Experimental tests of relativistic chemistry will update the periodic table

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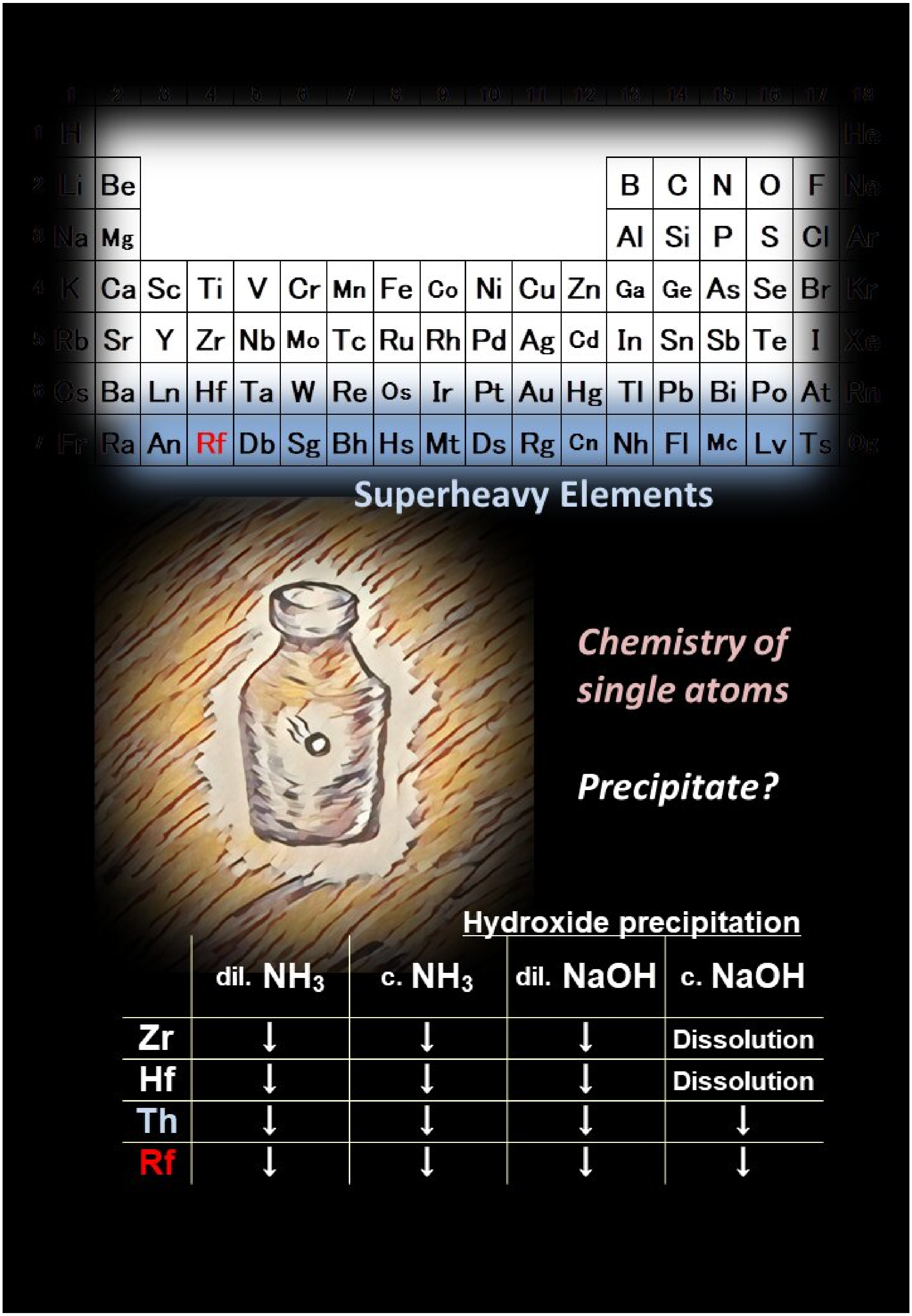
Be B C N O F
Mg Al Si P S Cl
Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br
Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I
Ba Ln Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At
Ra An Rf Db Sg Bh Hs Mt Ds Rg Cn Nh Fl Mc Lv Ts
Superheavy Elements
Chemistry of single atoms
Precipitate?
Hydroxide precipitation
dil. NH3 | c. NH3 | dil. NaOH | c. NaOH
Zr ↓ ↓ ↓ Dissolution
Hf ↓ ↓ ↓ Dissolution
Th ↓ ↓ ↓ ↓
Rf ↓ ↓ ↓ ↓

Fig.1 Brief overview of the present study. Credit: Osaka University

All chemistry students are taught about the periodic table, an organization of the elements that helps you identify and predict trends in their properties. For example, science fiction writers sometimes describe life based on the element silicon because it is in the same column in the periodic table as carbon.

However, there are deviations from expected periodic trends. For example, lead and tin are in the same column in the periodic table and thus should have similar properties. However, whilst lead-acid batteries are common in cars, tin-acid batteries don't work. Nowadays we know that this is because most of the energy in lead-acid batteries is attributable to relativistic chemistry but such chemistry was unknown to the researchers who originally proposed the periodic table.

Relativistic chemistry is difficult to study in the superheavy elements, because such elements are generally produced one at a time in nuclear fission reactions and deteriorate quickly. Nevertheless, having the ability to study the chemistry of superheavy elements could uncover new applications for superheavy elements and for common lighter elements, such as lead and gold.

In a recent study in *Nature Chemistry*, researchers from Osaka University studied how single atoms of superheavy rutherfordium metal react with two classes of common bases. Such experiments will help researchers use relativistic principles to better utilize the chemistry of many elements.

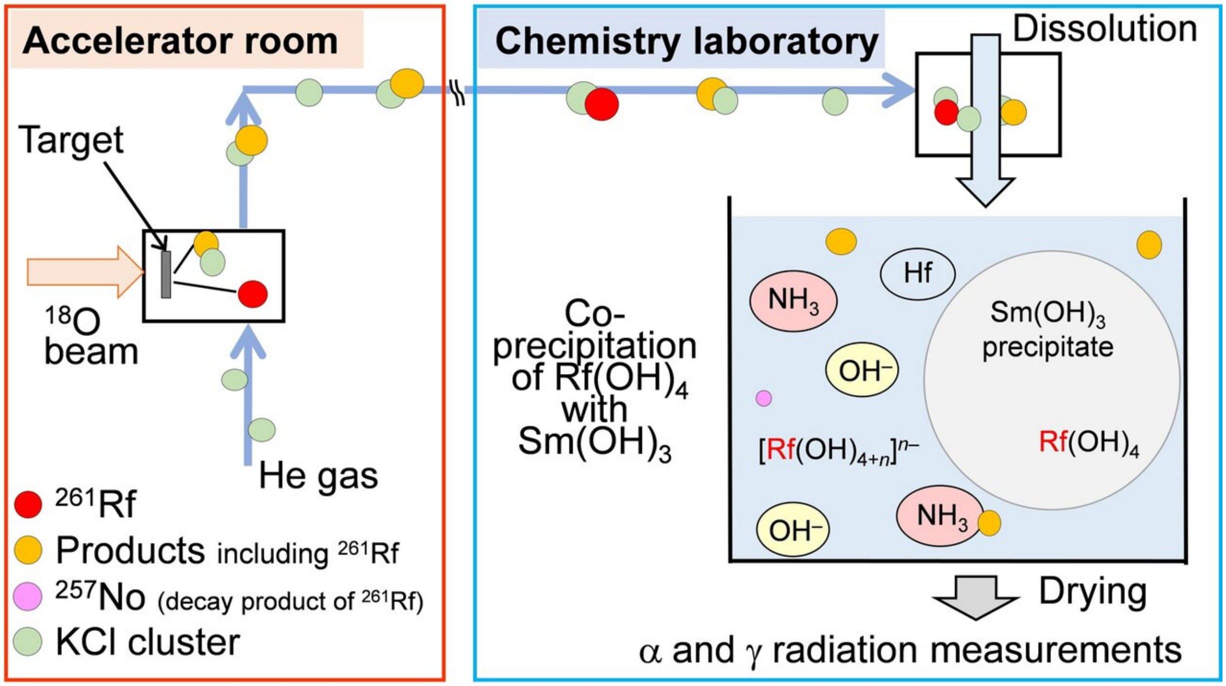

Fig.2 Schematic diagram of online co-precipitation experiment of ^{261}Rf. (credit: Osaka University

"We prepared single atoms of rutherfordium at RIKEN accelerator research facility, and attempted to react these atoms with either hydroxide bases or amine bases," explains Yoshitaka Kasamatsu, lead author on the study. "Radioactivity measurements indicated the end result."

Researchers can better understand relativistic chemistry from such experiments. For example, rutherfordium forms precipitate compounds with hydroxide base at all concentrations of base, yet its homologues zirconium and hafnium in high concentrations. This difference in reactivity may be attributable to relativistic chemistry.

"If we had a way to produce a pure rutherfordium precipitate in larger quantities, we could move forward with proposing practical applications ," says senior author Atsushi Shinohara. "In the meantime, our studies will help researchers systematically explore the chemistry of superheavy elements."

Relativistic chemistry explains why bulk gold metal is not silver-colored, as one would expect based on periodic table predictions. Such chemistry also explains why mercury metal is a liquid at room temperature, despite periodic table predictions. There may be many unforeseen applications that arise from learning about the chemistry of superheavy elements. These discoveries will depend on newly reported protocols and ongoing fundamental studies such as this one by Osaka University researchers.

More information: Co-precipitation behaviour of single atoms of rutherfordium in basic solutions. *Nature Chemistry*. DOI: 10.1038/s41557-020-00634-6

Provided by Osaka University

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