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FRONTIERS IN NUCLEAR AND CHEMICAL STUDIES OF THE UPPERMOST ELEMENTS IN THE PERIODIC TABLE

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The study of the nuclear and chemical properties of the elements at the uppermost end of the periodic table is particularly challenging. In this paper I will restrict my discussion to the elements beyond mendelevium (Z=101) because such studies involve unique challenges and opportunities. Isotopes of these elements are short-lived and, therefore, must be studied near the site of production; they must be produced with charged particle beams at accelerators rather than via neutron capture; the use of radioactive heavy actinide targets is often required and the number of atoms produced is so small that any chemistry to be performed must be done on an "atom-at-a-time" basis. Given all these requirements, constraints, and challenges, why is it worthwhile to try to perform nuclear and chemical studies of these elements? In addition to the scientific excitement inherent in studies at the "edge of stability", can we learn anything of fundamental scientific importance that we couldn't study more easily in other regions of the periodic table?

From the standpoint of the nuclear properties of these elements, the question is relatively easy to answer. Spontaneous fission (SF) is an increasingly more probable mode of decay as one goes to higher Z elements. In fact, since SF does not occur in elements lighter than thorium (Z=90), this process can only be studied in the heavy elements. Insights into the mechanisms of fission, fission barriers, nuclear structure, and the limits to nuclear stability can be gained by studies of SF, a process in which no external energy is introduced into the nucleus and which is exquisitely sensitive to nuclear shell effects and relatively small changes in nuclear structure. The competition between SF, alpha emission, and other decay modes can only be investigated in the heavy elements region. Such information is essential in the development of nuclear models which can predict the decay properties of still heavier elements and the ultimate limit to the extension of the periodic table.

Studies of the chemical properties are equally interesting and it has already been shown [1-3] that these cannot simply be extrapolated from the known properties of lighter homologs in the periodic table. In fact, in the case of the heaviest actinides and the transactinides, it was of great importance to demonstrate experimentally that the filling of the 5f shell is completed at lawrencium (Z=103), thus ending the actinide series, and that rutherfordium (104) and hahnium (105) have properties similar to the group 4 and 5 elements. It is postulated that they are the beginning of the new 6d transition series. Even a comparison of the most rudimentary chemical behavior of these elements with that of their lighter homologs is important in assessing the validity of predictions based on extrapolation of the trends shown in a given group in the periodic table. Such information can also help in investigating the possible influence of relativistic effects on the chemical behavior of these heavy elements. For example, relativistic effects may alter the relative stability of the 7s, 6d, 7p valence electrons so that other oxidation states may be stabilized and the ionic radii may even be affected. Early calculations indicated that the ground-state configuration of element 104 might be $[Rn]5f^{14}7s^27p^2$ rather than $[Rn]5f^{14}6d^27s^2$, as expected by analogy to its lighter homolog, hafnium. However, more recent calculations indicate a ground state configuration which is predominantly $6d7s^27p$ while that for Ha (105) is predominantly $6d^37s^2$.

It should be emphasized that investigations of chemical properties depend on a knowledge of the nuclear properties in order to positively identify the species being investigated. Conversely, a knowledge of the chemical properties can be used to separate new isotopes and positively identify their Z. Thus studies of nuclear and chemical properties are synergistic and should ideally be carried out hand-in-hand.

To date, both gas and aqueous phase properties of elements as heavy as 104 and 105 have been investigated, even though their longest-lived known isotopes are only 65 second and 35 seconds, respectively. (See references 1-3 for recent reviews of the properties of elements 103, 104, and 105.) Studies of the chemical properties of 0.8-second $^{263}106$ can probably be conducted using the microSISAK technique, if methods for detecting the alpha and/or SF activity can be devised which avoid the time-consuming step of evaporating the resulting solutions.

Knowledge of the chemical properties of element 105 has recently permitted isolation and identification of the new isotope, ^{263}Ha, which has a half-life of about 27 seconds, unexpectedly long. The SF half-lives of about 40 minutes and greater than 36-hours for ^{261}Lr and ^{262}Lr, respectively indicate large hindrance factors relative to their even proton-even neutron neighbors. These measurements support previous observations that an odd proton or odd neutron can greatly hinder decay by SF [4] and make it appear promising that isotopes of elements 107 and 109 which are long enough to permit chemical, as well as nuclear studies, may exist if methods for their production can be developed.

References:

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素粒子物理学のフロンティア

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今、素粒子物理学は大きな曲り角にさしかかっている。実験、理論の両面で。

ここ数年の間に、TRISTAN（高エネルギー物理学研究所）、TEVATRON（フェルミ研究所）、LEP（欧州連合原子核研究機構）、HERA（ドイツ電子シンクロトロン研究所）が稼働を始め、多くのデータを提供している。一方、理論面では、ゲージ理論の枠組のなかで、電磁力と弱い力が電弱力として統合され、さらに強い力をも含む一本化された力の研究が進んでいる。実験屋（おそらく理論屋も）は、未知のエネルギー領域において現在の標準理論を超えた新しい現象が観測されることを期待した。ところが・・・・・・である。つぎつぎに発表されるデータは、標準理論によってみごとに説明されてしまうのだ。

では標準理論は完璧に正しいのだろうか。実はこの理論では、Glashow-Weinberg-Salamによって考え出された「電弱相互作用の対称性の自発的破れ」が仮定されている。これは、弱い相互作用を伝播するウィークボソンの質量（陽子の約１００倍）を生成するためのメカニズムで、標準理論のもっとも重要な部分である。ところが、この対称性の自発的破れの起源が、まだまったく解明されていないのである。

標準理論では、６個づつのクォークとレプトン、４つの基本的な力を伝播する4種類のゲージ粒子、さらにヒッグスとよぶスピン０の２個の粒子が仮定されている。これらの粒子がもつ基本的な物理量、たとえば質量は、はじめから理論のなかにパラメーターとして与えられている。さらに標準理論は、相互作用の強さやヒッグスポテンシャルを記述するパラメーターなど多くのパラメーターを含んでおり、現象論の域を出てはいないのである。

今日の高エネルギー物理学における最大の課題は、対称性の自発的破れの起源を実験的に明らかにし、さらに「標準理論」を超えた新しい現象を発見することである。このような目的に沿って、いくつかの新しいプロジェクトも計画されている。本講演では、高エネルギー物理学の現状と将来の展望を実験面を中心にしてのべてみたい。

ひろせたちしげ

FRONTIER OF ELEMENTARY PARTICLE PHYSICS

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Presennt status of elemenntary particle physics is reviewed in terms of experimental results obtained from recently constructed big accelerators,such as TRISTAN(KEK),TEVATRON(Fermi Lab.),LEP(CERN) and HERA(DESY). Various experiments using these accelerators clarify that the electro-weak theory i.e."Standard Theory" can commpletely describe all data observed .

However SandardTheory contains lots of parameters e.g.masses of quarks and leptons and thus this theory cannot be beyond phenomenology.Then I will also present the status of some future prjects in which new aspects of Standard Theory are expected to be revealed and hopefully new phenomena beyobd Standard Theory will be discovered.

EXPONENTIAL GROWTH AND DECAY IN RADIOCHEMICAL EDUCATION

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The Twentieth Century - which might well be called the "Nuclear Century" - opened with the discovery of X-rays by Roentgen and the nuclear atom by Rutherford, and may close with the definitive answer to the question of the "missing solar neutrinos" and the mechanism of energy production in the sun. Between these two epoch-defining events are sandwiched a multitute of extraordinary discoveries in nuclear science: artificial radioactivity, fission and fusion, the characterization of ^{43}Tc, ^{61}Pm and the trans-Uranium elements, ^{14}C dating, the Mossbauer effect, and hot-atom chemistry, to name only a few. These discoveries have brought about the conception, adolescence, and maturing of nuclear science and have been marked by the awarding of more than 20 Nobel prizes in Chemistry and Physics, and the accompanying recognition of the centrality of this field to our understanding of the fundamental description of nature at the Angstrom and sub-Angstrom level.

The educational aspects of this field - at least in the United States - has been strongly influenced by several key events : the inception of "big science" in the late 30's, typified by the work of Lawrence and his group at Berkeley; the discovery and exploitation of fission in relation to national policy by Fermi, Oppenheimer, Bethe, Teller *et al.* and the Manhattan Project operations; the formation of the Atomic Energy Commission and its vesting of policy-making decisions in civilian hands; the creation of the U.S. National Science Foundation in 1950 along the lines originally conceived by Bush; and finally, the development, exploitation, control, and regulation of the production of nuclear power for civilian uses in the post-WWI years and the establishment of the International Atomic Energy Agency as suggested by Eisenhower. These events provide the matrix within which nuclear science - and specifically, the field of *Nuclear- and Radiochemistry* - has developed as an academic sub-discipline in U. S. Universities. Were it not for the inescapable time frame imposed by the radioactive decay lifetimes of the fission product debris of nuclear power generation and weapons production (and their destruction in the post "cold war" era), the gradual fading-out of nuclear science from the educational enterprise in U.S. Universities would be a benign matter, simply ascribed to the natural history of science and its dynamics. However, these nuclear lifetime "facts of life" impose on us and on coming generations, a special task, as it relates to the training of future generations of students who are competent to address the pressing problems existing in this field. The prospects for successfully addressing this task will be examined in some detail.