$\sigma_{N,P}$, $\sigma_{N,2N}$, σ_A, σ_{TR}, $\sigma_{NON\text{-}EL}$, $\bar{\alpha}$, $\xi\sigma_{EL}$, $\nu\sigma_F$, $\bar{\mu}\sigma_{EL}$, and σ_R. The spectrum is constructed from a combination of fission, E^{-n}, power series, Maxwellian or input spectra.

4. Method of Solution: Group-averaged cross sections are obtained by flux weighting in nonresonance groups and by the use of ARES II for resonance groups.
5. Restrictions on the Complexity of the Problem: The following limits may not be exceeded: 300 groups, 21 elements and 5 flux regions.
6. Typical Running Time: Twenty-one elements with all 19 parameters can be processed in 6 min using 18 to 54 groups.
7. Unusual Features of the Code: GRAVE requires the neutron cross-section master tape prepared by the MOMUS program. Punched output is available on option.
8. Related and Auxiliary Programs:
   a) MOMUS - prepares and updates neutron cross-section master tape.
   b) PRISM - produces elastic, inelastic and total transfer matrices.
9. Status: In production.
10. *References:*

[1]R. A. Blaine and J. S. Temple, "GRAVE, A Group Cross Section Averaging Program," NAA-SR-MEMO-9276 (December, 1963).

[2]R. A. Blaine, "Modificatiosn of the GRAVE Program," Atomics International Internal Letter, dated January, 1965.

[3]F. L. Fillmore and B. D. O'Reilly, "ARES-II, A Resonance Integral Code," NAA-SR-MEMO-8889 (August, 1963).

[4]R. A. Blaine, "MOMUS, A Program to Construct, Up-Date and Modify the Neutron Microscopic Cross Section Master Tape," NAA-SR-MEMO-8823 (August, 1963).

11. Machine Requirements: 32 K, IBM 7094.
12. Programing Languages Used: FORTRAN (95%) and FAP (5%)
13. Operating System or Monitor Under Which Program is Executed: Standard IBM FORTRAN monitor.
14. Any Other Programing or Operating Information or Restrictions: None.
15. Material Available:
    a) GRAVE source deck (including ARES II)—3500 cards;
    b) ARES Library—500 cards;
    c) Sample data;
    d) References 1, 2, and 3, as listed above.
    (MOMUS must be requested separately.)

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1. Name of Code: I.N.S. 10-1
2. Computer for Which Code Designed: IBM 1620 with a 40K core
   Programing System: FORTRAN II
3. Nature of Problem Solved: I.N.S. 10-1 is used to obtain starting points for least-squares analysis of elastic alpha-particle-scattering data. It was written specifically for oxygen-16 but is suitable for other zero-spin nuclei. The program compares an experimental angular distribution with the angular distribution calculated from a set of phase shifts. A mesh of phase shifts is studied and from the χ^2 calculated for each mesh point, minima in χ^2 are selected where χ^2 is the sum of the squares of the deviations between the experimental and calculated cross sections.
4. Method of Solution: Computation of the scattering cross section is by use of the formula given by Blatt and Biedenharn[1] and the program is divided into two main parts:

   a) Initializing

   b) χ^2 calculation.

   a) All data are read and stored, and computations and subroutines which would otherwise become repetitive, if included in the main calculation, are evaluated. This cycle is performed once only.

   b) Values of χ^2 are obtained for each set of phase shifts, and the phase shifts are incremented so as to cover a complete mesh. Repetitive calculations are kept to a minimum in this section in view of the large number of mesh points to be examined.

5. Restrictions on Complexity of Problem: As written the program will accept up to 15 values of Θ (scattering angle) and up to 10 phase shifts (δ_l). These limits could be extended provided storage was available. The main restriction for the 1620 is in time. If a large number of mesh points are to be studied, it is recommended that a faster computer be used. For example an IBM-7090 would reduce computing time by a factor $\approx 10^3$.
6. Typical Running Time: On the 1620 with 15 values of Θ and four of δ_l the program takes about 50 sec to initialize and 65 sec per mesh point thereafter.
7. Status: Program is in use and details are available from I.N.S.
8. *References:*

[1]Blatt and Biedenharn, *Rev. Mod. Phys.* **24,** 258 (1952).

[2]G. Pallo, "A Computer Program for Analysis of Data on the Elastic Scattering of Alpha Particles by Oxygen," Institute of Nuclear Sciences Report—INS-R-19. (This report gives full details of the program.)

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1. Program Names: PDQ-5 and PDQ-6
2. Computer for Which Programs are Designed: Philco-212 Programing System: The programs are written in FORTRAN II language. They operate on the Philco-212 computer under control of the BKS monitor system and also make use of the Bettis FORTRAN subroutine package. Conversion to another computer would require translation of the subroutine package and, for efficient operation, a rather extensive modification of the programs.

3. Nature of Problem Solved: PDQ-5 and PDQ-6 solve the two-dimensional neutron-diffusion-depletion problem with up to five lethargy groups. The geometry is rectangular or cylindrical in PDQ-5 and hexagonal in PDQ-6, and both programs provide for variable mesh spacing. Zero-flux, zero-current, and rotational symmetry boundary conditions are available. Between 300 and 500 mesh points are permitted in each coordinate direction, and problems in excess of 50 000 points have been run successfully.
4. Method of Solution: A standard five-point difference approximation is used in PDQ-5 and a seven-point Ritz approximation is used in PDQ-6. The flux iterations of both programs utilize single-line successive over-relaxation, and the source iterations are accelerated by Chebyshev extrapolation. Macroscopic cross sections may be input directly or may be calculated from few-group microscopic cross sections and nuclide concentrations. Time-dependent cross sections are represented in tabular form as functions of the pointwise concentrations of up to three nuclides. The exact form of the depletion equations is specified in the input, and roundoff is carefully controlled in the solution of these equations. During the depletion time interval, the flux is assumed not to vary in shape. Within this interval, however, the cross sections may vary as step functions and the level of the thermal flux may be adjusted to account for changes in fission rate and thus maintain a nearly constant power level.
5. Running Time: For several thousand problems, the average running time in minutes has been observed to be the number of group points divided by 1000. Particular problems may exhibit wide variation from this due to the accuracy required or the convergence difficulties encountered.
6. Present Status: The programs are currently in use and may be obtained by domestic users from

   TUG Executive Secretary
   Philco Computer Division
   3900 Welsh Road
   Willow Grove, Pennsylvania

7. *References:*

[1]W. R. Cadwell, P. F. Buerger and C. J. Pfeifer, "The PDQ-5 and PDQ-6 Programs for the Solution of the Two-Dimensional Neutron Diffusion-Depletion Problem," WAPD-TM-477 (January 1965).

[2]R. J. Breen, O. J. Marlowe and C. J. Pfeifer, "HARMONY: System for Nuclear Reactor Depletion Computation," WAPD-TM-478 (January 1965).

[3]L. A. Hageman and C. J. Pfeifer, "The Utilization of the Neutron Diffusion Program PDQ-5," WAPD-TM-395 (January 1965).

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