Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION 2013

CHEMISTRY

CHIEF EXAMINER’S REPORT

Contents

1. Introduction

1.1 Syllabus Structure

The current Leaving Certificate Chemistry syllabus was first examined in 2002. The syllabus consists of a core and options; the optional material is an expansion of some of the topics in the core. The syllabus material consists of approximately 70% pure chemistry and 30% applied chemistry. The syllabus also has a practical dimension with specified practical activities. A number of these activities are designated as *mandatory* experiments that the students must carry out during the two years of the programme. All material specified in the syllabus document is examinable.

The syllabus is differentiated into Ordinary level and Higher level in terms of range of material and depth of treatment. All Ordinary level material, with the exception of one mandatory experiment, forms part of the Higher level syllabus. At Ordinary level, students are expected to study one option from syllabus units designated 1A, 1B, 2A and 2B – the A options and the B options are examinable in alternate years (the B option featuring in 2013). At Higher level, students are expected to study, in its entirety, either Option 1 (i.e. 1A and 1B) or Option 2 (i.e. 2A and 2B).

Note: This report should be read in conjunction with the examination papers, the published marking schemes and the syllabus. The examination papers and marking schemes are available on the State Examination Commission's website www.examinations.ie and the syllabus is available at www.curriculumonline.ie.

1.2 Assessment Specification

At each level, the syllabus is assessed through a terminal written examination of three hours duration. The two examination papers have almost the same structure and rubrics. Both are divided into Section A, which assesses the mandatory practical work, and Section B, which assesses learning derived from theory as well as practical activities. Candidates in both cases are required to answer at least two of three questions in Section A and eight questions in total. There are 11 questions from which to choose, the last two questions carrying an internal choice where a candidate is required to attempt two of three parts. All questions carry equal marks (50) and the maximum mark that can be obtained is therefore 400.

At Higher level the topics examined in a number of questions are prescribed as follows: Question 1 is based on *volumetric analysis;* Question 2 is based on *practical Organic Chemistry*; Question 4 consists of eleven short questions from across the syllabus, of which eight must be answered correctly for full marks. At least one full question examines *atomic structure*, *trends in the periodic table* and *bonding* and another examines Section 5 of the syllabus. In addition, the examination paper must contain at least half a question on each of the two topics *rates of reaction* and *equilibrium*. Question 10 and Question 11 consist of three parts, any two of which must be answered correctly for full marks and the topics of the sub-parts of these two questions may be unrelated. It has been the practice for the last short question of Question 4 and the third part of Question 11 to examine the material specified in the Options section of the syllabus.

At Ordinary level, similarly, a question specification applies: Question 1 is based on *practical Organic Chemistry* and Question 2 is based on *volumetric analysis*. Question 4 consists of eleven short questions from across the syllabus, of which eight must be answered. There must be at least one full question that examines Sections 1 and 2 of the syllabus (*atomic structure*, *bonding*, etc) and another that examines Sections 5 and 7. As at Higher level, at Ordinary level Question 10 and Question 11 both consist of three parts, any two of which must be answered and the topics of the sub-parts of these two questions may be unrelated. It has been the practice for the last short question of Question 4 and the third part of Question 11 to examine the material specified in the Options section of the syllabus.

The close correspondence between the structures of the papers at the two levels facilitates mixed-level teaching. It also facilitates candidates unsure of which level they might take in remaining at Higher level for as long as possible.

1.3 Participation Trends

Table 1 gives the overall participation rates of candidates in Leaving Certificate Chemistry for the last five years. There has been a steady increase in the number of Leaving Certificate students taking Chemistry since the first examination of the current syllabus in 2002 and an increase in the percentage of the overall candidature taking Chemistry during that time. In 2012 there was a significant increase of 409 candidates with a further slight increase of 69 candidates in 2013. These increases are set against a decrease in the total Leaving Certificate cohort in 2012 compared to previous years.

Year	Chemistry candidature	Total Leaving Certificate candidature*	Chemistry as % of total
2009	7403	54196	13.7
2010	7548	54481	13.9
2011	7677	54341	14.1
2012	8086	52589	15.4
2013	8155	52767	15.5

*Total Leaving Certificate candidature excludes Leaving Certificate Applied candidates.

Table 1: participation in Leaving Certificate Chemistry, 2009 to 2012

The breakdown in terms of participation at Higher and Ordinary levels over the last five years is given in **Table 2**. The breakdown in terms of gender at Higher level and at Ordinary level over the last five years is given in **Table 3** and **Table 4** respectively.

Year	Total Chemistry candidature	Number at Ordinary level	Number at Higher level	% Ordinary level	% Higher level
2009	7403	1366	6037	18.5	81.5
2010	7548	1250	6298	16.6	83.4
2011	7677	1405	6272	18.3	81.7
2012	8086	1381	6705	17.1	82.9
2013	8155	1399	6756	17.2	82.8

Table 2: number and percentage of candidates at each level, 2009 to 2013

Year	Total Higher level	Female Candidates	Male Candidates	Female as % of total	Male as % of total
2009	6037	3423	2614	56.7	43.3
2010	6298	3610	2688	57.3	42.7
2011	6272	3529	2743	56.3	43.7
2012	6705	3672	3033	54.8	45.2
2013	6756	3658	3098	54.1	45.9

Table 3: gender composition of Higher level cohort, 2009 to 2013

Year	Total Ordinary level	Female Candidates	Male Candidates	Female as % of total	Male as % of total
2009	1366	693	673	50.7	49.3
2010	1250	638	612	51.0	49.0
2011	1405	713	692	50.7	49.3
2012	1381	672	709	48.7	51.3
2013	1399	670	729	47.9	52.1

Table 4: gender composition of Ordinary level cohort, 2009 to 2013

2. Performance of candidates

2.1 Higher Level Statistics

The distribution of grades awarded over the last five years is given in **Table 5** (lettered grades) and **Table 6** (sub-grades).

Year	A	B	C	A, B, C	D	E	F	NG	E, F, NG
2009	21.9	31.1	24.5	77.5	15.6	4.6	1.8	0.5	6.9
2010	20.8	29.4	25.2	75.3	16.7	5.3	2.2	0.6	8.0
2011	21.9	30.5	23.6	76.0	15.3	5.6	2.4	0.6	8.7
2012	19.9	28.5	23.9	72.3	18.5	5.9	2.5	0.6	8.9
2013	20.4	27.8	25.2	73.4	18.5	5.7	1.8	0.6	8.1

Table 5 Percentage of candidates awarded each lettered grade in Higher Level Chemistry, 2009 – 2013

Year	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
2009	12.5	9.4	10.4	10.8	10.0	8.4	8.1	8.0	4.5	4.9	6.2	4.6	1.8	0.5
2010	9.7	11.1	9.7	10.2	9.4	8.5	8.6	8.1	5.4	5.0	6.3	5.3	2.2	0.6
2011	11.4	10.5	10.5	10.9	9.1	7.9	8.3	7.4	4.8	4.5	6.1	5.6	2.4	0.6
2012	11.5	8.4	9.9	9.5	9.1	8.2	7.3	8.7	5.3	6.1	7.1	5.9	2.5	0.6
2013	9.4	11.0	8.2	9.7	9.9	8.4	7.9	8.9	6.3	5.6	6.6	5.7	1.8	0.6

Table 6 Percentage of candidates awarded each sub-grade in Higher Level Chemistry, 2009 – 2013

The distribution of sub-grades by gender over the last five years is given in **Table 7** (female candidates) and **Table 8** (male candidates).

Year	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
2009	12.0	9.9	10.7	11.1	10.5	8.4	8.2	8.3	4.4	4.6	5.7	4.1	1.6	0.4
2010	9.0	11.9	10.1	10.4	9.4	8.9	8.8	7.8	5.4	4.8	6.4	5.0	1.7	0.3
2011	11.0	10.9	11.1	11.4	9.2	8.4	8.6	6.9	4.6	4.1	5.6	5.5	2.2	0.5
2012	10.3	8.5	10.7	10.2	9.8	8.5	7.2	8.6	5.8	6.4	6.4	5.4	1.9	0.3
2013	8.7	10.7	7.9	9.8	10.1	8.6	8.4	9.7	6.6	5.7	6.5	5.3	1.7	0.4

Table 7: Percentage of female candidates awarded each sub-grade in Higher Level Chemistry, 2009 – 2013

Year	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
2009	13.1	8.8	9.9	10.4	9.3	8.3	8.0	7.6	4.7	5.2	6.9	5.4	2.0	0.5
2010	10.5	9.9	9.2	9.9	9.4	7.9	8.4	8.5	5.3	5.3	6.2	5.7	2.8	0.9
2011	11.9	10.0	9.8	10.2	9.0	7.1	7.9	8.1	5.0	4.9	6.7	5.8	2.6	0.9
2012	12.8	8.4	9.0	8.7	8.1	7.9	7.4	8.8	4.7	5.7	7.9	6.5	3.3	0.9
2013	10.3	11.3	8.4	9.6	9.8	8.2	7.3	8.0	5.9	5.6	6.6	6.2	1.9	0.8

Table 8: Percentage of male candidates awarded each sub-grade in Higher Level Chemistry, 2009 – 2013

These results show a marginally higher percentage of male candidates achieving the A grades than female candidates in the last two years. This change coincides with an increase in the cohort size in 2012 and 2013. Previously, the total female A grade percentages slightly exceeded the male, with the males consistently scoring slightly more A1s than the females. Male candidates were consistently awarded more grades in the E, F and NG range than females in this five year period.

2.2 Ordinary Level Statistics

The distribution of grades awarded over the last five years is given in **Table 9** (lettered grades) and **Table 10** (sub-grades).

Year	A	B	C	A, B, C	D	E	F	NG	E, F, NG
2009	9.2	25.5	28.4	63.1	21.5	8.7	5.6	1.0	15.4
2010	7.6	22.2	26.3	56.1	25.4	10.1	6.8	1.6	18.5
2011	9.0	27.3	28.3	64.6	22.6	6.8	4.8	1.2	12.8
2012	7.6	22.1	29.8	59.4	24.0	9.9	4.8	1.9	16.6
2013	7.1	21.4	29.7	58.2	23.6	10.3	6.0	1.9	18.2

Table 9: Percentage of candidates awarded each lettered grade in Ordinary Level Chemistry, 2009 – 2013

Year	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
2009	3.0	6.2	5.9	8.6	11.0	10.7	8.6	9.1	5.3	6.8	9.4	8.7	5.6	1.0
2010	2.2	5.4	4.9	8.6	8.7	9.1	9.1	8.1	7.9	7.7	9.8	10.1	6.8	1.6
2011	3.3	5.8	7.5	8.9	10.9	9.3	8.6	10.4	7.8	7.0	7.8	6.8	4.8	1.2
2012	2.0	5.6	4.9	8.2	9.0	10.4	10.0	9.3	7.9	7.4	8.7	9.9	4.8	1.9
2013	2.6	4.5	4.2	7.5	9.7	9.2	10.2	10.3	7.6	6.9	9.1	10.3	6.0	1.9

Table 10 Percentage of candidates awarded each sub-grade in Ordinary Level Chemistry, 2009 – 2013

The distribution of sub-grades by gender over the last five years is given in **Table 11** (female candidates) and **Table 12** (male candidates).

Year	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
2009	3.6	7.9	7.1	9.4	10.7	11.0	9.4	7.9	5.9	5.3	9.1	7.6	4.5	0.6
2010	3.6	7.7	6.6	10.8	8.6	8.6	11.1	7.4	6.1	7.4	8.8	8.5	4.5	0.3
2011	4.2	7.7	9.1	11.5	9.8	9.3	8.4	10.5	7.4	5.5	6.9	4.5	4.3	0.8
2012	3.0	7.4	6.7	9.1	9.8	11.0	9.7	7.7	6.5	7.1	8.8	8.3	3.3	1.5
2013	3.4	5.8	6.0	9.6	10.6	9.0	10.0	10.7	6.9	6.6	8.2	7.6	4.9	0.7

Table 11 Percentage of female candidates awarded each sub-grade in Ordinary Level Chemistry, 2009 – 2013

Year	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
2009	2.4	4.5	4.8	7.7	11.3	10.4	7.9	10.3	4.8	8.3	9.7	9.8	6.8	1.5
2010	0.8	2.9	3.1	6.4	8.8	9.6	7.0	8.8	9.8	8.0	10.8	11.8	9.2	2.9
2011	2.3	3.8	5.8	6.2	12.0	9.4	8.8	10.3	8.2	8.5	8.7	9.1	5.3	1.6
2012	1.1	3.8	3.2	7.3	8.2	9.9	10.3	10.9	9.2	7.6	8.6	11.4	6.2	2.3
2013	1.8	3.3	2.6	5.6	8.9	9.5	10.4	9.9	8.2	7.3	9.9	12.8	7.0	2.9

Table 12 Percentage of male candidates awarded each sub-grade in Ordinary Level Chemistry, 2009 – 2013

These results show that female candidates at Ordinary level have consistently outperformed their male counterparts over the last five years. In 2013, the female ABC rate was 65.1% compared to the male ABC rate of 52.0% while the female EF & NG rate was 13.2 % compared to the male rate of 22.7%. In 2013 the female D rate was 21.7% while the male D rate was 25.4%.

3. Analysis of Candidate Performance

3.1 Question popularity & scoring

Higher Level

Table 13 is a summary based on an analysis of a random selection of 460 scripts (approximately 7% of all scripts).

Question	Popularity (% attempts)	Rank order in popularity	Average mark, out of 50 (and as %)	Rank order in average mark	Topic
1	86.3	3	33.8 (67.6)	6	Volumetric Analysis (O_2)
2	70.4	5	28.4 (56.7)	11	Organic Practical - General
3	65.6	9	28.9 (57.7)	10	Heat of Reaction
4	88.0	2	34.5 (68.9)	4	Miscellaneous
5	70.0	6, 7	33.1 (66.3)	7	Atom
6	88.9	1	35.3 (70.7)	2	Organic Chemistry
7	50.9	11	31.4 (62.8)	9	Rates of Reaction
8	55.2	10	32.6 (65.2)	8	Organic Chemistry
9	70.0	6, 7	35.4 (70.8)	1	Equilibrium
10	68.7	8	33.9 (67.7)	5	(a) Bonding (b) Redox/Stoichiometry (c) Radioactivity
11	83.0	4	34.6 (69.3)	3	(a) First Ionisation Energy (b) Bases / pH (c) **A** Electrochemistry **B** Industrial Chemistry

Table 13: popularity of and average mark for each question, Higher Level Chemistry

The average mark per question was 32.9 (with a standard deviation of 2.4). The small standard deviation indicates that average scoring was consistent across the questions. The best answered question was Question 9 – traditionally not popular and usually less well-answered.

Question 1, Question 4, Question 6 and Question 11 were answered by more than 80% of candidates in the sample, although the last of the three parts of Question 11 (of which two were to be answered) was very rarely attempted. Even the least popular questions, Question 7 and Question 8, were attempted by more than half of the candidates. These figures are indicative of good course coverage of topics in schools.

Questions 11A(c)A and 11(c)B on the material designated Option 1 (Industrial & Atmospheric Chemistry) and Option 2 (Materials & Electrochemistry) in the syllabus were very unpopular, with Option 2 the less popular of the two.

Ordinary Level

Table 12 is a summary based on an analysis of a random selection of 80 scripts (approximately 6% of all scripts).

Question	Popularity (% attempts)	Rank order in popularity	Average mark, out of 50 (and as %)	Rank order in average mark	Topic
1	80.0	6	29.5 (59.0)	3	Soap Preparation
2	90.0	3	30.2 (60.4)	2	Volumetric Analysis
3	70.0	7	25.6 (51.2)	7	Mandatory Experiments 1.1, 1.2 and 2.1
4	93.8	2	26.3 (52.6)	5, 6	Miscellaneous
5	81.3	5	21.1 (42.2)	11	Atom
6	68.8	8, 9	25.4 (50.8)	8	Organic Chemistry
7	68.8	8, 9	23.2 (46.4)	9	Acid-Base Theory/Water Analysis
8	45.0	11	28.4 (56.8)	4	Organic Chemistry
9	82.5	4	26.3 (52.6)	5, 6	Rates of Reaction
10	65.0	10	22.5 (45.0)	10	(a) Electronegativity (b) Stoichiometry (c) Chromatography
11	97.5	1	31.2 (62.4)	1	(a) Atomic Structure (b) Purification of Water (c) **A** Atmospheric Chemistry **B** Materials

Table 14: popularity of and average mark for each question, Ordinary Level Chemistry

The average mark per question was 26.3 (with a standard deviation of 3.0). The relatively small standard deviation indicates that average scoring was consistent across the questions. Question 11 was the best answered and most popular question. Some candidates answered surplus questions. However, 22.5% of candidates did not attempt the required 8 questions.

Question 1, Question 2, Question 4, Question 5, Question 9 and Question 11 were all attempted by 80% or more of the candidates in the sample. The least popular question, Question 8, was still attempted by 45% of the candidates. These figures indicate good course coverage of topics in schools.

Questions 11A(c) A and 11(c)B on the material designated Option 1B (Atmospheric Chemistry) and Option 2B (Electrochemistry) in the syllabus were very unpopular, with Option 2 the less popular of the two.

3.2 Attainment of Key Syllabus Objectives, Engagement and Performance

The 2013 candidates' engagement with and attainment of the *key syllabus objectives*, namely, (i) knowledge, (ii) understanding, (iii) skills, (iv) competence and (v) attitudes, were considered in terms of some of their responses to items on the Higher Level and Ordinary Level examination papers. Responses were also analysed in terms of candidate achievement in respect of *different levels in the cognitive domain*: (i) knowledge, understanding, (ii) application and analysis and (iii) synthesis and evaluation. To avoid repetition, these analyses are combined below with the phrases in bold referring to specific syllabus objectives. Some observations on common errors or types of poor response are included. The comments should be considered in conjunction with the syllabus document, the examination papers and the published marking schemes.

Higher Level

Knowledge and Understanding

Some questions required recall of **facts** or **basic chemical terminology** in short responses, e.g. Question 1(e) (*Name the indicator used in the titration.*), Question 5(b) (*What colour is observed in a flame test on lithium chloride?*). Most candidates answered these items correctly. A common incorrect answer for the indicator was 'eriochrome black T', and 'green' was frequently given as an incorrect flame colour.

Other questions, required the learner to demonstrate his or her broader and deeper **knowledge of chemical principles** and **theories**, and necessitated greater attention to detail and accuracy of recall for full marks, e.g. Question 4(b) (*Define relative atomic mass.*), Question 4(h) (*State*

Charles' law.). In their answers, a number of candidates omitted the word 'average' from their definitions of relative atomic mass and neglected to refer to a fixed mass of gas or the kelvin (absolute) temperature scale when stating Charles' law.

Candidates were required to show **knowledge of historical**, **economic**, **environmental** and **social aspects** of Chemistry in a number of questions including 5(a), 10(c)B, 4(i) and 10(c). In general, social and applied issues of Chemistry are well integrated into teaching and learning practices and candidates responded as well to examination questions on the social and applied aspects of a topic as they did to the topic as a whole. **Advances in Chemistry** and **understanding of the application of scientific method** were explored throughout Question 5. The average mark in this question exceeded 66%, indicating reasonably good engagement and attainment with this syllabus objective.

Several question parts assessed the learner's ability to **understand** syllabus material. Candidates were required to restate concepts or **principles** in their own words, e.g. Question 5(b) (*Use Bohr's atomic theory of 1913 to account for the emission spectrum of hydrogen.*) and Question 8(c) (*Describe the mechanism of reaction **W***.). Examiners reported that Question 5(b) was moderately well answered but very few candidates provided enough detail in their answers to show a sufficiently thorough understanding of the topic to be awarded full marks. Examiners recorded that the mechanism in Question 8(c) was not well answered; some candidates referred incorrectly to free radicals and others confused partial charges and full charges.

Application and Analysis

Candidates were required to **apply laws** and **principles** to answer Q4 (a) (*Write the electron configuration (s, p, etc) of a zinc atom in its ground state.*) and Question 4(d) (*Give the shape and corresponding bond angle for a molecule of formula* $\mathbf{QX_4}$ *where* **Q** *is an element from Group 4 of the periodic table.*). While many candidates showed that they were able to apply the rules for assigning low energy electrons to subshells, some were unable to assign the ten highest energy electrons of zinc correctly. Many candidates who were able to correctly analyse $\mathbf{QX_4}$ for shape, were unable to deduce the correct bond angle.

Questions 1(f), 3(e), 6(c), 9(c), 10(b)(ii) and 11(b), worth between 12 and 18 marks, required candidates to **translate verbal information into mathematical form** and vice versa. Candidates were required to recognise a problem, interpret information, apply mathematical analysis, rules or a formula, **perform** a sequence of **chemical calculations** to arrive at a solution and manipulate units. Questions 4(c), 4(e), and 10(c)(iv) were shorter mathematical analyses worth 6 marks each. The quality of answering varied from calculation to calculation.

The volumetric analysis in Question 1(f) was competently performed by many candidates. However, many used an incorrect ratio (1:4) in their calculations and therefore omitted to calculate the required molarity of iodine. Incorrect multiplying of interim answers by five, use of 16 as the relative atomic mass of oxygen (O_2) and multiplying by 100 instead of 1000 or division by 1000 to get ppm were errors that were regularly observed by the examiners. Question 3(e) contained the most challenging calculation but the calculation in Question 6(e), based on the same section of the syllabus, was excellently answered despite the fact that five heats of reaction had to be manipulated instead of the usual four. Candidates who used an approach based on a summation of heats of reaction made more errors than those who used a cancellation approach. Question 9(c) was well answered, although some candidates were unable to manipulate the equilibrium quantities given (for the first time this year) in scientific notation. Weaker candidates struggled with the molar ratios in Question 10(b)(ii). In Question 11(b), requiring the calculation of the pH of a weak base, the answering standard varied from very poor to perfect. Question 10(c)(iv) was poorly answered indicating that, while many candidates had a good qualitative understanding of radioactivity, few were able to perform a basic calculation related to half-lives.

Interpretation of the graph of first ionisation energies in Q11(a) required the ability to **analyse critically** the complex relationships between atomic radius, nuclear charge, screening effect of electrons in inner shells, number of shells and stable electron configurations and recognising patterns to be able to **translate scientific information in verbal, graphical and mathematical form.** Questions on this topic are traditionally not well answered. As in other years, many candidates used the terms shell, sub-level and orbital incorrectly. Nonetheless in 2013, Question 11(a) was both popular and reasonably well answered.

Organisation of ideas and differentiation competencies were required in Question 6(d) and in all parts of Question 10(a). In Question 6(d), the descriptions of the bonding between the carbon atoms and the hydrogen atoms in benzene were reasonably good, but the descriptions of the bonding between the carbon atoms of benzene were poor. The average quality of the work presented for Question 10(a) was not good. Although some candidates wrote a lot, their responses were confused, showing familiarity with the intramolecular bonding and intermolecular forces but lacking thorough differentiation of ideas and demonstrating an inability to draw the correct conclusions. For example, many answers to the question requiring an explanation for the difference in the boiling points of hydrogen and oxygen referred to the single bond in hydrogen and the double bond in oxygen but did not develop any argument from that statement.

Synthesis and Evaluation

Question 1(h) (*Kits, designed for use in the field, allow the dissolved oxygen concentration to be measured immediately on collection of the sample. Why is the immediate determination of dissolved oxygen considered best practice?*) required **critical assessment** based on prior knowledge. This question, based on a scenario candidates were unlikely to have previously considered, tested candidates' ability to **explain an unfamiliar**, to **understand how chemistry is used to solve problems in society** and **how chemistry relates to everyday life**. Good answering required generalisation to a context new to the candidates. This is a challenging skill and many answers were unsatisfactory. This type of question serves as a discriminator of achievement in the higher order cognitive skills.

In Question 2(e) the abilities of the candidates to evaluate and synthesise were tested. Candidates were required to identify, in a diagram, a flaw in a set-up of a steam distillation apparatus and state how it could have been rectified. While many candidates engaged well with this question and often went to the trouble of drawing their proposed alternative assembly of apparatus, few candidates identified the serious *safety* flaw in the arrangement and few provided the intended answer of lowering the safety tube under the level of water in the steam generator, concentrating instead on modifications that would improve *rate* or *yield*. Many suggested the inclusion of a steam trap in the assembly or a modification involving the use of wire gauze with the Bunsen burner. These responses were deemed to be acceptable solutions as they showed candidate evaluation of the faulty set-up and synthesis of alternative arrangements that would improve the rate of collection or yield of product.

Construction of balanced chemical equations is a test of synthetic skill and of **application of laws**. Questions 4(f), 4(k)A and 4(k)B and 11(c)A(iv) all provided opportunities for candidates to display their levels of engagement and attainment in this key skill. In particular, Question 4(f) involved a chemical reaction from the core part of the syllabus and was poorly answered as were the other question parts (referring to the less popular Option parts of the syllabus).

In Question 9(d) (effect of changing temperature on K_c) candidates were required to appraise information and justify their conclusions. Some were able to **critically analyse** the information provided and reach the correct conclusion but were unable to satisfactorily justify their decision.

Question 6(b)(iii) (***Predict*** *whether A or B has the higher octane number. Justify your answer*.) is an example of a question requiring candidates to apply judgement based on prior knowledge and offer a defence of a selection. It was well answered.

Skills

The ability of candidates to **perform experiments safely and co-operatively, select and manipulate suitable apparatus and make accurate observations and measurements** as required by the syllabus cannot be determined in a written paper. Section A of the examination paper provides candidates with an opportunity to demonstrate their familiarity with using chemicals and handling laboratory apparatus, but it cannot distinguish between knowledge and understanding of practical work in chemistry gained through laboratory experience and that acquired from textbooks, video, etc. Candidates were also questioned about observations made when carrying out experiments, e.g. Question 1(c) (*What was observed on addition of the concentrated sulphuric acid followed by mixing of the contents of the bottle?*), problems associated with conducting an experiment, e.g. Question 1(a) (*Why was it important to avoid trapping air bubbles each time the stopper was inserted into the sample bottle and when using the dropper?*), precautions taken to reduce errors, Question 3(d) (*State **two** ways of ensuring that the rise in temperature was measured as accurately as possible.*) and **perform experiments safely** e.g. Question 2(e) (*The diagram shows a steam distillation apparatus assembled incorrectly by one of the students. Identify the flaw in the assembly and state how it should have been rectified*.). Few candidates identified the serious safety flaw in the arrangement, but many suggested other modifications as described earlier.

While such questions cannot guarantee the completion of experimental work in class, they clearly reward candidates who have carried out such work and engaged with the mandatory experiments on the syllabus.

Section A does test engagement with and attainment of the key syllabus objectives of **interpretation of experimental data** and **assessment of the accuracy of experimental results**. In Questions 1(f) and 3(e), candidates were required to interpret experimental results, apply rules or formulae not provided to the data supplied, perform calculations, manipulate units, and so on. As described earlier, the volumetric analysis in Question 1(f) was competently performed by many candidates and the thermochemical analysis in Question 3(e) was more challenging for many candidates. In Question 2(d) candidates were required to assess the accuracy of experimental results. In Questions 1(d) and 2(c) candidates were required to **report experimental procedures in a concise, accurate and comprehensible way**.

Ordinary Level

Knowledge and Understanding

A number of questions in the 2013 Ordinary level paper required simple recognition and recall of previously learned **facts**, **principles** and **chemical terminology** in the form of short answers, (‘name’, ‘what term’, etc), e.g. Question 2 (c) (*Name the type of flask labelled **B** in the diagram.*), Question 4(j) (*When a drop of soluble blue ink was added to water in a beaker, the ink spread out until the water was uniformly coloured. What term is used for the spreading out of the ink?*), Question 6 (a) (*Name two major sources of hydrocarbons.*), Question 9(c) (*Name two catalysts found in the catalytic converter of a car.*). These included questions that nearly all Ordinary level candidates could reasonably be expected to answer well, along with some more discriminating questions on less well known facts. In answering Question 2(c) most candidates identified **B** correctly as a volumetric flask. Question 4(j) about diffusion was poorly answered. Few candidates correctly named two sources of hydrocarbons in Question 6(a) or two catalytic converter catalysts required by Question 9(c).

Other questions requiring the learners to demonstrate their ability to memorise information were more demanding, necessitating longer answers with greater detail for full marks, e.g. Question 4(c) (*What is an endothermic reaction?*), Question 7(a) (*Define (i) acid, (ii) base, according to the theory of Arrhenius.*) and Question 11(a) (*Define electronegativity*.). Those candidates who had memorised and were able to show **knowledge of theory**, definitions and laws were rewarded. While most candidates gave Brønsted-Lowry definitions instead of the requested Arrhenius definitions for acid and base in Question 7, these answers were accepted. Most candidates were awarded only partial marks for partially correct definitions of electronegativity. Candidates answered Question 4(c) well.

Questions related to **social** (5(c), 6, 11(b), 11(c)A and 11(c)B), **historical** (5(b), 7(a), 11(a)), **technological** (9(e), 10(c)), **environmental** (9(e), 11(c)A) and **economic** (6, 11(b), 11(c)B) **aspects of chemistry** gave candidates opportunities to demonstrate a range of learning across different units of the syllabus. Candidates were observed to have had a better knowledge of social aspects than historical facts about chemistry.

There are several examples to illustrate where question parts assessed **comprehension** of **basic chemical principles** and **methods** and ability to **report experimental procedures**, by asking for explanations or restatements of concepts in candidates' own words, e.g. Questions 1(e) (*What is brine? How was the precipitate of soap removed from the brine?*), 2 (d) (*How would you have ensured that all of the solution in the beaker was transferred to flask **B**?*), 9(e) (*Give **one** way in which the use of a catalytic converter benefits the environment.*) and 10(a) (*Explain why electronegativity values (i) increase across a period (ii) decrease down a group, in the periodic table.)* Examiners reported that in Question 1(e) few candidates knew what brine is and most were unable to give a correct way of removing it from the soap, many showing their lack of **understanding** by suggesting distillation as the method. Most candidates were able to describe one way of ensuring that all of the solution in the beaker was transferred to flask **B** but many answers were awarded only partial marks because they lacked detailed description. In Question 9(e) most candidates gave acceptable answers. Nearly all candidates struggled to explain the trends in electronegativity. This is a difficult abstract concept at Ordinary level. However, in Question 10(c) (iii), candidates were able to describe a chromatography experiment and were able to do so acceptably. Candidates continue to perform poorly whenever descriptive writing is required in terms of answers lacking clear expression or being too brief or inaccurate. In particular, candidates performed especially poorly in Question 10(a) where an explanation related to an abstract concept was required.

Understanding of **how chemistry relates to everyday life** and the candidates' ability **to discuss public issues relating to chemistry** and **advances in chemistry** and **their influence on our lives** was examined in Questions 11(b), 11(c) and 11(c)B(iv) (*Mention two common methods used to protect metals from corrosion*.) Question 11(b) (*re purification of water for drinking*) was very well answered, while answers to Question 11(c) typically lacked coherent argument and Question 11(c)B(iv) was rarely attempted.

Application and Analysis

Questions 4(a), 4(g), 5(d), 6b(ii) and 10(a) required candidates to extract scientific information from text, interpret data and/or apply rules or demonstrate their **competence in organising chemical ideas and statements**. All except Question 10(a) were reasonably well answered. For example, Question 5(d), (*Draw a diagram showing the arrangement of electrons in an atom of carbon–14. Use dots (•) or crosses (×) to represent the electrons.*), required analysis to determine the number of electrons involved and application of rules to produce the correct drawing. Many candidates showed some knowledge of the rules for filling electrons into atoms although some applied the rules to 14 electrons instead of 6, showing confusion about interpretation of the term ‘carbon-14’. Question 10(a), (*Use electronegativity values (formulae and tables booklet, page 81) to predict the bonding – ionic, covalent or polar – in the following substances: hydrogen chloride (HCl), sodium chloride (NaCl) and hydrogen (H_2).*), involved simple data handling, but candidates’ answers were observed to be poor.

Questions 2(f) and 7(c), were **calculations** worth 12 marks each and Question 10(b) consisted of stoichiometric calculations worth 25 marks. In each case, candidates were required to recognise the problem, apply rules or formulae (not provided) to the data supplied, **solve the problem**, manipulate units, etc. The quality of answering varied from calculation to calculation, indicating that the attainment of the relevant chemical problem solving learning objectives is uneven. Candidates managed the volumetric analysis calculation quite well, probably as a result of practice and revision, based on the fact that volumetric analysis is the prescribed topic of Question 2 and that such calculations have been a regular feature of this question in the past. Few, however, were able to proceed from the first answer in moles per litre to give their second answer in terms of grams per litre. Despite the fact that Question 7(c) only required analysis of quantities and scaling to convert units, most candidates were unable to manipulate the data provided. Most candidates were unable to cope with the stoichiometric calculations in Question 10(b), indicating that candidates have difficulty in engaging with information presented in the form of balanced equations that are perceived as difficult.

Synthesis and Evaluation

In Question 1(f), (*Why was it necessary to wash the soap before it was used? Why should warm water not have been used to wash it?*), the second part required critical assessment based on prior knowledge to a context new to the candidates. Examiners reported that candidates gave a plausible explanation displaying an understanding of the need to remove impurities by washing, even though few mentioned NaOH as the impurity. Candidates attempted to justify the use of hot water for the washing, so while the engagement of such candidates was good, their performance was less so.

Questions 9(d) and 11(c)B tested the ability of the candidates to evaluate. In both cases candidates were required to predict a result based on certain criteria and give a reason for their prediction. In Question 9(d), most correctly predicted the results but few could offer a coherent reason for their selection. Question 11(c)B was rarely attempted and poorly answered.

Finally, Question 5 (a), (*You will notice, from the values given on page 79 of the formulae and tables booklet, that the relative atomic mass of an element is rarely a whole number. Give a reason for this.*), was a relatively difficult question where evaluation skills were required and most candidates were unable to answer it.

Construction of an equilibrium constant expression is a test of synthetic skill. Question 4(i) was such a question and was reasonably well answered by those who attempted it. Synthesis by modification of component parts was a skill required by those attempting Question 4(b). It was poorly answered. Synthesis was again required to answer Question 8(b) and, once again, candidates struggled. Many obtained only attempt marks for drawing ethene.

Skills

As is the case at Higher Level, the ability of candidates to **perform experiments safely and co-operatively, select and manipulate suitable apparatus and make accurate observations and measurements** as required by the syllabus cannot be determined in the written examination paper at Ordinary Level. Section A of the examination paper again attempts to provide candidates with an opportunity to demonstrate their familiarity with using chemicals and handling laboratory apparatus and to recall observations, but it cannot distinguish between knowledge and understanding of practical work in chemistry gained through laboratory experience and that acquired from textbooks, video, etc. Question 3(a), (*In the case of each salt, state the colour you would expect it to give to a Bunsen flame.*), questioned candidates about observations made when carrying out experiments. Question 3(d) (*How would you have ensured that all of the solution in the beaker was transferred to flask **B**?*) required candidate knowledge of procedure and precautions taken to reduce errors, and Question 2(e) (*What material could have been added to the flask to ensure smooth boiling?*), required knowledge about how to **perform experiments safely**. Most candidates were able to recall some flame colours and were able to attempt Question 3(d) about transferring the solution to flask **B**. Most candidates were familiar with the use of anti-bumping material.

Again at Ordinary Level, such questions cannot guarantee the completion of experimental work in class. However, they clearly reward candidates who have carried out such work and engaged with the mandatory experiments on the syllabus. Furthermore, at this level too the examination tests the extent of engagement with and attainment of the key syllabus objectives of **interpretation of experimental data** and **assessment of the accuracy of experimental results.** In Question 2(f) and again in Question 7(c), candidates were required to interpret experimental results, apply rules or formulae (not provided) to the data supplied, perform calculations, manipulate units, etc. The volumetric analysis in Question 2(f) was competently performed by many candidates but the water analysis in Question 7(c) was more challenging for many candidates and very few were able to describe it correctly. In Question 2(d), candidates were required to assess the accuracy of experimental results. In Questions 2(e) and 10(c)(iii), candidates were required to **report experimental procedures in a concise, accurate and comprehensible way**. Most candidates were awarded full marks for both of these apparently well known procedures.

4. Conclusions

Candidates at both Higher and Ordinary levels were tested across the range of cognitive skills and in reporting of experimental procedures and interpretation of experimental data as described above. At both Higher and Ordinary levels, only those who had demonstrated good engagement and attainment across the range of skills were awarded high grades.

Higher Level

Good appreciation of knowledge and understanding of basic chemical facts and concepts was demonstrated by most candidates. Most candidates were able to attempt the calculations and other numerical analyses but some candidate work indicated insufficient practice. Fewer candidates were awarded marks where generalisation or applying learned material in new situations was required.

Many candidates whose work was of a reasonable standard in some respects, nonetheless displayed a lack of appreciation of the precision of language expected in answering. Some candidates' answers, such as statements of definitions and laws, lacked detail or accuracy.

Organic chemistry constitutes a significant part of the syllabus and this fact is reflected in the quantity of Organic chemistry featured in the examination paper. Organic chemistry questions were popular and well answered suggesting good candidate knowledge and understanding of the component parts and their relationships and a good mastery of this chemistry subdiscipline, involving organisation of ideas, seeing patterns in structures, properties, reactions and uses of organic chemicals. However, Organic chemistry mechanisms, while frequently examined, remain poorly answered (Question 8).

About two-thirds of candidates attempted at least one surplus question. This suggests good course coverage in school and in study. It also suggests that time does not represent an issue in completing the examination.

In general, candidates followed instructions correctly and presented their work in a satisfactory manner.

Ordinary Level

Many candidates whose work was of a reasonable standard in some respects, nonetheless, displayed a lack of knowledge of basic chemical information, such as definitions. Since learning such information is straightforward in comparison to some of the other skills they displayed, this suggests that they placed insufficient emphasis on it.

Analysis demonstrated by candidates in text-based responses ranged from good to poor but the average performance in applications involving calculations or handling numerical data was weaker. Routine calculations were not as well executed as might be expected, suggesting a lack of practice.

The absence of a kinetics graph had an impact – its inclusion leads to the corresponding question being popular and high scoring. Candidates may therefore be over-reliant on an expectation of its inclusion.

Organic chemistry constitutes a significant part of the syllabus and this fact is reflected in the quantity of Organic chemistry featured in the examination papers. However, this topic, while popular and well answered at Higher Level, presents a greater challenge to Ordinary Level candidates. This suggests insufficient recognition of the importance of this subject area and the need for organisation of its component parts, recognising relationships and patterns, by the candidates in preparation for the examination.

In general, most candidates followed instructions correctly. However, a significant percentage of the cohort did not attempt the minimum number of questions.

5. Recommendations to Teachers and Students

The comments below refer to both levels unless otherwise specified, although the depth of detail and understanding required of candidates at Ordinary level is obviously less than that expected at Higher level.

5.1 Preparing for the examination

While students should learn and be able to recall key facts, laws and definitions accurately, understanding is essential to being able to engage fully with most questions.

Study time should be devoted to the key syllabus topics that underpin the subject, namely, atomic structure (at Higher level paying particular attention to the distinction between shell, sublevel and orbital), the structure and trends in the periodic table and bonding. Focusing on links between key facts in teaching and in study will help organise knowledge and enhance understanding. Students should practise writing explanations of complex concepts in their own words.

Carry out all of the mandatory practical work and other practical activities specified in the syllabus. When revising for Section A, students should give consideration to the *reasons* for experimental procedures in addition to memorising the reagents, apparatus and methods.

Students should learn how to correctly round off decimals in a calculation.

Organic chemistry constitutes a significant element of the syllabus and of the examination. An appropriate amount of class-time and study-time should therefore be devoted to it. At Higher level, organic reaction mechanisms continue to be poorly answered and therefore additional focus on mechanisms in class and in study is warranted.

Make appropriate use of past examination questions as a guide to question style and scope.

- A review of past examination papers will show that certain facts and statements of laws and definitions feature frequently because of their fundamental importance in Chemistry.
- Past examination questions show the scope of questions that can be posed on a particular topic and can be used to encourage thorough revision.
- As stated in Section 1.2, the theme of several questions on the examination paper is prescribed. However, the exact topic, emphasis or style of the component parts of any question is not predictable. Students should expect some material to be examined in a novel way every year and should study all sections of the syllabus and be prepared to answer any style of question on a given topic.

- Past examination papers can be used to practice problem solving questions.
- Past examination papers can be used to practice the time management skills required to do well in an examination.

Marking schemes may be used to inform teachers and learners of solutions to problems and the main points of answers to previous examination questions. However, the notes to teachers and students accompanying the published marking schemes about their use should be carefully taken into consideration.

5.2 In the examination

Candidate understanding of chemistry should be expressed using clear, concise and correct language. Some answering in examinations has insufficient detail.

- At Higher Level, candidates need to elaborate sufficiently to include essential details in their answering in order to achieve full marks. Questions containing the cues 'Describe' or 'Explain' generally require an answer in the form of a sentence or sentences. Answers in the form of a phrase or a word are rarely sufficient for full marks in such questions.

- At Ordinary Level, answers frequently consisted of phrases where fully expressed statements were required and single words were often given where phrases would have been more appropriate.

Incorrect terminology, such as the use of 'clear' instead of 'colourless', 'lower meniscus' instead of 'bottom of the meniscus' will cause the loss of marks.

Avoid abbreviations - other than standard grammatical abbreviations or, in calculations only, the standard abbreviations used in the Formulae and Tables booklet.

It is recommended that candidates write in black or blue.

Where diagrams are required, large, clear, labelled diagrams should be included. Pencil is recommended for drawing diagrams and graphs.

Other diagrams may be and should be used to help a candidate describe concepts but a diagram alone is rarely sufficient for full marks when the question requires a description or an explanation.

Candidates should label their answers to correspond with the question and present their work clearly in terms of legibility and layout.

Candidates are cautioned against attempting surplus questions at the expense of spending sufficient time on the questions that they anticipate will contribute to their final mark.

Ordinary level candidates in particular are encouraged to try to engage as fully as possible with the examination paper as follows:

- use the full three-hour examination time
- attempt at least 8 questions
- understand that there is no negative marking and any attempts to answer parts of questions may earn marks and that partial marks are frequently awarded for partially correct answers
- try to add (an)other detail(s) to the first response given to parts of questions where the question cue is ‘explain’ or ‘describe’
- spend time working on diagrams
- spend time on calculations – marks are awarded for attempts that show partial knowledge or understanding and for work that is *part* of the solution.