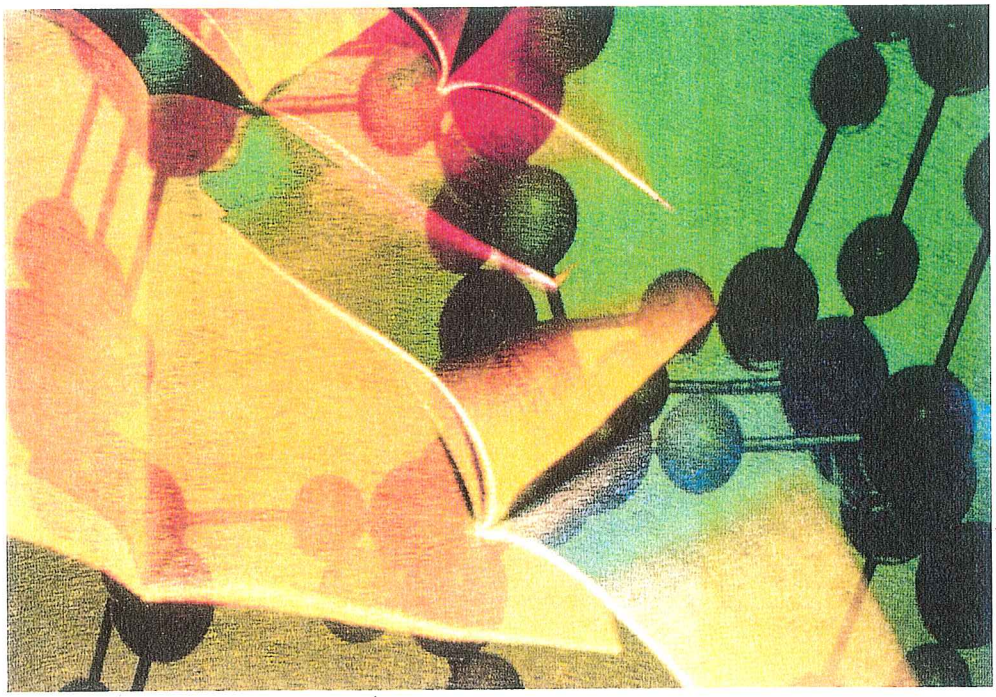
A Strategy for Chemistry Research

Recommendations



Norges forskningsråd
The Research Council of Norway

A Strategy for Chemistry Research

Recommendations

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To the Research Council of Norway

The Chemistry Planning Committee for research at Norwegian universities and colleges hereby submits the following report.

The task has been to prepare a plan for how the Research Council of Norway, Division of Science and Technology, can contribute to, and strengthen the field of chemistry research in Norway. The work was based on the recent international evaluation of chemistry research at Norwegian universities and colleges, comments and information from the evaluated institutions, and our own judgement. The scope of the work was given by a specific mandate, and the field (chemistry) was defined to include the evaluated groups.

The Chemistry Planning Committee is in agreement in its recommendations and conclusions. We hope that this document may serve as a tool for the Research Council's future work in this area.

Bjørn Hafskjold
leader

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Klaus-Joachim Jens	Walter Lund	Norvald Nesse

Geir Walsø
secretary

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SAMMENDRAG

Kjemisk forskning av høy kvalitet er av essensiell betydning for det moderne samfunnet. Norsk økonomi er i høy grad avhengig av vår kjemiske prosessindustri og dens evne til å utvikle, produsere og markedsføre nye kjemiske produkter. Utvikling innen produksjon av nye medisiner, matvarer og materialer er basert på nyvinninger i kjemi. Mange av de miljømessige problemstillinger som vi støter på i dag, er av en slik karakter at det kreves nye vitenskapelig baserte løsninger før det kan skje en videre framgang.

Med et slikt utgangspunkt kunne en vente at kjemi var et blomstrende forskningsfelt i Norge. Det er imidlertid grunn til å være bekymret over situasjonen, som poengtert av Weitkamp-komiteen (Weitkamp *et al*., 1997). Selv om norsk kjemisk, petrokjemisk og metallurgisk industri er konkurransedyktig internasjonalt, og uteksaminerte kandidater fra universitetene våre er attraktive også i utlandet, er det for få faggrupper i forskningsfronten i Norge. Som følge av en nedgang i bevilgningene er antall vitenskapelige stillinger i kjemi ved universitetene redusert i de senere år. I løpet av de nærmeste årene vil et betydelig antall universitetsansatte kjemikere gå av for aldersgrensen. Samtidig er universitetene blitt betydelig mindre konkurransedyktige med hensyn til å rekruttere vitenskapelig personale. Siden bevilgningene ikke har holdt følge med kostnadsøkningen, er situasjonen for grunnleggende forskning også blitt betraktelig verre. Norges forskningsråd og Regjeringen burde anerkjenne at forskning er viktig for framgangen i det norske samfunnet, og at kostnadene til eksperimentell virksomhet er økende.

Universitetene (inklusive de vitenskapelige høgskolene) og de statlige høgskolene må selv aktivt handle for å møte framtiden. Tiltak må iverksettes for å utvikle både infrastruktur, organisering av virksomheten og personalet innenfor normale budsjettrammer. Det forventes en økning i industristøttet forskning ved universitetene på områder av stor betydning for industrien. Forskningsrådet må på sin side rette stor oppmerksomhet mot langsiktig, grunnleggende kjemisk forskning og støtte prosjekter belagt med risiko eller usikkerhet med hensyn til oppnådde resultater. Norsk kjemisk forskning bør sikte mot å ligge i forskningsfronten på utvalgte områder. Dette vil normalt kreve ressursbidrag fra både universitetene, industrien og Forskningsrådet.

De anbefalinger Fagplanutvalget gir til Forskningsrådet er basert på evalueringen av kjemisk forskning ved universitetene og de statlige høgskolene (Weitkamp *et al*., 1997), kommentarer og informasjon fra de institusjonene som er evaluert, i tillegg til utvalgets egne vurderinger. De fleste anbefalingene kan iverksettes i løpet av de nærmeste årene. Fagplanutvalget har derfor ikke eksplisitt uttrykt noen tidshorisont for de enkelte forslag.

Fagplanutvalget gir følgende anbefalinger:

Med hensyn til bevilgningenes størrelse

⇒ Den statistiske analysen presentert av Weitkamp-komiteen viser at de offentlige bevilgninger til kjemisk forskning ved norske universiteter og høgskoler er for lav.

Med hensyn til Forskningsrådets virkemidler

⇒ Universitetene bør inviteres til å spille en mer aktiv rolle ved utforming av Forskningsrådets strategier.

⇒ Strategiske universitetsprogrammer bør i større grad rettes mot å realisere Forskningsrådets nasjonale strategi.

⇒ Bevilgningene til frie prosjekter bør økes, og programmenes omfang bør gjøres bredere.

⇒ Forskningsrådet bør videreutvikle sitt system for forskningsevaluering basert på

- kvalitet, som uttrykt gjennom *peer reviews* og målt ut fra publisering i internasjonale, anerkjente tidsskrifter, relativ siterings-indeks, samt andre faktorer som indikerer kvalitet.
- evne til å initiere, utvikle og vedlikeholde internasjonale samarbeidsprosjekter.
- evne til å bygge og vedlikeholde nasjonale forskningsnettverk.
- evne til å bygge og vedlikeholde et stimulerende studentmiljø.

⇒ Forskningsrådet bør utvide den internasjonale karakteren på sine rådgivende (*peer*) grupper ved evaluering og anbefaling av søknader. Søknadene bør derfor skrives på engelsk.

Med hensyn til fokus på viktige områder

⇒ Støtte bør gis mer selektivt til områder der Norge har et konkurransefortrinn ut fra landets naturressurser eller etablert kompetanse, og til internasjonalt viktige felt der norske forskningsgrupper kan forventes å bidra. Støtte til grunnleggende forskning innen begge disse kategoriene må styrkes.

⇒ Støtte fra Forskningsrådet til de statlige høgskolene bør begrenses til grupper som samarbeider med tilsvarende forskningsgrupper ved et universitet.

⇒ Forskningsrådet bør arrangere seminarer med internasjonale og nasjonale forskere med sikte på diskutere framtidig nasjonal forskningsstrategi og tiltak.

⇒ Universitetene (og de statlige høgskolene) bør som en del av sitt ansvar bruke alle tilgjengelige muligheter gjennom en fornyelse av staben som følge av naturlig avgang til å utvikle områder definert ut fra deres egne strategiske planer og med tilstrekkelig hensyn til Forskningsrådets nasjonale strategi.

Med hensyn til internasjonalt samarbeid

⇒ Antall stipend for å invitere høyt kvalifiserte forskere til Norge for korte perioder (3-12 måneder) bør økes.

⇒ Antall stipend for å invitere unge, utenlandske forskere (*post doc*-kandidater) til Norge bør økes.

⇒ Antall *post doc*-stipend for at norske forskere kan oppholde seg i utlandet bør økes.

⇒ Total bevilgning allokert av Forskningsrådet til støtte av utenlandsopphold under forskertermin bør økes. Det bør innføres et mer fleksibelt system for å tillate kortere utenlandsopphold enn tre måneder.

⇒ Universitetene bør utnytte mulighetene i EU-programmene for samarbeid i nettverk, inklusive støtte til utenlandsopphold for norske *post doc*-kandidater.

Med hensyn til rekruttering

⇒ Antall doktor- og *post doc*-stipend bør økes, fordi dette er en forutsetning for å øke og forbedre norsk kjemisk forskning.

⇒ Doktorstudenter og *post doc*-kandidater bør fortrinnsvis inkluderes i en aktiv forskningsgruppe, for å kunne dra fordel av det stimulerende miljø som et prosjektlag representerer. Bevilgning til driftsmidler knyttet til hvert stipend bør økes, men differensieres i henhold til behovene.

⇒ Et utvekslingsprogram med industrien bør re-etableres for at universitetsansatte kan utvikle relevansen av sin egen forskning og industriansatte kan konsentrere seg om passende vitenskapelige tema.

Med hensyn til mobilitet innen Norge

⇒ Forskningsrådet bør stimulere til arrangement av flere nasjonale og internasjonale seminarer og konferanser. Støtte til de nasjonale "vintermøtene" i biokjemi, organisk kjemi, med flere bør videreføres.

⇒ Forskningsrådet bør stimulere etablering av nettverk. Utbyttet av slike nettverk bør evalueres jevnlig.

⇒ Forskningsrådet bør opprettholde sin nåværende reisestøtte til nasjonale doktorgradskurs.

Med hensyn til lederskap

⇒ Forskningsrådet bør klart uttrykke at de forventer et forskningsstrategisk lederskap på instituttnivå ved universiteter og høgskoler.

Med hensyn til utstyr

⇒ Forskningsrådet bør øke bevilgningen til avansert vitenskapelig utstyr, inklusive "mellom-stort" utstyr (i området KNOK 100-700).

Med hensyn til prioriteringer innen og mellom de ulike kjemiområdene og universitetene

⇒ *Katalyse* er et svært viktig felt for norsk kjemisk industri. Området har sterke grupper, og det er vitenskapelig sett utfordrende. Prioritet bør gis til aktivitetene ved UiO og NTNU.

⇒ *Syntetisk organisk kjemi* er et viktig vitenskapelig felt. Det er stor bekymring for feltets svake posisjon i Norge. Området bør stimuleres ved alle universitetene, men det bør skje en spesialisert arbeidsdeling i henhold til andre lokale, sterke områder.

⇒ *Kjemisk prosessteknologi* er i hovedsak et felt som bare forekommer ved NTNU, som har et nasjonalt ansvar innen dette området. Feltet er av essensiell betydning for norsk industri, og bør støttes. Rekruttering av vitenskapelig personale innen dette feltet bør vises spesiell oppmerksomhet.

⇒ *Uorganisk kjemi* og *Materialvitenskap* er viktige områder for norsk industri, og bør gis høy prioritet ved UiO og NTNU. Grunnleggende forskning bør vektlegges spesielt.

⇒ *Teoretisk kjemi* er et tema ved alle universitetene, og bør støttes. Etablering et nasjonalt nettverk bør prioriteres.

⇒ Innen *Eksperimentell fysikalsk kjemi* bør det prioriteres å støtte spesialiserte utstyrsenheter. Forskningsrådet bør særlig evaluere virksomheten innen kjernemagnetisk resonans (NMR) og vurdere å gi støtte til nytt, avansert utstyr innen dette området.

⇒ *Strukturkjemi*-feltet har rike tradisjoner i Norge. Universitetene bør etablere en arbeidsdeling seg i mellom med hensyn til spesialisering innen dette feltet.

⇒ *Kolloid- og overflatekjemi* er et blomstrende område ved UiB og UiO, som bør få fortsatt betydelig støtte.

⇒ *Analytisk kjemi* har sin sterke posisjon ved UiO, og det er viktig at dette fagmiljøet blir opprettholdt. Virksomhet innen kjemometri bør stimuleres, spesielt ved UiB.

⇒ *Miljøkjemi* bør være et viktig forskningsområde ved UiO og NTNU.

⇒ Den nasjonal aktiviteten i *Kjernekjemi* bør forsette ved UiO.

EXECUTIVE SUMMARY

Chemistry research of high quality is essential for the modern society. The Norwegian economy depends to a large extent on our chemical process industry and its ability to develop, produce, and market new chemical products. Progress in the production of new medicine, food, and materials must be based on innovations in chemistry. Today, many environmental issues have matured to a state where new scientifically based solutions are required before progress can be made.

On this basis, one would expect that chemistry as a research area is flourishing in Norway. However, as pointed out by the Weitkamp Committee (Weitkamp *et al.*, 1997), there is reason for great concern. Although the chemical, petrochemical, and metallurgical industries compete well on the world scene, and our graduate students may compete successfully on the international job market, the number of groups at the cutting edge of chemistry research is too small in Norway. The number of scientific positions in chemistry at the universities have declined in recent years, owing to insufficient public financial support. During the next few years, a significant number of chemists will retire from their university positions, but the universities have become drastically less competitive on the job market. The conditions for basic research have also deteriorated, because the funding has not kept up with the increased expenses. The Research Council and the Government should recognise that research is essential for the prosperity of the Norwegian society, and that experimental research is becoming increasingly expensive.

The universities and colleges must take corrective actions to prepare for the future. Actions related to infrastructure, organisation, and personnel development should be taken within the normal budgets. Industry-supported research at the universities will probably continue to grow in areas of high relevance to the industry. However, the Research Council should give greater attention to long-term basic research in chemistry, and it should support projects also where there is a risk of failure. Norwegian chemistry research should aim for the cutting edge in selected areas, but a combination of resources from the universities, industry, and the Research Council will usually be required.

The Chemistry Planning Committee offers a number of recommendations to the Research Council, based on the recent evaluation of chemistry research at Norwegian universities and colleges (Weitkamp *et al.*, 1997), comments and information from the evaluated institutions, in addition to its own judgement. Most of the recommendations may be implemented within very few years. The Chemistry Planning Committee has therefore not explicitly indicated the time horizon of each recommendation.

The recommendations from the Chemistry Planning Committee are:

With respect to level of funding

⇒ The statistical analysis made by the Weitkamp Committee shows that public funding to chemistry research at the Norwegian universities and colleges is too low, and should be increased.

With respect to the Research Council's tools

⇒ The universities should be invited to play a more active role in forming the Research Council's strategies.

⇒ The strategic university programmes should be more targeted towards realisation of the Research Council's national strategy.

⇒ The funding of free projects should be increased, and the scopes of the programmes should be made wider.

⇒ The Research Council should further develop its system for evaluation of research based on

- quality, as assessed by peer reviews and measured by the publication rate in international, reviewed journals, their relative citation index, and other factors used to probe quality.
- ability to induce, develop, and maintain international co-operations.
- ability to build and maintain national research networks.
- ability to build and maintain a stimulating student environment.

⇒ The Research Council should extend the international character of its peer advisory panel to evaluate and recommend on grant applications, which should be written in English.

With respect to focus on important areas

⇒ Support should be given more selectively to areas in which Norway has a pre-competitive advantage due to its natural resources or established competence, and to internationally important fields in which Norwegian research groups are expected to contribute. Support to basic research in both of these categories should be strengthened.

⇒ Support from the Research Council to the colleges should be limited to groups that collaborate with corresponding university research groups.

⇒ The Research Council should organise workshops with international and national scientists in order to discuss future national strategies and actions.

⇒ The universities (and colleges) should as their responsibility use all opportunities available through renewal of retirements to focus research positions into areas of development defined by their own strategic plans and with due respect to the national strategy of the Research Council.

With respect to international interaction

⇒ The number of grants or scholarships aiming to invite top-level scientists to Norway for a period of time (3-12 months) should be increased.

⇒ The number of scholarships to invite young, foreign scientists at the *post doc* level to Norway should be increased.

⇒ The number of *post doc's* scholarships for Norwegian scientists to go abroad should be increased.

⇒ The total amount allocated by the Research Council to sabbatical leaves should be increased. A more flexible system should be used, allowing shorter periods than three months for staying abroad.

⇒ The universities should better exploit the opportunities given by the EU programmes for network co-operation, including support for Norwegian *post doc's* to stay abroad.

With respect to recruitment

⇒ The number of doctoral and post doctoral scholarships should be increased, as it is a pre-requisite in order to expand and improve the chemistry research in Norway.

⇒ Doctorate students and *post doc's* should preferably be included in an active research group, benefiting from the stimulating environment of a project team. Funding of consumables connected to each scholarship should be increased, but differentiated according to need.

⇒ An interchange programme with the industry should be re-established so that faculty members can improve the relevance of their research and industry employees can concentrate on an appropriate scientific topic.

With respect to mobility in Norway

⇒ More seminars and conferences, national as well as international ones, should be stimulated. The support given to the national "winter meetings" in biochemistry, organic chemistry, and likewise should be continued.

⇒ The Research Council should stimulate the establishment of networks. The outcome of the networks should be evaluated on a regular basis.

⇒ The Research Council should maintain their present travel support to national doctorate courses.

With respect to leadership

⇒ The Research Council should clearly express that they expect a leadership in research strategy at the department level of the universities and colleges.

With respect to equipment

⇒ The Research Council should increase the grants for advanced scientific equipment, including "medium sized" equipment (in the range of KNOK 100-700).

With respect to priorities for the various chemistry topics and universities

⇒ *Catalysis* is a very important field for the Norwegian chemical industry, strong groups exists, and the area is scientifically challenging. Priority should be given to the activities at UiO and NTNU.

⇒ *Synthetic organic chemistry* is a scientifically important field. There is great concern for its weak position in Norway. The area should be stimulated at all universities, but specialised according to other local, strong areas.

⇒ *Chemical engineering* is a topic mainly at NTNU, which has a national responsibility in this field. It is of vital importance for the Norwegian industry, and should be supported. Recruiting scientific personnel in chemical engineering should be given special attention.

⇒ *Inorganic chemistry* and *Materials science* are important for the Norwegian industry, and should be given high priority at UiO and NTNU. Emphasis should be on basic research.

⇒ *Theoretical chemistry* is a topic at all universities, and should be supported. Priority should be given to establish a national network.

⇒ In *Experimental physical chemistry*, priority should be given to specialised equipment. In particular, the Research Council should evaluate the nuclear magnetic resonance (NMR) activities and consider supporting new, advanced equipment in this area.

⇒ *Structural chemistry* is an area with rich history in Norway. The universities should specialise more in various aspects of this field.

⇒ *Colloid and surface chemistry* is flourishing at UiB and UiO, which should continue to receive significant support.

⇒ *Analytical chemistry* has its stronghold at UiO, and it is vital that this environment is maintained. The chemometrics activities should be stimulated, notably at UiB.

⇒ *Environmental chemistry* should be a significant research field at UiO and NTNU.

⇒ The national activity in *Nuclear chemistry* should continue at UiO.

INTRODUCTION

This is the report of the Chemistry Planning Committee set up by the Research Council of Norway to recommend priorities and actions by the council with respect to research in chemistry and chemical engineering at the Norwegian universities and colleges. Prior to this work an international panel (in this report named as the Weitkamp Committee) had evaluated chemistry research at Norwegian universities and colleges (Weitkamp *et al.*, 1997).

The Chemistry Planning Committee

The members of the Chemistry Planning Committee have been:

Professor Bjørn Hafskjold, Department of Physical Chemistry, Norwegian University of Science and Technology (NTNU), Trondheim (leader)
Department head Bjørg Andresen, Institute for Energy Technology (IFE), Kjeller
Associate professor Knut Børve, Department of Chemistry, University of Bergen (UiB)
Professor Odd Gropen, Department of Chemistry, University of Tromsø (UiTø)
Research manager Klaus-Joachim Jens, Borealis, Stathelle
Professor Walter Lund, Department of Chemistry, University of Oslo (UiO)
Professor Norvald Nesse, Department of Chemical Engineering, NTNU, Trondheim

Faculty director Geir Walsø, Faculty of Chemistry and Biology, NTNU, Trondheim, has been secretary for the planning committee.

The committee had eight meetings from November 1997 to September 1998. Representatives from the Research Council also attended these meetings.

The mandate

According to the mandate, the Chemistry Planning Committee should recommend on:

⇒ Actions for strengthening the field of chemistry (in Norway)
⇒ Utilisation of economic means and specific priority actions within three alternative budget situations: Reduction, zero growth, and increase, including relevant actions carried out by the universities and colleges themselves within their own budget planning
⇒ Actions for contributing to better co-operation, flexibility and mobility between research groups, and to a better national co-ordination and sharing of responsibilities
⇒ Specific fields/research groups which should be given special attention
⇒ The recruitment situation
⇒ Actions for promoting the mobility and increased internationalisation

The complete mandate is given in the Appendix.

The report

The committee has chosen to present the report with its recommendations under the following headings:

Challenges

This chapter shows the importance of chemistry in the society, both from a national and an international point of view.

Tasks and tools

This chapter describes the situation of research in chemistry on the national scene. The Chemistry Planning Committee recommends actions concerning the general level of funding, the tools of the Research Council, important areas that need special attention, international interaction, mobility within Norway, recruitment, departmental leadership at the universities, and equipment investments, operation, and maintenance.

Priorities

Under this heading the Chemistry Planning Committee sums up the situation based on the report by the Weitkamp Committee, comments from the various departments, and an analysis made by the planning committee itself. The recommendations are made for each sub-field of chemistry, with a few exceptions, in consistence with the main research areas presented by the Weitkamp Committee. The sequence of presenting the areas gives no priority of one field to the other.

For each area, the Chemistry Planning Committee gives recommendations within the three alternative budget situations: 5% reduction, zero growth, and 5-10% increase. The committee also makes suggestions with respect to national co-ordination and to local actions.

CHALLENGES

Chemistry has traditionally had a strong position in Norway, both from scientific and industrial points of view. An outstanding industrial example is Norsk Hydro, based on the research of Kristian Birkeland, which has developed to a significant chemical and metallurgical company in the world. The Nobel laureate, Odd Hassel, pioneered a research activity in structural chemistry that has since dominated the Norwegian physical chemistry research. These and many other Norwegian scientists have contributed to the development of the chemical industry and science community. They have put Norway in leading positions in some areas of chemistry research. It is a challenge to continue this tradition of science and entrepreneur-ship while at the same time stimulate change and flexibility.

Norway has rich natural resources: Fisheries, oil, gas, forests, minerals, and hydroelectric power. This abundance has been fortunate for the development of the economy and standard of living in Norway. The challenge to the universities is to create new ideas and make critical, independent analyses of the developments.

Chemistry is also associated with some of the problems in society today. The smoke and smell from chemical plants, which once were a sign of growth and prosperity in local communities is today known as an environmental problem and a dirty side of chemistry. Although this environmental problem is well identified and to a large extent solved, use of new chemical products and better understanding of the environment's tolerance to emissions give new challenges to chemists. Improved analytical techniques have shown that pollutants to ground, water, and air that were not considered dangerous or just not known, present some of today's environmental hazards. Chemicals adsorbed to dust from roads and certain chemicals used in construction work are just two examples.

Industrial ecology is an emerging science, which is related to many aspects of chemistry. The most universal measure of a sustainable development may be found in thermodynamics as produced entropy. Specific challenges are analyses of chemical parameters, especially their variations over times that are long compared to the memory of humans, and understanding of the interaction between human activities and the nature.

The Norwegian chemical industry has been dominated by the fact that Norway has had plentiful natural resources, including cheap electrical energy. This has made Norway largely a producer of raw materials, such as lumber, pulp, metals, fish, and in recent years also oil and gas. This industry has been developed to a very advanced level, for instance is the Norwegian aluminium industry a world leader in energy efficiency of aluminium production, which is a major reason why this industry has been so successful. Some of the technical solutions in e.g. enhanced oil recovery are based on very complex chemistry, and skilled chemists have indeed contributed significantly to the high recovery from Norwegian oil reservoirs. However, there are still many challenges today, for instance in the fertiliser industry to produce qualities according to customer specifications, in the metallurgical industry to produce more consumer-end products, and in the process industry to develop cleaner (or zero-emission) processes.

One of the major issues in the world today is the energy situation. Chemists contribute to the development of renewable energy sources, such as solar energy. Norwegian chemists are active in solar energy research. However, improved production and better use of fossil fuels

remain the major challenge due to the importance of this type of energy in the Norwegian (and world) economy. Processing and deposition of carbon dioxide is a major problem that requires skilled chemists. Conversion of chemical energy to electricity in fuel cells is a research area that is active in Norway, and where major challenges to chemists are found.

Many of the technical solutions that improve the quality of life depend on materials that did not exist some decades ago. Indeed, materials science is probably the most extensive research area today. For instance, the technical success of fuel cells, and batteries that would represent a breakthrough for zero-emission transportation, depends on finding suitable materials. Norway has had outstanding chemists in the area of functional materials, notably John Ugelstad who developed a process for production of monodisperse polystyrene particles that have found a wide range of applications, especially in medicine. There are tremendous challenges to chemists and materials scientists to develop new functional materials for use in medicine, electronics, households, etc. Materials that are made for construction (structural materials), have also seen a significant development, especially composite materials. A new, exciting area is development of smart materials, e.g. materials that can repair or correct themselves if they do not function the way they were designed for.

The gap between basic science and application is reduced, as seen for instance in developing new medicines in the pharmaceutical industry. An important element in this is molecular technology, i.e. the technology of designing functional or chemical properties by planned molecular design. This is a rapidly growing field for chemists, leaning heavily on theoretical and computational chemistry, which in turn has been made possible by the development of large-scale computers. Some examples where the combination of theoretical and practical developments will interact more strongly in the future are catalysis, surface chemistry, functional materials, and biotechnology.

Norway has vast resources related to the marine environment, and Norwegian chemists have been very active in marine biology and biochemistry. Fish farming is in many respects an immature industry, and challenges for chemists will likely come in food production based on fish as raw material, operation of fish farms, and marine pollution.

A rapidly growing area that is not within the scope of this report, but where chemists play an important role, is in life sciences. Biochemistry has had an enormous progress during the last few decades, from determining the structure of DNA to the Human Genome Project. The basic understanding acquired is put into industrial use in biotechnology, such as in fermentation and use of biopolymers.

An entirely different aspect of challenges in chemistry is the relation between the science community and society at large. Many sides of chemistry have a negative image, caused by the impact of chemical industry on the environment. Nevertheless, chemists are needed to solve many problems and find new solutions in today's society. It is therefore very important that recruitment to chemistry studies and to natural sciences at large is strengthened. This has to start early in school, where a major problem in Norway today is that there are too few teachers that have specialised in the natural science.

The contact between industry and academia should be strengthened on the basis that industrial development in the future will depend more and more on scientifically founded knowledge, and academia should provide an independent and necessary correction to industry.

These challenges should be met with a more active Norwegian research policy for chemistry. More effort should be put into the important areas, the number of groups that are in the forefront of chemistry research, as well as the level of funding, should be increased. The interactions between Norwegian and foreign scientists should be improved, academic personnel and students should be supported to interact nationally and internationally through mobility programmes, and recruitment of scientific personnel should be strengthened.

TASKS AND TOOLS

Chemistry research of high quality is essential for the industry to achieve a sustainable balance between utilisation and consumption of resources, to develop new products and processes, and to be cost-effective. However, the value of research goes beyond the industry. Independent and corrective scientific communities working in a long-term perspective, are important because they provide a base of knowledge available to governmental institutions, the educational system, and the public. Competent individuals represent a valuable and necessary resource for the society in order to maintain and further develop our quality of life.

The research must be based on high scientific quality with respect to training of personnel, equipment, and infrastructure. Training will include formal education, international experience, and interaction with other universities, industry and governmental regulatory institutions. Scientific equipment includes local equipment, equipment in national centres, and access to super-national centres. Infrastructure includes laboratory facilities, forum for national and international meetings, seminars, and modes of effective communication.

The evaluation of the chemistry research at the Norwegian universities and colleges by the Weitkamp Committee (Weitkamp *et al.*, 1997) has revealed that there are serious deficiencies in the structure and funding of Norwegian chemistry in order to fulfil the main goals defined above. To remedy this situation the goals presented below should be set by the Research Council.

Level of funding

It is well documented by the Weitkamp Committee that the field of chemistry has suffered from less attention by the authorities and that the funding for chemical research has decreased as compared to other fields of science.

The general financial situation for research in natural science and technology has declined over the last (5-10) years (example: A reduction of 5,6% from 1993 to 1995, as shown by Weitkamp *et al.*, 1997), leaving less and less resources for investments in scientific equipment and for expenses of running the research (and even the teaching) activities. During the same period grants from the Research Council have to some extent compensated this lack of resources, mainly for large, advanced scientific equipment. However, the need for "medium sized" equipment (in the range of KNOK 100-700) is repeatedly expressed by all universities. In conclusion, it may be stated that the level of long term investments of the Norwegian society in higher education and research has dramatically eroded. This has to be seen in a context where comparable nations have increased their investments in research, measured as a fraction of the gross national product.

There is an immediate need to reverse this critical development. It is necessary to make the authorities aware of the fact that research in general, and especially in an experimental field such as chemistry, is indeed expensive. They should be reminded that investments in chemical research is essential for the prosperity of the Norwegian society. Success in selected areas of research depends on a solid educational fundament, and it is of vital importance that this basis is strengthened.

The table below shows the importance of some on-shore based industries for the Norwegian export. All of these industries depend on highly qualified technical personnel, preferably educated in Norway. Taking into account the annual turnover of these industries and especially that about 95% of the products from them are exported out of Norway, it is inconsistent to reduce the funding of research and education at the universities and colleges, providing candidates for these industries.

Table 1. Objectives for various branches of industry, numbers in NOK billions;
(Source: PROSMAT 2000, the Research Council of Norway, Division of Industry and Energy)

Branch	**Annual turnover produced in Norway in 1992**	**Expected increase in turnover in Norway in 2005**	**Expected reduction in expenses**
Pulp and paper	12	5	1
Light metals	15	9	3
Ferro alloys	5	No change	1
Petrochemistry/ plastics	17	7	3
Fine and special chemicals	5	5	-

The Research Council plays an important role in directing support and resources to the various fields of science, and the Chemistry Planning Committee recommends to give greater attention to the field of chemistry because the relevant industry generates a significant share of the Norwegian on-shore based export value.

The Research Council's tools

As an overall objective, the Research Council should support chemistry research aiming to develop and maintain

- a sustainable, innovative, and competitive chemical industry
- independent and corrective scientific communities of international standards at the universities and research institutions
- competent specialists and individuals with a broad range of experience

In this report, the Chemistry Planning Committee points out certain areas to be supported by the various tools available defined by the council (*Strategi for Naturvitenskap og teknologi 1996-2000*):

- Free projects (i.e. projects not covered by strategic and national programmes)
- Strategic programmes
- National programmes for basic research and network co-operation

The balance of funding between free projects, strategic programmes, and national programmes is difficult and should be focused. The Chemistry Planning Committee recommends that the universities should be invited to play a more active role in forming the Research Council's strategies.

The funding of free projects should be increased. The strategic university programmes should be more targeted towards realisation of the Research Council's national strategy, and the scopes of the national programmes should be made wider.

In order to point out new areas of possible attention, it is recommended that the Research Council should organise workshops with international and national scientists in order to discuss future national strategies.

For the universities the challenge is to:
- present (political) arguments for an overall increase in funding to the universities
- present (political) arguments for an increase of the budget of the Research Council allocated for investments
- agree upon a national sharing of responsibilities, thus concentrating some activities at certain universities (as national "centres")
- increase the part of their own budgets allocated for scientific equipment

The Weitkamp Committee points out that the goal of Norwegian research funding policy must be to provide a climate where centres of international excellence can develop and flourish. One of the specific goals must be to increase the number of groups that are at the forefront of chemistry research, as shown by their publication rates, citation rates and peer reviews.

The Chemistry Planning Committee supports this conclusion strongly. The committee recommends that the Research Council should further develop its system for evaluation of research based on
- quality, as assessed by peer reviews and measured by the publication rate in international, reviewed journals, their relative citation index, and other factors used to probe quality
- ability to induce, develop, and maintain international co-operations
- ability to build and maintain national research networks
- ability to build and maintain a stimulating student environment

The Chemistry Planning Committee also recommends to extend the international character of its peer advisory panel to the Research Council for evaluation and recommendation on grant applications**.** Thus the applications to the council need to be presented in English. It is further recommended that the universities (and colleges) should develop mechanisms for support to selective groups based on the criteria listed above.

Focus on important areas

An obvious statement for a small country like Norway is that not all areas in chemistry could be covered by each university. The grants given to the universities by the Ministry of Education, Research, and Church Affairs have in the last years to a large extent been correlated to student numbers (number of candidates, number of credits, etc). In the future, due to a change in the funding procedures, the grants will probably be split in two parts, one

related to teaching and the other to the research. Still, given a stagnant or even decreasing situation in student numbers in the future, it is possible that the ministry allocations for running the universities will not increase. However, this is an unfortunate situation, especially regarding the fact that chemical research is of great importance to the Norwegian economy. If this will be the situation, the only possible way to establish new activities is to close down existing ones. This also implies a need to concentrate particular activities at one or two of the universities, being able to meet the responsibility of having a certain capacity and competence on a national scale. The distribution of each field must be chosen from criteria such as

- national needs
- international evaluation and standing
- relations to connected institutions
- available equipment, infrastructure

It is the opinion of the Chemistry Planning Committee that support from the Research Council to the colleges should only be given to college research groups that have collaboration with a corresponding university research group. As a rule, equipment granted to such collaborations should be located at the university partner. This is based on the fact that most of the groups at the colleges are close to or below critical size. Partnership with university groups is in accordance with the objective to improve national co-ordination and sharing of responsibilities between the various fields and research groups, providing a better total utilisation of resources.

The Weitkamp Committee implies that the research in chemistry in Norway to a large extent is based on traditions. There has been little staff mobility between the universities, and too few new areas have been explored over the years. Those changes that have taken place, appear to be towards applied rather than basic research. The committee further states that Norwegian structures are rather rigid, leadership is often poor, and strategy is insufficiently developed. This lack of planning has resulted in missed opportunities, as expressed by the Weitkamp Committee, which recommends that the research in chemistry should concentrate on areas within chemistry that are important to Norway, and such areas that are weakly developed should be strengthened. Support should be given to fields in which Norway has a pre-competitive advantage due to its natural resources or established competence.

The Chemistry Planning Committee supports this view, which is in accordance with priorities given by the Research Council itself (*Innspill til Forskningsmeldingen 1998, side 13*). Furthermore, the committee recommends that the council should especially provide support to basic research in such areas. However, support should also be given to internationally important fields in which Norwegian research groups are expected to give contributions.

Establishing new research areas at the universities in the near future will probably have to be at the expense of existing ones. Closing down fields of research calls for a more active strategic planning than often is the case, and the ability to transform the activity to new areas could possibly be among the criteria for measuring success of a research group.

The Chemistry Planning Committee recommends that support to new projects should primarily be given to proven strong groups (based on their ability to present quality and the breadth of their activities) and to the project's relevance to Norway (pre-competitive areas).

In addition, supporting free projects are appropriate means for scientific renewal, and it is recommended to at least sustain the number of free projects.

In order to ensure renewal of research topics in a context of structured research, special attention has to be paid to “seed funding”, i.e. funding directed towards opening up new areas of research.

International interaction

The communication between Norwegian scientists and leading scientific groups abroad working in areas of importance to Norway, should be improved. The Research Council may play an important role in this respect.

One of the most important tools for stimulating international co-operation, is the opportunity of faculty members to be given sabbatical leave, usually for one year, for carrying out research at a university or research institute abroad. With the exception of UiTø, making use of the sabbatical year is not as common as preferred.

The Chemistry Planning Committee recommends that the total sum from the Research Council for granting sabbaticals should be increased. This will make it possible to support a greater number of faculty members per year than is the case today, aiming at the accepted university "standard" of a sabbatical leave every seventh year. The grants allocated to support a stay at a foreign university or research institution should give a full economic compensation. The typical family situation in Norway is that both man and wife are working, and it is also rather common that they both have a professional career. Thus, one whole year is often a too long period to be away from the job for the spouse. The Chemistry Planning Committee recommends to establish a more flexible system, allowing shorter periods than three months for staying abroad.

In order to connect the Norwegian research community better to the international arena, as well as fostering personal international relationships, the Weitkamp Committee recommends the Research Council to promote workshops and weekend “retreats”, designed to involve special topics and high-level invited speakers. The Chemistry Planning Committee supports the conclusions of the Weitkamp Committee that more colloquia, seminars and conferences, national as well as international ones, should be organised, and the Research Council should give special funding for such activities. The support given to the "winter meetings" in biochemistry, organic chemistry and likewise should be continued.

The universities are recommended to exploit the opportunities given by the EU programmes for network co-operation, including support for foreign stays for Norwegian *post doc's*. This opportunity has not been exploited satisfactorily in EU's 4th framework programme.

International stimulation to the research groups is not only accomplished by making it possible for Norwegian scientific personnel to stay abroad for a period of time. The planning committee recommends to increase the number of grants or scholarships aiming to invite top-level scientists to Norway for a period of time (3-12 months), to prevent an introspective attitude in the research groups. The number of scholarships to invite young, foreign scientists

at the *post doc* level to Norway should be increased, as well as the number of *post doc's* scholarships for Norwegian scientists to go abroad.

Mechanisms should be created for evaluating the use of funding after closing the scholarship/project. Furthermore mechanisms need to be created to use this data in a learning phase, providing a better fundament for future funding in accordance with the intentions.

Mobility within Norway

Mobility at the national level is important for stimulating new ideas, making personal contacts, getting access to scientific instrumentation, and improved co-ordination of research. The Weitkamp Committee states that there is little mobility of staff between the Norwegian universities. This may have several explanations, one being the present procedure of being appointed professor. As until a few years ago, the usual way of becoming a full professor was to apply for a vacant chair, often at another university. The present procedure is to give all faculty members the right to become a professor at their own university, provided that the qualifications are adequate.

To some extent, the lack of mobility may be compensated by increased national co-operation. The Weitkamp Committee suggests, and the Chemistry Planning Committee supports the establishment of formalised networks, funded by the Research Council, in a number of areas within chemistry. These areas are indicated under *Priorities* in the next chapter. The outcome of the networks should be evaluated on a regular basis. A potential secondary effect of networks may be increased mobility, in particular at the doctorate level.

To increase mutual understanding and cross-fertilisation, an interchange programme with the industry should be re-established so that faculty members can improve the relevance of their research and industry employees can concentrate on an appropriate scientific topic.

Turning to the question of student mobility, the Chemistry Planning Committee finds that implementing similar undergraduate curricula in the basic fields like chemistry, physics and mathematics, would be the best way of facilitating mobility. At advanced graduate and doctorate level, national courses which draw on local competence are powerful means of achieving mobility. However, financing courses of the latter kind is not a task for the Research Council, but is rather a co-operative responsibility of the universities. Even so, travel costs should be supported by the Research Council.

Recruitment

The average age of the scientific personnel in the field of chemistry and other natural sciences at the universities and colleges is rather high. During the next ten years, roughly half the number of the professors in chemistry and chemical engineering will retire. Thus a very important task in this period is to strengthen the recruitment of scientific personnel. To provide a smooth renewal, it is recommended that the Research Council provides several types of scholarships for dr.-students, *post doc's,* and senior researchers (retiring professors).

The Weitkamp Committee points out that the number of dr.-students pr million capita is dramatically lower in Norway (8) than other European countries (about 20). Increasing the number of doctorates in Norway would provide a larger pool for recruiting scientific personnel to faculty positions as well as to the industry. An equally important aspect is that doctoral students constitute a key resource in chemistry research at the universities. Increasing the number of doctoral scholarships is a prerequisite in order to expand and improve research within chemistry in Norway. Dr.-students and *post doc'*s should preferable be included in an active research group, benefiting from the stimulating environment of a project team. The Chemistry Planning Committee recommends to provide a realistic funding of consumables connected to each scholarship.

In a positive vein, the high rate of renewal of the staff gives the universities a unique opportunity of implementing structural changes. The universities (and colleges) should as their responsibility use all opportunities available through renewal of retirements to focus research positions into areas of development defined by their own strategic plans and with due respect to the national strategy of the Research Council.

Leadership

As mentioned above, the Weitkamp Committee states that university leadership and strategy planning are insufficiently developed in Norway. In order to implement a long-term strategy for chemistry research in Norway, the Research Council should clearly express that they expect a leadership in research strategy at the department level of the universities and colleges.

The role of the head of the department is gradually changing at the universities in Norway. Previously, the head was often elected on a "your turn" basis, and the position was considered to be an administrative head rather than a scientific leader. However, today the responsibilities of the head of the department as a leader has been well defined (UiO, 1996; NTNU, 1998). The head shall ensure good economic and personal conditions for research, promote quality and productivity, and propose strategic aims and priorities. Relevant documentation of the productivity of the staff, both in research and education, is an important tool for this work. However, the experience of the Weitkamp Committee was obviously that this new role of the department head has so far had little impact on the leadership of the departments. However, leadership as it is often seen in the industry, is contradictory to the Act of universities and colleges, which has a more democratic basis.

Because of the increasing importance of, and demands on the head of department, it is essential that the universities and colleges establish stimulating means that make it attractive to accept a departmental leadership.

Some of the universities have recently made organisational changes, which may give legitimacy to sub-units such as sections or research groups. One of the advantages of this structure is that the head of department can find support for practising the leadership through a board of section or group leaders.

A research group is the basic unit in the research activities of the department. The group may have a more or less formal status within the departmental structure, and may be established with a temporary function to ensure a dynamic response to its mandate.

The objectives of a research group are to develop a stimulating scientific environment for colleagues working on related topics, to supervise graduate and doctorate students, to stimulate team building, to build networks and contacts to other groups, and to ensure robustness with respect to changes in personnel structure, budget, and scientific topics.

The number of employees within a research group may vary through its lifetime. To achieve an optimal size, the group may include

- a clear leadership
- two or more associate fellows at the post doctorate level
- two or more dr.-students
- two more graduate students
- necessary technical support; this might be shared by other research groups within the department

Students at the graduate and doctorate level should work on related projects providing a stimulating environment, where fellow students can be a partner for discussion, sharing of equipment and techniques, etc.

Equipment - investments, operation and maintenance

The Weitkamp Committee gives an overall impression that the standard of the scientific equipment for chemical research at the Norwegian universities is rather high. The Chemistry Planning Committee strongly disagrees with this description. According to the planning committee's analysis, there is a clear need for further support to chemical instrumentation, from smaller units to high-cost instruments (see also *Level of funding* above).

In the present, situation the problems are:

- In a system with a stagnant (or even decreasing) lump sum budgeting, and with a rather large part of the grants allocated for salaries (80-90%), the "left overs" for investments and running expenses are decreasing in an accelerating way. Several departments (faculties) could hardly find room for investments neither in 1997 nor in 1998.
- Investments made possible by grants from the Research Council usually depends upon a separate split funding by the department/faculty itself. As a consequence of the deteriorating financial situation of the universities, there are no means available for top financing such investments, as are usually or often required.
- The more sophisticated the equipment is, the more expensive it is to operate. Running expenses may often prevent an optimal use of the equipment, and do not stimulate possible users to make use of the technique. In worst cases, the equipment will not be used at all.
- Larger, advanced equipment and instruments will usually need a dedicated operator on a full time basis. If no such position (technician or engineer) is available (which is often the case), a temporary solution is to leave the operating responsibility to a dr.-student. This is usually a vulnerable situation giving no security for a continuous operation and maintenance of the instrument.

To make it attractive to be employed at the universities, it is necessary to improve the working conditions for faculty members. The Research Council plays a very important role in this, as it is the dominant economic resource for buying medium sized and large, advanced scientific equipment. It is recommended that there should be an increase in the grants for scientific equipment. However, support for technical assistance, as recommended by the Weitkamp Committee, should be achieved through internal re-allocations of positions at the universities themselves.

PRIORITIES

In this chapter, the Chemistry Planning Committee recommends priorities with respect to national co-ordination of the various topics within chemistry research, and to what extent the topics should be funded at the various universities and colleges. The committee also suggests local actions to be taken by the universities themselves. The national co-ordination should be observed, and in some cases funded by the Research Council. The support to the various topics and universities/colleges should be made by the Research Council, and the Chemistry Planning Committee has, in accordance with the mandate discussed three different scenarios: 5% reduction in the Research Council's budget to chemistry research, no change, and 5-10% increase (relative to the current situation). In many cases, the Chemistry Planning Committee refers to recommendations in the previous scenario by "as above" rather than repeating the previous scenario. Usually, the more optimistic scenarios include additional recommendations to the Research Council. Our suggestions with respect to local actions are meant to be followed up by the individual universities and colleges, independent of support from the council.

The division of this chapter into sub-chapters follows largely the one made by the Weitkamp Committee, and is not an indication of the topic's importance. For instance, *Polymer chemistry* is not a separate topic, but included in *Materials science* and in *Colloid and surface chemistry*. Following the Weitkamp Committee, the Chemistry Planning Committee has also split up the vast field of *Physical chemistry* into its dominant sub-fields in which there is active research in Norway.

The Chemistry Planning Committee has pointed out areas that should be strengthened, even in the budget reduction scenario. This implies that funding of areas not mentioned should be correspondingly reduced.

ORGANIC CHEMISTRY

Background

As stated by the Weitkamp Committee, organic chemistry is probably on a world scale one of the most active areas of chemistry, and against this background, the committee stresses great concern for the current situation for organic chemistry in Norway. Little cutting edge research is being done at present, and the Weitkamp Committee's impression is that, within few years there will be very few organic chemists (probably less than five) operating in Norway approaching an internationally recognised high standard. The industry, the research institutes as well as the universities themselves, need candidates with a research background in organic chemistry. Research in the field is being carried out at all the universities of Norway.

Recommendations by the Weitkamp Committee

In order to strengthen the field, the Weitkamp Committee recommends to:

- put resources into one major centre for organic synthesis and build up the area at the other universities.

- provide sufficient resources for running expenses into the area.
- develop targeted programmes (examples: Organic materials, polymers, petrochemicals).

It is further recommended that the University of Oslo (UiO) should formulate a succession plan, and an active recruiting process is recommended to maintain the world-class effort in organic synthesis. Action should be taking to retain skilled technicians and to establish regular seminars and group meetings involving all groups working in the field of organic chemistry.

At the University of Bergen (UiB) it is recommended an addition of 3-4 young people to work at the interface organometallic chemistry/asymmetric catalysis/biological chemistry. Special focus should be set on "win win" combinations with other established research areas at the university, and gain greater visibility by publishing more primary literature.

Recommendations from the Chemistry Planning Committee

The Chemistry Planning Committee disagrees with the Weitkamp Committee on establishing a national centre in organic chemistry synthesis. Still, it has to be ensured that the know-how and knowledge pool existing in Oslo is sustained. The area should in addition be priority developed at the other institutions.

National co-ordination

At UiO, the group should be stimulated to maintain the present (international) standard in organic synthesis. Support should also be given to the activity in organometallic chemistry, related to synthesis, as well as basic research in the field. This is also discussed under *Catalysis* later in this chapter.

Much of the activity in organic chemistry at UiB is concentrated on isolation and characterisation of natural products (plant extracts) and development of new methods for analysis of organic compounds in marine and geochemical systems. As the activity in organic synthesis at UiB is below critical size, it is recommended that this activity should be strengthened and focused on synthetic aspects of natural products, thus facilitating extensive collaboration with the department and a stronger overall impact towards natural products and projects at the chemistry/biology interface.

Also at the University of Tromsø (UiTø) the main activity should be maintained in the field on organic synthesis, including problems in the organometallic field. The collaboration with groups in pharmacy and medicinal chemistry should be further developed, and this activity should be supported.

As of January 1, 1999, at Norwegian University of Science and Technology (NTNU), the present departments of Chemistry, Inorganic Chemistry, Organic Chemistry, Physical Chemistry will merge to form a new Department of Chemistry. This will facilitate the co-ordination of the various activities in organic chemistry at this institution. This merging of the organic chemists into one (large) department *could* result in a decrease of the number of staff members. The main activity should preferably be on organic synthesis, but it is

recommended to change the focus towards projects of more technological relevance (organic materials, petrochemicals, polymers).

Financial support from the Research Council

On a national level, there should be no cuts in the budgets of organic chemistry. This would be necessary to provide a basis for a greater attention to this field of chemistry with great potentials and relevance for Norway concerning refining of raw materials.

- *5% cuts in the Research Council budgets*

The overall research activity at *all* universities should be sheltered against any cuts in the budgets. The support given to NTNU should be for stimulating the suggested change.

- *No change in the Research Council budgets*

As above.

- *5%-10% increase in the Research Council budgets*

As above, and in addition:
⇒ The activity at UiO should be stimulated by additional *post doc's* and research fellowships.
⇒ The activity at UiB should given increased funding, especially for *post doc's* and research fellowships to increase the number of group members, stimulating work at the interface of chemistry and biology.
⇒ At UiTø increased funding should be given to support collaborations with pharmacy and medicinal chemistry.

Suggestions with respect to local action

At UiB a new faculty position should be established in the field of synthesis of natural products.

At NTNU, the activity in organic chemistry might benefit on a closer co-operation with the field of polymer chemistry and petrochemistry. As a consequence of the close connection to other groups (within the Faculty, at SINTEF Chemistry, and at Statoil Research Centre) working in these areas, there is a scientific basis for the organic chemistry group at NTNU to concentrate the work on organic materials, polymers and petrochemicals. This would also form a basis for attracting external funding in the field.

INORGANIC CHEMISTRY

Background

Inorganic chemistry is traditionally a strong research area in Norway, partly due to work by world-class scientists over two or three generations, and partly due to the strong position of the Norwegian metallurgical industries. The basic research is closely connected to structural chemistry. The universities have found their specialities. UiO focuses on inorganic materials,

NTNU on light metals, and UiB on transition metals and bio-inorganic chemistry. Currently, there is no activity in inorganic chemistry at UiTø.

Recommendations by the Weitkamp Committee

The activities in inorganic chemistry at the Department of Chemistry at UiO, are of high quality and productivity. The Weitkamp Committee recommends that the inorganic chemistry and materials group should exploit the potential of its basic research to applications, improve employment opportunities for its students, and reduce its teaching load. This may be achieved through co-operation with corresponding SINTEF group in Oslo. The research should continue to receive substantial support.

The main activity at the Department of Inorganic Chemistry at NTNU, is electrolysis of light metals, which is of a high international standard. This is discussed below under *Materials Science*. The Weitkamp Committee states that the department is productive, but the projects are scattered over too wide a range of topics. The committee recommends that the activities in inorganic chemistry at the Department of Chemistry at NTNU, are continued with priority over other activities in this department, and that co-operation with other Norwegian groups on this research should be developed.

The activities in inorganic chemistry at the Department of Chemistry at UiB, cover synthetic inorganic chemistry and structural chemistry. Both groups have extensive expertise and international co-operation in their field, and good publication rates. The groups suffer from lack of competent students and few connections with the industry. The Weitkamp Committee recommends for both groups that collaboration within the division of inorganic chemistry should be strengthened. The division should make a choice: Either re-orient towards materials and heterogeneous catalysis or towards biochemical applications. Furthermore, the division should attract more industry funding and replace retirees with expertise in transition metals and solid-state chemistry.

The biophysical/bio-inorganic chemistry group at UiB has valuable international connections and there is significant collaboration with biochemists, biotechnologists and surface chemists. The Weitkamp Committee recommends that the group collaborates more with strong groups in biology/biochemistry, and gives specific advice with respect to their research topics.

Comments from the various departments

The Weitkamp Committee gives the impression that the equipment situation is satisfactory for the groups working in inorganic chemistry and materials science, which is contradictory to the groups' own assessment of the situation, especially at UiO.

UiB has planned to increase the staff in synthetic inorganic chemistry and catalysis by one person.

On January 1, 1999, at NTNU, the present departments of Chemistry, Inorganic Chemistry, Organic Chemistry, Physical Chemistry will merge to form a new Department of Chemistry. This will facilitate the co-ordination of the various activities in inorganic chemistry at this institution.

Recommendations from the Chemistry Planning Committee

National co-ordination

It seems that Norwegian research in inorganic chemistry is well balanced between the three universities working in the field. The Chemistry Planning Committee recommends that UiTø too, should establish research in inorganic chemistry.

The equipment situation is variable, and as the equipment required in the field is often expensive, it is important that its use should be co-ordinated, both within and between the universities.

The Weitkamp Committee emphasises bio-inorganic chemistry as a new, exciting research area, in which groups at UiB and at NTNU already have activities. Research in bio-inorganic chemistry should be encouraged and supported.

Financial support from the Research Council

- *5% cut in the Research Council budgets*

Substantial support for doctorate students and *post doc* positions should be given at UiO and NTNU, with emphasis on basic research. Research related to catalysis should be given high priority.

- *No change in the Research Council budgets*

As above, and in addition: Funding of large, advanced equipment should be increased. Support should be given to the group at UiB, to stimulate intra-departmental co-operation towards catalysis.

- *5-10% increase in the Research Council budgets*

As above.

Suggestions with respect to local action

The inorganic chemistry and materials group at UiO should be encouraged to develop/extend its applied research in collaboration with the corresponding SINTEF groups, and to establish more active collaboration with NTNU.

The synchrotron group and the group working on fluoride glasses, perovskites, and sol-gel technology at NTNU should establish a more active collaboration between themselves.

The groups at UiB should be stimulated to collaborate with the group at NTNU in the area of heterogeneous catalysis and with the group at UiO in extending their work towards biochemical applications.

Support for technical assistance, as recommended by the Weitkamp Committee, should be achieved through internal re-allocations of positions at the universities themselves.

MATERIALS SCIENCE

Background

Materials may be divided into functional materials and structural materials. Functional materials constitutes one of the most active research areas in natural sciences and technology today. This research is significant also in Norway, but more attention has been paid to structural materials due to the industrial importance of light metals, steel, other metallurgical products, wood, concrete, and to some extent also to polymers.

The field *Materials science* is to some extent overlapping with *Inorganic chemistry, Catalysis, Polymer chemistry,* and *Colloid and surface chemistry*. As a consequence, the same research groups are included under several topic headings. It is especially difficult to distinguish between materials science and inorganic chemistry.

Research on functional materials is also carried out in the fields of physics and electrical engineering at the Norwegian universities. There is active co-operation between scientists working in physics and inorganic chemistry at UiO through the materials science centre, and at NTNU. None of the research groups at the colleges are active in materials science.

As of January 1, 1999, at NTNU, the Department of Industrial Electrochemistry will merge with Department of Metallurgy. The latter department, which also is a part of Faculty of Chemistry and Biology, was not included in the chemistry evaluation. It has two main groups, one working in the field of process metallurgy and one in physical metallurgy. Their main focus is on production of steel and light metals. The groups enjoy extensive co-operation with the industry and with SINTEF, they have satisfactory equipment, and good publication rates. Their weak points are lack of competent students and that relatively many staff members are close to the retirement age. The new department will be responsible for a new study program on materials technology.

There is also a strong group in bio-polymers (NOBIPOL) at NTNU. Bio-polymers have extensive applications in foodstuffs and printing dyes, and in recent years also in medicine. This activity is considered to be a part of biochemistry, and was thus not included neither in the evaluation by the Weitkamp Committee nor in the present work.

Recommendations from the Weitkamp Committee

At the national level, the Weitkamp Committee recommends that UiO should continue to receive substantial support for their research on solid-state inorganic materials. Increased support should be given to projects at NTNU, which carry high international and industrial impact, take an innovative approach, and include a fair amount of basic research.

The work on high-temperature defect structures in the electrochemistry and materials science group at UiO has a leading position in the world. The Weitkamp Committee recommends that the group should be increased in size, that emphasis should be placed on the relationship between materials' structure and properties, and that the co-operation with other groups at UiO should be improved.

The primary research area at the Department of Inorganic Chemistry at NTNU is directed at the production of light metals. The department has very good contact with industry and well developed collaboration with institutions in Norway and abroad. The Weitkamp Committee recommends that the range of research topics should be directed towards more basic research.

The Department of Industrial Electrochemistry at NTNU works on production of light metals and electrochemical materials technology. The department has strong co-operation with SINTEF, the industry, and other institutions. The Weitkamp Committee recommends that the department should form a strategy for promising research areas, engage more in basic research, hire personnel with emphasis on proven research excellence, and further improve the co-operation within the faculty.

The polymer, colloid, and surface chemistry group at UiO works on various physico-chemical topics on polymers and colloids. The group has a good publication record, and its topics of interest have good potential for application by the Norwegian industry. The Weitkamp Committee recommends that the group should interact more closely with other groups at UiO and with the domestic and the European industry.

Also the colloid and surface group at UiB performs research of relevance to materials science, as discussed under *Colloid and Surface Chemistry* further below in this chapter.

The polymer chemistry group at the Department of Industrial Chemistry at NTNU, works on emulsion polymerisation, monodisperse polymer particles, and polyolefin chemistry. The group is a world leader on monodisperse particles. It co-operates actively with SINTEF and has an ideal balance between theoretical and experimental work. The Weitkamp Committee warns that the polymer chemistry research may stagnate in a tradition on monodisperse particles, and recommends new focal points to be identified.

Recommendations from the Chemistry Planning Committee

National co-ordination

Research in materials science requires expensive and specialised analytical equipment. It is therefore important to co-ordinate the use of such equipment, both within and between universities.

Irrespective of the budget situation, it is quite clear that the activities at UiO and at NTNU in materials science should be maintained at a high level.

It seems that work in polymer chemistry could benefit from a national co-operation based on the observation that the group at NTNU focuses on synthesis and the group at UiO focuses on physico-chemical properties. There is a strong European research drive on the physico-

chemical properties of polymers, and Norway has a good position to participate in this with a better co-ordination of its efforts.

There is little research on composite materials in Norway. Some work should be initiated in this area, preferably as a co-operation between UiO, NTNU, and SINTEF.

Financial support from the Research Council

- *5% cut in the Research Council budgets*

⇒ The electrochemistry and materials science group at UiO should continue to receive support for doctorate students and *post doc* positions.
⇒ Polymer chemistry both at UiO and at NTNU should receive support after a critical selection of basic research projects, aiming at top international level and attracting leading scientists from abroad to work in Norway.

- *No change in the Research Council budgets*

As above, and in addition:
⇒ The light metals groups at NTNU should be given increased funds to do more basic research.
⇒ Funding of doctorate students and post doctorate positions should be increased.
⇒ Funding of equipment should be increased.

- *5-10% increase in the Research Council budgets*

As above.

Suggestions with respect to local action

The electrochemistry and materials science group at UiO should be encouraged to develop and extend their applied research in collaboration with SINTEF, and to establish more active collaboration with NTNU.

The light metals group at NTNU should collaborate more actively with corresponding groups at the new Department of Materials Technology and Electrochemistry.

The polymer chemistry group at NTNU should interact with the groups working in organic chemistry at the same university.

Support for technical assistance should be achieved through internal re-allocations of positions within the universities.

PHYSICAL CHEMISTRY: THEORETICAL CHEMISTRY AND STATISTICAL MECHANICS

Background

Theoretical chemistry is established with groups of varying size at all four universities. Historically, the field has changed from development of methods to more emphasis on applications. Today, many standard packages exist that handle theoretical problems in many areas of chemistry. This is true for quantum chemistry as well as molecular mechanics and molecular dynamics. This should be looked upon as a valuable support to other methods in studying chemical problems. Many experimental groups utilise this possibility successfully. There is, however, certain important areas of chemistry, such as chemical reactions on surfaces, that are not accessible with the methods of today. In order to meet the needs for theoretical tools in such areas, it is important to maintain method development as a research field.

Statistical thermodynamics is not a well established activity in chemistry in Norway, but strong groups exist in physics, both at UiO and at NTNU. There are additional activities in chemistry with emphasis on computer simulations at the latter university and at Telemark College. World trends show that combinations of quantum mechanics and statistical thermodynamics are developing rapidly.

The field thermodynamics is discussed under *Experimental physical chemistry*, including an important, theoretical activity at NTNU.

Recommendations from the Weitkamp Committee

The Weitkamp Committee states in the conclusions that the strength of the field should be maintained, although perhaps not at all the universities, and that there should be a shift, possibly through targeted research programmes, toward the key issues of contemporary chemistry.

Recommendations from the Chemistry Planning Committee

National co-ordination

Theoretical chemistry should be a topic at all universities, and should be supported.

To maintain the activity in computational chemistry, it is important that the Research Council maintain its support to supercomputing through the national programme.

The Research Council should be instrumental in establishing and supporting national networks as indicated by the Weitkamp Committee. Statistical thermodynamics should be combined with the national network in theoretical chemistry, with a node for statistical mechanics at NTNU.

Financial support from the Research Council

- *5% cut in the Research Council budgets*

The present support should be maintained. Funding should be used to stimulate building of a national network in theoretical chemistry.

- *No change in the Research Council budgets*

As above.

- *5-10% increase in the Research Council budgets*

As above, and in addition: There should be an increase in the general support to the field.

Suggestions with respect to local action

A second faculty position should be created at UiB, and links should be established with the Department of Informatics in order to attract graduate students able to develop methods.

At UiO an activity in dynamics should be established.

At NTNU a group in computational chemistry should be established. It will be important for this group to participate in a national network in theoretical chemistry, as suggested by the Weitkamp Committee.

PHYSICAL CHEMISTRY: EXPERIMENTAL PHYSICAL CHEMISTRY

Background

There are groups in experimental physical chemistry at all four universities. Strong activities were identified in surface and colloid chemistry at UiB, in thermodynamics at NTNU, and in spectroscopy at UiO. *Structural chemistry* is treated separately below and *Colloid and Surface Chemistry* is discussed under a separate heading in this chapter. Vibrational spectroscopy as well as NMR seem to be well represented at all universities, whereas mass-spectroscopy as a research field is only established at UiO. However, there is little basic research on these techniques in Norway. Spectroscopy is used in all areas of chemistry with standard equipment. The only established group in molecular spectroscopy is found at UiO.

Experimental (measurement for thermodynamic properties, phase diagrams, etc.) and theoretical (modelling of thermodynamic properties, equations of state) thermodynamics are carried out at NTNU.

Recommendations from the Weitkamp Committee

The Weitkamp Committee recommends that UiO should support the efforts to find adequate financing of equipment, and to elaborate strategies for better collaboration between the groups working with spectroscopic methods.

Recommendations from the Chemistry Planning Committee

National co-ordination

The Research Council should carry out the planned evaluation of the NMR research in Norway. On the basis of this evaluation, the council should consider to supplement the current instrumentation with a new, ultra high field (800-1000 MHz) instrument, which should preferably be located close to the majority of the users, and at, or in close contact with a university.

There seems to be a need for national co-ordination only in the field of NMR.

Financial support from the Research Council

- *5% cut in the Research Council budgets*

It is important to make sufficient funding for instrumentation available for these activities.

- *No change in the Research Council budgets*

As above, and in addition: Priority should be given to experimental thermodynamics at NTNU, vibrational spectroscopy and mass spectrometry at UiO, and colloid and surface chemistry at UiB. The latter subject is discussed further below in this report.

- *5-10% increase in the Research Council budgets*

As above.

PHYSICAL CHEMISTRY: STRUCTURAL CHEMISTRY

Background

Research in structural chemistry involves important techniques, of which X-ray crystallography is one of the most essential. This area is well represented in Norway. The activities at NTNU, at UiO, and at UiB tend to follow the traditions in X-ray single crystal diffraction, whereas the group at UiTø has specialised in protein crystallography. An important initiative is the establishment of the Swiss-Norwegian beam line at the European Synchrotron Radiation Facility (ESRF) in Grenoble.

At NTNU and at UiO there are also groups in electron diffraction, and an activity in microwave spectroscopy is found at the latter university.

Recommendations from the Weitkamp Committee

The Weitkamp Committee states that the effort in structural chemistry is more than adequate. The committee recommends that the ESRF activity and that of the protein crystallography group at UiTø should be kept at least at the present level.

The committee further suggests that it should be discussed on a national level whether Norway really *should* keep an international activity in electron diffraction, and whether adequate equipment and staffing should be maintained for X-ray single crystal diffraction at each university.

Recommendations from the Chemistry Planning Committee

National co-ordination

The electron diffraction activity and microwave spectroscopy groups are the only ones of their kind in Norway. A long-term continuation of the experimental activity would require major investments in new instrumentation. The Chemistry Planning Committee finds this research of minor importance for Norway, and it does not justify such investments.

In synchrotron studies research co-operation between Norwegian groups should be developed further to make full use of the potential the synchrotron methods offer to solve problems where other methods fail. The Research Council should also support projects which employ synchrotron facilities other than at ESRF, when technical or scientific arguments justify this.

Financial support from the Research Council

- *5% cut in the Research Council budgets*

It is important to make sufficient funding for instrumentation available for the x-ray single crystal diffraction at all universities, and for the continuation of the protein structure activity at UiTø.

- *No change in the Research Council budgets*

As above.

- *5-10% increase in the Research Council budgets*

As above, and in addition: Support to an additional group in protein crystallography at UiO should be considered.

ANALYTICAL CHEMISTRY

Background

All research in chemistry is based on data obtained by chemical analysis, but when the term analytical chemistry is used, the emphasis is on method development, and not routine applications of established methods. A series of advanced instrumental methods are available for the qualitative and quantitative determination of chemical elements and their compounds.

The Norwegian industry and the research institutes have a strong need for candidates with a research background in advanced instrumental methods of analysis.

There is research in analytical chemistry at all of the universities except at UiTø, but the group at the Department of Chemistry at UiO has by far the broadest activity, covering different techniques in atomic absorption, emission and mass spectrometry as well as advanced chromatographic and electrophoretic techniques. There is little overlap between the different university research groups.

Chemometric methods are widely used in analytical chemistry, and are therefore included here, although such methods are used in many branches of chemistry. The strongest group is at UiB, but research is also carried out at the Department of Physical Chemistry at NTNU and at Telemark College.

Recommendations from the Weitkamp Committee

The Weitkamp Committee concludes that analytical chemistry is underdeveloped at the universities outside of the Oslo area, although there is some analytical activity connected with environmental and organic chemistry. Given the importance of analytical chemistry, serious consideration should be given to strengthening the position of the subject at the universities outside Oslo. This is especially important for NTNU, where there is a need for materials and surface analysis. However, the expansion of analytical research and education should not be made at the expense of the groups at UiO and at the Agricultural university of Norway (NLH), which both have strong internationally recognised research records, according to the committee, which also recommends continued support to the dynamic chemometrics group at UiB.

Comments from the various departments

The statement by the Weitkamp Committee that there are only two chairs in analytical chemistry in Norway is not correct. There are three chairs at UiO, and also professors of analytical chemistry at UiB, NTNU, and NLH. The activities at the Department of Pharmacy at UiO and at the Department of Chemistry at UiB are probably underrated in the report. The Weitkamp Committee recommends stronger interaction between the groups in chemistry and pharmacy at UiO. However, there is already considerable co-operation between these groups.

Recommendations from the Chemistry Planning Committee

Financial support from the Research Council

- *5% cut in the Research Council budgets*

⇒ Support to analytical chemistry should primarily be given to UiO, which has the major research group.

⇒ In addition, support should be given to the chemometrics group at UiB.

- *No change in the Research Council budgets*

As above, and in addition: The group at NLH should receive some support.

- *5-10% increase in the Research Council budgets*

As above, and in addition:

⇒ NTNU should receive support, to strengthen their research in analytical chemistry, focusing on surface and materials analysis/characterisation techniques, and aiming at becoming a national centre in this field, as suggested by the Weitkamp Committee.

⇒ The groups at UiO and at UiB should receive increased support.

Suggestions with respect to local action

It is recommended from the Chemistry Planning Committee that NTNU should establish a research group in surface and materials analysis. Here, the inclusion of the new LA-ICP-MS facility at the Geological Survey of Norway (NGU) should be considered.

COLLOID AND SURFACE CHEMISTRY

Background

A wide range of industries are dependent on colloid technology or the exploitation of surface based phenomena. Examples taken from the Norwegian industry cover areas like paint, pulp and paper, pharmaceuticals, cement, water purification, food, detergency, and, in particular, the recovery and transport of oil and natural gas. The latter line of activity offers a number of colloid and surface chemistry related challenges, including drilling mud, gel plugging of reservoirs, breaking of oil emulsions and foams, breaking of gas hydrates, and multiphase flow.

There are research groups working in the field of colloid and surface chemistry at the chemistry departments at UiO and UiB. In addition, research in some colloid and surface chemical topics is carried out at NTNU. The sol-gel technology is a research topic at the Department of Inorganic Chemistry, the Department of Chemical Engineering is engaged in pulp and paper related research, whereas the polymer group at the Department of Industrial Chemistry is studying polymerisation from colloidal solutions, with an emphasis on emulsions. The pulp and paper activity should be revitalised with an emphasis on world-wide trends and new key technologies.

The planned re-localisation of the Norwegian Pulp and Paper Research Institute (PFI) to Trondheim may become an important element when forming a strategy for the pulp and paper activity at NTNU (see also under *Chemical engineering* below).

Recommendations from the Weitkamp Committee

At UiO, the colloid and surface activity is focused on polymers as exemplified by topics like gel formation and associating polymers, making it a unique combination in the field in

Norway. Enhanced interaction with the industry as well as other activities within the chemistry department is recommended.

Highly original and innovative research is carried out by the colloid and surface chemistry group at UiB, pursuing a wide range of topics encompassing both basic and applied aspects. Collaboration with industry and research institutions world-wide is very extensive, and, summarising, this is one of the few chemistry groups in Norway performing research at the cutting edge. It is recommended that the activity which is of relevance to heterogeneous catalysis is strengthened by adding one position, as well as a general consolidation of the group.

Recommendations from the Chemistry Planning Committee

National co-ordination

There are important overlaps between research in colloid and surface chemistry and various other areas. Consequently, the recommendations given by the Chemistry Planning Committee, should be seen in relation to those given for the fields of *Catalysis, Material sciences,* and *Physical chemistry*.

The colloid and surface chemistry activities at NTNU are subordinate to major research topics at three departments. Both with respect to the sol-gel technique and polymerisation from colloidal solutions, it may be beneficial to co-ordinate the activity with the relevant groups at UiO and UiB. These latter groups perform complementary research with only a small overlap among themselves, and it is important to maintain both lines of activities intact.

Financial support from the Research Council

- *5% cut in the Research Council budgets*

The funding should be limited to the colloid and surface activities at UiO and at UiB.

- *No change in the Research Council budgets*

As above, and in addition: Some support should be given to the activity at NTNU.

- *5-10% increase in the Research Council budgets*

As above.

Suggestions with respect to local action

The situation for the pulp and paper group at NTNU may require special attention. A possible course of action is to assign the task of considering future research directions to an *ad hoc* committee consisting of representatives for the industry, the Department of Chemical Engineering, PFI and external academia.

At UiB it is recommended that the activity which is of relevance to heterogeneous catalysis is strengthened by adding one faculty position to the group, as well as consolidating the group.

CATALYSIS

Background

The Norwegian process industry, as exemplified by the national refining and gas processing industry, polymer industry, etc, represents a significant part of the on-shore based export industry. Heterogeneous catalysis is an important factor contributing to the technological competitiveness of the industry. Therefore it is most important that sufficient volume of high quality research is conducted at the Norwegian universities.

In general, it may be noted that there are two major catalyst research communities in Norway, one at NTNU and the other at UiO. Both communities have good and fruitful interaction with SINTEF as well as the industry.

Recently efforts supported by the Research Council have been undertaken by industry, SINTEF and academia to develop new catalysts and processes (*Methanol to Olefins, Gas to Middle Distillates,* etc).

There seems to be a link between the high evaluation appraisal of the Norwegian catalysis research community and the resources that have been put into the area especially during the second half of the 1980's by the Research Council and the industry. In other words, internationally high performing university research can be sustained and developed if sufficient funding is available.

Efforts supported by the Research Council are also undertaken in the area of polyolefin catalyst development. The development is a common effort touching into the areas of organic synthesis, catalyst testing, inorganic chemistry, engineering sciences and polymer science.

Recommendations by the Weitkamp Committee

The general conclusion of the Weitkamp Committee is that the Norwegian catalysis community carries out high quality research which should be supported or even expanded. The Research Council funding is critical for all of them and should be increased.

The petrochemistry and catalysis group at NTNU is evaluated to be well respected at the international level, and holds a position of scientific leadership in Europe.

The comments on the catalysis group at UiO are that within the niches discovered and occupied by the group, it has acquired an indisputable world-wide reputation and established intense, long-lasting scientific contacts over the world.

On the background of the importance of petroleum and gas processing for the Norwegian economy, the Weitkamp Committee recommends that an additional group in the field of heterogeneous catalysis at UiB would seem desirable.

Comments from the various departments

The catalysis research groups at NTNU and at UiO have pointed out that current support to the area by the Research Council is already marginal. Therefore they do not recommend spreading of the already scarce resources through establishing a third research group in catalysis.

Recommendation from the Chemistry Planning Committee

It is the opinion of the Chemistry Planning Committee that, given the importance of Norway as a oil and gas producing nation, there should be room for further activities in catalysis. A prerequisite is, however, the maintenance and development of the well established high quality research groups already operating in the field. Furthermore, the field of heterogeneous catalysis should have potential to be developed into an even more international cutting edge area.

It should be noted that strong groups are established in related areas. Catalysis is a truly interdisciplinary science and interaction towards the chemical engineering sciences, theoretical chemistry, homogeneous catalysis, material sciences (inorganic synthesis, surface science, colloid science) have to be kept in mind. These research areas need to be in vigorous, high quality development in order to support a cutting edge catalysis research community in Norway.

Homogeneous catalysis is an internationally active research area, especially in view to environmentally friendly production of organic bulk and fine chemicals. There is little activity in Norway in this field. Thus, the Chemistry Planning Committee does not recommend special support to this area. However, the area of organometallic chemistry should be supported deliberately in order to sustain a possible national "seed" if homogeneous catalysis needs to be developed on a national level in the future.

National co-ordination

A national co-ordination is already in existence since the community at NTNU focuses on catalysis mainly on the background of chemical engineering sciences, while the group at UiO is firmly embedded in its inorganic chemistry background, focusing synthesis of catalysts in addition to catalyst testing and characterisation. Further development of the area of catalysis should be through evolutionary growth based on existing high quality expertise.

Financial support from the Research Council

Catalysis for petrochemistry and the environment should be singled out as a candidate for further development for a cutting edge research area. National co-operation and cluster development should be fostered not only between university groups, but should also include relevant research activities at SINTEF.

- *5% cut in the Research Council budgets*

Funding of existing groups at UiO and NTNU should be maintained.

- *No change in the Research Council budgets*

As above, and in addition: Support should be given to stimulate the development of catalysis related activities in Bergen.

- *5-10% increase in the Research Council budgets*

As above, and in addition: Support should be given to creating an environment for the fostering of a new catalysis group in Bergen.

Suggestions with respect to local action

The groups in inorganic chemistry and in colloid and surface chemistry at UiB should orient its work to include research related to catalysis.

CHEMICAL ENGINEERING

Background

Chemical engineering comprises a wide field of activities, based on mathematics, physics and chemistry, to be used in industrialising chemical processes. University research in chemical engineering is mainly located at the departments of Chemical Engineering and Industrial Chemistry, NTNU. The two departments will merge as of January 1, 1999, to make a new Department of Chemical Engineering. The departments cover most of the chemical engineering topics of importance to the Norwegian process industry, including oil and gas, petrochemical, and the pulp and paper industries.

Some additional activities are located at Telemark College, which has defined research groups on applied thermodynamics, membrane gas separation, and particulate flow.

Applied chemistry is closely related to production processes for specific products. Petrochemistry is covered under the heading *Catalysis*, and polymer chemistry is covered under the headings *Materials science* and *Colloid and surface chemistry.* These fields will therefore not be commented upon in the following.

Recommendations from the Weitkamp Committee

The Weitkamp Committee states that research in applied chemistry and chemical engineering appears to be mainly concentrated at NTNU. It is generally recommended that support to these activities should be maintained. Among the major research areas identified are: Heterogeneous catalysis, process systems engineering, separation processes and applied thermodynamics, and polymer science and technology. The groups of the two first areas are especially noted for carrying out research of excellent quality. Also, the research in some

areas of separation technology, as crystallisation and in reactor modelling, is considered to be of high quality and should be supported.

It is recognised by the Weitkamp Committee that the group on pulp and paper technology has a special position related to the important paper industry i Norway. The committee sees opportunities to identify new key technologies in this field, e.g. advanced coatings and high value added products (see also comments under *Colloid and surface chemistry*).

Both the Chemical Engineering and Industrial Chemistry departments are at present in a phase of recruiting new staff members. The Weitkamp Committee states that the departments have a good potential for development if they succeed in this renewal process, and the committee recommends that replacement should preferably be done at the associate professor level.

Valuable research work in the fields of applied thermodynamics and gas hydrates is being pursued at "certain colleges" (Telemark), but in view of the limited size and equipment a closer co-operation with established universities is recommended.

Recommendations from the Chemistry Planning Committee

It is internationally accepted that emission of carbon dioxide and certain other gases has to be reduced to avoid dangerous man-made climate changes. Norway has a very important aluminium-, ferrosilica- and oil/gas industry with high energy consumption and large carbon dioxide emissions. The economic consequences of a forced reduction in production rates to fulfil international agreements of maximum emission may be severe. To avoid this, it is urgent to develop more energy efficient and less polluting production processes. The research efforts have to be increased immediately if the results should be brought to industrialisation during the next decade. On this background the Chemistry Planning Committee finds it difficult to accept any reduction in the funding of chemical engineering research.

Renewal of the staff with highly qualified candidates is difficult in competition with industry as the salaries there are much higher. The planning committee will propose that new staff members should be given sufficient support to initiate and develop their own research areas within the department strategy, during the first years of their employment. Also extended use of the opportunities to give differentiated and higher salaries for the scientific staff should be considered.

The Weitkamp Committee states in the description of the pulp and paper group that its role is perhaps more educational than strictly directed towards research. The Chemistry Planning Committee disagrees on this, as the group has had a good production rate both of publications and dr.-candidates during the last years. Attention should be given to the fact that the Norwegian Pulp and Paper Research Institute (PFI) has recently moved from Oslo to Trondheim. The pulp and paper group at the Department of Chemical Engineering will be relocated in the new building of PFI, and this should give great opportunities for even more activity and initiation of projects in co-operation with the institute (see also comments under *Colloid and surface chemistry*).

National co-ordination

The research groups in the field of chemical engineering at NTNU and Telemark College are more supplementary than competing. Because of the smaller size and specialisation of the latter group, the existing co-operation with the former and relevant groups/researchers at the other universities should be encouraged and enhanced.

Financial support from the Research Council

- *5% cut in the Research Council budgets*

Support should primarily be given to activities at NTNU with preference to the existing strong activities in process systems engineering, reactor modelling and separation processes. Research fellowships both at the doctorate and *post doc* level will be an important support in connection with renewal of the staff. Support must also be given to adequate instrumentation.

- *No change in the Research Council budgets*

As above, and in addition: At the Telemark College preference should be given to the strong groups on membrane separations of gases and applied thermodynamics, collaborating with the corresponding groups at NTNU.

- *5-10% increase in the Research Council budgets*

As above.

Suggestions with respect to local action

NTNU should be very selective in proposing new projects, but some attention should be given to new projects in the field of pulp and paper technology.

ENVIRONMENTAL CHEMISTRY

Background

The modern society must rely on sustainable growth, which requires that various environmental issues should be faced. The impact of modern technology on the environment must be assessed, and processes that can lead to a reduction in the environmental load must be developed. So far, most research efforts have gone into monitoring the environment. The problems of acid rain has been the main research topic at UiO, while the efforts at NTNU has been concentrated on the effect of heavy metal contamination of natural ecosystems.

Different aspects of radioactive fallout has been in focus at NLH. At UiB, the activity has been on process development and environmental monitoring related to industrial projects.

Recommendations from the Weitkamp Committee

With the exception of UiTø, environmental chemistry is represented in one form or another at all universities. The Weitkamp Committee considers that the strongest groups are at UiO and NLH. Both are analytically oriented and have long experience in environmental monitoring and problem-solving. However, it is also pointed out in the report that the group at NTNU maintains a high level of activity. The groups have extensive international collaboration, and their programmes aim at offering a complete chain from sampling to modelling. The Weitkamp Committee states that this type of comprehensive approach should be encouraged.

Recommendations from the Chemistry Planning Committee

National co-ordination

The group at NTNU is probably underrated in the report. There is little overlap between the different research groups, and no particular measures towards a national co-ordination is required.

Support to the group at NLH is discussed under the heading *Analytical chemistry* above.

Financial support from the Research Council

- *5% cut in the Research Council budgets*

The research groups at UiO and at NTNU should be supported.

- *No change in the Research Council budgets*

As above.

- *5-10% increase in the Research Council budgets*

As above, and in addition: Also groups at the other universities should be supported.

Suggestions with respect to local action

Close co-operation with the groups in analytical chemistry is recommended, in accordance with recommendations from the Weitkamp Committee. However, the potential of positive synergy effects is stronger at UiO than at NTNU, because of the relatively low activity in analytical chemistry at the latter university.

NUCLEAR CHEMISTRY

Background

Although Norway has no commercial nuclear power plants, such plants exist in the neighbour countries, and the coastal area is also affected by discharges from installations in the United Kingdom. Therefore, there is a need for competence in different areas of nuclear chemistry and radiochemistry. Radiochemical methods are also important in other branches of chemistry, in particular for analytical, environmental, biochemical, and clinical applications. Research in nuclear reactions and structure has been carried out by Norwegian researchers for many years, based on the use of international facilities such as CERN.

Research in nuclear chemistry is mainly carried out at UiO. The group is adequately staffed and is involved both in basic and applied research: Cancer therapy and radio-analytical chemistry. The latter methods are also used by the group at the Agricultural university of Norway. The general level of the research at UiO meets good international standards, and the group has access to major European and American facilities in the field. The group is the only centre which educates students in radiochemistry.

NTNU had until recently competence in nuclear chemistry, but the equipment and the facilities for this activity are shut down with the retirement of the faculty member responsible for the field.

Recommendations from the Weitkamp Committee

The Weitkamp Committee recommends to use the developed skills at UiO to attract industrial and medical partners, especially through EU-sponsored programmes. The group should concentrate on the more prominent projects it is currently conducting.

Recommendations from the Chemistry Planning Committee

National co-ordination

The group at UiO is the only one in Norway. An expansion of the activity to the other universities is not suggested. However, it is essential that activity in this field is maintained.

Financial support from the Research Council

- *5% cut in the Research Council budgets*

Considering that the group at UiO is the only in this field in the country, support should be maintained.

- *No change in the Research Council budgets*

As above.

- *5-10% increase*

As above.

Suggestions with respect to local action

Clinical and environmental applications are encouraged, in collaboration with relevant Norwegian research groups in these fields.

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Weitkamp, J, Bünzli, J-C.G, Larsen, S, Niinistö, L, Pattenden, G, Ponton, J.W., and Utley, J.H.P.: *Chemistry Research at Norwegian Universities and Colleges - A Review*, The Research Council of Norway, Oslo 1997, 161 pp

APPENDIX

Mandate

The Chemistry Planning Committee is given the task to prepare a plan, advising the Research Council's Division of Science and Technology (NT) on how to contribute to and strengthen the field of chemistry (in Norway), in order to meet the present and future challenges. The plan must be based on the challenges facing the Norwegian universities and colleges for the research in chemistry, and recommendations on priority actions should be given from this point of view. The recommendations should include requisite actions on a short time basis, as well as actions with a ten year's horizon.

The plan should give recommendations on

- NT's utilisation of economic means and specific priority actions within three alternate budget situations: Zero growth, 5-10% increase, 5% reduction

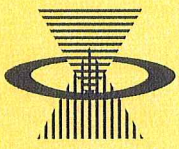
- NT's use of other actions for contributing to the development of research groups, and to better co-operation, flexibility and mobility between the groups.

- relevant actions carried out by the universities and colleges themselves within their own budget planning, specifically actions which can contribute to a better national co-ordination and sharing of responsibilities

The Chemistry Planning Committee is specifically asked to make considerations concerning
- specific fields/research groups which should be given special attention, based on selected areas where Norway should be in the lead internationally, special attention for new areas being important nationally, and potential areas given no priority, at all
- the situation for recruitment and the need for doctorate and post doctorate scholarships
- potential actions for promoting the mobility of Norwegian scientists, both nationally and internationally, and for contributing to increased internationalisation
- potential actions by the Research Council for improving national co-ordination and sharing of responsibilities between the various field and research groups, providing a better total utilisation of resources

The plan should take into consideration the need for basic research on those areas selected by the Research Council and considered to be of strategic importance also for other sections in the Council.

Relevant documents for the Chemistry Planning Committee are:
- *Strategi for Naturvitenskap og teknologi 1996-2000* (in Norwegian only)
- Research for the Future
- *Store satsinger, budsjettforslag 1998* (in Norwegian only)
- Chemistry Research at Norwegian Universities and Colleges - A Review
    - Comments from the institutions being evaluated
    - Comments from the Research Council divisions



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