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SCIENTIFIC CORRESPONDENCE

Sulphur-35 labelling

^{35}S-labelled amino acids and nucleotides are increasingly used in protein translation studies and making probes for genetic materials. The need for exercising utmost caution when using these products has been emphasized[1]. The impediment in the synthesis and application of ^{35}S-labelled compounds lies in their radiotoxicity to the biological system. While unleashing the energy of 48.8 keV (average), ^{35}S decay is expected to inflict cellular damage but this fact seems to have received scant attention. During the production of ^{35}S amino acids in our laboratory, we have observed growth inhibition and cell killing in micro-organisms exposed to ^{35}S milieu. We noticed that similar constraints have been experienced by others also. Therefore, we felt the need to understand the effects of ^{35}S β-particles at the cellular level. Here we discuss about the contribution of β-irradiation to ^{35}S cytotoxicity.

The cellular damage caused by β-particles in the absence of transmutational effect was assessed by subjecting the diploid yeast *Saccharomyces cerevisiae* strain D_7 to ^{35}S milieu under non-growth conditions (0–4°C). The strain reverts to tryptophan independence by intragenic recombination upon exposure to genotoxic agents[2]. Convertants are scored by plating the treated samples on omission medium not containing tryptophan. The detailed methodology is described elsewhere[3].

Induction of gene conversion is a reliable indicator of DNA damage[2]. ^{35}S negatrons (β-rays) were efficient in inflicting genotoxicity as judged by the induction of tryptophan prototrophy through gene conversion. Sublethal doses up to 100 Gy enhanced the gene conversion frequency in a dose-dependent manner. The survival response study reveals a mean lethal dose of 140 Gy. The relative biological effectiveness values of ^{35}S β-particles relative to ^{60}Co γ-rays for lethality and gene conversion were 1.6 and 1.7, respectively. When lethally irradiated cells were subjected to liquid-holding recovery (LHR), the survival increased significantly, indicating their ability to recover from potentially lethal damage. Such recovery depends on the nature of damage and the availability of inherent repairing process[4].

Another important aspect of ^{35}S decay, involving transmutation, has not been investigated by us. However, it has been shown that the transmutational effect is unlikely to contribute significantly to the lethality of ^{35}S-incorporated organism[5]. At the same time, the ability of ^{35}S to cause DNA lesions *in situ* and cell inactivation even under unincorporated state (without imposing transmutational insult) highlights the significance of negatrons. The radiosensitivity may be higher by many orders in the case of mammalian cell lines. Prolonged incubation and excessive addition of ^{35}S tracers in such sensitive systems may lead to misinterpretation of results. The potential of tracer doses to invalidate the results has also been reported for other radioisotope(s)[6]. Hence, the need arises for optimizing the level of ^{35}S to be used in various tracer applications such that the tracer itself does not interfere with the test system.

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Quantum mechanics was born out of Planck's struggle to understand the behaviour – or from a classical viewpoint, misbehaviour – of radiation. Over the years, most physicists have got used to thinking of atoms, molecules and solids in quantum terms but, paradoxically, photons still leave many uncomfortable. Prof. G. W. Series, himself a leading contributor to the experimental study of matter and light in interaction, expresses his feelings on some of these matters in this article. He does not question the outstanding experimental successes of quantum electrodynamics in its closer sphere but makes a plea for the study of alternatives, such as the Wheeler–Feynman absorber theory, which handle self-fields, the vacuum and other concepts in a way that may be found more physically appealing. Indeed, it is a revelation that considerable work has already been done on these lines by a small band of enthusiasts. This may appeal to some of our readers. Perhaps there are also others among them who will rise to the defence of the orthodox (and enormously successful) textbook point view, and it will be interesting to hear from them. After all, what is at stake is nothing less than giving the electromagnetic field a special, privileged role in our view of the world rather than embedding it in the all-encompassing framework of quantum theory.

—Editor

Sparks in the dark: Sidelights on quantum optics

G. W. Series

A critical eye is cast upon too-easy notions of photons and the concepts of the quantized electromagnetic field. Classical fields still have much to offer. The spontaneous emission of light by atoms must include radiation reaction as a physical cause. The Absorber Theory of Radiation, whose quantized formulation is based upon the quantization of atoms, forms an alternative to the conventional Quantum Theory of Radiation. Ultimately, radiation must be a branch of cosmology.

What is a photon?

Might it be said, perhaps, about photons, that familiarity breeds contempt? No, I would not argue that. But I would ask whether familiarity does not deaden the critical faculty. Your wavy line labelled *hv*, for example. It is shorthand, isn't it? But shorthand for what? And how many of us are content to live with *hv* as the first and last statement about photons?

Consider, for example, the photoelectric detection of a short pulse of light—let it be from a highly monochromatic (but low power) laser, say, in the neighbourhood of 5×10^{14} Hz. And let the pulse be 1 ps long, so that the spectral width is at least 10^{12} Hz. What, then, is ν, when the pulse allows only a few hundred oscillations to pass? Well, we can easily deal with that. We simply make a wave packet, a coherent superposition of monochromatic waves. But then we have to deal with phases and amplitudes, so what has become of our little bundles of energy labelled *hv*?

I came across coherent superpositions in the *emission* of light in the nineteen fifties, when we were applying the (then) new 'optical radio-frequency double resonance' technique to free atoms in a vapour; the atoms were excited by a lamp emitting resonance radiation while an oscillating magnetic field at radio-frequency in resonance with a Zeeman structure in the excited states, produced by a static magnetic field, was applied to the vapour. The fluorescent light from the atoms was strongly modulated at the r.f. frequency. How was one to interpret this on the photon picture? The atoms were radiating independently of each other, by spontaneous emission. But each atom was in a superposition, *induced* by the continuous-wave r.f. field, of the Zeeman states. On the picture, then, that each atom emitted its photon independently of the others, every photon was a coherent superposition of two frequencies, $\nu \pm \frac{1}{2}\delta$, where δ was the r.f. frequency. Moreover, although these photons were being emitted at random times, the phase relations within the superposition were such that the net effect of many such photons was a strong modulation at δ. This was, for the ordinary physicist, an unfamiliar state of affairs, though there was nothing fundamentally remarkable in it for your sophisticated quantum field theorist. He would express an arbitrary radiation field as a superposition of modes of plane waves of sharp frequency, extending throughout space and

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