Letter to the Editor

A Mechanism for UO_2/Sodium Thermal Interactions

It has been suggested in a recent paper[1] that the violent interactions which are observed when sodium is injected into molten UO_2 (Ref. 2) may be explained on the assumption of liquid-liquid contact and homogeneous nucleation. It has also been suggested, however, that in the converse experimental situation when UO_2 is dropped into sodium, the observation of fine fragmentation with low explosive yields[3] may be understood in terms of thermal stress fragmentation, because the UO_2 freezes on contact with sodium.[4]

Since the contact temperature of UO_2 and sodium is well below the UO_2 solidification temperature, a frozen shell must form both for UO_2 in sodium and sodium in UO_2, thus preventing the sustained liquid-liquid contact which may be necessary to ensure high superheats. However, we note that the existence of such a frozen shell also avoids the requirement for high superheats to explain the energetic interactions observed with sodium in UO_2. If we assume that the shell will be subject to pressure from the heated sodium, then it will at some stage rupture, rapidly dispersing the sodium in a large excess of UO_2. This is just the condition required to obtain a high explosive yield. For instance, assuming that fine dispersion occurs during the expansion of the drop over a distance ~1 drop radius, the mixture ratio will be ~7:1 by volume. This will give a mixture temperature close to the original UO_2 temperature and a maximum thermodynamic yield ~5 kJ/g of sodium.

On the other hand, for a drop of UO_2 in sodium, the 1:7 mixture ratio will give a mixture temperature ~1160°C (for sodium at 500°C and UO_2 at 2800°C), which scarcely exceeds the normal sodium boiling point.

An additional factor, illustrated recently by Costa,[5] is that while the frozen shell will be subject to liquid pressurization alone in the case of a UO_2 drop in sodium, for the case of sodium in UO_2, it is likely that there will be some vapor (or gas) trapped with the sodium in the shell, and this will delay pressurization until the sodium is heated sufficiently to exert a significant vapor pressure. The dispersion energy will then be enormously increased over that for a UO_2 drop in sodium.

Thus, we may conclude that both types of experimental observation may be understood in terms of the single hypothesis of UO_2 shell freezing.

It should be noted, however, that such processes are likely to act only as trigger mechanisms for coherent large scale explosions, since autocatalytic release through frozen shell bursting, as with superheated drop nucleation, could only occur from very special initial conditions. The most plausible explanation for the occasional authentic large scale event is that autocatalytic mixing occurs because of explosive expansion,[6] and it is this possibility that requires experimental investigation.

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