on their megaparsecs, and high-energy physicists remain attached to the electron-volt. You don't hear much talk of gigapascals on the evening weather forecast.

Hebra devotes a chapter each to time, length, mass, heat and so on, and offers some entertaining titbits about the genesis of what we are now pleased to call standard units. It is hard to know what sort of reader he is addressing. He explains at some length that the second is one-sixtieth of one-sixtieth of one twenty-fourth of a solar day, because the Babylonians were fond of twelves (although they forgot to tell us why), and he takes a couple of muddled pages to sketch the oddities of Earth's orbit that make the solar day an elusive and untrustworthy quantity. But then he finishes by saying in a single brief paragraph that an official second is now so many vibrations of a caesium atom. He doesn't think it necessary to explain what sort of vibrations he means or how they are counted with the necessary accuracy.

Although Hebra is described as a science writer and engineering consultant, scientific explanation is not his strength. In the chapter on heat and energy, he confuses phlogiston with caloric, claims that James Watt invented the steam engine and thereby proved that phlogiston does not exist, and says that Kelvin established the absolute zero of temperature by observing that the ideal gas law implies zero volume at a sufficient degree of cold. In fact, this point had made been a century and half earlier, but its significance was far from clear. Kelvin instead used Carnot's theory of heat engines to define a temperature scale through mechanics, and only after taking hints from Joule and Clausius did he realize there must be an absolute zero.

Hebra's obvious preference for engineering over science produces some of the better parts of the book. I was pleased to learn that viscosity is sometimes measured in Engler's degrees, which are related, naturally enough, to the speed with which a fluid passes through an Engler viscometer. If you're trying to figure out what diameter of piping to use in your molasses factory, this may well be a handy number. Quick: what's viscosity in SI units?

The author finishes with a modest plea that the United States might one day summon the nerve to go wholeheartedly metric. But he admits that this would cost a huge amount of money, and in any case many of his examples demonstrate the possibly unintended point that practicality often wins out over scientific rationality for perfectly good reasons — or at least reasonably good reasons. Perhaps manufacturers of electrical appliances should offer to give up British thermal units provided that astrophysicists agree to banish parsecs and solar masses. ■

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Science in culture

Green revolution: Wilhelm Ostwald's paintings put his theories about colour into practice.

Painting by numbers

Chemist Wilhelm Ostwald added colour to the art world.

Philip Ball

This picture might look like the barely competent effort of a disciple of Caspar David Friedrich, but Wilhelm Ostwald intended that his deeply romantic seascape would, by virtue of its 'scientific' colouring, be beyond criticism.

Ostwald, the 1909 Nobel laureate who pioneered the discipline of physical chemistry, was an enthusiastic amateur painter. His works, some of which have recently been published for the first time in *De Artes Chemiae* (Lothar Beyer and Rainer Behrends, Passage, 2003), show that he was not without talent, although he was stylistically conservative and was more or less untouched by modernism.

But Ostwald's artistic endeavours are more than a marginal curiosity, for his theories on colour were hugely influential in the early decades of the twentieth century, in both fine art and industry. Ostwald's paintings reveal how he thought his ideas should be put into practice.

There is a long-standing view that red, yellow and blue are the only three primary colours, but Ostwald defied this: in his *Colour Primer* (1916), he included green as a primary, later awarding it a large segment of his colour wheel. While not of course denying that green can be mixed from blue and yellow, he followed the psychologist Ewald Hering in asserting that green is perceptually autonomous. Ostwald's colour theory was much discussed by Piet Mondrian and his colleagues in the De Stijl group of painters, and may have led Mondrian to use a distinctly greenish yellow in his grid-like compositions of around 1920, as though he was trying to accommodate yellow and green in a single primary.

The most important aspect of Ostwald's colour theory, however, was the role he assigned to grey. His attempts to map colour space followed those of Albert Munsell, whom Ostwald met in 1905. Munsell tried to quantify and standardize colours according to parameters of hue, saturation and brightness. The last of these was particularly important to Ostwald, who introduced a grey scale into colour space. He believed that a scale of perceptually equal steps in the brightness of a colour could be achieved by adding black and white in ratios that followed a logarithmic progression. This, he said, provided a scheme for achieving perfect tonal balance and harmonious colour composition in a painting.

Ostwald used his fame as a chemist to impress his colour theory on the German paint industry. In 1912 he joined the Deutsche Werkbund, an organization dedicated to introducing standardization into industrial design, and in 1914 he arranged an exhibition of commercial paints and dyes. Eventually Ostwald established his own pigment factory, called Energie.

The idea that colour composition could be pursued in an objective, 'scientific' way found echoes in the 1920s at the Bauhaus school of art and design in Weimar, Germany, where Paul Klee and Wassily Kandinsky taught. Kandinsky believed that a carefully chosen arrangement of colours could pluck the emotional strings of the soul as deliberately as a pianist strikes notes on the keyboard. He assigned dogmatic meanings, established through psychological tests, to specific colours.

Ostwald was a controversial figure at the Bauhaus, where he lectured in 1927. He was asked to join the advisory board the following year, but his response is not recorded. His eagerness to 'correct' painters who did not use colour 'properly' — he once announced that Titian had used a blue two tones too high — grated on the sensibilities of some artists. Kandinsky became sympathetic to Ostwald's ideas, but Klee was unwilling to be fettered by any scientific theory of colour. Ostwald's rules, he said, meant "renouncing the wealth of the soul. Thanks, but no thanks."

➧ www.wilhelm-ostwald.de

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