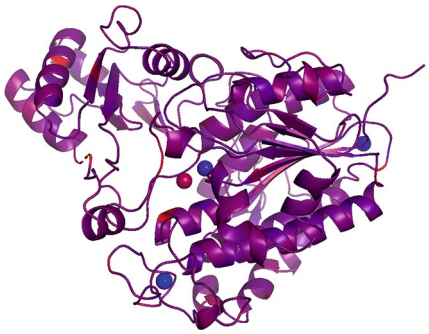
The katalytic speedometer

As a unit for enzyme activity, the katal is enigmatic but struggles to find widespread acceptance. Soumitra Athavale tells its story.

In the 1 second taken to read the title of this article, a single glycolytic enzyme in your eye muscle has processed about 50 glucose molecules, 10 million potassium ions have blazed through a neuronal ion channel, an RNA polymerase has strung together a message 60 nucleotides long and a bicarbonate transporter in a red blood cell has expelled 100,000 carbon dioxide molecules, on their way into the depths of the birch leaf outside the window, where another enzyme — RuBisCo — will return one of them to glucose[1].

The unceasing action of these protein catalysts keeps the biological world afloat. They are the engines, propellers and transistors of the microscopic world, and just like their mechanical analogues, these machines possess their own 'tech. specs'. The determination of these specs requires careful study, most often achieved by purifying the protein and recapitulating its catalytic properties with methods from biochemistry and enzyme kinetics in a controlled environment. Enzymologists have historically used the yardstick of enzyme activity to compare the catalytic performance of protein preparations. It is defined as the amount of reactant transformed by the enzyme per unit time — much like the average speed of a car during a journey.

Conventionally, enzyme activity has been specified in term of enzyme units (U): 1 U of an enzyme is the amount that transforms 1 µmol of reactants in 1 min. A vial of shrimp alkaline phosphatase (pictured), an enzyme that splits phosphate, labelled '500 units' is thus expected to hydrolyze 500 µmol of substrate in 1 min. This activity is contingent upon other reaction parameters like concentration, temperature and buffer conditions being maintained at defined values. A formal adoption of this measure into the SI system was completed in 1999 by the introduction of the unit katal (from the Greek word *katalysis*, meaning dissolve), which defines enzyme activity in terms of mol s^{-1} rather than µmole min^{-1}



(ref. [2]). The phosphatase vial thus has an activity of 8.3 µkatal. It is important to note that such an activity measure does not provide any direct fundamental insight into the enzyme's catalytic properties, but is rather a macroscopic parameter applicable only under specific reaction conditions. Conveniently, this information is used to estimate the amount of enzyme preparation required for a transformation. The contingent reaction conditions differ from enzyme to enzyme — each protein has unique characteristics; therefore, optimal performance is case-dependent. If proteins were imagined as stars powering the microscopic universe, enzyme activity would be akin to apparent brightness and not absolute luminosity.

In a hypothetical collection of vials containing about 1 µmol of the myriad enzymes of life, activities would span over 8 orders of magnitude. The most sluggish ones measuring to around 10 nkatal will be dwarfed by the superstars like triose phosphate isomerase and superoxide dismutase, clocking in at a staggering 0.1 katal. A barely visible sprinkle of the isomerase enzyme in a cup full of its substrate, glyceraldehyde-3-phosphate, would complete its transformation in a single second. The fastest catalysts are limited only by the diffusion rate of reactants into the active site. However, such extreme examples are rare — most enzymes hover around the 10 µkatal mark[3].

Variations of the katal such as katal l^{-1}, which normalize enzyme concentration, allow quantitative comparison among different preparations. A push to include a catalysis unit grounded in the SI system was set in motion as early as 1962[2]. Now, despite the admission of the katal into the SI system more than two decades ago, its adoption in academia and industry is still sporadic as the use of enzyme units remains widespread. This is perhaps because the activity unit fits the experimental scales at which academic biochemists most often work. An enzymologist exploring the activity of an enzyme will be working on a small scale of µmoles rather than moles and making measurements in minutes rather than seconds — thus making the activity unit a natural choice. Moreover, the accumulation of measurements in activity units over many years, especially in industry, contributes to inertia against changing to the katal. Commercially available enzymes are still predominantly rated in terms of activity units. Indeed, the classical status of the activity unit is cemented into textbooks and biochemistry education and there appears little incentive for a shift. Journals and biomedical practitioners encouraging use of the katal for uniformity can induce a transition. As of now, the katal continues to be the outside option. ❐

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