Table 3. Recovery owing to cysteine after 20,000 r of x-rays (calibrated by non-irradiated cells).

Treatment before irradiation	Treatment after irradiation	Survival (%)
Malonic acid, $10^{-3}M$	Cysteine, $10^{-3}M$	67.2 ± 2.4
None	Cysteine, $10^{-3}M$	72.1 ± 2.6

Table 4. Sensitization by maleic acid applied before 20,000 r of x-rays (2000 cells were counted as a whole, and calibration was held by control).

Molar concn. of maleic acid in Nägeli's soln.	Survival (%)	
	Irradiated	Non-irradiated
10^{-3}	22.6	85.3
10^{-4}	36.1	96.2
10^{-5}	43.4	102.1
0	47.1	100

acid was not used (compare Table 2 with third line of Table 1). This may be explained on the hypothesis that fumaric or aspartic acid removes the block produced in the tricarboxylic acid cycle by malonic acid.

In other experiments, cysteine was added to the Nägeli agar to reactivate altered sulfhydryl groups in the irradiated cells (Table 3). Although there was a substantial recovery owing to cysteine (compare Table 1 with Table 3), the sensitizing action of malonic acid was not completely overcome by the cysteine; there was the statistical significance of the difference between 67.2 and 72.1 percent.

The effect of maleic acid on radiosensitivity is shown by the data in Table 4. This acid, in concentrations less than $10^{-3}M$, has no inhibiting influence on growth of the yeast cell but seems to sensitize the cell to radiation, the effect varying directly with concentration in the culture medium. However, its concentration and distribution in the cell are unknown.

M. Kiga
Y. Ando
H. Koike

Department of Radiology, Showa Medical School, Tokyo, Japan

References and Notes

1. Fricke *et al.*, *J. Chem. Phys.* 6 (1938); J. Weiss, *Nature* 153, 748 (1944).
2. Barron *et al.*, *J. Gen. Physiol.* 32 (1948); H. M. Patt, *Science* 110, 213 (1949).
3. Devick, *Brit. J. Radiol.* 25, 481 (1952); D. W. Bekkum, *et al.*, *Brit. J. Radiol.* 27, 127 (1954).

28 March 1955

Tests of a Soil Sterilant for Forestry Use

The chemical compound 3-(*P*-chlorophenyl)-1,1-dimethylurea (CMU) (*1*) has been tested in the sand hills of western Florida to determine whether it would kill scrub oaks and wire grass and permit reforestation with planted pines. CMU (*2*) is a nonvolatile, slightly acid, grayish-white powder with a very low solubility in water (230 ppm). It has relatively low flammability and mammalian toxicity.

The chemical was applied to the soil as an aqueous suspension in 10 dosages from 0 to 37 lb/acre in March 1953, each treatment being replicated four times. Mortality of woody plants was determined by actual stem count, while ground cover was surveyed by line-spot transects. The results are based on differences between pretreatment and post-treatment vegetation surveys.

A vegetation survey that was made 16 mo after application showed that dosages of 11 lb or more per acre had controlled scrub oaks of all sizes. Twenty-two pounds or more was necessary to control grass and other ground cover. Necrosis first appeared around the leaf margins of oaks and on the tips of pines and grasses. Oaks (*Quercus laevis* and *Q. incana*) that received dosages of 22 lb or more lost as many as three sets of leaves during the first growing season after treatment. Wire grass (*Aristida stricta*), the pretreatment dominant, was nearly eradicated at dosages around 7 lb/acre, but it was replaced by *Sorghastrum nutans, Panicum virgatum, Andropogon scoparius,* and *Andropogon floridanus* during the second growing season after treatment (Table 1). Ingressive grasses in treated plots were much taller and more vigorous than those in untreated border strips. Weed species that were the most resistant to CMU included cactus (*Opuntia* spp.), saw-palmetto (*Serenoa repens*), sassafras (*Sassafras albidum*), and yucca (*Yucca* spp.).

Table 1. Mortality of oaks and ground cover at end of second growing season after application of CMU to the soil.

Dosage (lb/acre)	Mortality (%)			
	Oaks 8 ft and taller	Oaks 4–8 ft tall	Oaks 1–4 ft tall	Ground cover
0	0	19	13	5
1	26	0	0	31
2	23	12	19	11
4	57	20	4	14
7	87	84	13	14
11	98	99	97	3
16	100	100	99	43
22	100	100	99	74
29	100	100	100	86
37	100	94	97	79

Forty-nine slash pines (*Pinus elliottii* Engelm.) were planted in each plot in January 1954, 9 mo after application of the chemical. Analyses of soil samples for residual CMU were made in July 1954. Phytotoxic amounts were found even in soil that had received dosages of 4 lb/acre; pine survival counts made in September 1954 revealed that 24 percent of the trees in this treatment were dead or severely chlorotic. Pines in the 37-lb treatment suffered 98-percent mortality and injury. The persistence of CMU even at low dosages makes its value for use in forestry questionable.

Frank W. Woods*

Southern Forest Experiment Station, Forest Service, U.S. Department of Agriculture

Notes

1. It is also known as Karmex W.
2. E. I. du Pont de Nemours and Co. supplied the chemicals that were used in this study and made analyses of soil samples.

* Stationed at East Gulfcoast Research Center, Marianna, Fla.

13 June 1955

Sound of Boiling

An interest in the sound of boiling liquids has been apparent for years. Chemical plant operators in charge of evaporators and reboilers sometimes judge the performance of their equipment by the noise emitted. A general superstition is that the louder the noise of boiling the better the performance of the equipment. The noise that occurs as a hot metal is quenched in a liquid has received notice. A change in pitch accompanies the drop in temperature (*1*). The noise accompanying the overloading and resulting burnout of electric heaters immersed in water has been reviewed (*2*).

Researchers also occasionally depend on the sound of boiling. When boiling data are obtained, it is important to know which type of boiling is occurring. Boiling can occur by at least three different mechanisms. These are different to the eye and the ear and also in the manner in which the heat transfer depends on the temperature driving force.

The relationship between the heat-transfer rate and the over-all temperature driving force for each type of boiling, with methyl alcohol, is shown in Fig. 1. The short crosslines indicate the boundaries between the types of boiling: nucleate, transition, and film boiling.

Visual studies of the types of boiling have been made with still photography, using exposures of 10^{-6} sec, and with motion pictures at a speed of 4000 frames/sec (*3*). These studies show, as described here, that the manner of formation of vapor bubbles is entirely different in each of the three types of boiling.

The purpose of the investigation described here (*4*) was to determine how the sound of boiling depends on the type of boiling.

Methyl alcohol was boiled at atmospheric pressure at 148°F in a glass boiler, approximately 1 gal of liquid being employed. Heat was supplied from a horizontal copper bayonet heater 6 in. long and 3/8 in. in diameter. Saturated steam at various pressures condensed inside this heater tube. The methanol vapors passed overhead, where they were condensed and returned to the boiler. Measurements included the heat-transfer rate from the tube to the methanol and also the over-all temperature difference between the steam and the methanol.

The sound measurements were made through a crystal microphone located 6 in. from the boiler wall at the same elevation as the heating tube. Interposed between the boiler wall and the heater tube was 1 in. of liquid methanol. The microphone was mounted directly on a General Radio Co. sound level meter, Type 759-B. This meter indicated the intensity of the total sound in decibels in the frequency range from 25 to 7500 cy/sec.

Preliminary tests showed that the background noise was severe during ordinary working hours. Therefore the final data were obtained late at night when the background noise was not significant.

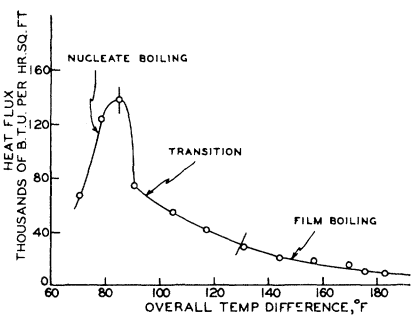

Fig. 1. Boiling curve for methanol.

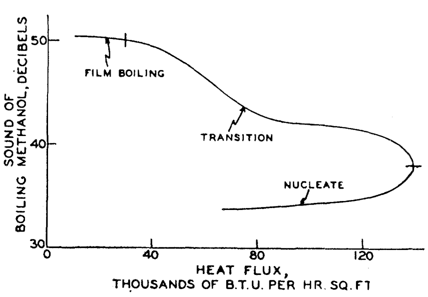

Fig. 2. Effect of heat flux on the sound of boiling methanol.

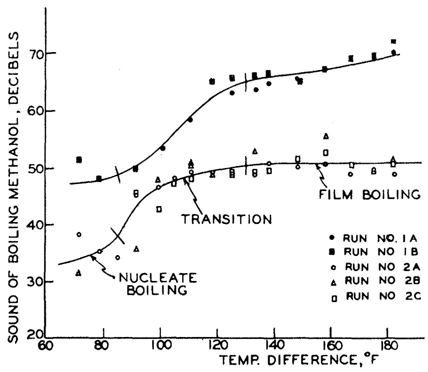

Fig. 3. Effect of temperature driving force on the sound of boiling methanol.

The sound of boiling is indeed a function of the heat-transfer rate during boiling (Fig. 2), but not in the way generally imagined. Contrary to popular opinion, the sound does *not* increase continuously with the heat flux. Inasmuch as the heat-transfer rate is a function of the temperature driving force, the sound is a function also of the temperature difference between the hot solid and the boiling liquid (Fig. 3).

During nucleate boiling any increase in the temperature difference causes an increase in the heat flux and an accompanying increase in the sound intensity. Nucleate boiling—that is, repeated, systematic, bubble formation at specific locations on the hot solid—ceases at a temperature difference of 85°F, and transition boiling exists from this value up to about 130°F. During transition boiling, bubbles form violently and explosively at random locations on the hot tube. The sound increases steadily as the transition region is traversed. However, although the sound increases, the heat flux decreases. Above a temperature difference of 130°F, film boiling occurs and the sound level is rather uniform. During film boiling, the hot solid is blanketed with a film of vapor, and no solid-liquid contact occurs. The heat transfer becomes very poor. A trained listener should be able to distinguish between nucleate boiling and film boiling by ear. He would have difficulty in classifying the transition type of boiling.

Runs 2A, 2B, and 2C (Fig. 3) show that the reproducibility of results, on a single night, was close. A small, but possibly important, difference exists between run 2B and the other two. Run 2B was made with successively increasing values of the temperature difference; runs 2A and 2C were made in the reverse direction. Hysteresis in boiling curves (heat transfer rate versus temperature difference) has been reported by at least one group of observers (*5*). The sound measurements support their observations.

A pertinent fact was discovered by taking data on two different nights. Runs 1A and 1B were taken 5 nights prior to the second series. The relationships are the same qualitatively on the two occasions, but they are different quantitatively. On the second occasion (runs 2A to 2C), great care was taken to make sure that the copper tube was highly polished and that the methanol was well degassed. The sound of boiling is influenced either by the smoothness of the hot solid or by the dissolved gas content of the boiling liquid. Both of these possible causes are suspected. It is known that the heat-transfer rate during boiling is influenced both by the surface texture of the solid (*5*) and by the dissolved gas content of the liquid (*6*). Further tests will be needed to evaluate the individual effects of these two factors.

J. W. Westwater
A. J. Lowery, Jr.
F. S. Pramuk

Division of Chemical Engineering, University of Illinois, Urbana

References and Notes

1. J. W. Marx and B. I. Davis, *J. Appl. Phys.* **23**, 1354 (1952).
2. K. Goldman, Nuclear Development Associates, White Plains, N.Y., *NDA 10-68*, 1953.
3. J. W. Westwater and J. G. Santangelo, *Ind. Eng. Chem.*, in press.
4. This research was supported by the National Science Foundation.
5. C. Corty and A. S. Foust, annual meeting, Am. Inst. Chem. Engrs., St. Louis, Mo., preprint No. 1 (1953).
6. F. R. Pike, P. D. Miller, Jr., K. O. Beatty, Jr., *ibid.*, preprint No. 2.

20 April 1955

Diffusion of Sodium Ions from Cerebral Tissue in vitro

The diffusion of inorganic ions from pieces of tissue into surrounding stirred aqueous media follows a double exponential time course (Fig. 1), which has been attributed to intracellular-extracellular tissue compartmentation (*1*). This interpretation is brought into question by the present observations (*2*), which afford strong presumptive evidence that, at least in the case of sodium diffusion from pieces of brain tissue *in vitro*, the double exponential curve depends upon other physical factors.

Figure 1 is the semilogarithmic plot of the concentration of radioactive sodium (*3*) remaining in pieces of brain after various times of diffusion. Since each point was established by 10 to 15 experimental determinations, and since each arm of the curve was fixed by several points, there would appear to be little question concerning the double exponential form of the curve. Its significance, nevertheless, is not uniquely determined.

In a general study of the physical laws