MPEMBA EFFECT

According to 'MATTER (Re-examined)'

Nainan K. Varghese, matterdoc@gmail.com
http://www.matterdoc.info

Abstract: Two equal volumes of water, one slightly warmer than the other, when placed in similar external conditions to freeze, warmer water is noticed to freeze before the other. This phenomenon, (called Mpemba effect), is the result of difference in rate of inter-atomic movements during cooling stages of macro bodies with different initial temperatures.

Keywords: Heating, Cooling, Latent stage, Mpemba effect.

Introduction:

Physical states are applicable only to macro bodies. Primarily, it is the inter-atomic/molecular distances that determine physical state of a macro body. Matter-content levels of atoms/molecules determine inter-atomic/molecular distances in a composite macro body. Heating or compressing a macro body reduces matter-content levels of its constituent 3D matter-particles. Similarly, cooling or reducing compression on a macro body increases matter-content levels of its constituent 3D matter-particles.

Heat or cold of a macro body is relative status of quantity of 3D matter its 'primary 3D matter particles' contains with respect to quantity of 3D matter in primary 3D matter particles of a reference macro body at standard external conditions. Quantity of 3D matter (and corresponding energy content about) of a primary 3D matter particle is determined by surrounding external pressure on it. As external pressure increases, primary 3D matter particle loses part of its matter-content into universal medium (along with loss of corresponding energy content) and its volume expands. This process is heating. As external pressure reduce, a primary 3D matter particle gains matter-content from universal medium (along with increase in corresponding energy content) and shrinks in volume. This process is cooling. [These conclusions are contrary to current physical theories and beliefs]. Alternative concept, presented in 'MATTER (Re-examined)' [3] describes a logical mechanism, operated by universal medium, for these actions.

Accordingly, raising external pressure lowers total matter-content of a macro body (with corresponding reduction in its energy content) and increases its volume. This generally leads to reduction in matter-density of the macro body. Lowering external pressure raises total matter-content of a macro body (with corresponding augmentation in its energy content) and reduces its volume. This generally leads to an increase in matter-density of the macro body. A macro body, existing in free space is at its highest matter (and energy) content and is at its lowest volume.

On cooling, matter and energy contents of all (primary 3D matter particles and hence) atoms in a macro body increase and their volumes decrease. Increase in matter-content increases gravitational attraction between atoms in a macro body. During cooling, atoms of a macro body move nearer and inter-atomic distances reduce. Conversely; on heating, matter and energy contents of all atoms in a macro body decrease and their volumes increase. Reduction in matter-content reduces gravitational attraction between atoms in a macro body. During heating, atoms of a macro body move farther and inter-atomic distances in the macro body increase.

Mpemba effect:

If two equal volumes of water, one slightly warmer than the other, are placed in similar external conditions to freeze, warmer water is noticed to freeze before the other. This phenomenon is called 'mpemba effect' (named after Erasto B. Mpemba, who noticed this phenomenon first, in modern times).

Let us consider two identical liquid macro bodies, 'A' and 'B', being cooled under similar surrounding conditions. Let freezing temperature of body-material is t_0° c. In macro bodies' stable states, all their molecules are in steady relative positions. There are no random motions corresponding to temperature level of macro bodies, as is believed today. We may neglect effects of 'Brownian motion' or any other natural (identical) convection in liquid macro bodies.

Let initial temperature of macro body, A, is t_1° c. In this stable state, all molecules of the macro body are steady in their relative positions. They have no linear acceleration or linear velocity towards neighbouring molecules. Cooling of macro body is affected by a reduction in its surrounding external pressure, produced by direct contact with cooler material. During cooling, constituent 3D primary matter-particles of molecules gain matter content from surrounding universal medium. As cooling process of macro body starts, its molecules move towards each other at increasing linear acceleration due to gravitational attraction. Their linear accelerations towards each other are subscribed by increases in gravitational attraction between them, due to increases in their matter-contents and reduction in distance between them. As and when temperature of macro body reaches freezing point t_0°c, neighbouring molecules would have reached proximity corresponding to freezing state of body-material. The macro body, A, changes its physical state from liquid state to solid state.

Let initial temperature of macro body, B, is t_2° c, slightly higher than initial temperature of macro body, A. In this stable state, all molecules of macro body are steady in their relative positions. They have no linear acceleration or linear velocity towards neighbouring molecules. Cooling of the macro body is affected by a reduction in its surrounding external pressure, produced by direct contact with cooler material. During cooling, constituent primary 3D matter-particles of molecules gain matter-content from surrounding universal medium. As cooling process of macro body starts, its molecules move towards each other at increasing acceleration due to gravitational attraction. Their accelerations towards each other are subscribed by increases in gravitational attraction between them, due to increases in their matter-contents and reduction in distance between them. As and when temperature of macro body, B, reaches temperature t_1° c, its molecules have already gained certain resultant velocity towards their neighbours. Although matter-contents and mutual gravitational attraction of molecules, at temperature t_1° c, are equal to those of atoms in macro body, A, (during its initial stage of cooling), these molecules are already under certain linear velocity towards their neighbours.

Further motions of these molecules are governed by accelerations due to gravitational attraction, as in the case of macro body, A, over and above their current linear velocities. Because of their initial linear velocities at temperature t_1°c, average velocities of molecules in macro body 'B', during its transition from temperature t_1°c to t_0°c are greater than average velocity of molecules in macro body, A, during similar transition. Hence, time taken by macro body, B, (which is initially at slightly higher temperature, t_2° c) to change its temperature from t_1° c to t_0° c is less than the time required for macro body, A, to change its temperature through the same range.

Figure 1 shows hypothetical cooling graphs of three identical samples of water, on either sides of its freezing point. Graphs are not according to scale. They are intended to illustrate the principle rather than to express definite experimental results. $A_1A_2A_3A_4$ shows cooling graph of a sample of hot water. $B_1B_2B_3B_4$ shows cooling graph of a sample of warm water. $C_1C_2C_3C_4$ shows cooling graph of a sample of slightly

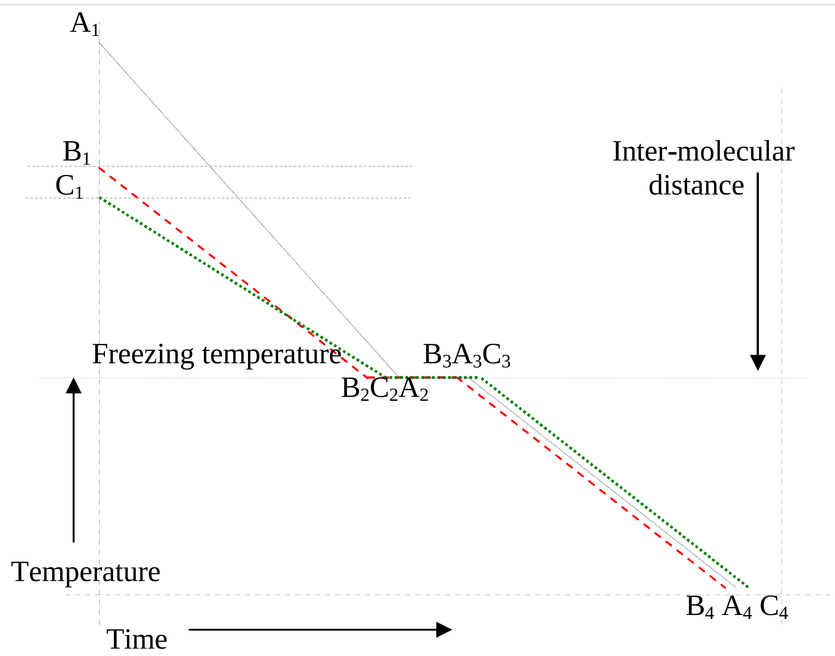

Figure 1

cooler water. Time is marked on horizontal coordinate. Temperature is measured on vertical coordinate. Relative distances between neighbouring molecules of water are assumed to be proportional to temperature of each sample.

A_1 is initial temperature of hot water. As cooling of this sample proceeds, its freezing point will be reached in time corresponding to position A_2. During latent stage from A_2 to A_3, temperature of the sample remains steady, while whole of the sample is frozen. Thereafter, sample continues to cool till sample's temperature reaches minimum possible temperature (absolute zero).

B_1 is initial temperature of warm water. As cooling of this sample proceeds, its freezing point will be reached in time corresponding to position B_2. During latent stage from B_2 to B_3, temperature of the sample remains steady, while whole of the sample is frozen. Thereafter, sample continues to cool till sample's temperature reaches minimum possible temperature (absolute zero).

C_1 is initial temperature of cooler water. As cooling of this sample proceeds, its freezing point will be reached in time corresponding to position C_2. During latent stage from C_2 to C_3, temperature of sample remains steady, while whole of the sample is frozen. Thereafter, sample continues to cool till sample's temperature reaches minimum possible temperature (absolute zero).

Comparing graphs of warmer and cooler samples, temperature B_1 is more than C_1. When temperature of warmer sample reaches initial temperature of cooler sample, its molecules already have certain relative velocity towards their neighbours and rate of its cooling is greater as shown by greater slope of B_1B_2, compared to C_1C_2. Hence, warmer sample will reach freezing temperature at B_2 earlier than cooler sample reaches freezing temperature at C_2.

Duration of latent stage depends on the rate cooling. Duration of latent state of hot water at its freezing point is much shorter than durations for other two samples. Duration of latent stage of cooler sample is longest. Cooling process, beyond freezing point, commences as soon as latent stage is completed. If cooling is continued, warmer sample will reach absolute zero temperature, earlier than other two samples. Cooler sample will be the last to reach absolute zero temperature.

Rate of cooling (absorption of matter-content) by constituent primary 3D matter-particles of a macro body depends on the difference between surrounding pressure (room temperature) and internal pressure (temperature) of the macro body. Whatever be the temperature of a macro body at any stage, its rate of cooling depends on initial conditions (difference between room temperature and temperature at the center of macro body, when it has started its cooling process). That is to say, that rate of cooling of a macro body does not directly depend only on its current temperature difference with room temperature at any instant, but it depends also on the initial difference between temperature of the macro body and the room temperature, when the cooling process started.

In the same conditions of room temperature, a slightly warmer macro body will cool down faster than a slightly cooler macro body. If initial temperature difference between macro bodies is very little, total time required for a hotter macro body to cool through certain range of temperature may be less than the total time required for a cooler macro body to cool through the same range of temperature. Thus, under same external conditions, slightly warmer water freezes faster than identical quantity of cooler water. This phenomenon is called the 'mpemba effect'.

Up to a smaller extent, parameters of surroundings, rate of evaporation, convection currents, changes in volume of fluid, initial temperature, nature of containers etc. may have their own influences on the rate of cooling and time taken to freeze fluids. However, main reason for mpemba effect remains the product of linear accelerations of constituent molecules of macro bodies towards each other, due to any reason. Convectional currents in macro bodies at any stage is bound to adversely affect mpemba effect.

Similar actions take place during heating of macro bodies also, but in reverse order. Slightly cooler macro body may reach next latent stage before slightly warmer macro body, under identical surrounding conditions. Thus, it is possible that slightly cooler macro body reaches higher latent stage, earlier than slightly warmer but identical macro body under similar surrounding conditions.

Conclusion:

Phenomenon of 'Mpemba effect' in fluid macro bodies is caused by linear accelerations of their constituent molecules towards each other, while they are being cooled.

References:

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