To Austen Angell on his 80^{th} birthday, in admiration of his scientific contributions, and in gratitude for the generosity he has shown and the inspiration he has provided to so many.

Contents

Preface

A diverse range of substances transform into an amorphous solid (glass) when cooled from a high temperature fluid state to temperatures below the freezing point (supercooled). Polymeric glasses, metallic glasses, chalcogenide glasses, in addition to oxide glasses, are some examples of well studied and technologically important types of glasses. Corresponding to the diversity of glass formers, their glass transition temperatures, structural relaxation properties in the liquid state, mechanical properties in the glass, glass forming ability, etc, also show a large diversity. Even while many fundamental issues concerning glass formers remain open, the necessity to organize the vast body of empirical knowledge about glass formers is ever more pressing. An organizing principle to rationalize the properties of glass formers, and thereby seek a fundamental understanding of their behaviour has been the notion of *fragility*, introduced and intensively studied by Prof. C. Austen Angell. The fragility of a glass forming liquid quantifies the rapidity of the rise of its viscosity as the glass transition temperature is approached. As a fundamental material property, the ability to predict, or at least rationalize, the fragility of a substance is an important challenge. The relationship between fragility and material properties such as the microscopic structure, nature of intermolecular interactions, composition, mechanical attributes such as the Poisson ratio, *etc*, have been probed by many workers' studies over the last two decades. Despite these efforts, a conclusive statement about the origin of fragility of glass formers (or in general, liquids at low temperatures) is yet to be formulated.

The "Symposium on Fragility", being held in the Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, India, during January 5 - 8, 2014, aims, therefore, to bring together a diverse group of active researchers who have explored the notion of fragility. In view of the seminal contributions to the study of fragility made by C. Austen Angell, who turned 80 in December 2013, this meeting is also an occasion for a felicitation and celebration of his contributions. The organizers of this meeting felt that a collection of articles that have explored the concept of fragility would be valuable to bring out on this occasion, which would also constitute a fitting tribute to Austen Angell. This special volume is the result, and contains a collection of articles and reprints on the topic of fragility by many leading scientists who have studied this aspect of glass forming behaviour. We hope that readers will find this compilation useful.

A. Lindsay Greer, Kenneth F. Kelton and Srikanth Sastry
JNCASR, Bengaluru, January 2014

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For Austen Angell

On the Occasion of his 80th Birthday

In late December 1989, I was a graduate student and on a visit home for Christmas. Hiding in the basement to avoid the usual Holiday commotion, I was reading a review article by Austen Angell on supercooled water. At that time I was completely new to research on water and just getting to know the literature. Trying to be a conscientious student, I was underlining the good parts with a pen and a ruler. After pouring over several pages I looked back and realized that I had just underlined almost every word. I recall thinking, "This Angell guy is pretty good!"

Reading that review was a turning point in my development as a researcher. Twenty-four years on, of course I now know that my initial experience with Austen Angell was not an unusual one. In a career that now spans more than 60 years, Austen has, seemingly with his every professional act, changed lives and opened doors to discovery for innumerable students and colleagues around the world, and across a broad swath of scientific disciplines.

Austen's objective accomplishments are impressive. After completing his BSc and MSc at Melbourne University in his native Australia, Austen earned a PhD in Chemistry at Imperial College, London in 1961. Following a postdoc at Argonne National Laboratory, he joined the Chemistry Department at Purdue University, where he was a member of faculty from 1966 until 1989. Austen then moved to Arizona State University, where he is currently a Regents' Professor of Chemistry and Biochemistry. Early in his career, Austen emerged as an international leader in the study of glass-forming liquids and the glass transition, and he has remained at the focal point of activity in this field ever since. Water has long been a particular interest of Austen's, but by no means the only interest. He has pioneered the study of glassy behavior in a tremendous range of systems, including in biological contexts such as protein folding. Austen has also made major contributions in many other areas, including studies of molten salts, and the electrochemistry of batteries and fuel cells. As a consequence of all these efforts, Austen is the author of more than 500 publications, and has a Hirsch index of more than 84. He is also the recipient of numerous awards, such the Morey Award of the American Ceramic Society, and the Hildebrand

Award of the American Chemical Society. Austen also has earned a number of more informal titles, bestowed with the greatest of affection and respect. These include the "Pope of Water", the "Guru of Glass", and (my personal favorite), "The Vitriarch".

However, I know that I am not alone in feeling that Austen's impact on science goes far beyond the enumeration of the accomplishments given above. Indeed, for decades now, Austen has served as the "Great Connector" within a huge community of scientists related to materials chemistry, physics, and engineering. The reasons are many, but also revealing. First, Austen is a walking, breathing Wikipedia of materials science. He possesses an almost supernatural capacity to perceive links between apparently disparate systems, and thus transfer insight between previously isolated communities. Perhaps his most notable contributions in this regard have occurred in glass science, where Austen has been instrumental in connecting theories originating from within the physics community, such as mode-coupling theory, with the vast knowledge-base of experimental chemists concerning a wide range of real materials.

Second, although he'll always be an experimentalist at his core, he moves comfortably into theory and simulations when his curiosity takes him there. Speaking as a simulationist, I know that our community has advanced immeasurably due to work inspired by, if not led by, Austen. His contributions to our current thinking on energy landscapes, from the standpoint of both theory and experiment, come to mind in this context.

Third, Austen seems to be most at home, and most energized, in the setting of a scientific conference. He is the omnipresent face in the first row, raising his index figure into the air to pose a question after *every* talk. His questions, while always constructive, also probe, challenge, and draw connections that the speaker may have missed. How many new investigations have resulted just from Austen's conference questions? Too many to count.

Finally, and I would say most importantly, we must give special recognition to the human warmth and generosity of spirit that Austen shows to all who approach him with questions, and to discuss new ideas. Austen has given his time and attention to scientists from every corner of the world, supporting new research initiatives, forging new collaborations, and helping researchers connect with each other across the gaps between disciplines. In particular, the time and attention that Austen devotes to young people, at all stages of their training, is inspirational, and has been pivotal for creating careers in science for so many of us, myself included. Austen always makes time for students and young scientists who seek him out, or who catch his eye with their work. When he thinks a new result from a young researcher is exciting, he makes a special effort to promote their work during his own talks, even if he is not directly involved. It has long been clear that Austen's highest priority is to bring the best new ideas into the light, for us all to see, no matter from where or from whom those ideas originate.

And so, from all of your students and colleagues, Happy Birthday, Austen. Thank you for inspiring us with your creativity, listening to our questions, and challenging us with yours. And thank you for connecting us, both with each other, and to the ideas that changed our work and our lives.

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Austen Angell with Ulf Pedersen and Nicholas Bailey at the Copenhagen "Fragility" symposium (Oct 2008) at the Niels Bohr Institute.

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