NEUTRON EMISSION OBSERVED DURING THE ELECTRICAL EXPLOSION OF DEUTERATED LIQUIDS OF METALLIC CONDUCTIVITY

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Impulse heating of Li/ND_3 solutions of metallic conductivity in a capacitor discharge circuit produces short-time neutron pulses of 10–50 ns duration right at the beginning of the discharge. The emission per pulse is variable but amounts up to more than 10^7 neutrons, originating from the D(d, n) ^{3}He reaction. The pulses appear with capacitor charge potentials above and even shortly below 100 kV and at pressures which allow only very small mean free path lengths of the plasma particles.

Concentrated solutions of alkali metals in liquid ammonia show metallic conductivity. The saturated solution of lithium in ammonia has a vapour pressure of less than 1 atm at room temperature and a specific conductivity resembling that of mercury ($10^4\ \Omega^{-1}$ cm^{-1}). The solution consists to about 70 atomic percent of hydrogen and can be kept for several hours, provided oxygen and moisture are excluded. A similar solution can be made with pure liquid ND_3.

If a capacitor bank is discharged via a laminar spout of such a solution at a surrounding pressure of 1 atm a gas discharge will be observed along the surface of the beam ("peripheral discharge") caused primarily by the low work function of electrons of the solution. As a result the body of the spout is heated from the outside as is the case for wire explosions in vacuo. Increasing the pressure of the surrounding gas or imbedding the liquid in a capillary allows to suppress or at least to delay the peripheral discharge so that the heating of the spout is started "from within". In this way the production of hot extremely dense plasmas is possible with densities up to 10^{22} particles per cm^3 containing a high percentage of deuterium.

In the Kiel experiments glass capillaries have been used, measuring 3–7 cm in length and 0.3–0.8 mm in diameter. The filled capillaries were closed at the ends with Cu pins. Explosions were performed in cylindrical chambers pressurized with 15 atm N_2, being part of coaxial leads. The remaining part of the circuit consisted of a condenser bank (5 μF max. 200 kV 100 kJ) and of a coaxial solid state switch. The ringing frequency of the total circuit was 4–6 μs varying with the dimensions of the discharge chamber and of the switch.

The neutrons were detected by six scintillation counters (Nuclear Enterprises NE 213 with photomultipliers Valvo XP 1040) arranged symmetrically in a circle of 1.2 m diameter around the discharge vessel. For screening against stray fields they are enclosed within Al-containers. Registration of the neutron pulses was effected by a chain of oscilloscopes connected in time sequence (Tektronix 7704 and 7503). Calibration was effected by means of an electrical neutron generator.

The time duration of the neutron pulses was 10–50 ns. They were observed at the beginning of the discharge only, not in a later phase. Occasionally some short, weak pulses were observed later which might be caused by stray neutrons of low energy.

Our measurements were not interfered with by X-ray emission. This was tested simply and convincingly in the following manner. Experiments made under identical conditions but using NH_3 instead of ND_3 showed no scintillations. X-rays, caused by fast neutrons scattered inelastically or by capture of neutrons which are already moderated cannot drastically alter the signal observed, as can easily be estimated considering the distribution of masses in the vicinity of the exploding liquid.

The main feature distinguishing our experiments from those done elsewhere [1–3] consists - besides the time resolved detection - in the fact that a homogeneous material of metallic conductivity of relatively low mean atomic weight, and containing a high percentage of deuterium is heated at conditions leaving only very small mean free path lengths for the heated particles.

It is well known that during the initial phase of wire explosions zones of relative low density develop within the vapour cloud [4]. However, in view of the experimental pressure used (several atm.) it seems improbable that electric fields develop within these zones which are high enough that the neutron emission observed could be caused by acceleration processes.

References

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