corresponds to $\phi \approx 1.2°$, so that Eq. 9 is not needed for this case.

If, through improved accuracy, an oscillation in the rotational period of Mercury could be observed, then from these formulas it would be possible to determine λ and ϕ from the period and amplitude of the oscillation. The period, which would be the best-determined quantity, depends only weakly on ϕ, for moderate ϕ, but strongly on λ, so that the oblateness parameter would be particularly well determined.

Finally, it should be noted that the methods used here are also applicable to other cases of synchronous rotation.

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Chromium-51 in Sea Water: Chemistry

Abstract. *Chromium-51 introduced into the Pacific Ocean from the Columbia River remains in the hexavalent state. Analysis of this radionuclide in sea water by hydroxide coprecipitation with iron is best accomplished if the chromium-51 is first reduced to the trivalent state.*

Chromium-51 is one of the most abundant radionuclides in effluent coolant waters from nuclear reactors at Hanford, Washington. Because the chemistry of chromium in terrestrial waters is not well known, it is not a simple matter to predict the distribution of Cr^{51} among solution, sediment, and biota. We now present data concerning the chemical form of Cr^{51} in sea water and on the analysis of Cr^{51} in sea water by coprecipitation with ferric hydroxide.

To precipitate certain radioactive trace elements, stable isotopes of the elements in question are usually added as carriers (*1*). Early efforts to recover radionuclides, produced at Hanford, from sea water samples taken off Oregon made use of carrier techniques (*2*). That is, $ZnCl_2$, $CrCl_3$, $CoCl_2$, and $MnCl_2$ were added to samples to assure recovery of Zn^{65}, Cr^{51}, Co^{60}, and Mn^{54} neutron-induced radionuclides known to be present in the Hanford effluent. The metals were removed from sea water by coprecipitation as hydroxides.

We used a similar process in our first tests of Oregon coastal waters, except that we used ferric hydroxide as a bulk precipitate and added lesser amounts of carrier Cr(III), Zn(II), and Mn(II). Gamma-ray analyses of precipitates thus obtained from 560 liters of sea water collected off Newport, Oregon, indicate the possible presence of Sb^{124} for which no carrier was added (Fig. 1, dotted line). In an effort to obtain maximum recovery of this radionuclide, we processed a duplicate sample using the same carriers with the addition of $SbCl_3$. Although no great increase in Sb^{124} recovery occurred, there was a striking gain in yield of Cr^{51} (Fig. 1, solid line). This phenomenon prompted a close examination of the chemistry of Cr^{51} in sea water and the precipitation process itself.

Only the valence states Cr(III) and Cr(VI) need be considered for chromium in surface waters since Cr(II) is unstable in aerated aqueous solution. Chromium from the reactor is introduced to the Columbia River as a hexavalent anion, $Cr_2O_7^{2-}$. At the *p*H of river water and in the concentration at which chromium appears, this ion should dissociate to yield CrO_4^{2-}. Nelson (*3*) found that most of the Cr^{51} in the river remains in solution as an anion, presumably CrO_4^{2-}. Krauskopf (*4*) calculated that CrO_4^{2-} is thermodynamically stable in open ocean water and showed that it is not appreciably removed from sea water by most common mineral surfaces or by plankton.

Trivalent chromium would probably be $Cr(OH)_2^{+}$ if in solution, or the hydrous oxide if in the solid phase. Nelson and Cutshall (*5*) concluded that any Cr(III) formed in the river is rapidly sorbed to sediment particles. Curl *et al.* (*6*) reported rapid sorption of Cr(III) to glass beads or plankton from sea water solutions. Johnson (*7*) found that particle-bound Cr^{51} is not displaced by sea water. Thus, Cr(VI) that becomes reduced to Cr(III) is susceptible to sedimentation and is not likely to be found in filtered water samples. However, it seems likely that most of the Cr^{51} entering the ocean in solution will remain in solution as CrO_4^{2-} and, indeed, our ability to measure Cr^{51} many kilometers from the river's mouth (*8*) reinforces this hypothesis.

At intermediate values of *p*H Cr(III) will coprecipitate with $Fe(OH)_3$, whereas Cr(VI) will not. Instead, Cr(VI) may be adsorbed and occluded, especially at *p*H values at which ferric hydroxide has a positive zeta-potential ($pH < 8.3$).

Chromium(III) carrier should not affect the recovery of Cr(VI). On the other hand, Cr(VI) should act as a "hold-back" carrier, and its addition should diminish the yield. If, however, the Cr(VI) is reduced to Cr(III), coprecipitation should be efficient. It seemed probable that the addition of Sb(III) carrier had unexpectedly caused this reduction, the yield thus being enhanced.

The following experiments were designed to resolve this point. In the laboratory Cr^{51} spikes, as Cr(III), were added to filtered sea water, and the yields checked with and without carriers. This was repeated for Cr^{51} as Cr(VI), plus additional tests with Sb(III) and Sn(II) as reducing agents. Results (Table 1) show that recovery of Cr(III) by coprecipation with $Fe(OH)_3$

Table 1. Recovery of Cr^{51} spikes by $Fe(OH)_3$ precipitates in the laboratory (percent).

Carrier added			Reducing agent added
None	Cr(III)	Cr(VI)	
	Chromium(III)		
98.3	99.1	98.1	
98.3	95.2	99.1	
	Chromium(VI)		
72.4	38.4	1.9	99.5 [Sb(III)]
27.3	15.9	2.2	99.6 [Sn(II)]

Table 2. Chromium-51 recovered from sea water samples by $Fe(OH)_3$ precipitates (pc/liter). All locations were 44°39'N.

Carrier added			Reducing agent added
None	Cr(III)	Cr(VI)	
	June 1965; 125°12'W		
13.4	24.7	4.7	53.3 [Sb(III)]
	8.2		59.1 [Sb(III)]
	August 1965; 125°38'W		
5.8	2.0		9.2 [Sb(III)]
			10.2 [Sn(II)]
	August 1965; 125°02'W		
		0.9	23.5 [Sb(III)]

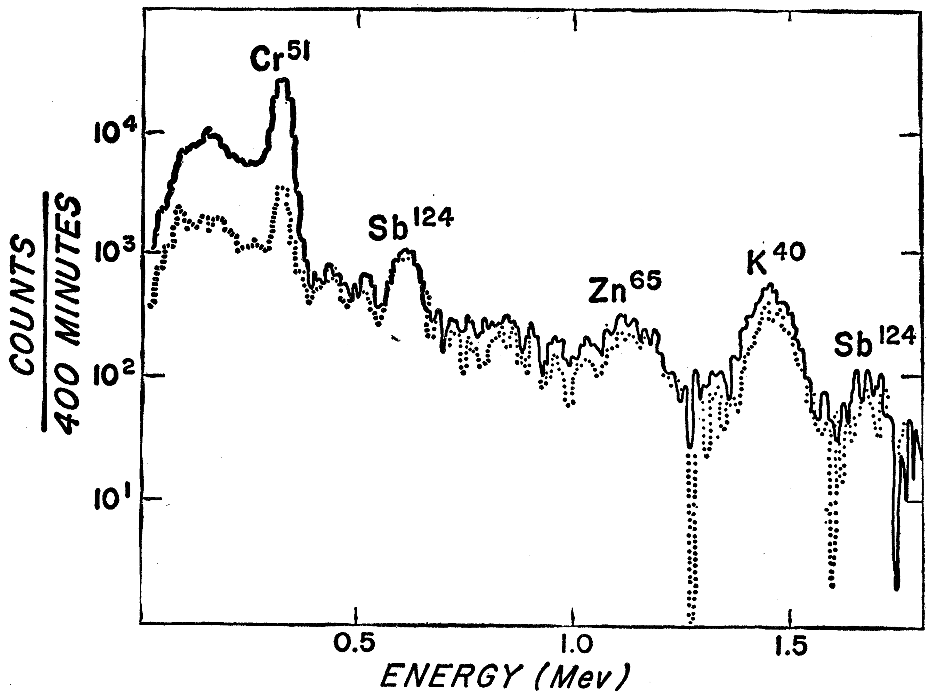

Fig. 1. Gamma-ray spectra of precipitates from 560-liter samples of sea water collected off Newport, Oregon, June 1965. Dotted line, Cr(III), Mn(II), and Zn(II) carrier were added; solid line, Sb(III), Cr(III), Mn(II), and Zn(II) were added. Enhancement of Cr^{51} is attributed to reduction of Cr(VI) to Cr(III) by Sb(III). The 1.69-Mev photopeak for Sb^{124} is not smooth because the counting rate is so low that random variations are seen.

was essentially complete, whether carrier was added or not. In the case of Cr(VI), recovery was incomplete and results were erratic when no carrier or Cr(III) carrier was used. Carrier Cr(VI) consistently reduced the yield. However, either reducing agent was effective in giving complete recovery.

Similar results were obtained at sea with proportionately larger samples and precipitates (Table 2). Laboratory and shipboard precipitates were made with 45 mg of Fe(III) and 0.64 ml of 28 percent NH_4OH per liter of solution. Similarly, carriers and reducing agents were added in the same proportion (5.3 mg of chloride salts or $K_2Cr_2O_7$ per liter) to the 250-ml laboratory tests and to the 560-liter shipboard samples. Aboard the U.S. Coast Guard cutter *Modoc*, in June, sampling was extended over an 18-hour period, during which time the ship drifted through waters of varying salinity. It was therefore necessary to rectify the counts to allow for the changing fraction of Columbia River water in our samples. All counts were corrected to a salinity of 29.2 per mil.

To obtain truly duplicate samples, the tests were repeated in August aboard the research vessel *Yaquina*. Levels of Cr^{51} were much lower because the tongue of low-salinity water observed in June (*8*) had spread greatly and become saltier. Rectification of these data was not required, since salinity values did not vary during the tests.

In every case maximum yield of Cr^{51} from sea water occurred when a reducing agent was added prior to precipitation. We conclude that Hanford-induced Cr^{51} remains principally in hexavalent form in the ocean. This conclusion is supported by the "hold-back" effect of Cr(VI) carrier. Since the Cr^{51} that we measure off Newport has been in contact with sea water for weeks or even months, we conclude that reduction of Cr(VI) to Cr(III) must occur only very slowly if at all. Any Cr(III) in the ocean or in the river would associate with particles and be lost to the sediments, while Cr(VI) would remain in solution. We have measured Cr^{51} in filtered sea water up to 525 km from the mouth of the Columbia River, and the results indicate that losses due to reduction to Cr(III) are small.

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Chloramphenicol-Specific Antibody

Abstract. *Antibody to the antibiotic chloramphenicol was obtained by immunizing rabbits with a chloramphenicol derivative coupled to bovine gamma globulin. Production of antibody was demonstrated by the precipitin and complement fixation reactions with "reduced chloramphenicol" coupled to rabbit serum albumin as the test antigen. Specificity of the antibody was confirmed in that crystalline chloramphenicol completely inhibited complement fixation and precipitin reactions. "Reduced chloramphenicol" coupled to human serum albumin provides an antigen for the detection of antibody to chloramphenicol, if it occurs in human serum in dyscrasias. With quantitative complement fixation, as little as* 10^{-5} *μg (4 ×* 10^{-14} *mole) of chloramphenicol was detectable by the inhibition assay.*

During the course of an investigation into the effect of chloramphenicol on animal cells growing in tissue culture, it became desirable to obtain antibody to the antibiotic. To determine whether this antibiotic would serve as an antigenic determinant, its nitro group was reduced (*1*) to the amine (Fig. 1) and coupled by diazotization (*2*) to the carrier protein, bovine gamma globulin (BGG). Detecting antigens were similarly prepared from the reduced chloramphenicol (RCAP) diazotized to rabbit serum albumin (RSA) and human serum albumin (HSA). Spectrophotometric analysis for azo groups (*3*) indicated an aver-