Meetings

Critical Phenomena

The year 1970, the one-hundredth anniversary of the publication by Thomas Andrews of his discovery of the critical point between liquid and vapor carbon dioxide, was marked by four major conferences on the subject of critical phenomena: the Midwinter Solid State Conference at the University of California at Irvine, in January; the Fordham Conference on Dynamical Aspects of Critical Phenomena in June; the Varenna Summer School on Critical Phenomena in August; and the Battelle Institute Colloquium on Critical Phenomena in Geneva and Gstaad, Switzerland, 7 to 12 September.

One may well ask why the interest in critical phenomena has increased to the point that four major conferences on the subject would be held in a single year. The centenary of Thomas Andrews' discovery appears to be coincidental. More important appears to be the hope that we might now be able to describe a group of remarkably similar continuous transitions between phases of a wide variety of materials, including fluids and fluid mixtures, magnets, alloys, superconductors, ferroelastics, ferroelectrics, and others, in terms of a single embracing theory.

As a result of the week-long Battelle colloquium, attended by some 70 mathematicians, physicists, chemists, and metallurgists, it was concluded that the experimental description of critical phenomena has been soundly established and that an empirical scaling equation of state of general applicability is available. However, a complete theoretical understanding of the scaling equation of state will require considerably more effort on the part of theoreticians. Another purpose of the meeting was to contrast the work by metallurgists on ordering and spinodal transitions in alloys with the work over the past decade by chemists and physicists on a general treatment of critical phenomena.

The colloquium was introduced by an account by Lars Onsager on the history of the development of his solution of the two-dimensional Ising model. The importance of the use of idealized but tractable models, which was first established by Onsager's work, was amplified by C. N. Yang on systems with one-dimension delta function interactions and by Mark Kac on the use of models. On the metallurgy side, J. M. Cahn (M.I.T.) introduced some of the experimental features of the study of metastability and phase separation in binary alloys.

One of the recent achievements in critical phenomena has been the development of a scaling equation of state that describes physical properties near the critical point with remarkable success. The form of the equation is essentially unchanged, and only certain scaling parameters vary from one material to another. Two groups of theoretical papers were introduced by Ben Widom (Cornell) and Paul Martin (Harvard), to facilitate discussion of the origins of the equation of state, whether in detailed study of models, or from a first-principle basis. Papers by B. Josephson (Cambridge) and M. J. Cooper (National Bureau of Standards) were concerned with expressing the scaling equation of state in terms of functions of only one or two parameters. A feature of Cooper's paper was that the equation of state so developed avoided treating the contiguous phases as precisely symmetrical. This feature helps to extend the use of scaling beyond the range in which one might ordinarily expect it to apply. C. Domb (King's College, London) developed a model of self-avoiding walks and scaling, which showed that, in some instances, a second scaling length is required. G. A. Baker, Jr., (Brookhaven) dealt with the establishment of inequalities which bound magnetization in the Ising-Heisenberg model. The conditions of concentration and temperature that permit spontaneous magnetization in dilute, random, Ising-Heisenberg systems were treated in a paper by G. S. Rushbrooke (Newcastle-upon-Tyne). The influence of dimensionality in the calculation of the critical exponents by H. S. Stanley (M.I.T.) suggested that the scaling exponents are monotonic functions of the dimensionality and approach their mean field limits for very large dimensionality. The study of critical exponents and the scaling equation of state by G. Jona-Lasinio (Rome), using the theory of the renormalization group of the basic, nonlinear equations gave an instance of the close relation between calculation *ab initio* of critical phenomena and calculations of strong-coupling phenomena in particle physics.

The overall topic was then subdivided into sessions on the development of spatial ordering, magnets and superconductors, and transport properties. The session on development of spatial ordering was introduced by L. Guttman (Argonne) who discussed the general knowledge of order-disorder transitions in binary alloys. Although most binary alloys have first-order transitions, in a few simple and body-centered cubic lattices a transition occurs apparently with no latent heat, and thus may be suitable for tests of the general theories developed for higher-order transitions. If the finite compressibility of real lattices is considered, at least one exactly soluble model suggests that the transition remains of higher order, but that the critical exponents are modified. D. de Fontaine (UCLA) and H. E. Cook (Ford) discussed attempts to unify the treatment of phase separation in binary solutions in the metastable region. C. B. Walker (Army Materials and Mechanics Research Center) discussed the measurement of long-range order in beta brass by x-ray diffraction. It was suggested that the divergence between his results and the neutron diffraction results of Als-Nielsen were due to differences in the interpretation of the Debye-Waller factors. The observation of critical phenomena in ferroelastic transitions of metals alloyed with hydrogen was reported by G. Alefeld (Jülich). P. C. Clapp (Ledgemont Laboratory) has calculated multisite correlation factors in Ising lattices to obtain better insight into the onset of ordering. A computer simulation of order-disorder phenomena was discussed by J. B. Cohen (Northwestern). The calculations avoid examination of dynamical details, thereby improving the speed of the calculations. The possibility was raised that this might lead to a violation of ergodicity, but the results do seem to simulate clustering realistically in both the ordered and the disordered phases.

The session on magnets and super-

conductors was introduced by R. B. Griffiths (Carnegie-Mellon). He reviewed the behavior of critical exponents when the position of the critical point itself depends on external parameters. He suggested that, on the basis of a smoothing postulate, one should expect all the intensive parameters affecting a system to enter into the description of the data on an equivalent basis. J. D. Litster (M.I.T.) discussed the first-order nematic-isotropic transition in liquid crystals. He showed that the Landau theory of critical phenomena gave a satisfactory description of the order parameter. A detailed discussion of the applicability of a scaling equation of state to magnets was presented by M. Vicentini-Missoni (Rome). She showed that the parametric form could give a good fit to data for several real magnets, but that the linear model needs further correction. J. S. Kouvel (University of Illinois at Chicago) reported a study of critical phenomena in Pd-Fe alloys. The data can in all cases be fitted well with the use of the scaling equation of state, and, in the case of the dilute Pd-Fe alloy, give further confirmation of the existence of the "giant moment." A study of fluctuation near the phase transition in one-dimensional superconductors was discussed by R. J. Warburton (Cornell). The lower dimensionality of the single thin whisker crystals makes accessible a critical region in a superconductor which is wider on the temperature scale than that of bulk superconductors. The data are sufficient to differentiate between some of the competing theories of the fluctuations.

The session on transport properties was divided into three parts. Work with the relatively new techniques of light scattering in fluids was discussed by G. Benedek (M.I.T.) and B. Volochine (Saclay). Benedek examined many of the facets of the problem of interpreting data obtained from the scattering of light by critical fluctuations in pure fluids, Xe and SF_6. An old discrepancy concerning the line widths in SF_6 above and below T_c (critical temperature) may have been resolved by data showing that a divisor, ρC_p (density time heat capacity at constant pressure), in the line-width expression does not, in fact, vary like a simple exponential along the coexistence curve. Volochine reported that data taken on the binary mixture cyclohexane-aniline were in very good agreement with the mode-mode coupling theory of Kawasaki. In the second part of transport properties, K. Kawasaki (Temple) discussed a theory giving the probability distribution function for the local hydrodynamic variables and the order parameter. The generalized Fokker-Planck equation he derived yields the previous results of dynamical scaling theory for magnets and the lambda transition in liquid helium. In binary liquid mixtures, a second scaling parameter appears to be required for some of the transport coefficients. New experiments with more traditional methods were reported by Peter Heller (Brandeis) and Martin Barmatz (Bell Telephone Laboratories). Heller has studied extensively transport properties in the uniaxial antiferromagnet, FeF_2, using both nuclear magnetic resonance (NMR) and neutron scattering techniques to differentiate between the contributions of the longitudinal and transverse susceptibilities to the NMR line widths. Barmatz has applied the scaling equation of state in the study of the lambda transition in helium in order to anticipate better the effects of gravity over the critical zone in a column of the fluid. The improved analysis of data thereby made possible gives results that again agree well with the theory of Kawasaki. The third part of the session on transport phenomena was concerned with the metal-insulator transition that was reported previously by T. M. Rice to exhibit some of the characteristics of critical points. David Adler (M.I.T.) reviewed the features of such conductivity transitions and discussed several possible mechanisms. T. M. Rice presented a theory on the Mott transition in V_2O_3. No conclusive evidence of critical phenomena in these transitions was presented.

In a final summary session intended to tie together the various aspects of the subject discussed earlier in the week, Widom discussed models displaying asymmetry of contiguous phases near T_c, Kac presented remarks concerning the remarkable applicability of molecular-field theory, and Benedek discussed briefly light studies of turbulent flow. Referencing Kelvin's famous 19th-century summary of the comfortable state of physics, Elliott Montroll (Rochester) summarized the current state of knowledge of critical phenomena. He observed that the experimental aspects are well established now, that the data appear to be well described by the phenomenological equations of static and dynamic scaling, but that it would be desirable to improve the theory so as to understand better "small clouds on the horizon," such as the origins of critical exponents and solutions for the nonlinear dynamical equations and the three-dimensional Ising model.

The proceedings of the colloquium will be the topic of a forthcoming McGraw-Hill publication, and will be inscribed in honor of Lars Onsager, "whose exact solution of the two-dimensional Ising model led the way to quantitative treatment of critical phenomena described in these proceedings."

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Forthcoming Events

January

10–13. American **Meteorological** Soc., New Orleans, La. (K. C. Spengler, AMS, 45 Beacon St., Boston, Mass. 02108)

11–13. **Systems Sciences,** 5th intern. conf., Honolulu, Hawaii. (Information Sciences Program, 2565 The Mall, Univ. of Hawaii, Honolulu 96822)

11–15. National Soc. of **Professional Engineers,** Dallas, Tex. (P. H. Robbins, NSPE, 2029 K St., NW, Washington, D.C. 20006)

13–14. **Molecular Basis of Electron Transport,** Biochemistry–Papanicolaou Cancer Research Inst., 4th annual, Miami Beach, Fla. (Biochemistry–PCRI Winter Symposia, P.O. Box 906, Biscayne Annex, Miami, Fla. 33152)

16. **Human Factors in the Design and Operation of the Highway Transportation System,** 5th annual workshop, Washington, D.C. (A. J. McKnight, 300 N. Washington St., Alexandria, Va. 22314)

17–19. American College of **Surgeons,** sectional mtg., Miami, Fla. (Communications Div., ACS, 55 Erie St., Chicago, Ill. 60611)

17–21. **Numerical Reactor Calculations** Symp., Intern. Atomic Energy Agency, Vienna, Austria. (J. H. Kane, Div. of Technical Information, U.S. Atomic Energy Commission, Washington, D.C. 20545)

19–21. American **Mathematical** Soc. and Mathematical Assoc. of America, Las Vegas, Nev. (A. B. Willcox, MAA, 1225 Connecticut Ave., NW, Washington, D.C. 20036)

23–27. American Soc. of **Heating, Refrigerating, and Air-Conditioning Engineers,** New Orleans, La. (A. T. Boggs III, ASHRACE, 345 E. 47 St., New York)

24–26. **Aerospace Sciences,** 10th mtg., New York, N.Y. (American Inst. of Aeronautics and Astronautics, 1290 Ave. of the Americas, New York 10019)