Chemistry

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Preface

Subject benchmark statements provide a means for the academic community to describe the nature and characteristics of programmes in a specific subject or subject area. They also represent general expectations about standards for the award of qualifications at a given level in terms of the attributes and capabilities that those possessing qualifications should have demonstrated.

This subject benchmark statement, together with others published concurrently, refers to the **bachelor's degree with honours**[1]. In addition, some subject benchmark statements provide guidance on integrated master's awards.

Subject benchmark statements are used for a variety of purposes. Primarily, they are an important external source of reference for higher education institutions (HEIs) when new programmes are being designed and developed in a subject area. They provide general guidance for articulating the learning outcomes associated with the programme but are not a specification of a detailed curriculum in the subject.

Subject benchmark statements also provide support to HEIs in pursuit of internal quality assurance. They enable the learning outcomes specified for a particular programme to be reviewed and evaluated against agreed general expectations about standards. Subject benchmark statements allow for flexibility and innovation in programme design and can stimulate academic discussion and debate upon the content of new and existing programmes within an agreed overall framework. Their use in supporting programme design, delivery and review within HEIs is supportive of moves towards an emphasis on institutional responsibility for standards and quality.

Subject benchmark statements may also be of interest to prospective students and employers, seeking information about the nature and standards of awards in a given subject or subject area.

The relationship between the standards set out in this document and those produced by professional, statutory or regulatory bodies for individual disciplines will be a matter for individual HEIs to consider in detail.

This subject benchmark statement represents a revised version of the original published in 2000. The review process was overseen by the Quality Assurance Agency for Higher Education (QAA) as part of a periodic review of all subject benchmark statements published in this year. The review and subsequent revision of the subject benchmark statement was undertaken by a group of subject specialists drawn from and acting on behalf of the subject community. The revised subject benchmark statement went through a full consultation with the wider academic community and stakeholder groups.

QAA publishes and distributes this subject benchmark statement and other subject benchmark statements developed by similar subject-specific groups.

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[1] This is equivalent to the honours degree in the Scottish Credit and Qualifications Framework (level 10) and in the Credit and Qualifications Framework for Wales (level 6).

The Disability Equality Duty (DED) came into force on 4 December 2006[2]. The DED requires public authorities, including HEIs, to act proactively on disability equality issues. The Duty complements the individual rights focus of the *Disability Discrimination Act* (DDA) and is aimed at improving public services and outcomes for disabled people as a whole. Responsibility for making sure that such duty is met lies with HEIs.

The Disability Rights Commission (DRC) has published guidance[3] to help HEIs prepare for the implementation of the Duty and provided illustrative examples on how to take the duty forward. HEIs are encouraged to read this guidance when considering their approach to engaging with components of the Academic Infrastructure[4], of which subject benchmark statements are a part.

Additional information that may assist HEIs when engaging with subject benchmark statements can be found in the DRC revised *Code of Practice: Post-16 Education*[5], and also through the Equality Challenge Unit[6] which is established to promote equality and diversity in higher education.

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[2] In England, Scotland and Wales

[3] Copies of the guidance *Further and higher education institutions and the Disability Equality Duty*, guidance for principals, vice-chancellors, governing boards and senior managers working in further education colleges and HEIs in England, Scotland and Wales, may be obtained from the DRC at www.drc-gb.org/employers_and_service_provider/disability_equality_duty/sectoral_guidance/further_and_higher_education.aspx

[4] An explanation of the Academic Infrastructure, and the roles of subject benchmark statements within it, is available at www.qaa.ac.uk/academicinfrastructure

[5] Copies of the DRC revised *Code of Practice: Post-16 Education* may be obtained from the DRC at www.drc-gb.org/employers_and_service_provider/education/higher_education.aspx

[6] Equality Challenge Unit, www.ecu.ac.uk

Foreword

This document is a revision of the subject benchmark statement for chemistry first published by QAA in 2000.

In 2005, QAA asked the Royal Society of Chemistry (RSC) to consider whether the benchmark statement for chemistry should be revised, and if so to what extent. It also asked the RSC to consider incorporating integrated master's degrees in accordance with United Kingdom (UK) qualifications frameworks and to take into account other relevant developments within higher education (HE) and the chemical science profession.

The review group for the subject benchmark statement for chemistry acknowledges the contribution of the original benchmarking group (2000) in preparing its original statement and recognises the valuable contribution of the statement to chemistry HE in the UK (and beyond) during the past six years.

In revising the statement, the review group seeks to maintain the original intentions and purposes while giving consideration to recent developments in the discipline, HE and the chemical science profession. Studies at master's level have been incorporated to provide one comprehensive benchmark statement for chemistry, covering not only bachelor's degrees with honours but also all master's degrees in chemistry, ie integrated master's degrees, typically titled MChem or MSci, and standalone master's degrees, typically titled MSc or MRes, but not studies leading to the award of MPhil.

The review group adopted this approach since it considered the statement should more clearly illustrate not only the commonalities of degrees in chemistry but, more importantly, the distinct differences at the two levels. It also provides evident articulation to existing UK qualification frameworks and the Framework of qualifications for the European Higher Education Area, which was agreed by Ministers as part of the Bologna Process and which draws on the Dublin descriptors.

Revisions to the original bachelor's degree with honours sections of the statement are minor in most respects. Possibly the most significant amendments are the redrafting of the essential subject matter components and the changes to the subject knowledge section to make it less specific. These were made to address the continually increasing breadth of the discipline and diversity of contemporary chemistry qualifications.

June 2007

1 Introduction

1.1 This statement sets out the benchmark threshold standards in chemistry. It focuses on four major aspects concerning programmes leading to bachelor's degree with honours and master's degree qualifications:

- the major aims and purposes that may be associated with degree programmes in chemistry
- an outline of subject-matter that may be expected to be covered in study programmes leading to such degree qualifications
- the abilities, competencies and skills to be developed in students through the study of chemistry
- recommendations concerning procedures appropriate for the teaching, learning and assessment of the knowledge, abilities and skills set out above.

1.2 This statement is intended to provide a broad framework within which HE providers can develop purposeful and challenging chemistry programmes that respond to the needs of their students, as well as to the evolving nature of the chemistry discipline. Its purpose is not to impose on HE providers a set of rigid conditions that would stifle innovation in programme development and in the design of learning experiences. It is hoped the statement will continue to make a valuable contribution to chemistry HE and assist in the maintenance of the standard of chemistry degrees and the graduates they supply to the job market.

1.3 Details of the aims, objectives and content of individual programmes will be found in the programme specifications and/or other documentation issued by HE providers.

2 Nature and extent of chemistry

2.1 Chemistry can be defined as the science that studies systematically the composition, properties, and reactivity of matter at the atomic and molecular level. Since matter is everything that can be touched, seen, smelt or felt, it follows that the scope of the chemistry discipline is essentially limitless.

2.2 The subject of chemistry has been divided traditionally into three main branches: organic chemistry - the chemistry of (most) substances containing the element carbon; inorganic chemistry - the chemistry of all other substances; and physical chemistry - the application of concepts and laws to chemical phenomena. Analytical chemistry, which is concerned with the identification of materials and the determination of composition, has become accepted generally as a fourth branch. The nature of chemistry is such that there are no distinct boundaries between the branches of the discipline or indeed with other disciplines.

2.3 Historically, bachelor's degrees with honours in chemistry were developed to encompass all the main branches with a consequent emphasis on breadth of study as well as depth. While a breadth of understanding remains relevant, modern chemistry is less likely to be categorised strictly in branches and, in reflecting this, degree programmes are designed increasingly on a thematic basis so encompassing topics that

overlap traditional branches and address the interfaces of chemistry with other disciplines, such as chemical biology and chemical physics, and with applied fields, such as environmental chemistry and materials chemistry.

2.4 Broadly-based degrees, commonly titled 'chemistry', remain relevant to the contemporary employment needs of the chemical science profession. Many HE providers now also award chemistry degrees with titles denoting a specialism, eg medicinal chemistry, analytical chemistry, environmental chemistry. These courses tend to attract students with more definite career aspirations. It is accepted that the extent of breadth of study and the depth to which individual topics are treated will vary with the nature of specific chemistry programmes. It is however critical for employers of chemists that specialist learning objectives in terms of chemistry reflect the degree title.

2.5 In reflecting the vocational nature of chemistry, many HE providers offer degree courses that incorporate a period of study in industry. Such placements are designed on the basis of an agreed programme of work acceptable to both the HE provider and industrial partner and usually involve both a major work-related chemistry project and some guided study.

3 Aims of degree programmes in chemistry

3.1 The general aims of degree programmes in chemistry should include:

- to instil in students an enthusiasm for chemistry, an appreciation of its application in different contexts and to involve them in an intellectually stimulating and satisfying experience of learning and studying
- to establish in students an appreciation of the importance and sustainability of the chemical sciences in an industrial, academic, economic, environmental and social context
- to develop in students, through an education in chemistry, a range of appropriate generic skills, of value in chemical and non-chemical employment.

3.2 The main aims of bachelor's degree with honours programmes in chemistry should include:

- to provide students with a broad and balanced appreciation of key chemical concepts
- to develop in students a range of practical skills so that they can understand and assess risks and work safely in the laboratory
- to develop in students the ability to apply standard methodology to the solution of problems in chemistry
- to provide students with a knowledge and skills base from which they can proceed to graduate employment or to further studies in chemistry or multi-disciplinary areas involving chemistry.

3.3 The main aims of master's degree programmes in chemistry should include:

- to extend students' comprehension of key chemical concepts and so provide them with an in-depth understanding of specialised areas of chemistry

- to provide students with the ability to plan and carry out experiments independently and assess the significance of outcomes
- to develop in students the ability to adapt and apply methodology to the solution of unfamiliar types of problems
- to instil a critical awareness of advances at the forefront of the chemical science discipline
- to prepare students effectively for professional employment or doctoral studies in the chemical sciences.

3.4 Integrated master's degree programmes (eg MChem, MSci) should encompass both honours and master's level aims. Master's degree programmes (eg MSc, MRes) should ensure, through admissions processes or additional study, that the honours level aims have been covered.

4 Subject knowledge and understanding

4.1 Each HE provider awarding qualifications in chemistry is free to decide on the content, nature and organisation of its courses or modules and thus chemistry programmes offered by individual HE providers will have their own particular characteristics. Articulation of learning outcomes in chemistry to relevant sections of QAA's qualifications frameworks is considered key.

4.2 Bachelor's degrees with honours programmes ensure that students:

- are fully conversant with major aspects of chemical terminology
- demonstrate a systematic understanding of fundamental physicochemical principles with the ability to apply that knowledge to the solution of theoretical and practical problems
- gain knowledge of a range of inorganic and organic materials
- can evidence their understanding of general synthetic pathways, including related isolation, purification and characterisation techniques
- develop an awareness of issues within chemistry that overlap with other related disciplines.

4.3 A systematic and broad understanding of key chemical concepts will be assumed prior to undertaking master's level study. Master's students will develop an in-depth knowledge and critical awareness of a substantial area of chemistry, and be suitably prepared for contemporary professional practice in the chemical sciences or for studying further at doctoral level.

4.4 While recognising that master's degrees can cover a very wide range of chemistry areas, the desirable characteristics of a degree programme in terms of activities to be undertaken by the student are given below.

Research training

- Project-specific experimental skills.
- Accessing literature.
- Planning, including evaluation of hazards and environmental effects.
- Making oral presentations, writing reports, including critical evaluation.
- Participating in colloquia.

Research project

- Implementation of planned experiments.
- Recording of data and their critical analysis.
- Dissertation.
- Outcome potentially publishable.

Advanced studies

- In area of specialism to support research topic.
- Complementary studies outside, but cognate to, area of specialism.

Problem-solving

- Development of general strategies including the identification of additional information required and problems where there is not a unique solution.
- Application of advanced studies to the solution of problems.

Professional studies

- Ethics and societal responsibilities.
- Environmental impact.
- Sustainability.

4.5 The proportion of each activity will vary depending upon the programme's learning objectives. However, research studies (training and project) are likely to form at least one-half of the master's level studies.

5 Abilities and skills

5.1 Students studying chemistry degree programmes are expected to develop a wide range of different abilities and skills. These may be divided into three broad categories:

- chemistry-related cognitive abilities and skills, ie abilities and skills relating to intellectual tasks, including problem-solving
- chemistry-related practical skills, eg skills relating to the conduct of laboratory work
- generic skills that may be developed in the context of chemistry and are of a general nature and applicable in many other contexts.

5.2 The main abilities and skills that students are expected to have developed by the end of their programme in chemistry are as follows.

Chemistry-related cognitive abilities and skills

5.3 In bachelor's degree with honours programmes:

- the ability to demonstrate knowledge and understanding of essential facts, concepts, principles and theories relating to the subject areas identified above
- the ability to apply such knowledge and understanding to the solution of qualitative and quantitative problems mostly of a familiar nature
- the ability to recognise and analyse problems and plan strategies for their solution
- skills in the evaluation, interpretation and synthesis of chemical information and data
- skills in the practical application of theory using computer software and models
- skills in communicating scientific material and arguments
- information technology (IT) and data-processing skills, relating to chemical information and data.

5.4 Additionally in master's degree programmes:

- the ability to adapt and apply methodology to the solution of unfamiliar problems
- the ability to assimilate, evaluate and present research results objectively
- skills required to undertake a research project the outcome of which is of a quality that is potentially publishable.

Chemistry-related practical skills

5.5 In bachelor's degree with honours programmes:

- skills in the safe-handling of chemical materials, taking into account their physical and chemical properties including any specific hazards associated with their use and the ability to conduct risk assessments
- skills required for the conduct of documented laboratory procedures involved in synthetic and analytical work, in relation to both inorganic and organic systems
- skills in the monitoring, by observation and measurement, of chemical properties, events or changes, and the systematic and reliable recording and documentation thereof
- skills in the operation of standard chemical instrumentation
- the ability to interpret and explain the limits of accuracy of their own experimental data in terms of significance and underlying theory.

5.6 Additionally in master's degree programmes:

- the ability to select appropriate techniques and procedures

- competence in the planning, design and execution of experiments
- skills required to work independently and be self-critical in the evaluation of risks, experimental procedures and outcomes
- the ability to use an understanding of the limits of accuracy of experimental data to inform the planning of future work.

Generic skills

5.7 In bachelor's degree with honours programmes:

- communication skills, covering both written and oral communication
- problem-solving skills, relating to qualitative and quantitative information
- numeracy and mathematical skills, including such aspects as error analysis order-of-magnitude estimations, correct use of units and modes of data presentation
- information retrieval skills, in relation to primary and secondary information sources, including information retrieval through online computer searches
- IT skills
- interpersonal skills, relating to the ability to interact with other people and to engage in teamworking
- time management and organisational skills, as evidenced by the ability to plan and implement efficient and effective modes of working
- skills needed to undertake appropriate further training of a professional nature.

5.8 Additionally in master's degree programmes:

- problem-solving skills including the demonstration of self-direction and originality
- the ability to communicate and interact with professionals from other disciplines
- the ability to exercise initiative and personal responsibility
- the ability to make decisions in complex and unpredictable situations
- independent learning ability required for continuing professional development.

6 Teaching, learning and assessment

6.1 Teaching and learning strategies should be designed fundamentally to provide students with the necessary subject knowledge, understanding, abilities and skills for the chemical science profession.

6.2 HE providers should use a variety of teaching methods to ensure that students remain engaged, motivated and challenged to learn. Chemistry as a subject for learning is amenable to the full range of teaching methodologies, whether well established or innovative. Additionally, the chemical science profession requires graduates who are safe and competent practical workers and so it is crucial that there is a substantial laboratory-based practical component. Teaching methods must ultimately be valid, effective and meet the stated learning objectives.

6.3 It is essential that the procedures used for the assessment of students' achievement in chemistry correspond to the knowledge, abilities and skills that are to be developed through their degree programme.

6.4 Evidence on which the assessment of student achievement is based should include:

- formal examinations, including a significant proportion of 'unseen' examinations
- laboratory reports and skills
- problem-solving exercises
- oral presentations
- planning, conduct and reporting of project work.

6.5 Additional evidence of use for the assessment of student achievement may include:

- essay assignments
- portfolios on chemical activities undertaken
- literature surveys and evaluations
- collaborative project work
- preparation and displays of 'posters' reporting project work
- reports on external placements (where appropriate).

6.6 At the master's level, there will be a strong emphasis on requiring students to apply their knowledge of chemistry to the solution of unfamiliar problems. Assessment of the research project, based upon much of the evidence listed above, will be crucial in determining whether master's level learning outcomes have been achieved.

7 Benchmark standards

7.1 All students graduating with a degree in chemistry are expected to demonstrate that they have acquired the knowledge, abilities and skills in the areas identified in the foregoing sections.

7.2 The following statements describe generally the threshold level of competence for holders of a bachelor's degree with honours in chemistry:

- a basic knowledge and understanding of the content covered in the course is evident
- problems of a routine nature are generally adequately solved
- standard laboratory experiments can be carried out safely and with reasonable success though the significance and limitations of experimental data and/or observations may not be fully recognised
- generic skills have been developed to a basic level.

7.3 The following statements describe the typical level of competence for holders of a bachelor's degree with honours in chemistry:

- knowledge base covers essential aspects of subject matter dealt with in the programme and shows some evidence of enquiry beyond this. Conceptual understanding is good
- problems of a familiar nature are solved in a logical manner, and solutions are generally correct or acceptable
- experimental work is carried out in a reliable and efficient manner
- performance in generic skills is sound and shows no significant deficiencies.

7.4 The typical level should apply to the majority of graduates who consequently will possess the potential to progress to a master's degree programme in chemistry.

7.5 The following statements describe generally the threshold level of competence for holders of a master's degree in chemistry:

- knowledge base extends to a systematic understanding and critical awareness of topics which are informed by the forefront of the discipline
- problems of an unfamiliar nature are tackled with appropriate methodology and taking into account the possible absence of complete data
- experimental work is carried out independently and with some originality
- substantial research project at the forefront of the discipline is completed effectively
- generic skills are developed appropriately for professional practice.

Appendix A - Membership of the review group for the subject benchmark statement for chemistry

Professor D Phillips (Chair)	Imperial College London
Dr A D Ashmore	Royal Society of Chemistry
Dr D W Barr (Secretary)	Royal Society of Chemistry
Dr P R Davies	Cardiff University
Professor R F W Jackson	University of Sheffield
Professor J Leonard	AstraZeneca plc
Professor D Littlejohn	University of Strathclyde
Dr G Nicholson	AWE plc
Professor F L Pearce	University College London
Professor C C Perry	Nottingham Trent University
Dr G J Price	University of Bath
Professor N V Richardson	University of St Andrews

Appendix B - Membership of the original benchmarking group for chemistry

Details below appear as published in the original subject benchmark statement for chemistry (2000).

Professor E W Abel (Chair)	University of Exeter
Professor P W Atkins	University of Oxford
Dr S J Gruber (Secretary)	Royal Society of Chemistry
Professor L I B Haines	University of North London
Professor R C F Jones	Open University
Professor R F Kempa	University of Keele
Professor M I Page	University of Huddersfield
Professor B J Parsons	North East Wales Institute
Professor D Phillips	Imperial College London
Professor D A Rice	University of Reading
Professor K Smith	University of Wales, Swansea
Professor A Townshend	University of Hull
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