

# Subject benchmark statement

**Chemistry**

December 2014

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## How can I use this document?

This document is a Subject Benchmark Statement for chemistry, that defines what can be expected of a graduate in the subject, in terms of what they might know, do and understand at the end of their studies.

You may want to read this document if you are:

- involved in the design, delivery and review of programmes of study in chemistry or related subjects
- a prospective student thinking about studying chemistry, or a current student of the subject, to find out what may be involved
- an employer, to find out about the knowledge and skills generally expected of a graduate in chemistry.

Explanations of unfamiliar terms used in this Subject Benchmark Statement can be found in QAA's glossary.<sup>1</sup>

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<sup>1</sup> The QAA glossary is available at: [www.qaa.ac.uk/about-us/glossary](http://www.qaa.ac.uk/about-us/glossary).

## About Subject Benchmark Statements

Subject Benchmark Statements form part of the UK Quality Code for Higher Education (the Quality Code) which sets out the Expectations that all providers of UK higher education reviewed by QAA are required to meet.<sup>2</sup> They are a component of Part A: Setting and Maintaining Academic Standards, which includes the Expectation that higher education providers 'consider and take account of relevant Subject Benchmark Statements' in order to secure threshold academic standards.<sup>3</sup>

Subject Benchmark Statements describe the nature of study and the academic standards expected of graduates in specific subject areas, and in respect of particular qualifications. They provide a picture of what graduates in a particular subject might reasonably be expected to know, do and understand at the end of their programme of study.

Subject Benchmark Statements are used as reference points in the design, delivery and review of academic programmes. They provide general guidance for articulating the learning outcomes associated with the programme but are not intended to represent a national curriculum in a subject or to prescribe set approaches to teaching, learning or assessment. Instead, they allow for flexibility and innovation in programme design within a framework agreed by the subject community. Further guidance about programme design, development and approval, learning and teaching, assessment of students, and programme monitoring and review is available in Part B: Assuring and Enhancing Academic Quality of the Quality Code in the following Chapters:<sup>4</sup>

- *Chapter B1: Programme Design, Development and Approval*
- *Chapter B3: Learning and Teaching*
- *Chapter B6: Assessment of Students and the Recognition of Prior Learning*
- *Chapter B8: Programme Monitoring and Review.*

For some subject areas, higher education providers may need to consider other reference points in addition to the Subject Benchmark Statement in designing, delivering and reviewing programmes. These may include requirements set out by professional, statutory and regulatory bodies, national occupational standards and industry or employer expectations. In such cases, the Subject Benchmark Statement may provide additional guidance around academic standards not covered by these requirements.<sup>5</sup> The relationship between academic and professional or regulatory requirements is made clear within individual statements, but it is the responsibility of individual higher education providers to decide how they use this information. The responsibility for academic standards remains with the higher education provider who awards the degree.

Subject Benchmark Statements are written and maintained by subject specialists drawn from and acting on behalf of the subject community. The process is facilitated by QAA. In order to ensure the continuing currency of Subject Benchmark Statements, QAA initiates regular reviews of their content, five years after first publication, and every seven years subsequently.

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<sup>2</sup> The Quality Code, available at [www.qaa.ac.uk/assuring-standards-and-quality/the-quality-code](http://www.qaa.ac.uk/assuring-standards-and-quality/the-quality-code), aligns with the *Standards and Guidelines for Quality Assurance in the European Higher Education Area*, available at: [www.engq.eu/wp-content/uploads/2013/06/ESG\\_3edition-2.pdf](http://www.engq.eu/wp-content/uploads/2013/06/ESG_3edition-2.pdf).

<sup>3</sup> Part A: Setting and Maintaining Academic Standards, available at: [www.qaa.ac.uk/assuring-standards-and-quality/the-quality-code/quality-code-part-a](http://www.qaa.ac.uk/assuring-standards-and-quality/the-quality-code/quality-code-part-a).

<sup>4</sup> Individual Chapters are available at: [www.qaa.ac.uk/assuring-standards-and-quality/the-quality-code/quality-code-part-b](http://www.qaa.ac.uk/assuring-standards-and-quality/the-quality-code/quality-code-part-b).

<sup>5</sup> See further Part A: Setting and Maintaining Academic Standards, available at: [www.qaa.ac.uk/assuring-standards-and-quality/the-quality-code/quality-code-part-a](http://www.qaa.ac.uk/assuring-standards-and-quality/the-quality-code/quality-code-part-a).

## **Relationship to legislation**

Higher education providers are responsible for meeting the requirements of legislation and any other regulatory requirements placed upon them, for example by funding bodies. The Quality Code does not interpret legislation nor does it incorporate statutory or regulatory requirements. Sources of information about other requirements and examples of guidance and good practice are signposted within the Subject Benchmark Statement where appropriate. Higher education providers are responsible for how they use these resources.<sup>6</sup>

## **Equality and diversity**

The Quality Code embeds consideration of equality and diversity matters throughout. Promoting equality involves treating everyone with equal dignity and worth, while also raising aspirations and supporting achievement for people with diverse requirements, entitlements and backgrounds. An inclusive environment for learning anticipates the varied requirements of learners, and aims to ensure that all students have equal access to educational opportunities. Higher education providers, staff and students all have a role in, and responsibility for, promoting equality.

Equality of opportunity involves enabling access for people who have differing individual requirements as well as eliminating arbitrary and unnecessary barriers to learning. In addition, disabled students and non-disabled students are offered learning opportunities that are equally accessible to them, by means of inclusive design wherever possible and by means of reasonable individual adjustments wherever necessary.

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<sup>6</sup> See further the *UK Quality Code for Higher Education: General Introduction*, available at: [www.qaa.ac.uk/publications/information-and-guidance/publication/?PubID=181](http://www.qaa.ac.uk/publications/information-and-guidance/publication/?PubID=181).

## About this Subject Benchmark Statement

This Subject Benchmark Statement refers to bachelor's degrees with honours and master's degrees in chemistry.<sup>7</sup>

This version of the statement forms its third edition, following initial publication in 2000 and review and revision in 2007.<sup>8</sup>

### Note on alignment with higher education sector coding systems

Programmes of study which use this Subject Benchmark Statement as a reference point are generally classified under the following codes in the Joint Academic Coding System (JACS).<sup>9</sup>

F100 (Chemistry); F110 (Applied chemistry); F111 (Industrial chemistry); F112 (Colour chemistry); F120 (Inorganic chemistry); F130 (Structural chemistry); F131 (Crystallography); F140 (Environmental chemistry); F141 (Marine chemistry); F150 (Medicinal chemistry); F151 (Pharmaceutical chemistry); F160 (Organic chemistry); F161 (Organometallic chemistry); F162 (Polymer chemistry); F163 (Bio-organic chemistry); F164 (Petrochemical chemistry); F165 (Biomolecular chemistry); F170 (Physical chemistry); F180 (Analytical chemistry); F190 (Chemistry not elsewhere classified); C720 (Biological chemistry); J421 (Textile chemistry).

### Summary of changes from the previous Subject Benchmark Statement (2007)

The statement has been revised and updated to take account of recent developments in the subject and in the chemical science profession, as well as wider developments across higher education.

Changes made include:

- clarification of the nature and extent of chemistry degree programmes
- the addition of references to ethics, societal and environmental concerns, innovation and intellectual property
- a change of focus from 'generic skills' to 'employability skills', with associated clarifications and additions
- the use of clearer language and terminology in response to feedback from employers and a student reader
- updates to reflect changes and development in teaching, learning and assessment (including technological developments).

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<sup>7</sup> Bachelor's degrees are at level 6 in *The Framework for Higher Education Qualifications in England, Wales and Northern Ireland* (2008) and level 10 in the *Scottish Credit and Qualifications Framework* (2001), and master's degrees are at level 7 and level 11 respectively.

<sup>8</sup> Further information is available in the *Recognition Scheme for Subject Benchmark Statements*, available at: [www.qaa.ac.uk/publications/information-and-guidance/publication?PubID=190](http://www.qaa.ac.uk/publications/information-and-guidance/publication?PubID=190).

<sup>9</sup> Further information about JACS is available at: [www.hesa.ac.uk/content/view/1776/649/](http://www.hesa.ac.uk/content/view/1776/649/).

# 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 associated with degree programmes in chemistry
- an outline of subject matter covered in study programmes leading to such degree qualifications
- the abilities, competencies and skills to be developed by students through the study of chemistry
- recommendations concerning procedures appropriate for the teaching, learning and assessment of the knowledge, abilities and skills developed by students through the study of chemistry.

1.2 This statement is intended to provide a broad framework within which higher education providers may develop purposeful and challenging chemistry programmes that respond to the needs of their students, as well as to the evolving nature of chemistry as a subject. Its purpose is not to impose on higher education providers a set of rigid conditions that 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 higher education 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 higher education 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, made visible, smelt or tasted, it follows that the scope of chemistry as a subject is very broad.

2.2 The nature of chemistry is such that there are no distinct boundaries between branches of the subject or indeed with other subjects. The subject comprises: 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; and analytical chemistry, which is concerned with the identification and quantification of materials and the determination of composition.

2.3 Degree programmes are designed increasingly by theme, covering topics that overlap the areas outlined in paragraph 2.2 and that address the interfaces of chemistry with other subjects (such as chemical biology and chemical physics) and with applied fields (such as environmental chemistry and materials chemistry).

2.4 Broadly based degree programmes are commonly titled 'chemistry'. These programmes are relevant to employment across the chemical science profession. Many higher education providers also award chemistry degrees with titles denoting a specialism, for example medicinal chemistry, analytical chemistry or environmental chemistry. It is accepted that the extent of breadth of study and the depth to which individual topics are treated varies with the nature of specific chemistry programmes. It is however critical for employers of chemists that specialist learning objectives in terms of chemistry are reflected in the degree title.

2.5 In reflecting the vocational nature of chemistry, many higher education providers offer degree programmes 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 higher education provider and the partner organisation and may 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 are:

- to instill 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 are:

- to provide students with broad and balanced knowledge and understanding of key chemical concepts
- to develop in students a range of practical skills so that they can understand and assess risks and work safely and competently 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 are:

- 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 instill a critical awareness of advances at the forefront of the chemical sciences
- to prepare students effectively for professional employment or research degrees in the chemical sciences.

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

## 4 Subject knowledge and understanding

4.1 Each higher education provider awarding qualifications in chemistry defines the content, nature and organisation of its programmes and modules. Consequently chemistry programmes offered by individual higher education providers will have their own particular characteristics.

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
- demonstrate, with supporting evidence, their understanding of synthesis, including related isolation, purification and characterisation techniques
- demonstrate an understanding of the qualitative and quantitative aspects of chemical metrology and the importance of traceability
- develop an awareness of issues within chemistry that overlap with other related subjects
- develop knowledge and understanding of ethics, societal responsibilities, environmental impact and sustainability, in the context of chemistry
- develop an understanding of safe working practice, in terms of managing chemical toxicity, chemical stability and chemical reactivity, through knowledge-based risk assessments
- read and engage with scientific literature.

4.3 A systematic and broad understanding of key chemical concepts is assumed prior to undertaking master's level study. Master's students develop an in-depth knowledge and critical awareness of a substantial area of chemistry, and are suitably prepared for employment 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, the following activities are likely to confer the necessary knowledge and understanding.

### Research training

- Development of project-specific experimental skills.
- Reading and engaging with scientific literature.
- Planning, including evaluation of hazards and environmental effects.
- Making oral presentations and writing reports, including critical evaluation.
- Attending and participating in discussions with other researchers (for example, colloquia).

### Research project

- Implementation of planned experiments.
- Recording of data and their critical analysis.
- Production of a dissertation reporting outcomes that are potentially publishable (in a peer-reviewed publication).

### Specialist studies

- Advanced studies in areas of specialism, such as the use of peer-reviewed scientific literature.
- 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

- Development of knowledge and understanding of:
  - ethics
  - societal responsibilities
  - environmental impact
  - sustainability
  - intellectual property
  - innovation and exploitation of commercial opportunities.

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 half of the master's level studies.

## 5 Abilities and skills

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

- chemistry-related cognitive abilities and skills, such as abilities and skills relating to intellectual tasks, including problem solving
- chemistry-related practical skills, for example skills relating to the conduct of laboratory work
- professional skills that may be developed in the context of chemistry and are of a general nature and applicable in many other contexts, for example, interpersonal, time management and organisational skills.

5.2 The main abilities and skills that students are expected to have developed by the end of their programme in chemistry are detailed in paragraphs 5.3 to 5.8.

### Chemistry-related cognitive abilities and skills

5.3 In bachelor's degree with honours programmes, students develop:

- the ability to demonstrate knowledge and understanding of essential facts, concepts, principles and theories relating to the subject areas covered in their programme
- the ability to apply such knowledge and understanding to the solution of qualitative and quantitative problems that are mostly of a familiar nature
- the ability to recognise and analyse problems and plan strategies for their solution
- skills in the generation, evaluation, interpretation and synthesis of chemical information and data
- skills in the practical application of theory using computational methodology and models
- skills in communicating scientific material and arguments
- information technology and data-processing skills, relating to chemical information and data.

5.4 Additionally in master's degree programmes, students develop:

- 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 reporting outcomes that are potentially publishable (in a peer-reviewed publication).

### Chemistry-related practical skills

5.5 In bachelor's degree with honours programmes, students develop:

- an ability to determine hazards associated with carrying out chemical experiments in terms of chemical toxicity, chemical stability and chemical reactivity and be able to find information to enable effective risk assessments to be carried out
- skills to handle chemicals safely and carry out experiments and chemical reactions in a safe manner, based on effective risk assessments
- skills required for the conduct of documented laboratory procedures involved in synthesis and analysis, 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 plan experimental procedures, given well defined objectives
- 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, students develop:

- 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 uncertainty of experimental data to inform the planning of future work.

## Professional skills

5.7 In bachelor's degree with honours programmes, students develop:

- communication skills, covering both written and oral communication with a variety of audiences
- skills in the employment of common conventions and standards in scientific writing, data presentation, and referencing literature
- problem-solving skills, relating to qualitative and quantitative information
- numeracy and mathematical skills, including handling data, algebra, functions, trigonometry, calculus, vectors and complex numbers, alongside error analysis, order-of-magnitude estimations, systematic use of scientific units and different types of data presentation
- information location and retrieval skills, in relation to primary and secondary information sources, and the ability to assess the quality of information accessed
- information technology skills which support the location, management, processing, analysis and presentation of scientific information
- basic 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 ways of working
- skills needed to undertake appropriate further training of a professional nature
- other relevant professional skills such as business awareness.

5.8 Additionally in master's degree programmes, students develop:

- problem-solving skills including the demonstration of self-direction, initiative and originality
- the ability to communicate and interact with professionals from other subjects
- the ability to make decisions in complex and unpredictable situations
- the ability to think critically in the context of data analysis and experimental design
- the ability to work in multi-disciplinary and multi-skilled teams
- independent learning skills required for continuing professional development.

## 6 Teaching, learning and assessment

6.1 Teaching and learning strategies are designed to provide students with appropriate subject knowledge, understanding, abilities and academic and professional skills for chemistry-based professions.

6.2 Higher education providers use appropriate teaching methods to ensure that students are engaged, motivated and challenged to learn. A wide range of teaching methodologies, both innovative and well established, are appropriate to the teaching of chemistry. The chemical science profession requires graduates who are safe and competent practical workers and so a substantial laboratory-based practical component is crucial. Teaching methods are ultimately effective in enabling students to meet the stated learning objectives.

6.3 The assessment of students' achievement in chemistry aligns with learning outcomes and is appropriate to the knowledge, abilities, academic and professional skills that the programme aims to develop.

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

- 'unseen' examinations or examination questions
- other written and oral examinations
- laboratory reports and skills
- problem-solving exercises
- oral presentations
- planning, conduct and reporting of project work (including the dissertation)
- literature surveys and evaluations
- outputs from collaborative work.

6.5 Sources of additional evidence for the assessment of student achievement may include:

- essay assignments
- portfolios on chemical activities undertaken
- preparation and displays of posters
- reports on external placements
- peer assessment
- reflective logs
- production of online and other media outputs such as video and audio.

6.6 At master's level, there is a strong emphasis on requiring students to apply their knowledge of chemistry to the solution of unfamiliar problems. Assessment of research skills is 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 knowledge, abilities, and academic and professional skills in the areas identified in sections 4 and 5.

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 programme is evident
- problems of a routine nature are generally adequately solved
- standard laboratory experiments are carried out safely and with reasonable success
- professional skills (for example, interpersonal, time management and organisational 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, safe and efficient manner, with demonstrable understanding of the significance and limitations of experimental data and observations
- professional skills are sound and show no significant deficiencies.

7.4 The typical level applies to the majority of graduates who consequently 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 current research in the subject
- 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, with some evidence of originality, and with appropriate risk assessments
- a substantial research project at the forefront of the subject is completed effectively
- professional skills are developed appropriately for the workplace.

## **Appendix A: Membership of the benchmarking and review groups for the Subject Benchmark Statement for chemistry**

### **Membership of the review group for the Subject Benchmark Statement for chemistry (2014)**

Professor Matthew Almond	University of Reading
Professor Peter Edwards	Cardiff University
Professor Richard Jackson	University of Sheffield
Professor David Littlejohn	University of Strathclyde
Dr David McGarvey	Keele University
Professor Nick Norman	University of Bristol
Professor Tina Overton	University of Hull
Professor Carole Perry	Nottingham Trent University
Professor David Phillips (Chair)	Imperial College London
Professor Colin Pulham	University of Edinburgh
Dr Paul Yates	Higher Education Academy
Dr Catherine Kerfoot	QAA

#### **Professional, statutory and regulatory body representatives**

Dr David Barr	Royal Society of Chemistry
Professor Jim Iley	Royal Society of Chemistry

#### **Employer representatives**

Dr Graeme Nicholson	AWE Plc
Professor John Leonard	Astrazeneca
Dr Paul Holland (reader)	EffecTech Ltd.

#### **Student reader**

Paul Brack	Loughborough University
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## **Membership of the review group for the Subject Benchmark Statement for chemistry (2007)**

Details provided below are as published in the second edition of the Subject Benchmark Statement.

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
Professor D Phillips (Chair)	Imperial College London
Dr G J Price	University of Bath
Professor N V Richardson	University of St Andrews

## **Membership of the original benchmarking group for chemistry (2000)**

Details provided below are as published in the original edition of the Subject Benchmark Statement.

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
Professor P Tasker	
Professor J M Winfield	University of Glasgow

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Southgate House, Southgate Street, Gloucester GL1 1UB

Tel: 01452 557 000

Email: [enquiries@qaa.ac.uk](mailto:enquiries@qaa.ac.uk)

Website: [www.qaa.ac.uk](http://www.qaa.ac.uk)

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