Next in rank to the Portland is the Naples Vase, so called because it is now preserved in the Naples Museum. It was discovered in 1837 in a tomb in Pompeii, and dates, therefore, from the first century A. D. Mr. Walter Butterworth has remarked that the scene represented on the carved surface of his vase might have been taken straight from the pastoral poetry of Sicily: shepherd boys playing musical instruments, sheep and goats feeding, vines, birds, conventional putti (boys' figures), masks, etc., all delightfully carved, leaving the figures and decorations in white relief on the purplish blue ground. Gaiety and lightsomeness permeate the composition. The design is full of charm.

The Auldjo Vase, also found at Pompeii, was for long in fragments. The bulk of the pieces, after passing through various hands, have now been brought together in the British Museum; but the vase is still incomplete. The design is of ivy leaves and other foliage with the fruit of the vine.

The cup in the possession of the Rothschild family is of olive-green glass which appears of a red or purple color by transmitted light. Round it are carved five figures in almost complete relief, said to represent the "Madness of Lycurgus." The glass is believed to date from early in the 3rd century A. D.

Glass is a Lobster

By F. W. PRESTON

ONCE upon a time (it is a hundred years or more ago) the French brought out a new dictionary, wherein things were to be defined with precision. The Lobster was defined as "a little red fish that runs sideways." Cuvier, the great French naturalist, observed that this definition would be perfect except for three things: that the lobster was not a fish, that it did not run sideways, and that it was not red till boiled.

In a very friendly way, I have frequently objected to the use of the definition of glass, that "glass is an undercooled liquid."

Glass has often been thus defined, but the definition has not meant very much to those of us who were not physical chemists. It has, in fact, tended to confusion among some who cannot readily admit that a thing is gold because it glitters, or that a palpable solid is a liquid because it possesses, in common with liquids, an obscure thermodynamical relationship to crystals.

The fact that glasses possess some of the properties of the liquids does not make them liquids, when they lack very emphatically the characteristic and diagnostic property of liquid, namely, the ability to flow. To take the contrary view, that it is permissible to call them liquids, is possibly justifiable in the private lives of thermodynamical chemists, but the word is scarcely admissible in public places. It involves redefining the word "liquid."

The dictionary defines a liquid as that which flows, and glass at room temperature is much less capable of flowing than such characteristic solids as iron or steel. It does not flow, as a liquid should, under infinitesimal stresses, or even under large stresses. In fact, if the estimates of Preston[1], and of Littleton[2] are correct, or approximately so, glass formed at the dawn of creation and subjected ever since to as high a stress as it will stand, would not have flowed at all.

On this basis, the mechanical, or "engineering," or man-in-the-street's, or lexicographer's, glass is *not* a liquid. We can only so regard it by concentrating our attention on a very limited aspect of the question.

[1]J. Am. Ceramic Soc.—pp. 374 and 377—July, 1932.
[2]Pittsburgh Meeting Am. Ceramic Soc., 1933, cf. Glass Industry, March, 1933—p. 31.

In the same way, a man on the top of Pikes Peak, who chose to disregard everything around him, and concentrated his attention entirely upon a small area in Denver seen through a powerful telescope, might say that from his point of view, America was a railroad station, and that the other properties of America were not relevant to this definition.

The physical chemist describes glass as a liquid because it is not in his eyes a gas and not a crystal. The fact that it shares with crystals as many properties as it shares with liquids is immaterial. By sufficiently restricting our viewpoint, however, and considering the behavior of the material towards X-rays, or something still less important, it ought to be possible to prove that glass "in a highly technical sense" is a gas.

Let us however, for the moment, leave the word "liquid" and think about "undercooled."

It is true that most glasses, at room temperature, are "undercooled," that is, are below their crystallizing temperature, the so-called "liquidus temperature," but there is nothing in the constitution of glasses to *demand* that they be below the liquidus.

In the ternary system Soda-Lime-Silica, one ternary eutectic at least, has a liquidus temperature of only 725° C. Dr. Morey[3] informs me that the liquidus temperature of part of the Soda-Magnesia-Silica system lies much lower. Kracek[4] in the Soda-Potash-Silica system finds one eutectic at 540° C. There is no reason to suppose that these are the lowest liquidus temperatures that will be found. One might very well expect to find lower ones in glasses of four components or more, and there is no apparent reason why the liquidus temperature should not, with some glasses, be below room temperature.

As we know the liquidus temperature of only a few glasses, the statement that glasses in general are below their crystallizing temperature is a considerable extrapolation. We are in danger of discovering glasses that are *not* "undercooled."

So we finally have glasses thus defined: "A glass is an undercooled liquid, lacking liquidity, and, as a rule, merely assumed to be undercooled."

[3]Verbally.
[4]J. Phys. Chem. XXXVI (Oct. 1932)—p. 2539.

One or two recent pronouncements are of interest here. Thus, Zachariasen[5] writes, "Glasses are described as supercooled liquids or as solids. The former term is justifiable from the point of view of physical chemistry, the latter from the theory of elasticity."

Again, Morey[6] writes, "It should be emphasized that in this discussion the term "liquid" is used in a highly technical sense. As used in connection with phase equilibrium studies, a liquid is a non-crystalline phase, not a gas, which limits the range of existence with increasing temperature of a crystalline phase, and the idea of fluidity or rigidity plays no part in this definition. The argument as to the propriety of calling a glass an undercooled liquid is pointless. There can be no question that a glass is a liquid from the point of view of phase equilibrium, and the circumstance that it may at the same time possess properties which according to some other definition are characteristic of a solid is not pertinent. Glasses, then, are undercooled liquids . . . ."

It would, I think, be very much better to say, "Glasses, then, sometimes possess some of the properties of undercooled liquids."

The proof that they are undercooled must be furnished in each individual case.

We have recently had the good fortune, apparently, to demolish the concept of a "Transformation Temperature" at which molten glass passes from a true liquid to a true glass. The papers of Morey[7] and Littleton[8] to the Joint Meeting at Washington in April of this year, seem definitely to have abolished this boundary. No one will shed tears at its demise, and the abolition of any apparent boundary between the liquid state and the glassy state will of course be a further argument in favor of considering glasses as overstiffened liquids.

But what we have established is not that glass is a liquid, but that it can solidify without crystallizing. This was known before, and was the current concept before the "Transformation Temperature" was invented to plague us.

We may apparently speak as follows:

When a liquid solidifies without crystallizing, it becomes a solid glass.

A material which normally thus solidifies, may when melted, be called a molten glass.

The material may be regarded as "glass" whether it is melted (liquid) or solid, just as iron may be molten or solid.

There is no specific temperature dividing liquid glass from solid glass. The transition is gradual.

The above statements will permit the continuance of the language of industrial glass men without seriously curtailing the rights of physical chemists. In their investigations they will continue to think of "glass" as being essentially a liquid: (this is mainly because they cannot continue their investigations as physical chemists when the glass is "solid," so they will always be working with it in a fairly liquid condition): in the privacy of their chambers they may speak of it as the "liquid phase": but in public they should not stress their word "liquid," lest they cause little ones to stumble.

Zachariasen[9] has given what appears to be a valuable interpretation of the probable structure of solid glass. I may paraphrase it thus, "Glass is a solid with a higgledy-piggledy lattice." It meets the ordinary requirements of physics and industry very well, and I think it also meets the requirements of the physical chemists.

It is the most solid (least fluid) form of solid, because it is least capable of flow. A viscosity may be assigned to it on theoretical grounds, as has been done by Littleton[10] and Preston[11], and this viscosity is finite, not infinite. But as shown by the latter writer, the viscosity is so high that, in a universe of granular structure (i. e., of molecular structure), in a universe also which is probably limited in extent and in duration, it has no physical meaning. Such a viscosity can never be *observed* in this universe, either by mortal man, or by the Gods on Olympus. The whole of space and time and all the forces of the universe could not produce one molecule's distance of flowage; could not, at room temperature, have displaced one molecule, viscously, from its attachments

A material which can stand the test of all eternity without slipping, is preferably regarded as a solid, possibly an impertinent solid.

If I build a frame house, I set my two-by-fours in a recognizable array, in vertical and horizontal positions, and with uniform spacings. I have to nail them together to keep them so, or the house will fall down. Such a house is a crystal.

If I hire a lot of pixies, trolls, or goblins, to run around on my house site, each with a two-by-four, carried at any old angle, without any system to their motion, each hobgoblin bumping into his fellows and changing his course continually: that is a liquid.

If I command every goblin to stop motionless, and then nail all the two-by-fours together at their nearest points or wherever they touch, that is a glass.

The motion makes the liquid: the nails make the solid: the orderliness makes the crystal: the higgledy-piggledyness makes the glass.

[5]W. H. Zachariasen—J. Am. Chem. Soc.—Vol. 54—p. 3841 (Oct. 1932).
[6]G. W. Morey. Joint Meeting of Am. Chem. Soc., and Am. Ceramic Soc. (Mar. 1933).
[7]Loc. cit.
[8]Preprinted abstract. cf. National Glass Budget—Apr. 1, 1933—p. 8.
[9]Loc. cit.
[10]Loc. cit.
[11]Loc. cit.

Plate Glass Production in April

The total production of polished plate glass by the member companies of the Association for the month of April, 1933, compiled by Secretary P. A. Hughes of the Plate Glass Manufacturers of America, was 4,679,776 sq. ft., as compared to 4,881,322 sq. ft. produced by the same Companies in the preceding month, March, 1933, and 5,025,008 sq. ft. produced by the Association members in the corresponding month last year, April, 1932.

April Construction Contracts

The April contract volume for construction of all types, according to the F. W. Dodge reports, amounted to $56,573,000; this contrasts with $59,958,500 for March and $121,704,800 for April of last year. For the first four months of 1933 contracts totaled $252,599,800 as against $407,783,500 for the corresponding period of 1932.