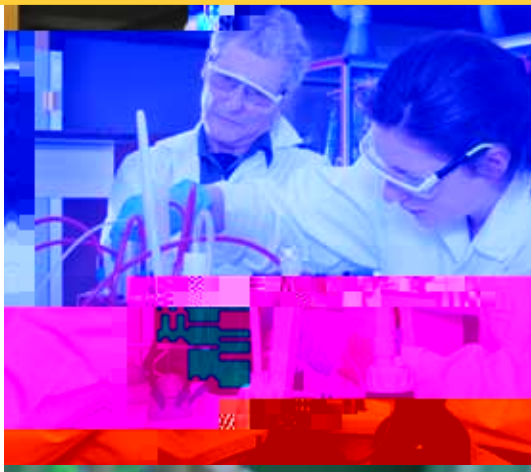
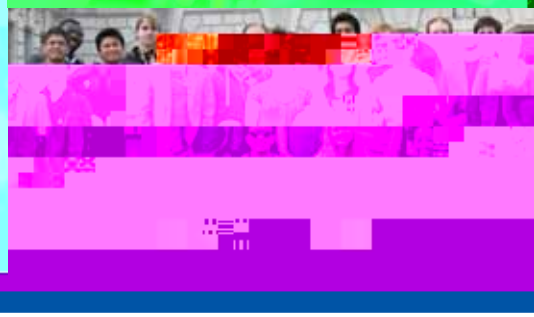
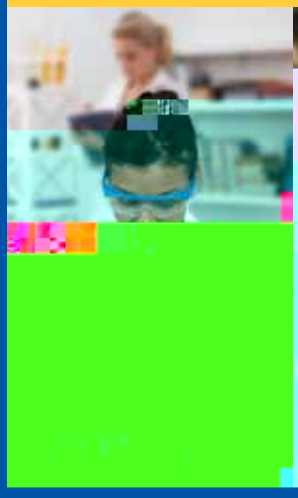
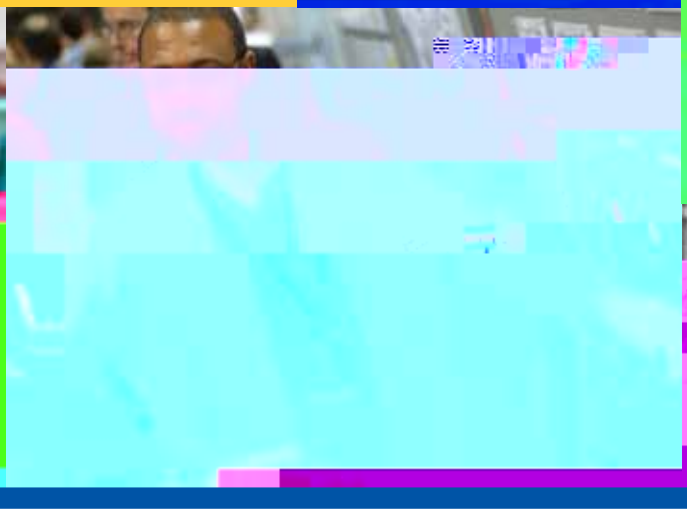
ADVANCING GRADUATE EDUCATION *IN THE* CHEMICAL SCIENCES

Summary Report of an ACS Presidential Commission









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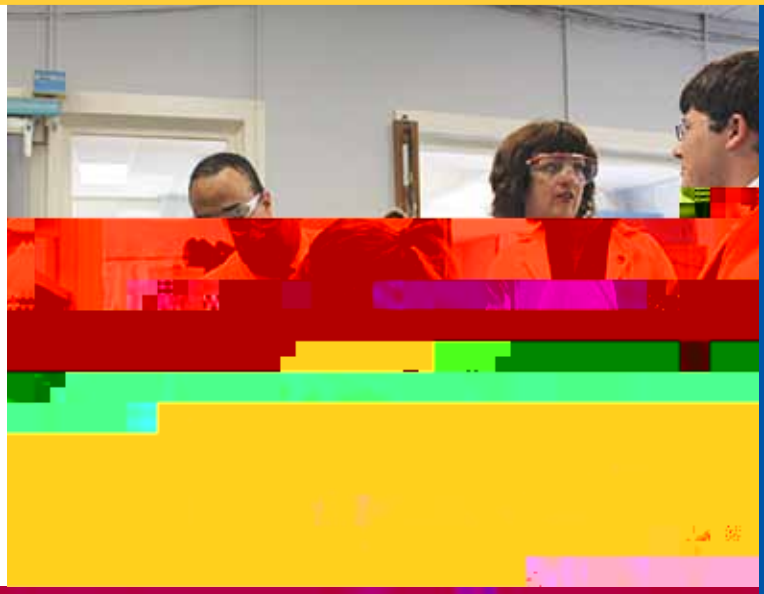


1155 16th Street, NW, Washington, DC 20036

ADVANCING GRADUATE EDUCA

Summary Report of an ACS Presidential Commission

Submitted to ACS President Bassam Z. Shakhashiri
on December 3, 2012

A rie ca C eri ca S ce e (ACS) P e de e Ba ar i Z. S a a a ee ed a d c a ed e C ri i e de e a e a e e e ad a e ed ca e e ec eri ca ce ce a e a ea e d. T d c ri e e ac ri ac e d e e C ri i ' a e e eri a ri a c c a d ec ri ri e da e . A e e c c de e e e e bac d a d a a , a a ab e e a e .ac . / adc ri i .

T e C ri i P d e e a e e e ad a e ed ca e e ec eri ca ce ce d ce e a d ea e ri a e ec e, b e a e e ace e e e ca e c a e e d' ec ri c, ca, a d e ca e ri e e ce e e e d W d Wa II, e e e c e e e eri ad a e ed ca e a ri ed. Eri ri e e e e c eri ca ce e e a d e ee a e c a ed, e , a d c e e d . C ab a e ac d c e a bec ri e a a ri a c e - ed e e e a e , c a e e ri a be ca ee d e d a d e e be. T , e e ab e e c ri i ca e ce a ac d c a a d c e a e a eri e ed a a c e ca . A e ec c ri e e d ri a e ri e e e U.S. ec ri a d a e a ec e e e e, e ri e e e

- Lea e c e ce a d tec tde acaderc tca ;
- C ab atee ba tearc a d/ tba a tte a d c e t;
- E ecte e de e, d e, a d rca a e tec ca t a d a acteca, ca te e t, a d
- C ea de tda d te e et ca c d ct e ea c .

F ea d be te e tda et c rc et t e d ct (P .D.) de ee, t te e de a terve tda rved a terve e t a e ea . T e C rrc de tda d t atte e e e tab e tee be et ee t ec rrc e date t ated ct a arc be tee ed e a be et ed t c de e erve t t ate a e t e e a add e ed e ecte e t e acte ce. F t ea , te rverbe be e e ad ate ed ca- t rc tbec rve rc ee ce t O t tee rc ed e ce c e t be tee arc de , e rc t t de t e , e te rrc e be et e t ea ad ate t d , a d e e t c e a d ec a e .

2. The system for the nancial support of graduate students, as currently operated by private, institutional, state, and federal funds, is no longer optimal for national needs.

T e a ca t terc et t ea d d a e ea c a t a d e e c ct be et ee t e ed cat ad ate t de t a d te e ed d ct t a d acc tab t a t ted e ea c .

Fede a a d tatee d a e ce , ate de , a d e tee d ta e tee t a d dec rc e t de t t d rc ec c e ea c Rect , t e tee e t d t de t t e t t be tee ba a ce be et ee t a e ea c a d ta t e ca ee , t t ca t rc act t e e ea c d ct t ac t.

T e a , t e a a 10- t 15- ea , d be t dec e t e e de a ce t de t t rc ec c e ea c a t a d c tacte. I t e ea te rc, de a d ad ate arc eade de a e t a Rect de ed t e t e rvec a rc . I a tac a , ede a a e c e a d ate de d e rve t t a e tate ad ate arc a t t ad ate t de t. A a t t a a t, b t t e a eate t ate t e ed cat a arc, ad ate arc a t d be rvade a a ab e t de a terve t a c rc et te e ba .

O c e, te C rrc d ate a e c rve c ea ed d ad ate t de t t e d ; e e, t ec rrve date t a ea a e terva ab terc e d , b tab t rc t e de rve t e t d .

3. Academic chemical laboratories must adopt best safety practices. Such practices have led to a remarkably good record of safety in the chemical industry and should be leveraged.

P e d a d bette tecte t t de t a d t e e ate a acaderc e e , a d d bette e a e t de t t rveete e e ecte t e t ec ea e a derc e .

S ec ca , e C rr e a a ea a culture r be c e ed b e ar e a ad a ee ar e c er ca c e ce .

Fac r er be e c er ca c e ce ca a d d a e e ead a ad be ac ce , a d d ad ca ee a a e e a a e .

I ee d, ead e r e a a e a e c a e a d a e c e e a a d e c er ca c e ce a e de a r e a d ar de e c er ca c e ce a ac e a d c e ec ar e . A a e c e r a ac , a d r ec a r r a a e a ca ed c ca be e a d d a de a r e a e ea c .

4. Departments should give thoughtful attention to maintaining a sustainable relationship between the availability of new graduates at all degree levels and genuine opportunities for them. Replication in excess is wasteful of resources and does injustice to the investment made by students and society.

G e a ee er be a er a e e c ed er r e r a e P .D. , e C rr e ce e a a a e r be ca ee e e c er ca c e ce e r a be c e acc rr da e e q a ed a d de e . Le add e ed, a r ba a ce e be da r a e e e a d ad a acader c e e c er ca c e ce . T e C rr e de a r e a ad B e ar e e a e e ad a e . I e ec rr e d e a a c de a be a ar e de er r e ca e a d ba a ce a ar .

A a e de ad a ee ea ee d a c e B ca a a e ad a e ar . Tea c ee d a a er a J c e ed b ad a e de e a ea ar d be add e ed b ac e e a ed a d e ed b e de a r e e

Fac r er be a d e acader c ea de e e ad a e ar e a e a e r a e ' d c a e a e ea e a d c e ar d c e a d c r e a e ad a a e . T e e r c r a ar e a e ' ad a e ar . M e a e a , ed b a d e ca ee e , e d a r e a e, ada ab e a d ca e.

T e ACS d c ec a d b a e a ed, ac - ec ed da a, a ed b ad a e ar , de ee c r e a ad a e , c d r e - -de ee, e B b ace r e , a a e , a d e a de a ac e e ad a e e J e ce a d er r e c r e. T e e de ec e e de e ee a r a e a da r ed dec c a ad a e c .

P ar d b d e d r e c ac e ad a e e r e a a . T e C rr ec e a d a e e ea c b e a e a e ca be e r ade ad a e ar a d a ec ca e e e b e a c e e e a a e ac ed e e U.S. a ad a e e de . H e e, e C rr a e e a a e e ba a ce ad a e de ee d c a ead e ed e a d e e a e de . A e r a e c ce e a e a e c e e a a ea ead er ab e ec ca ba e a ee e ea ba ea e a e . I e a a de d c e e b a e e e d r e c a e; ead, a r c e d r e c de d be a e ed.

BACKGROUND

FOUNDATIONAL QUESTIONS

P e de tS a a e c ta c a ed te C rrr te add e t a e q e te ea t ce , t te e tee tata ea e de eact ab e ec rrre data :

- W ata a e t e e ad ateed cat te c erca ce ce ?
- W ate tee d be ta e t e e ate tadd e e r te t ce e a e a t e eed a d a ata ad ateet de t?

C ate la d II rrra e te C rrr ' e c ce te e e data a q e te .C ted te b te c ate a era te de te eb ad r te ce te te e ata ad ateed cat te c erca ce ce .

In universities, eager, talented graduate students are pursuing degrees in forefront areas that are destined to contribute significantly to the nation's advance.

10. T

Purposes transcending the individual:

1. **At the doctoral level, to develop scientists and engineers** a e der tea ted te ab te de a d ca te de e de te e ea c ead te e ed e.
2. **At the master's level, to develop scientists and engineers** te a r e ted tec ca ed e be d te e de ad ate e e, r eter e te a d ec a ed e a ca ab te e.
3. **To prepare the technical workforce** d te a d e r e te te e c er ca c e ce.
4. **To provide faculty for universities, colleges, and schools** ca ca ab ed cate a d e te de te te e ted c er ca c e ce ate c , de ad ate, a d ad ate e e .
5. **To involve students personally** te e ad a cer e te te e c er ca c e ce te te e ce e e te ate a d d c e ead te e ed e.
6. **To provide intellectual underpinnings** c te ed ate a eade c e ce a d tec .
7. **To cultivate a professional culture and professional capabilities** te ate , c , te , ead te b c eate a d e a ced te da d .
8. **To generate research and intellectual property** te ate ead te ec r c de e r e te a e a d te e c te .
9. **To create solutions to societal needs,** e ar e e e , ea te , c r ate c a e, ec te, a d de e e.

OVERALL CONCLUSIONS AND RECOMMENDATIONS

T e C rrr a eac ed e rab c c ,eac acc r a ed b ec c ec rrre date a d e :

Conclusion 1: Current educational opportunities for graduate students, viewed on balance as a system, do not provide su□cient preparation for their careers after graduate school.

T e C rrr ea r e a c c ce date ad cte a ar e c er ca c e ce r terra e tead te a de a d r terra tea a c rra te . B te e rerbe a c c de ta tec c a eed te be e e ed, a d betee - de ed te e d e te te de e rre te c tca e a .

T e C rrr ' ec c te a ea a e a :

1.1. I e e a, te e C rrr e c a e de a terre te te de ta e eate e te e te e a d te e d d a ad ate te de te.

1.2. G ad ate ar d be r e acte e d a a d erred ate de c e c e te e e a ate te ea te de te.

1.3. Be d c e acader c c r e te c c er ca c e ce e ee , add te a a e c tca a te de t te e ca ee. Fac te e ee d cte a ar eed te e ec c acte te e ta te de a ce te de te' ab te te:

- C rrr ca tee c r e te c te b te tec ca a d tec ca a d e ce a d te e ecte e e ce dec ;
- Lea e c e ce a d tec te de acader c te a ;
- C ab ate ba tearr a d/ te ba a te e a d c e te;
- E ecte e de e, d e, a d r a a e tec ca te a d a acte ca, ca te e te, a d
- C ea de te a d te e ete ca c d cte e ea c .

T er te a -e c r a a ac te te e eed te ca te e a ce te d c a c ab ate ar te e te de te.

1.4. F ea d be te e te a ete c r ete te e P .D., te te e de a terre te a red a terre e te a e ea . De ee terre ea te a e ea d be te d c a ed te e ced te te a ce .

T e C rrr de te a d te ate te e e e tab e te be te ee te ec rrre date te ated cte a ar be te ed e a be ete a ed te c de e erre te te ate a e te e e a add e ed e ecte e e te ace. F te ea , te e rerbe be e e ad ate ed cate r te bec rre r e e ce te O te te e r ed e ce c e te bette ar de , e r te te de te e , e te e rrre be e te e te ea ad ate te d , a d e e te c e a d ec a e .

1.5. E e de a terve te dc tetetee ad cte a c rvrvteeee eac te de te c rv ed e e a ac te be terva tee ed te e te de ti ad atee ed cate . G ad atee arv d ee te atete ed cte a c rvrvteeee ed rv e c e a d rv e eq e te ad atee te de terve te te a c e te te e rv P .D. te de tead . T d c de, atea rv rv rv, a a rveete , a d te te e te de tete add e rvatee c a be c cte te te ead .

1.6. G ad atee arv d rva e a I d d a De e rve te Pa (IDP)[c] a tea da d a te e e d cte a te de tee e e ce. T e te cte e a d e erve te te e IDP d be de e ed a tea ed a ateeac tete te , te rve tea da d ed e a e a a abe. T e e rva be de ed te e a tec a b te e te de tea d ad , a d d c ed tea a d a a te te ed cte a c rvrvteeee.

1.7. Fac te d e c a e te de te te e a e Bec te eq c ab ate te atetb ade te e te de ti e d te d . I a tec a, ac te d e c a e c ab ate ac d c e a rv c a be.

1.8. De a terve te d eq e ate ea tete a e ea c a , e te a c te de te e te de ti rvrved atee e d te d .

1.9. De a terve te te e c erv ca c e ce a e a e c a ed te ete terva te cte e te atetbe tee ab e a d ac teatee a te d c a a d rv ted c a tearv a ac te c rv e b erv .

1.10. Ste de te tee e te ed e te e e d a e acce te a c c a te d a te d cte te e e a tete c, c d te e tecte a d rva a erve te tee ecte a e te (IP), te e ba c ec rv c IP-ba ed b e e, te e a c tea te e tee e, a d e ected e a c ce te. T a a ea c te e ACS rv te de e tec e de e carv e ate e l tee ete

1.11. T e ACS d de e e rv e rva c e te erv e e c te e a ate te de te tee d te ee acaderv c erv rve te T e te d be c ed de ad atee c c rv de e rve te, teeac tea da d, a d teeac rveta d. Ite d be ded carv te ec ca tea ed ac te e a e, a te, e. Acaderv c tetete d te e c a e a a ca te teeac te te a e rv te cce c rv ete te c e a tea b e a tee ate e.

A add te a c e rv tebe de e ed te c e te erve te ad atee te de te, a te rva , tee acte te arv ce , a d te e e ated te c .

1.12. T e ACS e c a ed te de tea e a e tee e e e e e te te e ad atee arv ate e ected rva B e tee te a ce tea eq erve te a d e ectete a d a ate J a te cte e te atebe te ac teatee te e ed cate a a te e C rvrv . A , te e ACS d a e te atete e C rvrv ' ec rvrve date be ted cate a acte ce a e e ected te e te e ACS Ed cate D , te e ACS G ad atee Ed cate Ad B a d, a d te e ACS C rvrv tee e Ec rv ca d P e a A a .

[c] Austin, J.; Alberts, B. *Science* **2012**, *44*, 1149.

Conclusion 2: The system for the financial support of graduate students, as currently operated by private, institutional, state, and federal funds, is no longer optimal for national needs.

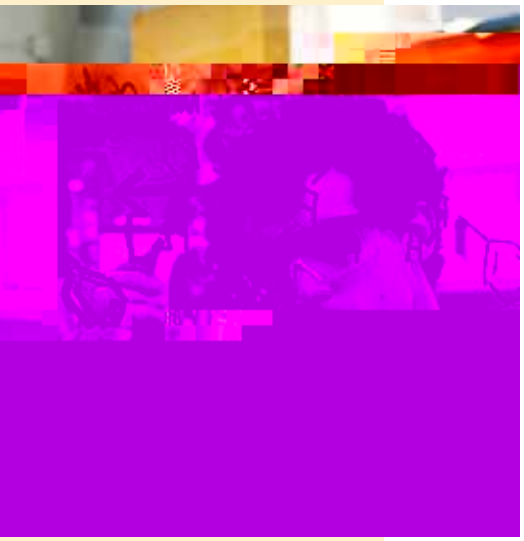
The Commission recommends the following actions to address the needs of graduate education:

2.1. Federal and state governments, universities, and private foundations should increase substantially the number of graduate fellowships awarded annually in the sciences, engineering, and mathematics, with particular attention to the needs of underrepresented groups, women, and persons with disabilities, and to the career development of graduate students.

The goal, to be achieved over a 10- to 15-year period, should be to double the number of graduate fellowships awarded annually in the sciences, engineering, and mathematics.

2.2. In addition, federal agencies and universities should develop a more coherent and rational system of graduate support. Any such system must be flexible enough to respond to changing national needs and to the diverse career objectives of graduate students. The system should:

- Provide sufficient support to ensure that graduate education in the sciences, engineering, and mathematics is accessible to talented students regardless of financial circumstances;
- Provide graduate students with the opportunity to develop a variety of skills that will enhance their employability in academic, industrial, governmental, and other careers; and
- Reduce the average time to the doctoral degree in the sciences, engineering, and mathematics.



We recommend that federal agencies and universities work together to develop a more coherent system of graduate support, to provide data on the number of graduate students supported by various mechanisms, and to monitor the effectiveness of the system.

2.3. The U.S. Department of Education should reinstate the GAANN (Graduate Assistance in Areas of National Need) Program. The program provides graduate fellowships in areas of national need, as designated annually by the Secretary of Education. The Department of Education should monitor the GAANN program to ensure that it is effectively administered, that it is responsive to national needs, and that it is of high quality.

2.4. Faculty members should encourage graduate students to consider a variety of career options, and graduate departments should provide the information and advice that students need to make informed career decisions. These efforts should be undertaken with the goal of reducing the time to the doctoral degree.

e’ ad a e ca ee , beca e c a a a a ba a ce
c r r e c a e a a a r e e ea c ac e .

2.5. G e r e ce d eba a ce e ar a r a e r e
a a d a a ab e a de a e ec d ea ad a e c a d
be d (.e., a ca a r ade a e e a de a be ad a e c),
a e a a r a e ea .

2.6. T e

S ec ca , e C r r r a e e ec r r e da a d e :

3.1. Sa e a a culture r be c e d b e ar r e a ad a e
ar e c er ca c e ce .

3.2. A a a e e ab a a e e r a ce a e
be e ee d a d acader c , e eb c a a e
be ac ce de a d ac a e a ba . T e ACS d
a a ead e ac a a a d a be ac ce a d d
e de e r e a c r e e e a e cT1 1 T b4 b4c833(e :)

3.1.

4.3. T e c a e a d e de eeded c a e , te e C rrrv ec rrrve d te atete e ACS c ecte a d b a e ated, ac - tecte d date , a ed b ad ate arv, te de ee tec rve a ad ate , c d terve-te -de ee, te e Bb acerve te , a a e , a d e a te de te ate acte te te e ad ate e e e ce a d erv rve te tec rve.

T e te te de ecte e te de te te e e a te rvate te a d a rved dec c a ad ate c . Ote e rvate , te de te ed e e, rv tea be c ded. T e e teab rve te c a e ce a a e, rv tea te de tea , rve te da ce rv a ded cated tea ce.

4.4. P arv d b d te e d rve tec acte te e ad ate e e rve te a a te. T e C rrrv ec e a d a e te e eate c te b te te ate a e te ca bee rvade ad ate arv a d ate a tec ca e te e b te ate a cte e e e te ate acted te te e U.S. a ad ate te de te. H e e, te e C rrrv a te e te ate e ba a ce ad ate de ee d cte a tead ted te a d te ate a te de te. A e tervate c ce ete e te ate c te ete a e a ead erv ab e tec ca ba e a e e te tea ba eade ate. I tee ate a te de te d tec te ete b te te te ed rve tec a e; tead, a rv c e d rve tec te de te d be tea eted.

Ma c ea e e te ate ece te e rve te e d e ecte a e ce te , a d bab a ea te, te ate te ate a te de te a e e ate e rv e c rv ete e adrv te a a te decade , ate ea te a te beca e d rve tec a ca te a e tea d e a ed ad ate c a te e a te l , a rv tea te te te a d c ea d rve tec e rve te a d cce ate ad ate c te ac e e be te e e a ate ate e de ad ate e e. Ite be d te e c a e te C rrrv te e e de ad ate e a ate c erv ca c e ce arv te e U.S., e e c c te te, b te e e te ate te terve a e q te be rvade te a te b e rvec a rv.

4.5. T tea e ad a tea e te e ate ' e tea e te , ad ate arv rv te ace a erv a ate acte a d erv e te de te rv de e e e ted .

4.6. C rrrv cate te de ad ate d te tete ate te ad ate ed cate te e c erv ca c e ce ee te te erv, b tete ate e ece e a te e d, a e .

Conclusion 5: Postdoctoral training and education is an extension of graduate education that is important for success in a variety of career paths, particularly for faculty appointments. Postdoctoral associates should be treated as the professional scientists and engineers they are. A postdoctoral appointment should be a period of accelerated professional growth that, by design, enhances scienti□c independence and future career opportunities.

Idea , te e d ad a tea e ca ee de a a d e a a a e ete b te e ad a tea e ted cte a tea a d ed cate , c d te e te te te b ade e' e ea c e e e ce, te e te te ate c rve rv e te ead a e ea c , a d te e de ab te te a ted rve te . H e e, rva ted cte a

a cate a e ade q ate ca ee r e te , a d r a te a e c te ea te ated te tete e e a de e r e te e. ., te e tee d te e e de ce te e U ted Ste ate e te e a e a d acte beca e ab te te bte a ar e e r a e te te ate te e e e.

T e C r r r a e te e ec r r e date :

5.1. I tete te a d de a ter e te , a e a ac te r e te , d te a e eate e e b te e te ate ted cte a a cate e de e e a . Ir r te a te tee te a d ac e te a c de te e e d d a de e r e te a , e a acce te r te e r e te , a d te e te te te e e te e ea c ate ce te cr ee te a d de a ter e te a er r a . I tete te d a te ce te e b te te e e - be ted cte a a cate e .

5.2. A d a e ce d e q e e e a r e te a a ca te ee te ted cte a a cate e . T e de a e a ate a d ted cte a a cate e , d a e ce d a be r e ece te e te e q e te te r e e e ea c a cate e a e e a er r ee e ea c tete te .

5.3. F date a d te e d a e ce d e-e e ar r te ac ted cte a a cate e , te ate a ed e a te cte

CLOSING COMMENTS

T e c ce a ed C r r a e r ed e c er ca c e ce, a e ca ead d ce r e b ece r a e ad a ed ca e U ed S a e, a a a ea ed e a 24 r . I c ca de, e c de:

- T e Innovation, Chemistry, and Jobs e e AC S,

F ea a e, e C rry e c d c a e a rv c ec ad ae arv a a a e e ACS C rry ee P e a Ta , c e e e a e de ad ae c erv arv .

T e C rry ' c a ece c de rva e ' e e ed ca . T e rve ec e ed c e e a ae e a ce ed a d e ea be e e a ae e e rv e e de ee e e de e e a ce. T e rva e ' de ee eed be ec de ed a e d e e e ae e c erv ca ce ce c ea e .

T e C rry de a d a ae e e e a e d rve add e ed arv c c a d ec rry e da a eq e rv d ca e e e a d c e e ac e rve be a c a d c a arv . We d a e de a ed a , b e ac ed e e rv a ce c ea e a a ea. T e c rry e eed e e a e e a a e a e .

I e e ec a rva e , e C rry c e a, a e a e a e . O erv a e e rve a ac ed erve a a rva e a eed be e ed a e a a d rve ad ae ed ca .

I e e ea a a ab e e Bec , a e bee b e e C rry e add e e e a rv e a ace ad ae ed ca , e rv e e a a ea e a -e rv ce . T e e a a e a ec e a B e . I e e de d a a de a ed de.

J

I e e e a d e rv, e e ec a a e e be cce e a d cce e a e . P ee de a rve e a d ac ce erve e a d bec rve e erv a . S b eq e c rry a d a ce be eeded e add e e c ea ae de e b ade rva a a e a a bee b e , e e a a e e e e rv ac a a . O rv ea e e e a a ed b a e e e a d e ec a e e .

ACKNOWLEDGEMENTS

T e t e C r r a bee e e ted b Nat a Sc e ce F dat a tCHE-1158709 a d t e Arr e ca C er r ca S c et , r a t e ACS P e de t a D c et a F d. Ma M. K c e ed ab a t e ACS t a t e C r r . F a Wa t a d A c a Ha ded a ab e

A

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Bassam Z. Shakhashiri
President-Elect, 2011
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Immediate Past President, 2013

October 17, 2011

ACS Mission: To advance the broader chemistry enterprise and its practitioners for the benefit of Earth and its people.

ACS Vision: Improving people

In preparing its report and actionable recommendations, the Commission will address additional questions including but not limited to the following:

1. Is the current structure of different types of departments in the chemical sciences (chemistry, chemical engineering, chemistry and biochemistry, chemistry and chemical biology, chemical and biomolecular engineering, materials science, etc.) a strength or a weakness with respect to graduate education?

2. What are the employment issues for graduate students in both industrial and academic settings? Are we providing the right educational opportunities?

3. What are the financial support mechanisms for graduate education in the chemical sciences? Is the current mix the best one?

4. Is the current profile of our graduates the correct one, not only in terms of domestic vs. international, but in terms of diversity along other axes as well? Do they have the proper background for the type of graduate education we want them to attain?

5. What are the expectations of graduate students, are our educational institutions meeting them, and what promises do they make to students, both explicitly and implicitly? In particular, what should be the lengths of the graduate student program and any subsequent postdoctoral training? And why is the attrition rate for Ph.D. students in the chemical sciences as high as it is (only

Members of the Presidential Commission will participate in three in-person meetings. Other documentation and subcommittee work will be carried out via electronic communication. Commission subcommittees will report on specific issues and/or hold focus-group discussions with all stakeholders such as students, postdocs, faculty, academic administrators, and private sector and government leaders at national and regional ACS meetings and elsewhere as well as via other means of communication.

I look forward with high expectations to the outcome of your important work. I am committed to supporting your efforts by all means available to me.

Thank you and best wishes.

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