

# Rubidium round-the-clock

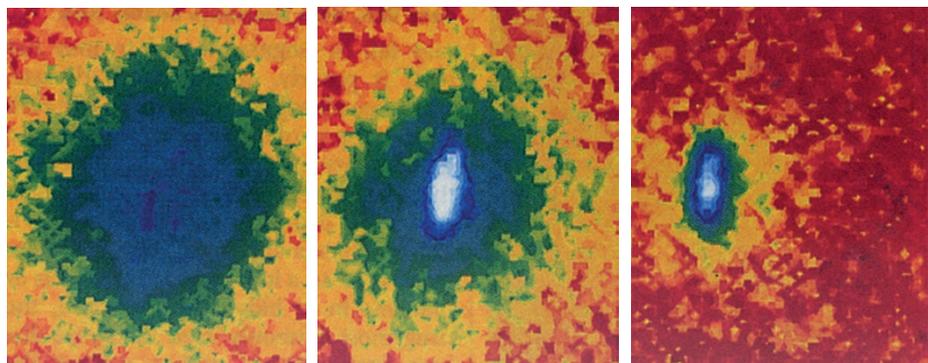
Iulia Georgescu explains why rubidium is atomic physicists' favourite chemical element.

Rubidium (Rb) was discovered in 1861 by physicist Gustav Kirchhoff — perhaps better known for his work on electrical circuits — together with chemist Robert Bunsen, in Heidelberg. Using their newly invented spectroscope to investigate the composition of a variety of samples they came across new elements: first caesium (Cs) in mineral water and then rubidium in the mineral lepidolite. Both were named after the colour of their emission lines — sky blue (*caesius*) and red (*rubidius*), respectively.

Element 37 firmly belongs to group I of the periodic table, with characteristics similar to those of the other alkali metals. A soft metal with a low melting point (39.3 °C), it reacts violently with water — even more so than sodium (typically used in high-school demonstrations) and potassium (already too dangerous for this purpose) in agreement with the increasing energy of the valence electron as one goes down the column. The hydrogen gas produced during the reaction of rubidium with water ignites in air; in fact, rubidium itself can spontaneously ignite in air.

Rubidium proved well suited to low-temperature experiments. In the 1990s cheap commercial laser diodes — such as those used in CD players — operating close to the wavelength used to laser-cool rubidium (780 nm) became readily available. The rubidium vapour required for these experiments is generated at accessible temperatures, just above that of the human body. These factors, together with rubidium's laser-cooling-friendly atomic energy level structure, made it the atom of choice for many atomic physics experiments.

In the early summer of 1995 Eric Cornell and Carl Wieman first managed to cool  $^{87}\text{Rb}$  vapour down to 170 nK (pictured), thus observing the strange state of matter predicted to arise near absolute zero temperatures by Satyendra Nath Bose and Albert Einstein seventy years beforehand. Any number of bosons — particles obeying Bose–Einstein statistics — can occupy the same quantum



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energy state. When cooled close to absolute zero, bosonic atoms collectively huddle into the lowest energy state, forming a 'Bose–Einstein condensate' — a single quantum mechanical entity observable at the near-macroscopic scale. Cornell and Wieman shared the 2001 Nobel Prize in Physics with Wolfgang Ketterle, who a few months later made the first sodium Bose–Einstein condensate.

In the past twenty years, rubidium Bose–Einstein condensates have enabled amazing progress in our understanding of quantum many-body phenomena and our ability to mimic exotic physics, like radiation emitted from black holes. Ultracold atomic gases are also key to technologies such as atomic clocks or sensors (gravitational, rotational, magnetic) with excellent sensitivity that exploit quantum mechanical effects.

Discovered together spectroscopically, caesium and rubidium currently both set our standards for time. The International System of Units' definition of the second is 9,192,631,770 periods of the transition frequency between two energy levels of  $^{133}\text{Cs}$ . For sixty years, since the first atomic clock, caesium has been the primary time and frequency standard. Rubidium clocks also make use of a hyperfine transition in the microwave region, and serve as secondary standards. However, their low cost, smaller size and greater stability make rubidium clocks ideal for many commercial applications including the Global Positioning System (GPS). Nowadays, rubidium clocks have been miniaturized to the size of a matchbox and

still have uncertainties of just  $10^{-12}$ . To put things into perspective, the current record is held by the strontium-87 ( $^{87}\text{Sr}$ ) optical lattice clock at  $10^{-18}$ , meaning that the clock should be accurate to within a second in 15 billion years.

That may be a long time on the human timescale, but not for rubidium. It only has two naturally occurring isotopes,  $^{85}\text{Rb}$  and  $^{87}\text{Rb}$ , the latter is radioactive with a half-life of 48.8 billion years. It decays to stable  $^{87}\text{Sr}$ , which turns out to be a very useful process as it gives us another rubidium clock — a geological one, used in rubidium–strontium dating.

Because rubidium is reasonably abundant in the Earth's crust, to determine the age of a rock one can compare the ratios of both  $^{87}\text{Rb}$  and its decay product  $^{87}\text{Sr}$  to the naturally occurring  $^{86}\text{Sr}$ . First used by Otto Hahn in the early 1940s, this rubidium–strontium dating method is very reliable for very long timescales, for instance 4.5 billion years — the age of the Earth.

I hope you now agree that rubidium rocks. □

IULIA GEORGESCU is a Senior Editor of *Nature Physics*.

## Correction

In the In Your Element article 'Strontium's scarlet sparkles' (*Nature Chem.* **7**, 940; 2015), the years in the first paragraph were incorrect. These were corrected in the online versions after print on 29 October 2015.

