

CONTENTS

Chapter	Page
I V. P. PESHKOV, CRITICAL VELOCITIES AND VORTICES IN SUPERFLUID HELIUM	1
1. Critical velocities in narrow channels, slits and films, 1. – 2. Critical velocities in wide channels, 11. – 3. Oscillating discs and spheres, 20 – 4. Persistent currents, 23. – 5. Summary of experimental data, 24. – 6. The Landau criterion and excitations in the superfluid, 26. – 7. Quantised vortex lines, 29. – 8. Concluding remarks, 35.	
II K. W. TACONIS and R. DE BRUYN OUBOTER, EQUILIBRIUM PROPERTIES OF LIQUID AND SOLID MIXTURES OF HELIUM THREE AND FOUR	38
1. Introduction, 38. – 2. The equilibrium between vapour and liquid mixtures (dew- and boiling-curve), 49. – 2.1. General survey of the experimental data, 49. – 2.2. Calculation of the excess chemical potentials and the excess Gibbs function, 51. – 2.3. The equilibrium between vapour and a dilute liquid mixture of ^3He in ^4He II; equilibrium with respect to the solute, 57. – 3. The equilibrium between the He I and the He II phase (λ -line) and between two liquid mixtures in the stratification region (the phase separation diagram), 59. – 3.1. The lambda transition, 59. – 3.2. The Keesom-Ehrenfest relations for a liquid mixture and the discontinuity in the slope of the first order equilibrium curves at the junction with the second order lambda-curve, 61. – 3.3. The phase separation diagram, 64. – 4. The osmotic equilibrium in He II (pseudo thermostatic equilibrium) and some applications, 72. – 4.1. The osmosis in He II derived from the equilibrium between pure liquid ^4He on one side and a mixture on the other side of a superleak (semipermeable wall); equilibrium with respect to the solvent, 72. – 4.2. The quasi-equilibrium between the osmotic and fountain force in the liquid mixture, when a heat current is present (the heat flush effect), yielding the diffusion coefficient and the heat conductivity of the mixtures, 74. – 4.3. The quasi-equilibrium between two mixtures of slightly different concentration in the He II region separated by a capillary, yielding the viscosity of the mixtures, 77. – 4.4. The quasi-equilibrium between two liquid mixtures of different concentration in the He II region, connected by the helium surface film, yielding the isothermal flow rate of these films, 80. – 4.5. A refrigeration cycle, as an application of the osmotic pressure and the heat of mixing, 81. – 5. The equilibrium between liquid and solid mixtures (freezing- and meltingcurve) and the phase-separation of solid mixtures, 84. – 5.1. The freezing pressures of ^3He - ^4He mixtures, 84. – 5.2. The equilibrium between two solid mixtures in the phase separation region, 87. – 5.3. The minima in the freezing curves of ^3He - ^4He mixtures and the minima in the melting curves of pure ^3He and pure ^4He , 90.	

III D. H. DOUGLASS, Jr. and L. M. FALICOV, THE SUPERCONDUCTING ENERGY GAP	97
1. Historical introduction, 97. – 2. The physical significance of an energy gap, 99. – 3. The theory of the superconducting energy gap, 102. – 3.1. Derivation of the energy gap equation, 102. – 3.2. Elementary excitations and density of states, 107. – 3.3. Temperature dependence of the energy gap, 111. – 3.4. Mechanisms for the effective electron interaction and solutions of the energy gap equation, 113. – 3.5. Magnetic field dependence of the gap, 123. – 3.6. Dependence of the energy gap on impurities and spatial inhomogeneities, 135. – 4. Theory of superconductive tunnelling, 140. – 4.1. Semphenomenological theory of electron tunnelling in superconductors, 140. – 4.2. Microscopic theory of electron tunnelling in superconductors, 146. – 5. Experimental determinations of the superconducting energy gap, 153. – 5.1. Specific heat and thermal conductivity, 153. – 5.2. Photon excitations across the gap, 157. – 5.3. Energy gap acoustic attenuation measurements, 167. – 5.4. Energy gap from electron tunnelling experiments, 172.	
IV G. J. VAN DEN BERG, ANOMALIES IN DILUTE METALLIC SOLUTIONS OF TRANSITION ELEMENTS	194
1. Historical remarks, 194. – 2. Electrical resistance and magnetoresistance, 198. – 2.1. “Diluted” alloys of transition metals of the first long period, 200. – 2.2. “Diluted” alloys of transition metals of the second long period, 208. – 2.3. “Diluted” alloys of transition metals of the third long period, 209. – 2.4. Transition metals also as solvents, 210. – 3. Thermal resistance, also in a magnetic field, 211. – 4. Thermoelectric power, 215. – 4.1. Normal metals as solvent, 216. – 4.2. Transition metals as solvent, 221. – 5. Magnetic properties, 222. – 5.1. The magnetic susceptibility, 222. – 5.2. Electron spin resonance, 227. – 5.3. Nuclear magnetic resonance; Knight shift, 228. – 5.4. The De Haas-Van Alphen effect, 230. – 5.5. Magnetic remanence, 231. – 6. Hall effect, 233. – 6.1. Noble-metal based alloys, 233. – 6.2. Transition-metal based alloys, 237. – 7. Specific heat, 238. – 8. Optical properties, 244. – 9. Theoretical considerations, 245. – 9.1. Resonance hypothesis, 245. – 9.2. Molecular field model, 246. – 9.3. Criticism of the molecular field treatment, 251. – 9.4. The “ion pair and isolated ions” treatments, 251. – 9.5. The virtual bound state treatment, 253. – 9.6. Conclusion, 259.	
V KEI YOSIDA, MAGNETIC STRUCTURES OF HEAVY RARE-EARTH METALS	265
1. Introduction, 265. – 2. Survey of experimental results, 268. – 3. Theoretical consideration, 275. – 4. Relation between the Fermi surface and the screw structure, 285. – 5. Summary, 292.	
VI C. DOMB and A. R. MIEDEMA, MAGNETIC TRANSITIONS	296
1. Introduction, 296. – 2. The Ising model, 299. – 2.1. General remarks. Thermodynamic properties, 299. – 2.2. Magnetic properties, 302. – 3. The Heisenberg model, 304. – 3.1. General remarks. Thermodynamic properties, 304. – 3.2. Magnetic properties, 305. – 4. Remarks on the analysis of experimental data, 307. – 4.1. Thermal data, 307. – 4.2. The exchange constant, 309. – 5. Experimental data, 310. – 5.1. Ferromagnets, 310. – 5.2. The rare earth metals, 318. – 5.3. Combined ferro- and antiferro-	

magnetism, 319. – 5.4. Antiferromagnetism, 322. – 5.5. Layer type anti-ferromagnets, 325. – 5.6. Antiferromagnetism in special lattices, 326. – 6. Comparison between experiment and theory, 333. – 6.1. Ferromagnets, 333. – 6.2. Cobalt tutton salts, 335. – 6.3. Antiferromagnets, 336. – 7. Conclusions, 339.

VII L. NÉEL, R. PAUTHENET and B. DREYFUS, THE RARE EARTH GARNETS 344

1. Introduction, 344. – 2. The magnetic properties of the rare earth garnets, 346. – 2.1. Preparation of the rare earth garnet-type ferrites, 346. – 2.2. Crystal structure, 348. – 2.3. Magnetostatic properties, 349. – 2.4. Magnetic interactions, 353. – 2.5. Interpretation of experimental results, 354. – 2.6. Temperature variation of the inverse of the paramagnetic susceptibility above the Curie point and the spontaneous magnetisation of yttrium ferrite, 358. – 2.7. Magnetic interactions between rare earth ions, 361. – 2.8. Thermal variation of the spontaneous magnetization and of the inverse of the paramagnetic susceptibility in the rare earth ferrites, 361. – 2.9. The rare earth gallates, 362. – 2.10. Europium and samarium ferrites, 365. – 2.11. Substitutions in the rare earth ferrites, 366. – 3. The levels of rare earth ions in the garnets, 369. – 3.1. Crystalline fields, 369. – 3.2. Specific heats, 370. – 3.3. Thermal conduction, 373. – 3.4. Spectroscopic investigations, 373. – 3.5. The visible and near infra-red spectrum, 374. – 3.6. The far infra-red spectrum, 376. – 3.7. Inelastic scattering of neutrons, 378. – 3.8. Giant anisotropy, 379. – 3.9. An example of the “reconstruction” of a garnet, 381.

VIII A. ABRAGAM and M. BORGHINI, DYNAMIC POLARIZATION OF NUCLEAR TARGETS 384

Introduction, 384. – 1. Dynamic polarization at low temperatures, 385. – 1.1. Electronic and nuclear paramagnetism: generalities, 385. – 1.2. Dynamic polarization: generalities, 395. – 2. Spin temperature theories of dynamic polarization, 400. – 2.1. Limit of very strong r.f. fields. Homogeneous spin systems, 401. – 2.2. Arbitrary r.f. field strengths. Homogeneous spin systems, 405. – 2.3. Homogeneous spin systems with nuclear spin diffusion. Solid effect theory, 411. – 2.4. Relaxation and polarization by unlike electronic spins in the case of nuclear spin diffusion (leakage), 412. – 2.5. Inhomogeneous electronic spin systems, 414. – 3. Experimental arrangements and results, 415. – 3.1. Experimental results, 415. – 3.2. Laboratory apparatus and large targets, 426. – 3.3. Thin targets, 433. – 4. Future developments, 440. – 4.1. Nuclei other than protons, 440. – 4.2. Target size and non-resonant dynamic methods, 441. – 4.3. Target materials, 445.

IX J. G. COLLINS and G. K. WHITE, THERMAL EXPANSION OF SOLIDS 450

1. Introduction, 450. – 2. Theory, 451. – 2.1. The Grüneisen γ , 451. – 2.2. Theoretical models, 453. – 2.3. Anisotropic materials, 455. – 2.4. Electronic and magnetic contributions to the thermal expansion, 456. – 3. Experimental methods, 457. – 3.1. Experimental techniques, 457. – 3.2. Analysis, 458. – 4. Dielectric solids, 460. – 4.1. Ionic solids, 460. – 4.2. Discussion of ionic solids, 463. – 4.3. Inert-gas solids, 464. – 5. Metals, 464. – 5.1. Isotropic elements, 464. – 5.2. Anisotropic metals, 467. – 5.3. Unusual metals, 469. – 6. Glasses and diamond-structure solids, 471. – 6.1. Glasses, 471. – 6.2. Diamond-structure solids, 472. – 6.3. Ice, 473. – 7. Superconductors, 473. – 8. Summary, 476.

X T. R. ROBERTS, R. H. SHERMAN, S. G. SYDORIAK and F. G. BRICK-WEDDE, THE 1962 ^3He SCALE OF TEMPERATURES	480
1. Introduction, 480. – 2. Brief historical review of earlier determinations of the ^3He vapor pressure-temperature relation, 482. – 3. Plan for development of the 1962 ^3He scale, 488. – 4. The 1961 L.A.S.L. intercomparisons of the ^3He and ^4He vapor pressures, 489. – 5. The determination of the critical pressure and temperature of ^3He , 491. – 6. Calculation of a vapor-pressure equation below 2 °K using a theoretical equation from statistical mechanics, 492. – 7. Extension of the vapor-pressure equation to the critical point, 493. – 8. The 1962 ^3He vapor-pressure scale, 494. – 9. An evaluation of the 1962 ^3He scale, 495. – 9.1. Fit of the input 1961 L.A.S.L. vapor-pressure data, 495. – 9.2. Fit of the experimental thermodynamic equation (ETE) scale, 496. – 9.3. Fit of the Argonne Laboratory vapor-pressure data, 499. – 9.4. Fit of the heat-of-vaporization data, 500. – 9.5. Fit of gas thermometer, isotherm and acoustic interferometer measurements, 503. – 10. Thermodynamic properties of ^3He consistent with the 1962 ^3He scale, 505. – 11. Corrections to the measured pressure of a ^3He vapor-pressure thermometer, 509. – 11.1. Correction for the ^4He impurity in ^3He , 509. – 11.2. Correction for the thermomolecular pressure ratio, 510. – 11.3. Hydrostatic pressure corrections, 511. – 12. Conclusion and considerations for the future, 511.	
AUTHOR INDEX	515
SUBJECT INDEX	527