essay question in part C, question 8 was the most facile. The most popular question in part C was 9 and its facility was 36%. The scoring for question 9 was not satisfactory. 53% of the students had scored 37 or less for question 9.

When the physical chemistry part of question 10 held the facility of 25%, the facility of general and inorganic parts were found to be 10% and 8% respectively. Though 62% had selected question 10, the percentage scoring 37 or less was 48%.



The facilities of the different subject areas in Paper II were as follows.

General Chemistry	30%
Inorganic Chemistry	40%
Physical Chemistry	33%
Organic Chemistry	38%
Industrial and Environmental Chemistry	24%

In Chemistry Paper II, the facility for industrial and environmental chemistry parts was 24%. This was the area showing minimum total facility in Paper II. The total facility of Paper II was about 35%.

Part III

3 Facts to be considered when answering questions and suggestions :

3.1. Facts to be considered when answering :

Common instructions :

* The candidates should read and understand well the basic instructions given in the question paper. They should be considerate as to the facts such as how many questions be answered in each section, which questions are compulsory, what time is affordable and how much marks are allocated. They should also read the questions carefully and select the questions with a clear mind set.

* When responding to the questions in Paper I, one option which is the most correct needs to be selected. Also, one cross must be placed clearly.

* When answering questions in Paper II, every new question should be started in a new page.

* Answers should be written in clear and correct handwriting.

* The candidates' index number should be written on every page in the relevant box.

* Numbers of questions, parts and sub parts should be indicated correctly.

* Long descriptions shouldn't be given when short specific answers are expected. Similarly short answers should be avoided in places where descriptive answers are preferred.

* According to the way the question is posed, facts should be presented logically and analytically.

* When answering Paper II, all the sub parts given under the main question should be read carefully and only the target answer relevant to each sub part should be presented.

* Care should be taken to manage time properly when answering questions.

* Candidates shouldn't use red and green pens to write answers.

* When the bell starts ringing indicating that the time set apart for writing is about to be over, all the answer scripts should be arranged and tied up properly.

* In order to manage time more effectively, it is better to answer the easier questions first and then more difficult ones rather than answering them in the given sequence.

Special instructions :

* In places where the chemical equations should be written, they should be balanced.

* In relevant occasions, correct units should be used.

* In chemical calculations, stoichiometric coefficients should be taken into consideration.

* When writing Lewis structures, lone pairs and charges should be indicated correctly.

* Correct methods must be followed when presenting organic reaction mechanisms.

3.2. Comments and suggestions about the teaching learning process :

* The questions based on practical activities generally are poorly answered. Thus the engagement of students in practical activities and related exercises is emphasized.

* Students' attention should also be drawn to the sections newly introduced to the syllabus. Students should be engaged in exercises to reinforce new subject areas such as quantization, entropy and Gibbs energy and relevant principles.

* Chemistry is a practical subject. Chemistry cannot be successfully learnt merely by cramming and memorising concepts. So, it is a must that the ability of solving problems using concepts learned be developed.

* In chemistry, practical activities and experiments are designed not only to develop the behavioural skills but also to develop the capacity of linking the practical observations and results with principles learnt in the classroom and arriving at conclusions. Therefore, both teachers and students should pay greater attention to the practical work.

* Attention should be paid to prepare short notes creatively and involve students in innovative exercises especially when teaching sections such as organic chemistry that are taught according to a systematic sequence.

* There is a need to develop in students the skill of indicating the electron movements by arrows when writing mechanisms in organic chemistry and the competence of deciding the mechanism relevant to a reaction in relation to the syllabus. Suitable strategies should also be adopted to enable them to apply the mechanisms to new situations.

* The units of the chemistry syllabus are mostly interconnected. Therefore, after studying a certain unit the students need to envision a concept of its wholeness in the form of a summary.

* It is of commonplace that students become unsuccessful due to weaknesses in mathematical simplifications though they have a correct understanding about the subject matter and concepts in chemistry. Therefore, a need has emerged to improve the mathematical knowledge of even the students with very good ordinary level results. The practice may involve mathematical operations, easy and short methods of simplification and the use of log tables.

* It is important to present the subject content by way of discussions rather than lectures during the learning teaching process. The students should be given a training on how subject matter can be applied in practice and used to solve problems related to similar situations.

* It is also appropriate to give a training on problem solving through analysis and synthesis of subject matter.

* Since the achievements in the last units of the syllabus is relatively low, much attention should be paid to them when covering the syllabus and also in the learning teaching process.