Chemistry as a Strategically Important and Vulnerable Subject

The Royal Society of Chemistry (RSC) welcomes the opportunity to respond to the call for evidence from the Higher Education Funding Council for England (HEFCE) on Chemistry in the higher education sector.

The Royal Society of Chemistry is the world's leading chemistry community, advancing excellence in the chemical sciences. With 48,000 members and a knowledge business that spans the globe, we are the UK's professional body for chemical scientists; a not-for-profit organisation with over 170 years of history and an international vision of the future. We promote, support and celebrate chemistry. We work to shape the future of the chemical sciences – for the benefit of science and humanity.

Summary

Continued and increased investment in chemistry as a research subject is essential as chemistry and chemists support all of the Eight Great Technologies and the industry sectors identified by BIS as integral to the UK's economic growth.

To meet the expertise requirements of the UK's growing science industries, growth in chemistry student numbers must continue. This will only be possible with increased capital investment in infrastructure and equipment and teaching to enable university chemistry departments, already at capacity and running a deficit, to expand or to support the start-up of new chemistry departments. **The Royal Society of Chemistry therefore recommends that Chemistry remain in price group B for teaching funding and has access to an appropriate proportion of the additional funding available for high-cost subjects within this price group.**

Strategic Importance

The UK's science base creates growth and jobs; the chemical sciences underpins most of the Eight Great Technologies outlined by the Government (all data from here unless specified).

In 2011, knowledge intensive industries (which include knowledge services as well as medium- to high-tech manufacturing, such as the chemicals and pharmaceuticals sector) accounted for around a third of UK output and a quarter of total employment. The chemicals sector accounted for £16,926m (or 1.2%) of the gross value added (GVA), the pharmaceuticals sector accounted for £10,023m (or 0.7%) and R&D accounted for £4290m (or 0.3%).

However, the contribution of the chemical sciences to the UK's economic growth and job market extends well beyond the chemicals and pharmaceuticals industries, contributing to the technologies identified by government as vital to the UK's strategy for industry: big data and energy efficient computing, satellites and commercial applications of space, robotics and autonomous systems, life sciences and synthetic biology, regenerative medicine, agri-science, advanced materials and nano-technology, and energy and its storage.

The chemical sciences play a vital role in improving materials security and efficiency through reusing, recycling, reducing and replacing the use of expensive or critical resources through: processes for recycling raw minerals; the development of alternative materials that avoid the use of critical raw minerals; improved extraction and processing of raw minerals; and a reduction in energy consumption in industrial and manufacturing processes. The supply of a number of elements and minerals essential to modern technology is at high risk and one-in-three UK manufacturers cite limited access to raw materials as a top business risk. The value to the EU economy of sectors dependent on access to raw materials is £1.12tn, and the UK imported £4.72bn worth of minerals in 2010.

> Advanced Materials: Graphene, a promising new material for energy, electronics and structural composites, is dependent on chemistry. One of the biggest challenges facing the application of graphene is producing enough high-quality material to supply the growing demand. Chemists at Durham Graphene Science have developed a process to synthesise graphene from ethanol. This process can produce tonnes of high-purity graphene per year. With the global market for its products predicted to be worth £650m by 2022, this is a key sector in which the UK leads, but requires continued investment to ensure we remain at the leading edge.[1]

Chemistry is also vital in understanding and mitigating the effects of water contamination, and can also support the development of more efficient desalination processes, purification technologies and portable technologies for analysing and treating contaminated groundwater. The global water treatment market was worth approximately £12bn in 2010 and is predicted to grow to £18bn by 2015. In the UK, the sewer network extends over 340,000 km and collects more than 11bn litres of wastewater every single day. This water has a wide range of contaminants that need to be removed, involving processes that are currently highly energy intensive.

> Nano-technology: One example of a recent technological advancement in the removal of wastewater contaminants is the method used by the UK company Arvia. Their technology can be deployed for the cheaper disposal of radioactive carbon-based materials in nuclear waste. With this market expected to exceed £70bn in the UK alone, Arvia's method could give the UK a significant edge.

By 2050, the world's population is expected to reach 9bn, and chemistry has a clear and central role in feeding this population through a variety of related areas ranging from crop protection and soil science to veterinary medicine.

> Agri-Science: Invented in the UK by chemists at Syngenta, Azoxystrobin is the world's number one fungicide and is selective, stable, easy to apply and safe for consumers and the environment. It is available in 100 countries and protects 120 types of crops, generating £620m in global sales annually. Syngenta is a global company with more than 2000 people employed across six UK sites.

The renewable energy sector already generates 270,000 jobs in the UK, estimated to grow to 400,000 jobs by 2020. Within the renewable energy sector, solar energy is the 3rd largest source in terms of globally installed capacity, and chemistry plays a key role in improving current solar energy technologies and in developing new ones.

> Energy and its storage: Globally, the photovoltaics market has potential growth of 170% by 2017, saves 53m tonnes of CO_2 and provides the equivalent energy needs of over 30m European households. With more than 70 companies in the UK – ranging from SMEs to large multinationals – that are involved in photovoltaics manufacturing at different points of the supply chain, the UK has a significant stake in this global market.

[1] http://www.rsc.org/science-activities/resource-efficiency/resources-that-dont-cost-the-earth.asp

Like its major competitors France, Germany and the USA, the UK specialises in aerospace, chemicals and pharmaceuticals, and in 2010 chemicals and related industries contributed the 6th largest share to UK export (reaching £24.4bn or 6% of total UK exports).

Analysis of patent data reveals that the UK is relatively specialised in organic chemistry, biotechnology and pharmaceuticals, civil engineering and medical technology and less specialised in optics, electronics, nano-technology, and information technology. This reflects the UK's strategic international contribution to R&D: international firms perform R&D in the UK and export its results, while many UK based innovators organise their inventive activities in a global context.

The number of small and medium-sized enterprises (SMEs) in chemical manufacture (2794), pharmaceutical product manufacture (379) and scientific research and development (3524) in the UK in 2012 is comparable with Germany and France. However, in terms of GVA the UK lags behind Germany in all three sectors, and behind France in the manufacture of basic pharmaceutical products and pharmaceutical preparations.

Vulnerability and Sustainability of Expertise

The UK is estimated to need over 910,000 science, research, engineering and technology professionals and associate professionals between 2010 and 2020 to support the development of those sectors identified by the Government as underpinning the country's strategy for industry.

Chemical science research demonstrates positive knowledge transfer: HEFCE calculated that the value of knowledge exchange was £3 billion in 2010 and £3.3 billion in 2011. In the academic year 2010/2011, total research funding was £179 million, which represents only a small increase compared with the two previous years (£177 million in 2008/2009 and £175 million in 2009/2010).

About 80% of the inventors of major UK blockbuster drugs in the past 40 years, accounting for annual sales of £15 billion, had their PhD training funded by EPSRC, but figures presented by the Science Minister David Willetts in December 2012 show the EPSRC expect to reduce the number of physical science and engineering PhD places they fund by 250 in 2013/14 compared to 2011/12. Over all the seven research councils, 500 fewer places are expected to be funded for STEM subjects, representing a net decrease of almost 10% in two years.

Undergraduates

The last few years have seen steady year-on-year growth of 3-6% in the number of first year undergraduate students enrolled on chemistry degree courses at UK universities, with the 2011/12 figures standing at 5355 students (**Appendix 2**). Whilst this upward trend in undergraduate numbers demonstrates the success both of significant funding and chemistry profile-raising activities among school students (such as "Chemistry for our Future" and the HE-STEM programme)[2] without an increase in capital investment, either to increase the size of current departments or to fund additional departments, student numbers will be unable to meet the demands of the UK's industry strategy because university chemistry departments are already at capacity.

[2] http://www.rsc.org/images/NFERFinalreport_tcm18-159340.pdf

Chemistry departments are expensive to run. *The Follow-up Study of the Finances of Chemistry and Physics Departments in UK Universities* showed that all ten chemistry departments in the sample were running a deficit in 2007/2008, which ranged from 8.7% to 77.9% of total research income.[3] Even with the shift of funding to tuition fees of £6-9k per student, university chemistry departments are running at a loss. The Royal Society of Chemistry and the Institute of Physics have commissioned a report to examine the current finances of university chemistry and physics departments.

Postgraduates

Research funding for chemistry comes from a variety of different sources, including Research Councils UK, charities, government bodies, industry, and public corporations from the UK, the EU and global sources. However, 42% comes from one funding council: £75.8m came from the EPSRC in 2010/11, with the next largest contribution coming from the BBSRC at £10.2m, less than 6% of the funding pool (**Appendix 1**).

The domination of the funding market by a single research council creates a potential vulnerability for chemistry, particularly at the postgraduate level where the sector has seen a shift in the way PhD students are funded towards centres for doctoral training (CDTs). While CDTs provide a means to raise the level of PhD training in a standardised way, making more UK graduates internationally competitive, there is a risk that the roll-out of CDTs could lead to research studentships being focussed in a narrower range of chemical science subjects. In addition, the ability of a CDT and its researchers to quickly change strategic direction based upon rapid developments in the scientific arena has been highlighted as a significant limitation of the model.

UK universities have shown impressive resourcefulness and diverse ways of increasing the amount of funding they receive in order to boost their numbers of PhD students. However, numbers of postgraduate students have shown less steady growth since 2004/05 and the decrease in student numbers between 2010/11 and 2011/12 (**Appendix 2**) suggest that at this level, chemistry remains a vulnerable subject, particularly at those small to medium sized departments that excel in niche areas.

Chemistry graduates play a vital role in many of the industrial sectors identified by the Department for Business, Innovation and Skills (BIS) as vital to the UK's economic growth: aerospace, agricultural technology, automotive, construction, information economy, international education, life sciences, nuclear, offshore wind, oil and gas and professional/business services.

In 2011/12, 39.9% of undergraduate students and 46.3% of postgraduate students entered manufacturing or research and development professions that feed into the aerospace, agricultural, automotive, construction, information economy, life sciences, nuclear, offshore wind, oil and gas and energy storage industries through the design of advanced materials, improvements in manufacturing processes and more efficient use of critical raw materials. The international education sector can draw from a pool of 10.4% of undergraduate students and 37.6% of postgraduate students entering teaching careers, and chemistry students make valuable additions to the professional and financial sectors, with 10.7% of undergraduates and 2.6% of postgraduates moving into these areas after graduation (**Appendix 4**)

[3] http://www.rsc.org/ScienceAndTechnology/Policy/Documents/financechem2010.asp

Sustainable chemistry research and innovation require a strong and steady supply of talented chemists. This depends on the adequate provision of specialist chemistry teachers to train the next generation of researchers and industry professionals.

Although 10.4% of undergraduate and 37.6% postgraduate chemists qualifying in 2012 entered the education sector (**Appendix 4**), the UK is facing a significant shortage of specialist chemistry teachers, despite the vital role these professionals have in supporting the chemistry talent pipeline.

The situation is particularly severe at primary level, where evidence suggests most pupils have made up their mind about science already: recent figures for England show that only 3% of teachers at primary level are science specialists (i.e. someone with both a degree and an initial teacher training qualification in science).

Inspiring and maintaining an interest in chemistry at secondary school is also hampered by a shortage of chemistry specialist teachers (a shortfall of 3700 in 2012), with chemistry often being taught at this level by teachers from other STEM disciplines, and by a lack of funding in schools and sixth form colleges for basic equipment needed to teach practical aspects of chemistry.

The shortage of teaching staff continues to be a problem at university level, with numbers having increased at a far slower rate than the number of undergraduate students they are expected to teach (**Appendix 5**). Of the 93 UK universities, 81 have chemistry departments, which employ 1610 academic staff with a teaching role (either teaching only or teaching and research). Furthermore, figures from HESA show that between 2008/09 and 2010/11, nearly 40% of chemistry departments have seen a decline in the number of research staff employed [HESA Staff Record 2004/05 – 2010/11].

Chemistry remains vulnerable in terms of the diversity of its student population, particularly at higher levels of study, but with chemistry graduates being very employable (only 8.1% of undergraduates and 5.3% of postgraduates are unemployed 6 months after graduation), the subject could have a role to play in addressing some of these diversity issues by improving social mobility.

Currently at 57% of the 2011/12 cohort, the number of male undergraduate chemistry students has increased at a slightly faster rate than the number of female students. Since the ratio of males to females in the relevant age-range has remained roughly equivalent for the last 50 years, this indicates that females are consistently under-represented in chemistry at undergraduate level (**Appendix 6**). The gender imbalance continues at postgraduate level with 61% of doctoral students being male in 2011/12, representing an improvement of only 2% since 2004/05.

The disparity in the socioeconomic backgrounds of undergraduate students has changed little in the last decade. In 2011/12 ~25% of undergraduate chemistry students came from families whose parents worked in technical, semi-routine or routine occupations, showing an under-representation of this group compared to the general UK population, where ~30% of families fall into this category[2] (**Appendix 7**). Work needs to be done to raise the aspirations of young people from poorer socioeconomic backgrounds and ensure that if they decide to study chemistry at university there are no financial barriers to them doing so.

In undergraduate chemistry, black Caribbean students are significantly under-represented relative to the overall numbers in the population. In contrast, Indian and Chinese students are more likely to read undergraduate chemistry than white students: Indian students are twice as likely, and Chinese students are three times as likely.[4] Whilst some ethnic minorities are more likely to continue in chemistry once they have completed an undergraduate degree in the subject, black Caribbean students are far less likely to continue beyond masters' level to complete a PhD (**Appendix 8**). Similarly, students in receipt of Disabled Student's Allowance (DSA) are very unlikely to continue to postgraduate study, whilst students with a declared disability not in receipt of DSA are equally represented at undergraduate and postgraduate levels (**Appendix 9**).

[4] The Royal Society of Chemistry and The Institute of Physics, 2006, *Representation of Ethnic Groups in Chemistry and Physics.* http://www.rsc.org/images/Ethnic%20Web_tcm18-53629.pdf

Appendix 1

Year-on-year trends in research funding for chemistry by source

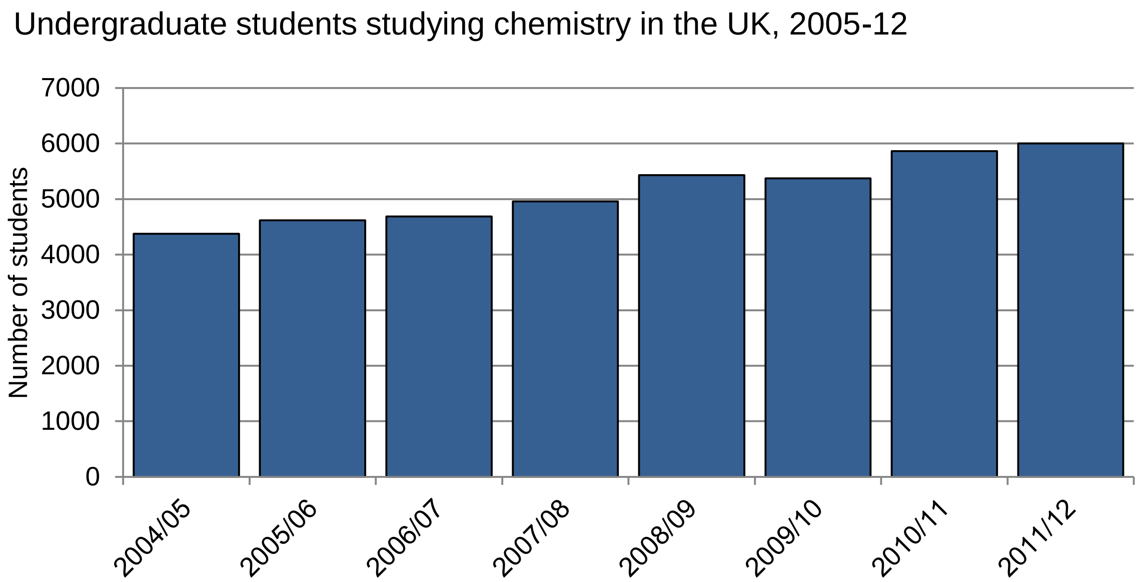
Source	Funding in £1000s					
	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12
BIS Research Councils, The Royal Society etc	92377	107276	112960	107994	103800	99725
UK-based charities (open competitive process)	9668	8219	9522	11108	11784	12729
UK-based charities (other)		863	1536	1537	842	706
UK central government bodies, local authorities, health & hospital authorities	11002	12751	11547	12732	12864	9889
UK industry, commerce and public corporations	16592	14667	14079	11889	13110	13366
EU governmental bodies	13560	14481	15686	18295	23749	30321
EU-based charities (open competitive process)		145	155	176	386	474
EU industry, commerce and public corporations		1422	1725	2295	2433	2495
EU other	1789	253	490	542	1035	978
Non-EU-based charities (open competitive process)		765	3809	810	948	354
Non-EU industry, commerce and public corporations		2230	2905	5525	4561	4851
Non-EU other	5548	2564	1288	1435	2727	3039
Other Sources	1285	1400	1308	1608	1315	1271
Total	**151821**	**167036**	**177010**	**175949**	**179554**	**180198**

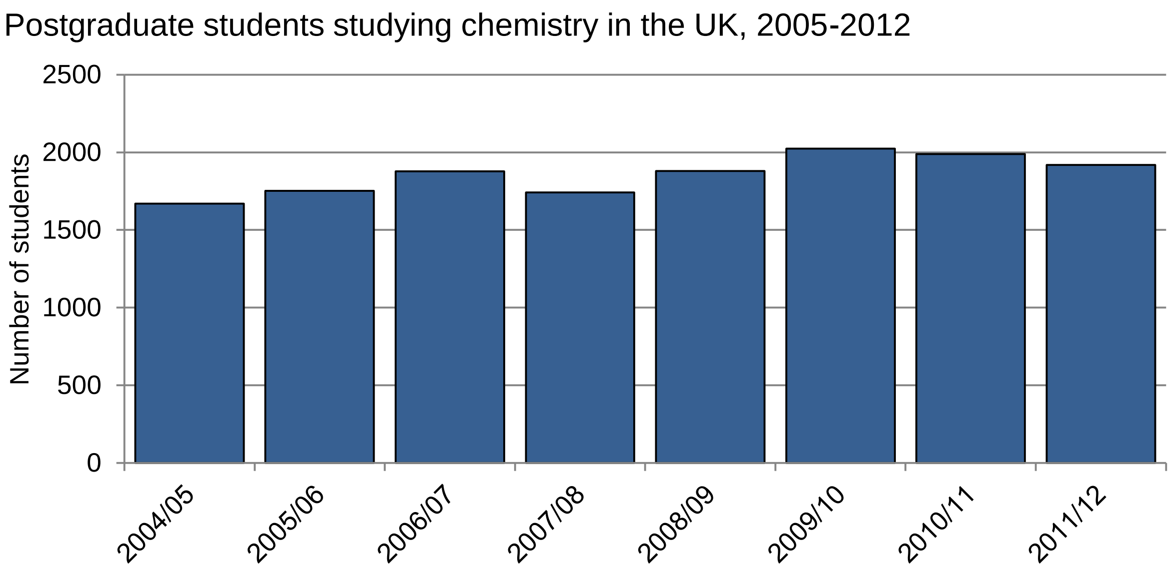
Year-on-year trends for research funding for chemistry from BIS research councils

Source	Funding in £1000s			
	2008/09	2009/10	2010/11	2011/12
Biotechnology & Biological Sciences Research Council	14417	12643	10229	8677
Medical Research Council	1643	2057	2697	2545
Natural Environment Research Council	5801	6007	5905	6037
Engineering & Physical Sciences Research Council	83132	79324	75767	73406
Economic & Social Research Council	42	35	46	21
Arts and Humanities Research Council	9	9	139	101
Science & Technology Facilities Council	789	1137	1034	809
Other (incl. BIS Research Councils, The Royal Society, British Academy & The Royal Society of Edinburgh sponsored research grants and contracts income not included above)	7127	6782	7993	8129
Total	**112960**	**107994**	**103800**	**99725**

Appendix 2

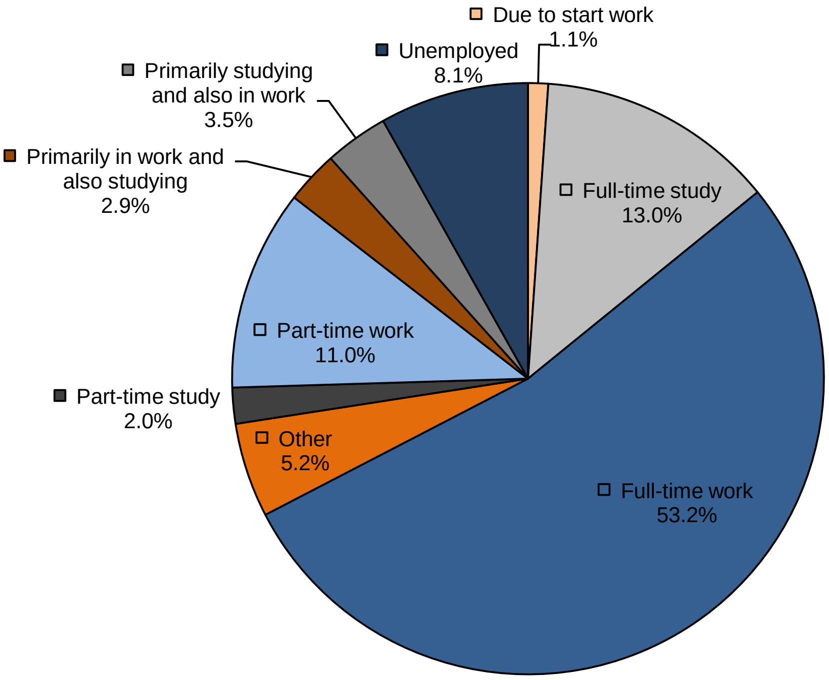
Year-on-year trends for numbers of chemistry students in their first year of study at UK universities at undergraduate and postgraduate levels.



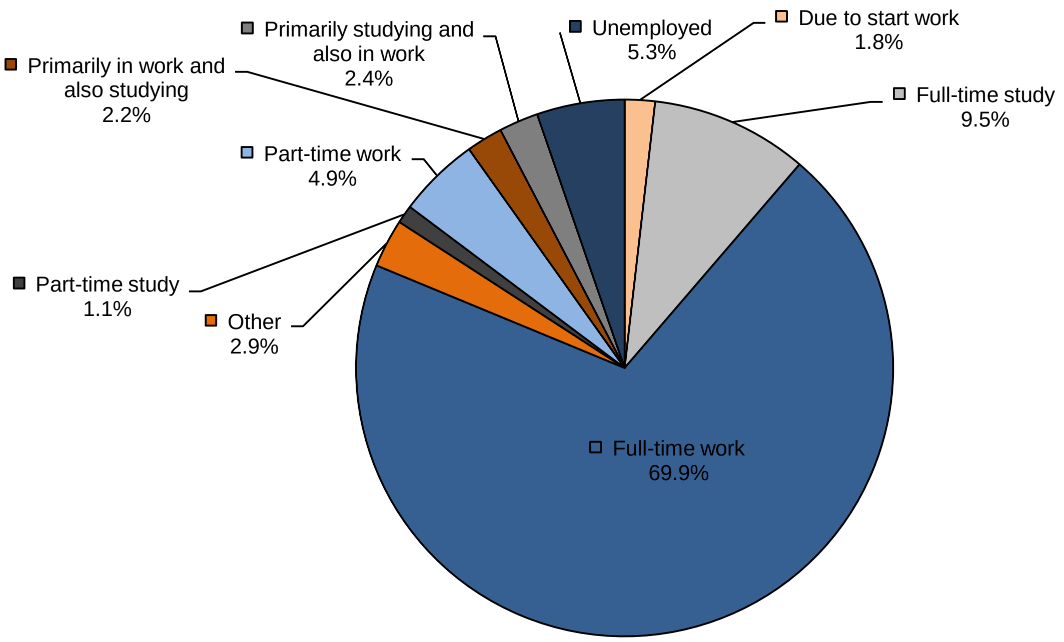


Appendix 3

Employment status of undergraduate leavers in chemistry for 2011/12

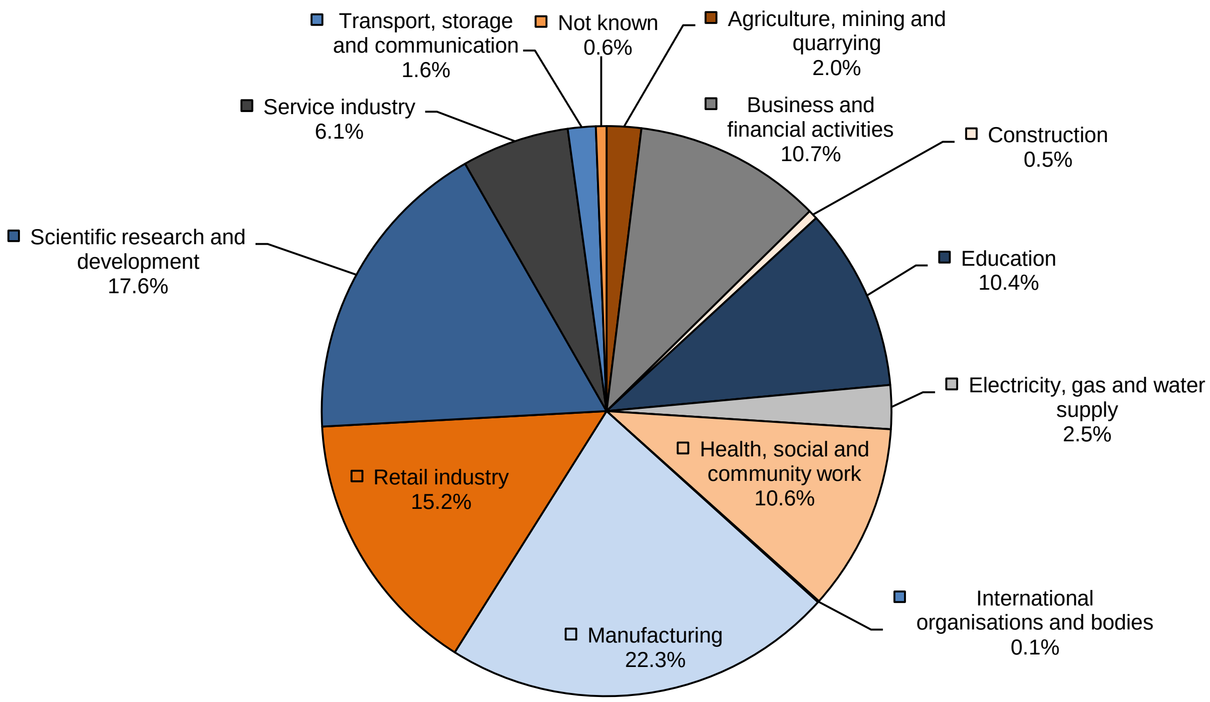


Employment status of postgraduate (doctoral) leavers in chemistry for 2011/12

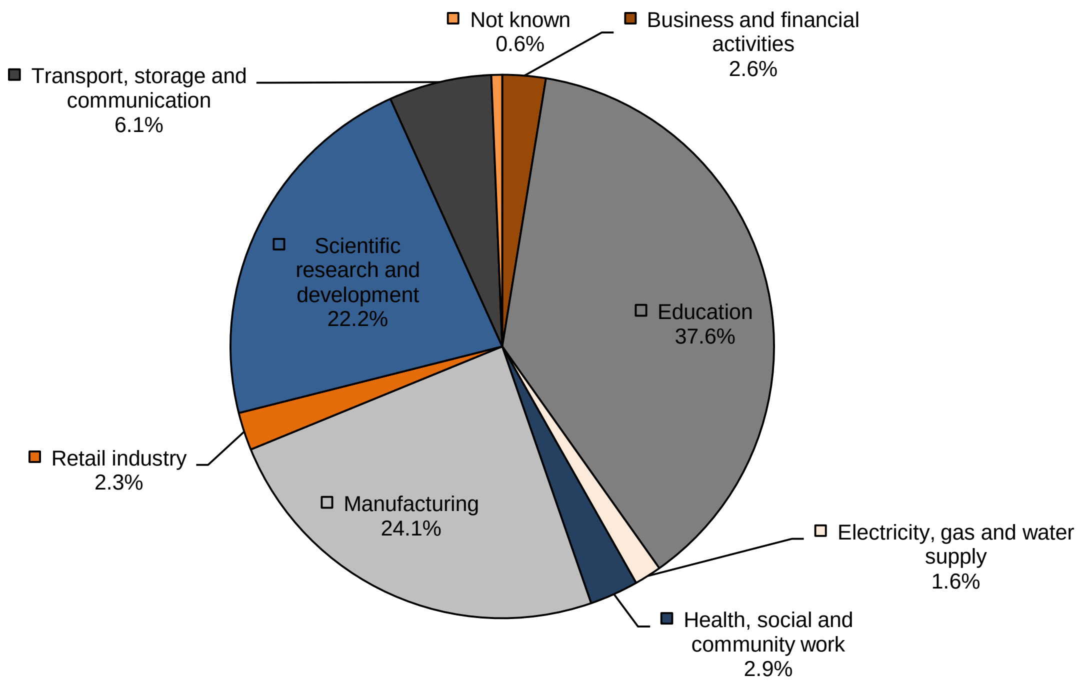


Appendix 4

Destination of undergraduate leavers in chemistry for 2011/12

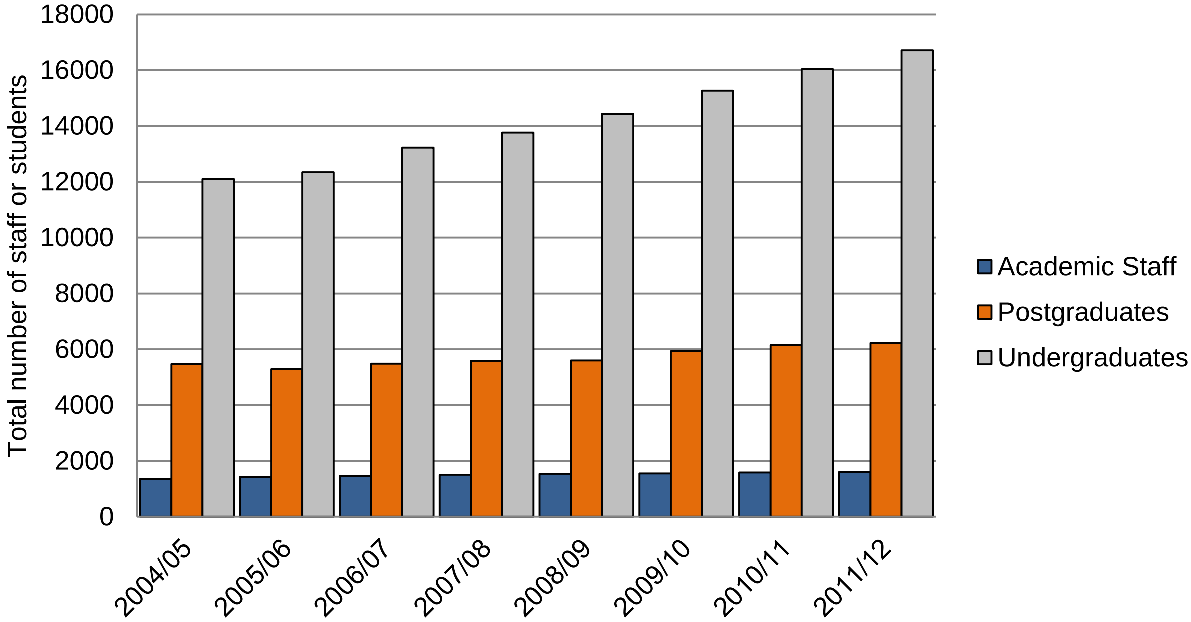


Destination of postgraduate (doctoral) leavers in chemistry for 2011/12



Appendix 5

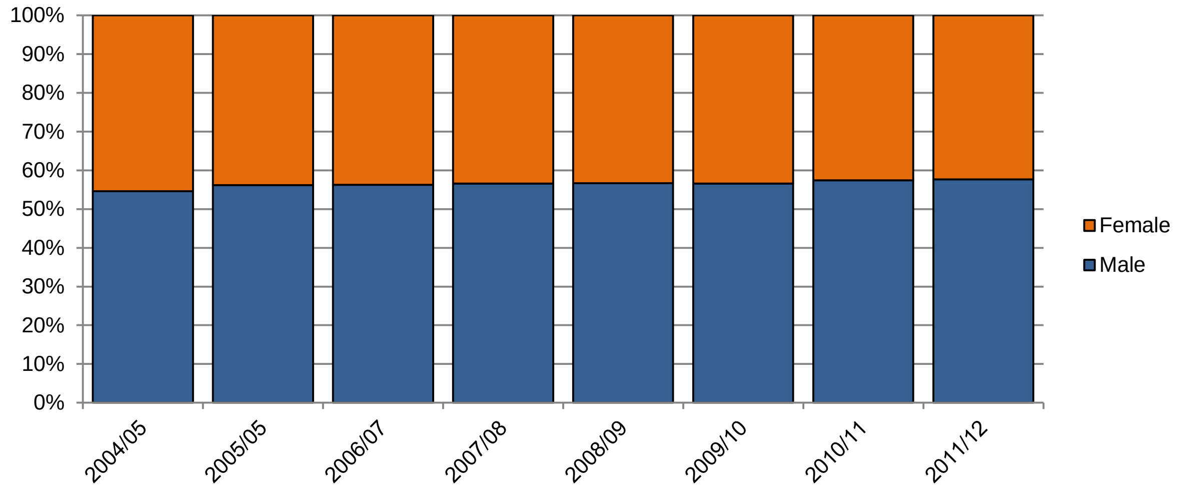
Academic teaching staff (either teaching plus research or teaching only) at UK universities compared to undergraduate and postgraduate student numbers, 2005-12



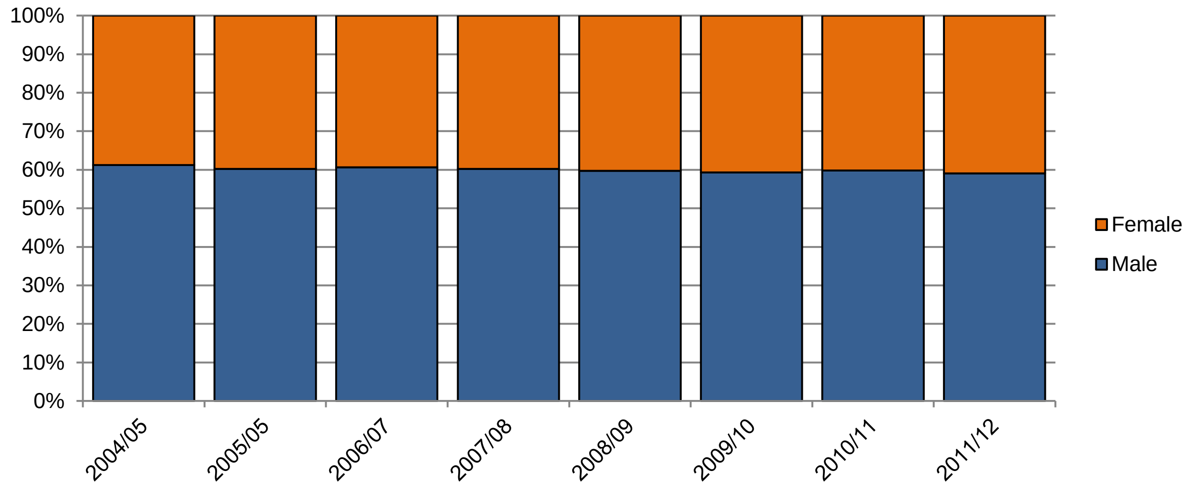
Appendix 6

Year-on-year trends for the gender balance of chemistry students in their first year of study at UK universities at undergraduate and postgraduate levels.

Gender balance of first year chemistry undergraduate students, 2005-12



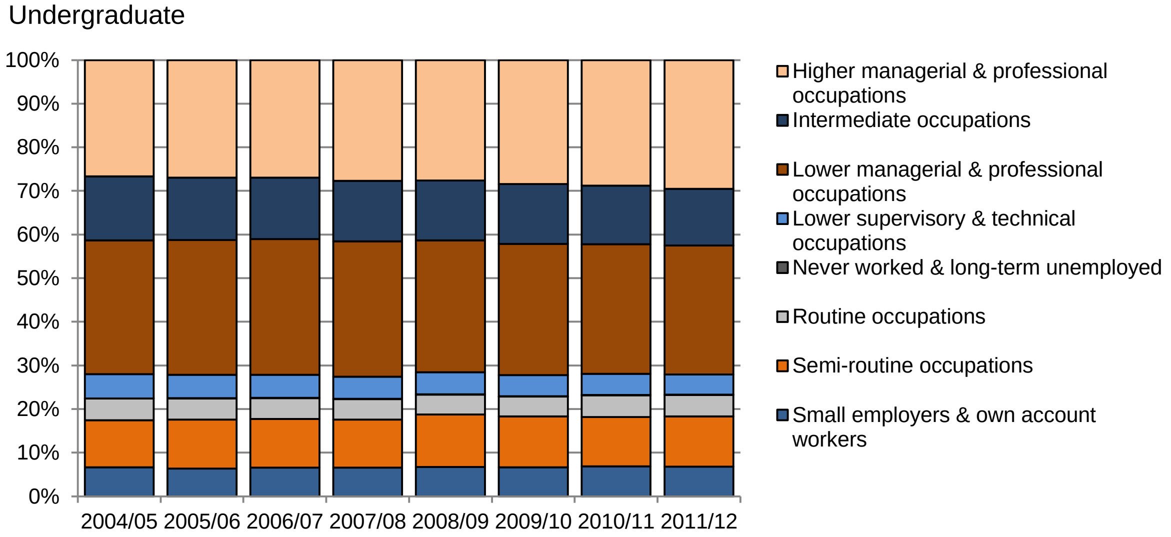
Gender balance of first year chemistry postgraduate students, 2005-12

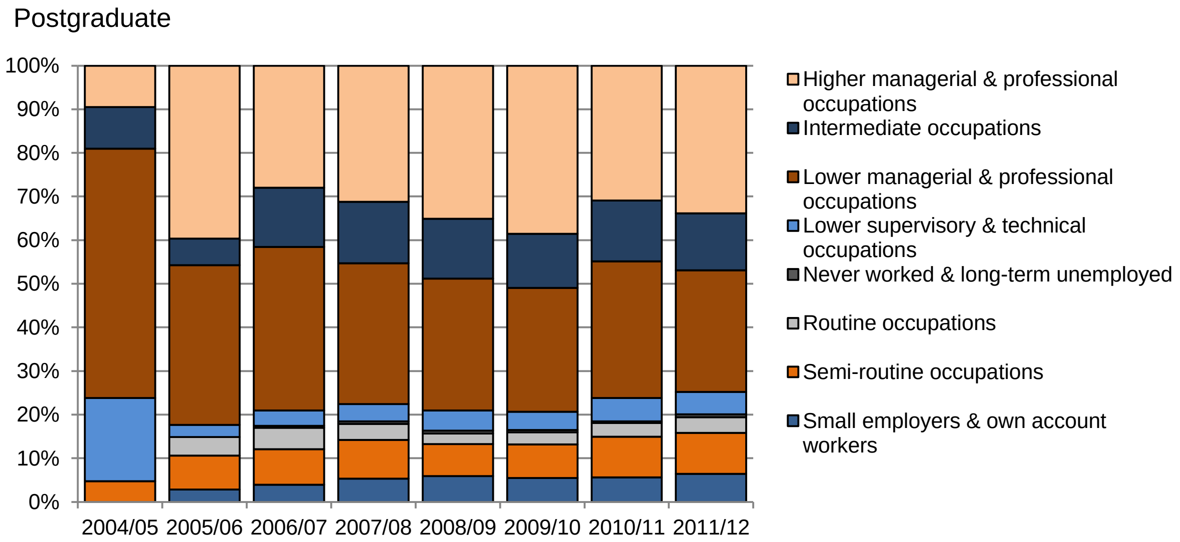


Appendix 7

Year-on-year trends for the socioeconomic background of chemistry students in their first year of study at UK universities at undergraduate and postgraduate levels.

N.B. It is difficult to draw conclusions about how socioeconomic classification changes at postgraduate level because the definition changes from the student's socioeconomic background (their parents' occupation) to their own socioeconomic status (their occupation) at the age of 21.

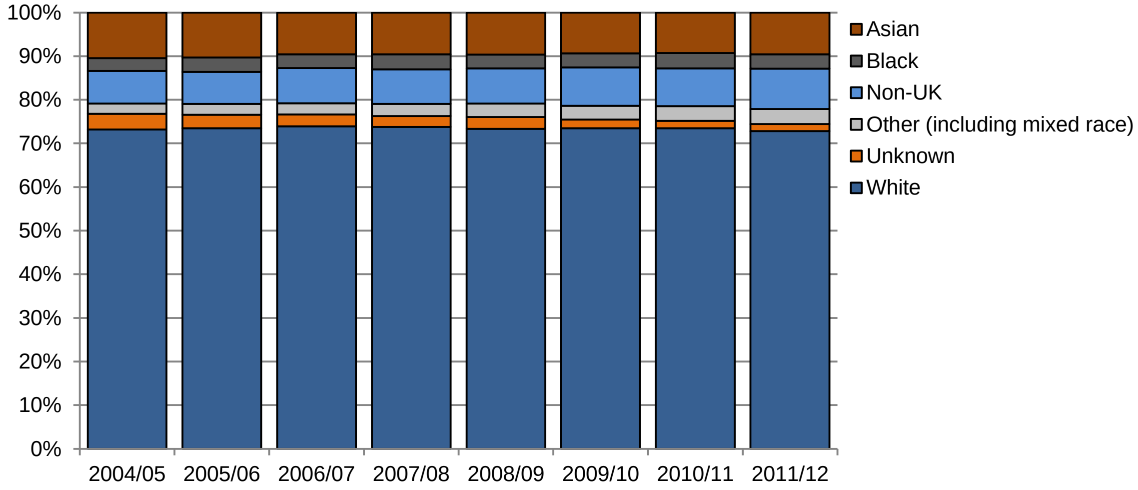




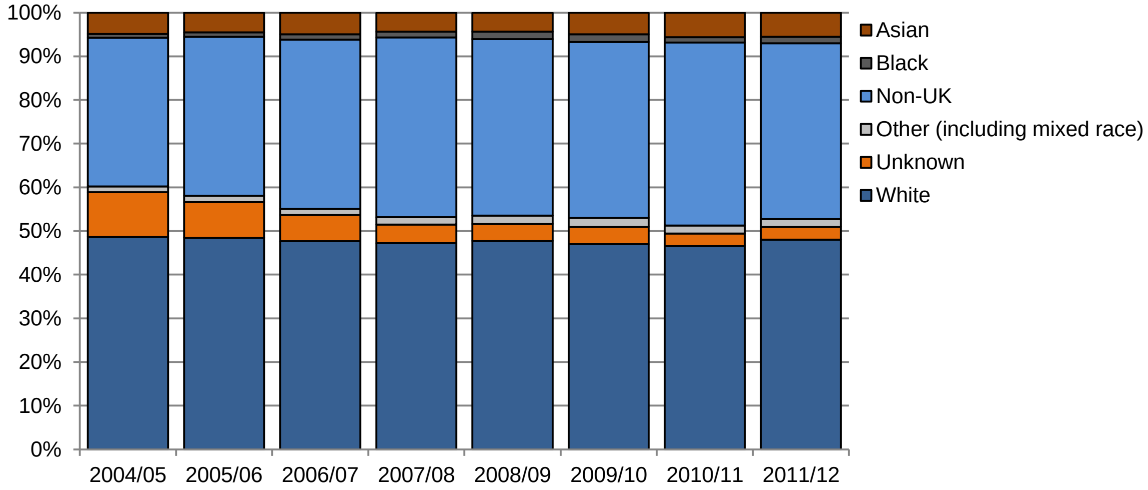
Appendix 8

Year-on-year trends for the ethnicity of chemistry students in their first year of study at UK universities at undergraduate and postgraduate levels.

Undergraduate



Postgraduate



Appendix 9

Year-on-year trends for the declared disability status of chemistry students in their first year of study at UK universities at undergraduate and postgraduate levels.