Thirty eight anomalies of water[1]

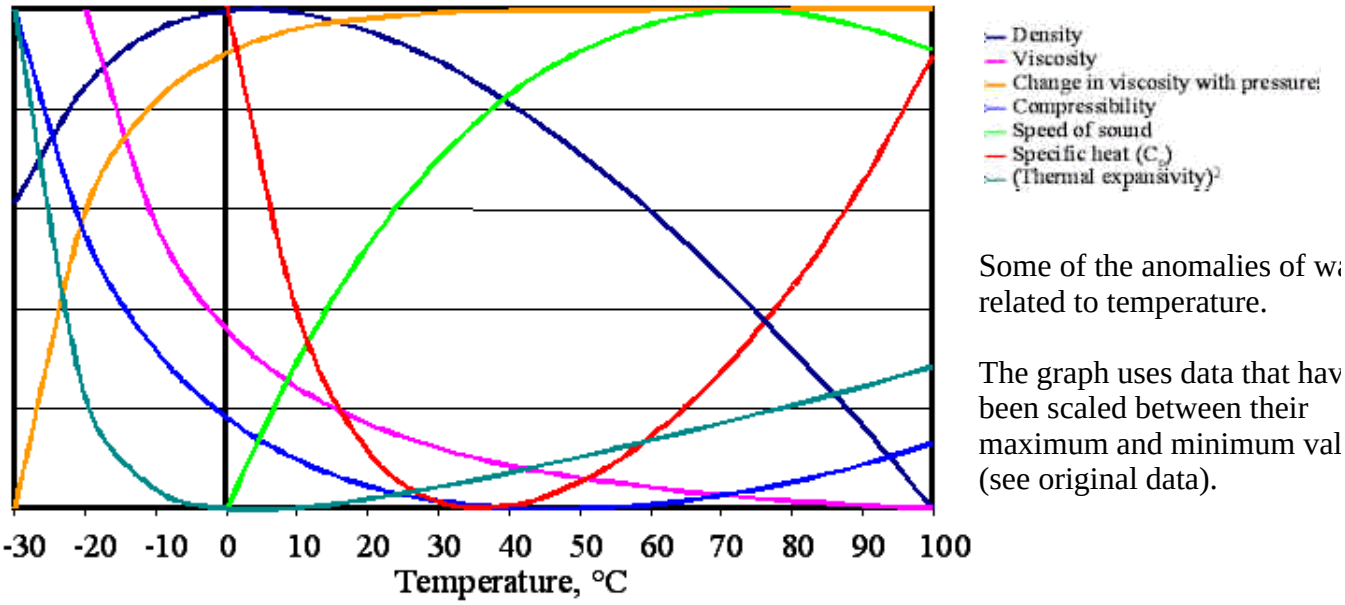
It has often been stated (e.g. [127]) that life depends on the anomalous properties of water. In particular, t large heat capacity and high water content in organisms contribute to thermal regulation and prevent loca temperature fluctuations. The high latent heat of evaporation gives resistance to dehydration and consider evaporative cooling. Water is an excellent solvent due to its polarity, high dielectric constant and small si particularly for polar and ionic compounds and salts.[2] It has unique hydration properties towards biologic macromolecules (particularly proteins and nucleic acids) that determine their three-dimensional structure hence their functions, in solution. This hydration forms gels that can reversibly undergo the gel-sol phase transitions that underlie many cellular mechanisms [351]. Water ionizes and allows easy proton exchange between molecules, so contributing to the richness of the ionic interactions in biology.

The density maximum at 4°C and low ice density results in (i) the necessity that all of a body of water (n just its surface) is close to 0°C before any freezing can occur, (ii) the freezing of rivers, lakes and oceans from the top down, so insulating the water from further freezing and allowing rapid thawing, and (iii) der driven thermal convection causing seasonal mixing in deeper temperate waters. The large heat capacity o oceans and seas allows them to act as heat reservoirs such that sea temperatures vary only a third as much land temperatures and so moderate our climate. The compressibility of water reduces the sea level by abo m giving us 5% more land. [65]

The anomalies

1. Water has unusually high melting point. [explanation]
2. Water has unusually high boiling point. [explanation]
3. Water has unusually high critical point. [explanation]
4. Water has unusually high surface tension and can bounce. [explanation]
5. Water has unusually high viscosity. [explanation]
6. Water has unusually high heat of vaporization. [explanation]
7. Water shrinks on melting. [explanation]
8. Water has a high density that increases on heating (up to 3.984°C). [explanation]
9. The number of nearest neighbors increases on melting. [explanation]
10. The number of nearest neighbors increases with temperature. [explanation]
11. Pressure reduces its melting point (13.35 MPa gives a melting point of -1°C) [explanation]
12. Pressure reduces the temperature of maximum density. [explanation]
13. D_2O and T_2O differ from H_2O in their physical properties much more than might be expected from increased mass; e.g. they have increasing temperatures of maximum density (11.185°C and 13.4°C respectively). [explanation]
14. Water shows an unusually large viscosity increase as the temperature is lowered. [explanation]
15. Water's viscosity decreases with pressure (at temperatures below 33°C). [explanation]
16. Water has unusually low compressibility. [explanation]
17. The compressibility drops as temperature increases down to a minimum at about 46.5°C. Below thi temperature, water is easier to compress as the temperature is lowered. [explanation]
18. Water has a low coefficient of expansion (thermal expansivity). [explanation]

19. Water's thermal expansivity reduces increasingly (becoming negative) at low temperatures. [explanation]
20. The speed of sound increases with temperature (up to a maximum at 73°C). [explanation]
21. Water has over twice the specific heat capacity of ice or steam. [explanation]
22. The specific heat capacity (C_P and C_V) is unusually high. [explanation]
23. The specific heat capacity (C_P) has a minimum (36°C). [explanation]
24. NMR spin-lattice relaxation are very small at low temperatures. [explanation]
25. Solutes have varying effects on properties such as density and viscosity. [explanation]
26. None of its solutions even approach thermodynamic ideality; even D_2O in H_2O is not ideal. [explanation]
27. X-ray diffraction shows an unusually detailed structure. [explanation]
28. Supercooled water has two phases and a second critical point at about -50°C. [explanation]
29. Liquid water may be supercooled, in tiny droplets, down to about -70°C. It may also be produced f glassy amorphous ice between -123°C and - 149°C [74] and may coexist with cubic ice up to -63°C [137]. [explanation]
30. Solid water exists in a wider variety of stable (and metastable) crystal and amorphous structures tha other materials. [explanation]
31. Hot water may freeze faster than cold water; the Mpemba effect. [explanation]
32. The refractive index of water has a maximum value at just below 0°C. [explanation]
33. The solubilities of non-polar gases in water decrease with temperature to a minimum and then rise. [explanation]
34. At low temperatures, the self-diffusion of water increases as the density and pressure increase. [explanation]
35. The thermal conductivity of water rises to a maximum at about 130°C and then falls. [explanation]
36. Proton and hydroxide ion mobilities are anomalously fast in an electric field [explanation]
37. The heat of fusion of water with temperature exhibits a maximum at -17°C [15]. [explanation]
38. The dielectric constant is high. [explanation]



Some of the anomalies of wa related to temperature.

The graph uses data that hav been scaled between their maximum and minimum val (see original data).

[1] Whether or not the properties of water are seen to be anomalous depends upon which materials water be compared and the interpretation of 'anomalous'. For example, it could well be argued that water posse exactly those properties that one might deduce from its structure (see e.g. [402]). Comparisons between v liquid sodium, argon and benzene appear to Franks [112] to indicate several of the properties given abov not being anomalous. However these materials are perhaps not the most typical of liquids. The list gives properties generally understood to make liquid water (and in one case ice) stand out from 'typical' liquid in one case solids). See [242] for a review concentrating on the non-anomalous properties of water; i.e. th that are the 'same' as for other liquids. [Back]

[2] It is therefore difficult to obtain really pure water. Note that ice, in contrast, is a very poor solvent. [B

Please submit comments and any other suggestions of water anomalies